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PROCEEDINGS

Extended Abstracts

3rd International Symposium on Agriculture 2023

"Self-Sustaining Agriculture: Way Forward for Food Security and Safety"

9th March 2023

Faculty of Agriculture
Eastern University, Sri Lanka
Chenkalady-30350

3rd International Symposium on Agriculture 2023

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Eastern University, Sri Lanka

3rd INTERNATIONAL SYMPOSIUM ON AGRICULTURE 2023

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MESSAGE FROM THE VICE CHANCELLOR
Eastern University, Sri Lanka

Self-Sustaining Agriculture: Way Forward for Food Security and Safety

I am so proud to be the Chair of the International Symposium on Agriculture by sharing this message. As the Engine of regional development, provocative researching for solutions is the key process of the University. This is a great opportunity to think and talk about the collaborative efforts for Regional Common Development towards Self-Sustaining Agriculture.

'The first rule of sustainability is to align with natural forces, or at least not try to defy them' says Paul Hawken, a great Environmentalist of this era. The tracks of ISA pave the way for contemporary researching on the said and comprehensively discuss ways and means to be Self-Sustained through a multi-disciplinary approach. Geospatial Technology is one of the key tracks to be highlighted where we lack very much up to date in Agricultural space. whether we are familiar with the term or not, is already a growing and thriving technology that we use or interact with regularly. Geospatial technology based agricultural Industry trending these days where Artificial Intelligence leads to green revolution at every point. As a Leading University in eastern region of Sri Lanka, the role of being as a think tank, our mission is technically facilitating precision Agriculture within our communities towards food security and safety.

Past two years unlike any other. Collectively we experienced trauma that pushed wellbeing to the forefront. COVID-19, unemployment, financial stress, parenting in a pandemic, homeschooling, working from home, social justice, and politics were just some of the issues that dominated the news. Those significantly dragged the option of Agricultural production far away. I believe this International symposium will call back the hope for future developments. The area under productive and sustainable agriculture in SDG s captures three dimensions of sustainable production: environmental, economic, and social. The measurement instrument - farm surveys give the flexibility to identify priorities and challenges within the three dimensions of sustainability. Land under productive and sustainable agriculture will be those farms and associated agricultural land area that satisfy the sustainability criteria of the SDG indicators which we have to focus on intensively to cater current context.

As, Development and commercialization are the research outcome, we must work out more on Farm Mechanization and Postharvest Technology in our region to maximize regoin's return of Investment. I really believe our Constructive research findings of this symposium would contribute to self-sustaining Agricultural Industry. It is my fervent hope that this Symposium would prove to be a productive forum that will facilitate the exchange of new ideas and make a substantial contribution towards the advancement of research culture Regionally, Nationally and Internationally.

I would like to appreciate the entire Organizing Committee for their untiring and innumerable efforts in organizing this Symposium. Finally, I wholeheartedly wish all the research presenters to deliver their findings and disseminate knowledge among the National and International community to be conscientized and compromise for Self-Sustained agricultural Initiations.

Prof. V. Kanagasingam
Vice-Chancellor
Eastern University, Sri Lanka

MESSAGE FROM THE CHIEF GUEST

I am glad that the Eastern University, Sri Lanka is organizing the 3rd International Symposium on Agriculture. The theme Sustainable Agriculture for achieving Food Security and Safety is very relevant and hope the deliberations will enable to frame policies and programmes for food security. The issues that we face have to be analysed from a multi - dimensional perspective to evolve comprehensive solutions. Research should lead to innovative solutions that ensure sustainability.

Organic farming, permaculture, agroforestry and bio intensive farming are some of the sustainable farming methods that use local inputs and ecological conditions for crop production. Organic farming concepts with integrated practices will help in maintaining soil fertility and pest control. Integrated farming at villages in a small scale within a farm will provide farm sustainability and yield enhancement. Strengthening home with crop diversity can increase resilience of the home garden to long term crisis periods and can be a source where it can provide balanced nutrition. Implementation of programs for promoting good practices of harvesting and transportation to reduce postharvest loss and transportation loss will make more food available for consumption. A comprehensive value chain management approach is essential rather than stage wise disintegrated solutions.

I wish the International symposium a grand success and the organizers for their efforts for promoting sustainable agriculture for the future.

Prof. V. Geethalakshmi
Vice Chancellor
Tamil Nadu Agricultural University (TNAU)
Coimbatore
India

MESSAGE FROM THE DEAN
Faculty of Agriculture
Eastern University, Sri Lanka

It is a great pleasure for me to give this message as the Dean, Faculty of Agriculture to the International Symposium on Agriculture (ISA – 2023). The faculty of Agriculture is the pioneer faculty at Eastern University. Which produces graduates of the highest professional standard to contribute towards technology enhancement, dissemination of knowledge & skill and involvement in sustained productivity in the Agricultural sector of Sri Lanka.

Dissemination of knowledge is a part of the responsibility of academics, and symposia like this will help to fulfill the responsibility of academics. International Symposium is an annual meeting place for scientists and professionals to share their research findings and innovative ideas and also a place for new collaborations. The symposium greatly encourages not only the academics of this faculty but also the graduate and Postgraduate students and research scholars from all over the world to present their innovative ideas and latest discoveries in the field of Agriculture. By becoming part of our Agricultural community and experiencing hands - on learning while building relationships among all stakeholders may bring our creativity, ideasand lived experiences to collectively solve the grand challenges of sustaining our national resources with confidence and feeding the world. The supportive and collaborative nature of the symposium will also build on our mission to support the community to withstand the great demand for agriculture.

The broad theme of this year's symposium is "Self-sustaining agriculture: Way forward for food security and safety" highlighting the need for new technologies to sustain agricultural production while safeguarding the environment for future generations. we need innovative solutions for our future food security and sustainability by mitigating climate change, and sustainable life on land and water. Environmentally friendly maintenance of land and water in a sustainable manner may facilitate food safety and security. I firmly believe that this symposium will bring a productive output in terms of food security and safety.

As we all know organizing this kind of event on annual basis is not an easy task. I would like to extend my gratitude to the organizing committee ISA – 2023 and the editorial board for all their hard work on this proceeding. I would like to thank all the authors who presented their research at the conference and eventually for the printing of this proceedings.

Prof. (Mrs.). P. Premanandarajah
Dean / Faculty of Agriculture
Eastern University, Sri Lanka

MESSAGE FROM THE COORDINATOR
3rd International Symposium on Agriculture

I am privileged to pen this message for the 3rd International Symposium on Agriculture 2023 (ISA 2023). The ISA 2023 provides a platform for exchanging ideas, views and showcasing creativity in line of academic dissemination of the scientists, academics, research scholars and students of their recent findings in the field of Agriculture. The ISA 2023 on the theme of "Self-Sustaining Agriculture: Way Forward for Food Security and Safety" addressing the current needs of Sri Lanka to be held on 09th March 2023 which is a testimony captures recent advancements towards self-sustaining agriculture.

The research articles in the fields of Plant production & protection, Climate smart agriculture, Food nutrition value addition & postharvest technology, Livestock, fisheries & aquaculture, Geospatial Technology & Precision Agriculture and Soil, water, environment & waste management will be presented in this ISA 2023. The new research initiatives from these articles will lead to enhance the agriculture sector of Sri Lanka and hence towards Self-sustaining Agriculture which will lead to food security and safety in Sri Lanka.

On behalf of the organizing committee I congratulate all the authors who contributed to the success of the ISA 2023 which will undoubtedly create greater awareness among scientists, academics, policy makers, students and farming communities.

Prof. S. Sutharsan
Coordinator / ISA-2023

MESSAGE FROM THE SECRETARY
3rd International Symposium on Agriculture

As the Secretary, I'm delighted and honoured to bring this message to the 3rd International Symposium on Agriculture (ISA-2023). This symposium under the theme of "*Self-sustaining Agriculture: Way forward for food security and safety*" provides an opportunity to the scientists, academicians and researchers to share their research findings and expertise knowledge with the scientific community as well as with other stakeholders including farming community.

The world, particularly the developing countries severely affected by the COVID-19 pandemic and the subsequent economic crisis. Agriculture development is one of the most powerful tools to end extreme poverty, boost prosperity and feed the ever-increasing population. Transforming the agriculture into a dynamic and high-growth sector is essential to speed up recovery, poverty reduction and inclusive growth.

Recognizing the benefits of bring local and international experts and researches in the field of agriculture together, the Faculty of Agriculture, Eastern University, Sri Lanka has decided to organize this ISA-2023 this year. I strongly believe that this symposium will be a remarkable event, providing some valuable opportunities on top notch research, showcasing innovative and problem-based studies in the field of agriculture.

I take this opportunity to welcome all the local and foreign participants for their presence and contributions and also thank our dedicated organizing committee members who worked relentlessly to make this symposium a very success.

Mr.M. Rajendran
Secretary / ISA-2023

KEY NOTE -1
3rd International Symposium on Agriculture

Sustainable Intensification of Crop Production in Sri Lanka in the face of Climate Change and Resource Constraints

Introduction and Focus

Sustainable intensification (SI) refers collectively to strategies and practices that aim to increase crop yields without adverse environmental impacts (i.e. with a proportionately lower increase in resource use) and without expanding the presently-cropped area. As such SI aims to conserve and, possibly, regenerate the resource base (i.e. land, soil fertility, water, biodiversity etc.) while meeting the food demand of a continuously increasing population. Climate change adds an overarching layer of challenges on all SI strategies. In this short presentation, I wish to focus on identifying SI strategies that are feasible in crop production systems in Sri Lanka. Then I will focus on exploring how the additional challenges posed by climate change on the feasible SI strategies may be addressed.

The challenges faced by the food production systems in Sri Lanka

The global population which reached 8 billion in 2022 is projected to rise to 9.7 billion in 2050 and 11 billion in 2100. The corresponding trend in Sri Lanka is different where the current (Feb. 2023) population of 21.65 million (0.27% of the global population) is projected to rise to 22.19 million in 2040 (0.24% of global). The annual rate of population growth in Sri Lanka which was 2.43% in 1967 has almost continuously declined to the present rate of 0.42% in 2020. These demographic trends will, to a certain extent, lessen the pressures exerted on food production targets and the demands exerted on essential environmental resources. However, many other natural and socio-economic drivers are likely to increase these pressures. Climate change is one such driver where the temperatures in key agroecological regions have been shown to have increased at rates which are greater than that of the global average temperatures. The recent economic down-turn and short-sighted government policies have combined to reduce the capacity of farmers to invest on essential inputs such as fertilizer, good quality seed and Good Agricultural Practices (GAPs) in crop management. This has left the soils impoverished and imbalanced in terms of essential plant nutrients and crops susceptible to a range of biotic (e.g. diseases and pests) and abiotic stresses (e.g. drought, heat, salinity, climate change).

Inadequate investment in research and development has left the national agricultural research system (NARS) severely depleted so that generation of new technologies through research to overcome these challenges has slowed down to a trickle. Similarly, the national agricultural extension network has been depleted, fragmented and made ineffective during the last three decades, thus depriving the farmers of knowledge and advise on existing and emerging technologies to overcome the challenges that they are facing. Furthermore, arguably, Sri Lankan agriculture and its farmers have, for a long time, been dependent on cultivation practices which are heavily reliant on addition of large quantities of external inputs (e.g. inorganic fertilizer and synthetic pesticides).

There has been inadequate attention, willingness and effort on the part of all stakeholders to introduce and engage in agricultural practices which are less demanding on external inputs and aim to regenerate and replenish the resource pool in the croplands that are being used to produce the crops. Now, the Sri Lankan Agriculture is at a critical juncture where the substantially reduced economic capacity to provide external inputs has forced its stakeholders to explore options and avenues which will enable them to meet the national agricultural production targets

with reduced inputs. Thus, I would argue that we have a 'window of opportunity' to steer the Sri Lankan Agriculture towards a more sustainable pathway while engaging in efforts to increase its productivity. This is where 'Sustainable Intensification', comes in to focus for Sri Lanka at the present juncture.

Strategies for Sustainable Intensification (SI) in Sri Lanka and required paradigm shifts

Any SI strategy should satisfy three criteria for it to be implementable, effective, and adopted by the farmers. First and foremost, the strategy should be based on valid scientific principles. In addition, its environmental cost should be minimum. Furthermore, the strategy should be within the economic capability of the potential end-users (e.g. farmers) and also socially and culturally acceptable. The specific SI strategies that satisfy the scientific, environmental and socio-economic criteria are different for different scales of agricultural production. Accordingly, the strategies that may be applicable to large scale and extensive production systems such as plantation crops and paddy would be different from the SI strategies that are suitable in small-scale and subsistence farming systems which produce a high proportion of the Other Field Crops (OFCs) and vegetables in Sri Lanka.

Some key paradigm shifts are essential in identifying feasible SI strategies for different production systems in Sri Lanka. Currently, the specific crops (and specific crop varieties) are selected via a crop-based approach, which is determined by climatic and soil considerations as well as by economic (e.g. market forces) and social considerations (e.g. farmer preference) with little consideration on sustaining and regenerating the resource base (e.g. nutrient recycling, soil conservation etc.). Selection of crops to be grown based on a 'Cropping Systems Approach' (instead of a crop-based approach) constitutes a key paradigm shift in moving Sri Lankan Agriculture towards SI. Such a paradigm shift forces all key players (e.g. farmers, researchers, extensionists and policy makers) to explore the possibility of crop rotations, crop mixtures (e.g. intercropping), cover crops, 'crops for the period between seasons' and fallowing, where minimizing resource losses and maximizing resource recycling are given due consideration in decision-making.

A second paradigm shift that is needed for SI of Sri Lankan Agriculture is to shift focus from attempting to maximize yield per unit land area to maximize yield per unit of limiting resources (e.g. maximizing yield per unit of water used and yield per unit of nitrogen used etc..). This requires a significant shift of focus in crop improvement programs through plant breeding from developing higher yielding varieties to developing varieties with greater resource use efficiency which give an adequate, but not necessarily the highest, yield. Development of these new resource-efficient varieties should be accompanied by the development of a range of new agronomic crop management practices/strategies/packages which focus on the key requirements of SI (i.e. sustainability of the resource base). In particular, these strategies include irrigation and water management practices which minimize evaporative losses while maximizing efficient delivery and uptake and nutrient management practices to minimize leaching and volatilization losses while releasing the nutrients which are fixed in the soil minerals.

Shifting from single strategy-based crop management to integrated crop management is the third paradigm shift that is needed to move Sri Lankan Agriculture towards SI. Most single strategy-based crop management practices (e.g. crop protection, nutrient management etc.) are heavily reliant on inorganic and synthetic substances. Broadening the strategies used and

thereby reducing their reliance on synthetic substances during crop protection (e.g. Integrated Pest Management) and nutrient management (Integrated Nutrient Management) addresses one of the key requirements of SI by ensuring protection of the agroecosystem and its services (e.g. biodiversity, clean water, safer food etc.).

Strategies to address the challenges posed by climate change on Sustainable Intensification

Cropping systems in all climatic zones of Sri Lanka at the lower (< 600 m above sea level) elevations are highly vulnerable to increasing temperatures and rainfall variability, two of the key features of climate change. Even those at higher elevations are not immune to these persistent trends in the climate because the crops and cropping systems at these elevations have evolved to be adapted to a lower temperature regime, which has been shown to be increasing at a faster rate than at the lower elevations. Accordingly, incorporation of heat tolerance to all crops grown in Sri Lanka via a focused and sustained plant breeding effort is an essential medium-to long-term need. Agronomic interventions to reduce the energy load on crops and soils should be introduced concurrently with the plant breeding efforts, which are not going to yield new heat tolerant varieties in the near future. In this regard, incorporation of shade in to agricultural fields via suitable tree and shrub species, preferably leguminous trees, will be a win-win situation where several requirements for SI can also be fulfilled. The reduced radiation energy on the crop surface will reduce canopy temperature and thereby reduce the incidence of heat stress. Concurrent reduction of evapotranspiration rates will contribute to conservation of water and thereby increase the crops' capacity to avoid possible drought periods. In addition to the amelioration of the crop's microclimate, when properly managed through lopping and pruning, the shade trees can provide a supply of organic material to the soil and thereby ensure nutrient recycling. A mulch of organic material will not only provide protection against building up excessive soil temperatures, but also help in conserving soil moisture. Furthermore, the input of organic materials, their decomposition will bring about significant changes in the soil microbial population and thereby set in motion many of the soil biological, physico-chemical and ecological processes which are required for sustained regeneration of soil fertility. Incorporation of leguminous tree/shrub species will enable the harnessing of their ability to fix atmospheric nitrogen and thereby potentially reduce the requirement of inorganic nitrogen fertilizer.

Climate change is likely to accelerate crop developmental processes via increasing temperatures. While increasing temperatures have the possibility to increase crop growth rates in currently cooler climates via increased photosynthetic rates, they are most likely to decrease growth rates in crops in the currently warmer climates via decreased photosynthetic rates and increased respiration rates. Similarly, all soil biological processes including decomposition of added organic material and release of nutrients through mineralization will be accelerated by the increased temperatures. Increased frequency of intermittent and terminal droughts will exert further limitations on crop growth and yields. These impacts of climate change will require careful fine tuning of the cropping systems and their management to increase resilience.

Many of the SI strategies have synergy with increasing crop resilience to climate change. For example, increasing water use efficiency of crops increase their drought tolerance. Strategies for increasing nutrient use efficiency can be synergized with strategies to reduce the emission greenhouse gases such as nitrous oxides. Alternative water management strategies such as Alternate Wetting and Drying (AWD) and aerobic rice, which are primarily designed to reduce

the total water use in rice cultivation, concurrently reduce methane emissions from rice fields. On the other hand, increased additions of organic material to crop lands could increase carbon dioxide emissions. Therefore, careful management of different SI strategies is needed to maximize their benefits while minimizing their adverse impacts.

Concluding remarks

Sri Lankan Agriculture is at a critical juncture at present with a huge cloud hanging over its sustainability and capacity to ensure national food security in the face of biophysical challenges such as climate change, decreasing soil fertility and stagnating yields and socio-economic challenges such as increasing costs of production and decreasing farmer profits. Meeting these challenges require paradigm shifts in the way all stakeholders (i.e. farmers, researchers, extensionists, policy makers and all others in the entire value chain) approach the task of producing sufficient and safe food to the Sri Lankan people in an economically and environmentally sustainable manner. This situation presents an opportunity to have a new perspective and seek innovative and 'out-of-the box' solutions, especially while the Sri Lankan Agriculture is struggling to recover from the upheavals of recent policy decisions. In this regard, Sustainable Intensification offers a strategy and a set of practices among many others to all stakeholders, especially the farmers, researchers, extensionists and policy makers, to serious consider implementing. It is significant to note that Sustainable Intensification is increasingly adopted by a wide range of countries in all continents. Hence, it is appropriate that Sri Lanka is not left behind, but explores the potential of Sustainable Intensification for resolving the critical issues that its food production system and its associated value chain faces.

W.A.J.M. De Costa
Senior Professor and Chair of Crop Science
Faculty of Agriculture
University of Peradeniya
Sri Lanka

KEY NOTE -2
3rd International Symposium on Agriculture

Trace Elements under Regenerative Management

The composition of New Zealand pastures has changed with time in response to increasing incidence of drought, resistance of livestock to anthelmintics, and adaptations to greenhouse gas emissions (Bryant et al., 2019). The traditional New Zealand pasture cover dominated by ryegrass and clover mixture has been gradually replaced by a range of forage species such as chicory and plantain. These forage species have shown greater adaptability to persist under dry conditions which are now becoming prevalent in New Zealand summers. Further, several studies have demonstrated that inclusion of chicory and plantain in grazing systems may lead to reductions in nitrous oxide emissions from farms. However, there are some known risks in the use of these forage species. For example, soil cadmium (Cd) concentration has been shown to be particularly enriched under long-term dairy land use in New Zealand due to the typically-intensive phosphorus fertilisation history of these farm systems (Stafford et al., 2018). Chicory has been shown to concentrate the trace metal Cd to a concentration that can be 50 times higher than in ryegrass (Stafford et al., 2016; Ubeynarayana et al., 2021). Increase in Cd intake by animals through forage can impact the health of both animals and humans, and there are strict limits on the maximum permissible concentration of Cd in food stuffs. Strong evidence has been presented in a recent Massey University study showed a significantly higher concentration of Cd in the liver of lambs eating chicory relative to ryegrass (Anderson et al., 2022).

In recent years, regenerative agriculture is increasingly being adopted in New Zealand. It is a farming practice that utilises diverse pasture species which include longer rooted species to improve numerous aspects of agriculture, including, soil microbial diversity, carbon sequestration, nutrient cycling, mitigation of greenhouse gas emissions, and animal welfare and production. Both the Ministry of Primary Industries (MPI) and the Primary Sector Council, New Zealand have recognised regenerative agriculture in the 'Fit for a Better World' vision for the agricultural sector (Ministry of Primary Industries, 2019). Diverse species are also known to accumulate a higher concentration of many essential trace metals (copper, zinc, iron, molybdenum, cobalt, and selenium) than ryegrass alone (Hogh-Jensen et al., 2006; Wei et al., 2022). This could be a solution for the occurrence of essential trace element deficiency in grazing animals. The majority of farm animals in New Zealand graze pasture year-round, inadequate intake of cobalt, copper, iodine, and selenium is prevalent (Grace and Knowles, 2012). Adequate levels of zinc in forage could reduce the incidence of facial eczema in sheep and cattle, an issue that is expected to increase in severity with climate change. On the other hand, a strong interaction with zinc has previously been reported, and zinc fertilisation is one recommended amelioration strategy for high Cd levels in crops (Fertiliser Association, 2019; Gray et al., 2019). Therefore, there is potential that the benefits associated with this greater concentration of essential trace elements will offset any risk of elevated Cd concentration in forage crops.

Further, recent Massey University studies by Matse et al., (2021, 2022) have demonstrated that copper is a main cofactor for ammonia monooxygenase (AMO) enzyme which catalyses the first step of ammonia oxidation to hydroxylamine in the nitrification process. We demonstrated

that an increase in soil bioavailable copper can increase nitrification, while a reduction in bioavailability can reduce the nitrification rate. Therefore, manipulating bioavailable copper in soil can be applied as a potential nitrification mitigation strategy in pastoral systems. The increase uptake of trace elements by forage species could be used to reduce the bioavailable copper concentration in soil and therefore inhibit AMO enzymic activity, and consequently the nitrification rate. Matse et al., (2023) have demonstrated that reducing soil bioavailable copper can reduce nitrification rate in urine patches by reducing the ammonia oxidizing bacteria *amoA* gene abundance. A reduction in ammonia oxidation reduces the accumulation of nitrate in soil and helps to keep nitrogen in the ammonia form. Reducing nitrate accumulation can also influence nitrous oxide emission in pastoral systems because nitrate is the main substrate of nitrous oxide emission. The use of forage species to reduce bioavailable copper in pastoral soils through increase in uptake can be a potential mitigation strategy that can not only have environmental benefits, but it can also have economic benefits by reducing the copper deficiency in pasture for grazing animals. A study about trace elements uptake and translocation in diverse pasture species under New Zealand's regenerative pastoral system now creates the opportunity for a project that can assess the possible impacts on the mobility of essential and toxic trace elements into plants and animals. A comprehensive MPI funded 7-year farmlet study has recently started at Massey University, comparing regenerative and contemporary pasture management under dairy and sheep systems.

In addition, the low trace element status of many New Zealand soils can lead to sub-optimal nutrient contents in our export agricultural products. This is a potential risk to the New Zealand economy as today's health-conscious consumers are becoming increasingly concerned about the health and nutritional value of their foods (e.g. Functional foods). In New Zealand, the chemical, physical and biological properties of tephra-rich soil represent an opportunity for agriculture and horticulture to lift production: soils influenced by volcanic activity cover 31 percent of the North Island of New Zealand's total land area. Our regenerative management project in allophanic soils targets a higher value for New Zealand agricultural products grown on the underutilised resource of volcanic lands.

Opportunities and risks differ regionally but experience with implementation of the New Zealand farming strategies and management practices may also help inform consideration of land management for high-value agriculture production elsewhere, in countries with less extreme climates, and higher quality soils such as Sri Lanka.

1. Anderson, CWN, Smith, SL, Jeyakumar, P, Thompson-Morrison, H & Cavanagh, JAE (2022). Forage crops and cadmium: How changing farming systems might impact cadmium accumulation in animals. *Science of the Total Environment. 827*, 154256. doi: 10.1016/j.scitotenv.2022.154256
2. Bryant, RH, Snow, VO, Shorten, PR, Welten, BG (2020). Can alternative forages substantially reduce N leaching? findings from a review and associated modelling, *New Zealand Journal of Agricultural Research*, 63(1), 3-28, doi: 10.1080/00288233.2019.1680395
3. Fertiliser Association (2019). Tiered Fertiliser Management System for soil cadmium [version 3]. Fertiliser Association of New Zealand, Wellington, New Zealand. 13 p. https://www.fertiliser.org.nz/includes/download.ashx?ID=156360.

4. Grace, N, & Knowles, SO (2012). Trace element supplementation of livestock in New Zealand: meeting the challenges of free-range grazing systems. *Veterinary Medicine International*. 2012, 639472. doi: 10.1155/2012/639472
5. Gray, CW, Yi, Z, Munir, K, Lehto, NJ, Robinson, BH, & Cavanagh, JAE (2019). Cadmium concentrations in New Zealand wheat: effect of cultivar type, soil properties, and crop management. *Journal of Environmental Quality*, 48, 701–708. doi: 10.2134/jeq2018.12.0430
6. Høgh-Jensen, H, Nielsen, B, & Thamsborg, MS (2006). Productivity and quality, competition and facilitation of chicory in ryegrass/legume-based pastures under various nitrogen supply levels. *European Journal of Agronomy*, 24, 247-256. doi:10.1016/j.eja.2005.10.007
7. Matse, DT, Jeyakumar, P, Bishop, P, & Anderson, CWN (2023). Copper induces nitrification by ammonia-oxidizing bacteria and archaea in pastoral soils. *Journal of Environmental Quality*. 15. doi: 10.1002/jeq2.20440
8. Matse, DT, Jeyakumar, P, Bishop, P, & Anderson, CWN (2022). Nitrate leaching mitigation options in two dairy pastoral soils and climatic conditions in New Zealand. *Plants*. 11(18), 2430. doi: 10.3390/plants11182430
9. Matse, DT, Jeyakumar, P, Bishop, P & Anderson, CWN (2021). Bioavailable Cu can influence nitrification rate in New Zealand dairy farm soils. *Journal of Soils and Sediments*. 22, 916-930. doi: 10.1007/s11368-021-03113-8
10. Ministry of Primary Industries (2019). Fit for a Better World (online). Available from https://fitforabetterworld.org.nz/
11. Stafford AD, Palmer AS, Jeyakumar P, Hedley MJ, & Anderson CWN (2018). Soil cadmium and New Zealand dairy farms: Impact of whole-farm contaminant variability on environmental management. *Agriculture, Ecosystems & Environment*, 254, 282-291. doi: 10.1016/j.agee.2017.11.033
12. Stafford, AD, Anderson, CWN, Hedley, MJ, & McDowell, RW (2016). Cadmium accumulation by forage species used in New Zealand livestock grazing systems. *Geoderma Regional*, 7, 11-18. doi: 10.1016/j.geodrs.2015.11.003
13. Ubeynarayana, N, Jeyakumar, P, Bishop, P, Pereira, RC, & Anderson, CWN (2021). Effect of soil cadmium on root organic acid secretion by forage crops. *Environmental Pollution*, 268. doi: 10.1016/j.envpol.2020.115839
14. Wei, Z, Maxwell, TMR, Robinson, B, & Dickinson, N (2022). Legume nutrition is improved by neighbouring grasses. *Plant Soil* 475, 443–455 (2022). doi: 10.1007/s11104-022-05379-4

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IMPACT OF WATER STRESS ON GROWTH AND YIELD PERFORMANCES OF TOMATO (*Lycopersicon esculentum* Mill)

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Abstract

Scarcity of water during "*Yala"* season is crucial problem specially for vegetables in Dry zone areas of Sri Lanka and the study of crop performances under water scarcity are important for efficient water usage in drier areas. Hence, the study was carried out for tomato (*Lycopersicon esculentum* Mill) with the objective to assess the growth and yield performances under different moisture levels at Department of Agronomy, Faculty of Agriculture, University of Jaffna, Kilinochchi during the period from January to May, 2015. Tomato variety KC-1 was selected and subjected to three treatments such as 100%, 85% and 70% of field capacity levels under randomized complete block design (RCBD) with fifteen replicates. The seedlings of tomato were transplanted in pots 21 days after sowing. The growth and yield parameters of plant height, number of leaves, flower formation and fruits setting, root depth, root volume, shoot: root volume ratio, flower abortion, fruit number and yield were measured and data were analyzed using analysis of variance (ANOVA). The study revealed that water stress caused significant decreases in growth parameters (plant height, leaf water content, leaf number) and yield parameters like flower and fruit number ultimately influence crop yield. The treatment 70 % of field capacity had significant impact on plant height and leaf numbers and it was reduced by 20.68% and 10.63% respectively. Root volume increased significantly by 18.5%. Shoot: root ratio also reduced by 9.1%. The highest reduction of flower formation (17.13%), and yield reductions were observed (38%) at 70 % of field capacity compared to 100% of field capacity. The significantly higher growth and number of flowers (4.15%) and 5% higher yield (36.508 t/ha) were recorded at 85% of field capacity compared to 100% of field capacity. It could be concluded that Tomato performed extremely well under 85% of field capacity and this is ideal for saving water rather than applying more water to maintain under full field capacity.

Keywords: Field capacity, growth, impact, tomato, water stress and yield

Introduction

Water stress is one the abiotic stress that affects the crop growth and yield. A plant becomes water stress either when water supply to roots becomes limiting or when the transpiration rates becomes intense. Drought stress (water deficit or low water availability) is a tricky problem that widely distributed worldwide over 1.2 billion ha in rain fed agricultural land (Passioura, 2007). These reasons emphasis on developing methods of irrigation that minimize water use or maximize the water use efficiency. Water deficit condition significantly influences the vegetative growth, physiological responses and yield especially in tomato under arid conditions. Deficit irrigation (DI) is one of the efficient water usage methods that could help not only in reducing production costs, but also in conserving water in order to minimizing leaching of nutrients and pesticides into ground water. In water-limiting production systems, DI as a management tool for tomatoes could be very effective in this respect. Tomato (*Lycopersicon esculentum* Mill) is one of the most popular and versatile vegetable crops that attain a high and

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stable growth and development under deficient moisture all over the world. It is sensitive to a number of environmental stresses; especially inadequate moisture stresses (Kalloo, 1993).

In Northern Province of Sri Lanka, scarcity of irrigation water is the common problem during *Yala* season due to less rainfall. There is an urgent need to increase the food production with limited water usage to satisfy food requirements. There were no literatures available regarding water stress study on vegetable crops in Northern region of Sri Lanka. This study is very important for better and efficient water management especially in *Yala* season. Therefore, a new study was carried out in Ariviyal Nagar, Kilinochchi to evaluate an "impact of water stress on growth and yield performance of tomato".

Materials and Methods

An experiment was conducted at Department of Agronomy, Faculty of Agriculture, Ariviyal Nagar in Kilinochchi during January to May, 2015 to evaluate the impact of root and shoot phenology on growth and yield performances of tomatoes under the water stress condition. The experimental site receives an average rainfall of 415.33 mm and average temperatures 28.4-34.5 ^{o}C (max) and 19.7- 24 ^{o}C (min). Twenty-one days old tomato seedlings were obtained from District Agricultural training Centre, Jaffna and transplanted two seedlings per pot that contained 18 kg potting mixture (at the ratio of 2:1 soil: compost). Pots were filled up to field capacity level and it was maintained as uniform up to two weeks. After two weeks of transplanting, three treatments were arranged in Completely Randomized Block design (RCBD) with 15 replicates under polyethylene covered structures. Pots were kept under the poly tunnel to avoid the rainfall impact. Treatments included T_1 (100% of field capacity), T_2 (85% of field capacity) and T_3 (70% of field capacity). The measured amount of water was added daily to maintain the above field capacity level by using soil moisture meter to compensate losses through evapotranspiration.

Parameters and Data collection

Growth parameters measured included: plant height(cm) from the stem base up to shoot apex, number of leaves, total number of flowers initiated and number of flowers which formed fruits data were collected at every 2 weeks' interval up to end of the experimental period. Root depth, root volume and shoot: root volume ratio were taken at 4 weeks' interval. The root and shoot volumes were measured by actual volume displacement, the volume of water displaced was measured when plant tissue is submerged in a vessel of water (Novoselov, 1960). Flower abortion (Infertile flower formation) rate (%) was calculated based on the formation of flower buds and fruit primordia.

$$\text{Flower abortion rate}(\%) = \frac{(\text{TFB} - \text{FRP})}{\text{TFB}}$$

Where, TFB-Total number of flower buds formed and TFR-Total number of fruits produced. Tomato fruits were harvested at ripening stage and fruit weight was measured. Equatorial diameter of the fruits and peel thickness were measured in 5 fruits from each treatment at every harvest by using Vernier calliper. Fruit length and fruit stalk length also were measured by using measuring tape. Dry and fresh weights were measured by using electronic balance. The reduction in the total yield compared with 100% of field capacity level, water saving and Water use efficiency (WUE) were computed as follows by using following equations (Zotarelli*et al.*, 2009).

$$\text{The reduction of yield} = \frac{(\text{Yield at 100\% of field capacity} - \text{Yield at of 70\% capacity})}{\text{Yield at 100\% of field capacity}}$$

$$\text{Water saving} = \frac{[Applied\ water\ at\ 100\%\ of\ F.C] - [\text{Appliedwater at 85\% or 70\% of F.C}]}{\text{Applied water at 100\% of F.C}}$$

$$\text{Water Use Efficiency (WUE)} = \frac{\text{Crop yield(kg/ha)}}{\text{(Total water supply)}}$$

Data analysis

The data collected were subjected to Analysis of Variance (ANOVA) using SAS version 9.1. Significant means were separated using the Duncan Multiple Range Test (DMRT) at $\alpha \leq 0.05$.

Results and Discussion

Plant Height

Changes in plant height were used to study the effect of water stress on growth of tomato plants. Plant height difference in tomato under 100% (T_1), 85% (T_2) and 70% (T_3) moisture regimes were significantly differed throughout the growing period (Figure 1). Plant height under treatments of 100% (T_1) and 85% moisture regimes (T_2) were not significantly differed at flowering stages, fruit setting and maturity stages. In seedling, there was a significant difference in plant height under the treatments of 100% (T_1) and 85% moisture regimes (T_2). Under 70% moisture regimes tomato showed 20.6% lesser plant height. The reason could be low increase in plant height under extreme deficit possibly due to reduced cell turgor which affects cell division and expansion (Luvaha *et al*., 2008).

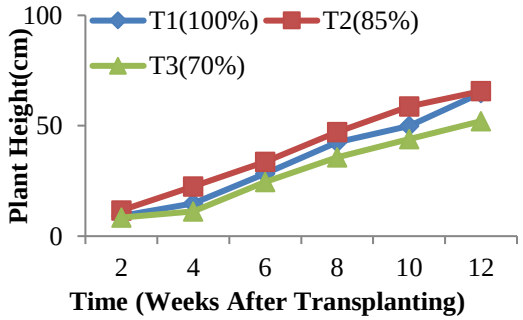

Figure 1: Plant height variations with different treatments

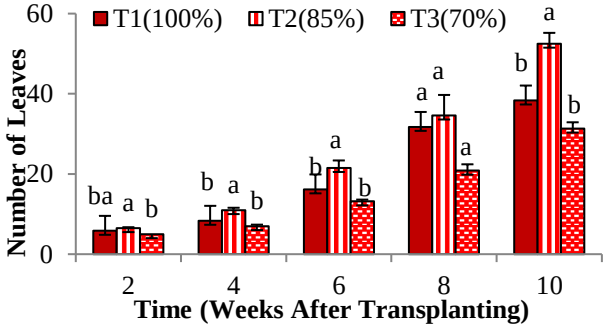

Figure 2: Leaf formation influenced by different treatments

Number of leaves

The highest leaf formation was observed (Figure 2) in moisture regimes 85% (T1), whereas the lowest leaf formation was observed in 70% moisture regimes (T_3). Water stress reduced the leaf number, relative leaf expansion rate and plant height depends on the stage of development, particularly when water stress occurred during the vegetative stage (Kacperska *et al*., 1989).

Flower formation and Fruit setting

The formation of number flowers was significantly differed among the treatments (Figure 3). At 85% moisture regimes, the highest flower formation was observed in tomato. Irrigation deficit in the initial growth period of tomato reduced the number of flowers leading to a decrease in the number of fruits and in the marketable yield (Colla *et al*., 1999). At 70% moisture regimes 17.13% flower number reduction and 4.15% highest number of flowers at 85% moisture regimes was observed compared to 100% moisture regimes. Water deficit (70% moisture regimes) had reduced the number of flowers produced. The highest percentage fruit formation was observed at 85% moisture regimes compared to other moisture regimes.Under the 70% moisture regimes,fruit formation had lowest number that showed the reduction of fruit number by 25.56% and highest at 85% moisture regimes by 33.9% compared to control. Water stress severely affects flower formation and later, fruit setting (Losada and Ridcon (1994).

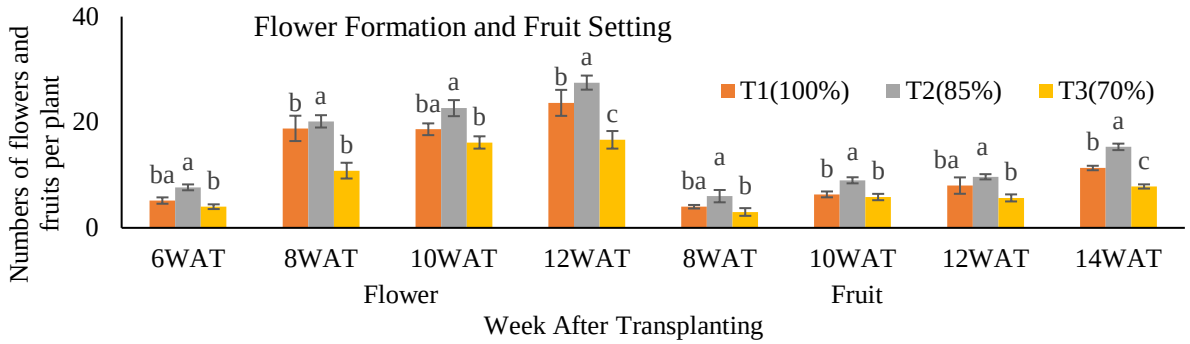

Figure 3: Flower development and fruit setting influenced by different treatments

Root Depth

The root depth had significantly differed in different moisture regimes in tomato. At moisture level 85%, plant had higher mean root depth and lesser mean depth under 100%. Water stress increased more root development. Tomato under 70% moisture regimes had deep rooting would become a more common trend in less extreme dry areas (Kummerow, 1980).

Root Volume

The moisture regimes had significant influenced on root volume in tomato. At 85% moisture regimes plant had higher root volume throughout the study and lower mean value under 100% moisture regimes. The adaptation of root for the water stress condition in that area.

Shoot: Root Volume Ratio

In tomato, initial stage after transplanting, shoot: root volume ratio was highest at 85% moisture regimes (moderate moisture level). But flowering and fruit setting time, root volume was highly significant than other treatments. Therefore, later stage the ratio was reduced under 85% moisture regimes.

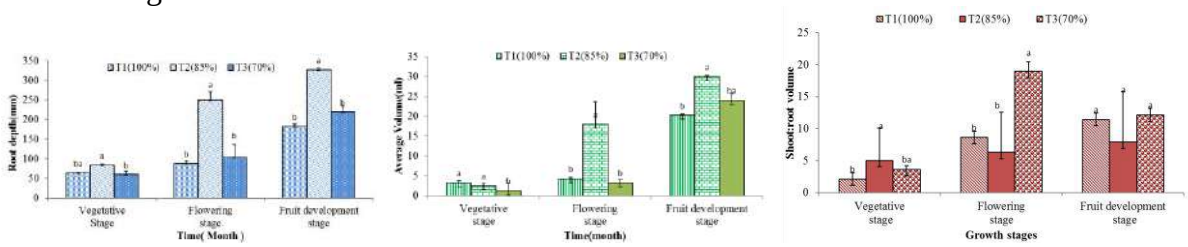

Figure 4: Root depth, root volume and shoot: root volume ratio influenced by different treatments in tomato.

Yield Parameters

Soil moisture deficit had an effect on abortion rate, fruit diameter, peel thickness, number of fruits per plant and yield per hectare.

Flower Abortion

The results confirmed significant differences in flower abortion among the treatments (Table 1). The highest percentage (43.67%) of aborted flowers was recorded in 70% moisture regimes in tomato. The plants showed less number of flowers abortion at 85% moisture regimes (moderate stressed plants). The number of flower buds that failed to form fruit, increased with a decrease in water levels. Mahendran and Bandara (2000) observed that when plants were exposed to moisture stress at the flowering stage, a severe flowering occurred.

Fruit Number and Yield

Significant differences were noted between the treatments regarding the number of fruits per plant and average length, diameter and weight of fruits. The lowest yield was obtained in 70% moisture regimes and there were not significant differences between 100% and 85% moisture

regimes. While the highest fruit yield of 36.51 t/ha was observed in plants subjected to the 85% moisture regimes in tomato.

Table 1: Effect of water stress on yield and yield attributes of tomatoes

Treatments	Yield (g/plant)	Flowers per plant	Fruits per Plant	Flower Abortion Rate (%)	Fruit fresh weight (g)	Fruit dry weight (g)	Fruit length (cm)	Fruit Diameter (cm)	Peel thickness (mm)
100%SM.R	1390.40[a]	48.17[a]	30.00[b]	37.72 [b]	48.85 [a]	10.80[a]	4.03[b]	3.95[b]	3.17[b]
85% S.M.R	1460.40[a]	50.17[a]	40.17[a]	19.93[c]	52.72[a]	11.90[a]	4.65[a]	4.41[a]	3.63[a]
70% S.M.R	861.50[b]	39.83[b]	22.33[c]	43.93[a]	37.04[b]	9.75[a]	3.73[c]	3.61[c]	2.21[c]

In a column, means followed by a common letter are not significantly different at 5 % level by DMRT.

Table 2: Potential yield reduction (%) and water saving (%) in different water level treatments

Treatments	Total Yield until 4Picking (kg/ha)	Total Water Applied (ml)	Crop WUE (kg/ha/ml)	Yield Ratio to 100%Moisture Level (%)	Yield Increase Reduction (%)	Water Saving (%)
T_1 (100%)	34760.79	23,910.00	1.45	100.00	0.00	0.00
T_2 (85%)	36508.77	20,490.00	1.79	105.02	+5.02	14.30
T_3 (70%)	21538.58	16,967.50	1.27	61.96	-38.04	29.04

In a column, means followed by a common letter are not significantly different at 5 % level by DMRT.

Conclusion

The tomato found to be sensitive to water stress especially if watering is limited. Different watering regimes affect the growth and yield of tomato at different growth stages. Water deficit reduced the plant growth by reducing number of leaves, leaf water content, and shoot height, flower and fruit number. Under water stress condition plant produced deeper root than the field capacity level (100%). Root: shoot ratio increased with increasing water deficit conditions. Crop growth and yield were increased under the 85 % moisture regimes and reduction was observed at 70 % moisture regimes. Therefore, in overall study based on the growth and yield of tomato, the best crop performances were obtained at 85% of moisture regimes and it saved the applied water considerably than field capacity level.

References

Adams, P. (1990), Effects of watering on the yield, quality and composition of tomatoes grown in bags of peat, *J. Hort.Sci65* (6):667-674.

Colla, G., R.Casa, B.Lo Cascio, F.Saccardo C.Leoni and O.Temperini. (1999), Response for processing tomato to water regimes and fertilization in central Italy.Acta Hort.487:531-535.

Kalloo,G. (1991). Introduction .In: Genetic Improvement of Tomato,ed,G.Kalloo,1,9 .*Monographs on Theoretical and Applied Genetics*,Vol. 14,Springer-Verlag,Berlin.

Losada, H.P.and Rincon. (1994), Influence of the crop water status on fruit setting and final fruit number in the processing tomato crop.*Acta Hort*.376:333-336.

Luvaha E., Netondo G.W. and Ouma G. (2008), Effect of water deficit on the physiological and morphological characteristics of mango (*Mangifera indica*) rootstock seedlings. American *Journal of Plant Physiology*. 3(1): 1-15.

Mahendran, S. & D.C. Bandara. (2000), Effects of soil moisture stress at different growth stages on vitamin C, capsaicin, and β-carotene contents of chilli (*Capsicum annum* L.) fruits and their impact on yield. *Tropical Agricultural Research* 12: 95-106.

Novoselov VS. (1960), A closed volumeter for plant root systems. Fiziologiya Rastenii 7:243-244.

Passioura, J.B. & Angus, J.F. (2007). Improving productivity of crops in water-limited environments. *Advances in Agronomy*, 106: 37–75.

Zotarelli L, Scholberg J, Dukes M, oz-Carpena R, Icerman J. (2009), Tomato yield, biomass accumulation, root distribution and irrigation water use efficiency on a sandy soil, as affected by nitrogen rate and irrigation scheduling. *Agric Water Manag*. 2009; 96:23-34.

THE EFFECTS OF DIFFERENT VERMIWASH ON THE CULTIVATION OF *Spirulina platensis*

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Abstract

The *Spirulina platensis* is quite spread all over the world due to its high nutritional value and *Spirulina* is capable to grow in various kinds of cultural media. Looking out for natural forms of fertilizers is increasing. This study aimed to determine the influence of various concentrations of vermiwash on the growth of *S.platensis*. Four concentrations of vermiwash fertilizer used (2, 5, 8 and 11 ml/L) and 10 ml/L of Zarrouk's medium was used as control. Among the treatments, the highest *Spirulina platensis* cell concentration was found in the concentration of 5 ml/L and also found to be the most effective concentration to increase in dry matter content of *Spirulina*. Consequently, it was seen that vermiwash have the potential to replace commercially used medium in S. *platensis* mass cultures to decrease the costs of production. This formulated vermiwash can be an effective nutrient solution for the mass cultivation of *Spirulina platensis.*

Keywords: Mass cultivation, *Spirulina*, vermiwash fertilizer

Introduction

Nowadays, the cost of fish feed is drastically increased, and this situation encourages us to use locally-available feeds and feed materials. The *Spirulina platensis* is the best source of essential nutrients and is easily cultivatable in different media (Hosseini *et al*., 2013). Spirulina is used as a complete or partial protein nutritional supplement in aquaculture through aquaculture feeds. Present *Spirulina cultivation* primarily depends on chemical fertilizers. The continuous use of chemical fertilizers has led to the contamination of water bodies and even food materials. This situation turned us to use organic fertilizers. The vermiwash obtained from vermicompost is an alternative liquid fertilizer to provide all essential nutrients for plant growth and production (Sreenivas, 2000). Therefore, the present study aimed to determine the influence of vermiwash in various concentrations on the growth of *Spirulina platensis*.

Materials and Methods

Preparation of Vermiwash

Vermicompost was prepared by using compost, cow dung and paddy straw. A tap fixed plastic container was selected. The layer of broken bricks and stone, coarse sand, fine sand, compost and cow dung with paddy straw were used to prepare the vermiwash container. Then, the earthworms (*Eisenia foetida*) were introduced into the compost in the container. The container was covered with gunny bags to shade the contents and protect them from direct sunlight. The clean water was sprinkled at regular intervals to maintain the moisture content of 70-80% humidity and temperature at 25-30 ºC. Vermiwash was collected after 45 days and used for further experiments.

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Determination of N, P, K percentages of Vermiwash

The pH, Nitrogen, Potassium and Phosphorus of Vermiwash were determined by using the methods described by Fishman and Friedman in 1989.

Preparation of Spirulina Mass Cultivation

Spirulina inoculum was collected from the Wet lab, Ornamental Fish breeding and Training centre, National Aquaculture Development Authority, Rambodagalla, Panagamuwa. The cultivation tanks were supplied with continuous light and aeration. The pH and temperature were maintained at 9-10 and 28 – 30 °C, respectively. After 24 hours, the sterilized vermiwash fertilizer was diluted with chlorinated water and 4 different treatment media were prepared. The five categories of formulation include vermiwash: culture media (T1- 2:1000, T2- 5:1000, T3- 8:1000, T4- 11:1000) and control (T5-10:1000 Zarrouks media) trials were separately maintained. Each treatment have three replicates.

Calculation of cell concentration and measurement of total dry weight

The cell density of all treatments was measured by using the Hemocytometer under the microscope (Tulashie and Salifu, 2017). The approximate total dry weight of the cultivation was manually measured.

Experimental Design

The completely randomized design was designed with triplicates. The data were statistically analysed using statistical analysis software version online academic packages. The one way ANOVA and for the mean separation, Duncan's multiple range test were performed at the significant level of $p<0.05$.

Results and Discussion

Composition of Vermiwash

The total N value of vermiwash fertilizer is 0.027%, the total P amount is 0.0057%, and the total K amount is 0.17% at the pH level of 8.9. Compared to commercial growth media used to cultivate *S. plantensis* the nutrient content in vermiwash was significantly low yet supported the growth of *spirulina* at a substantial growth rate.

Effect of different media on Cell growth during cultivation period

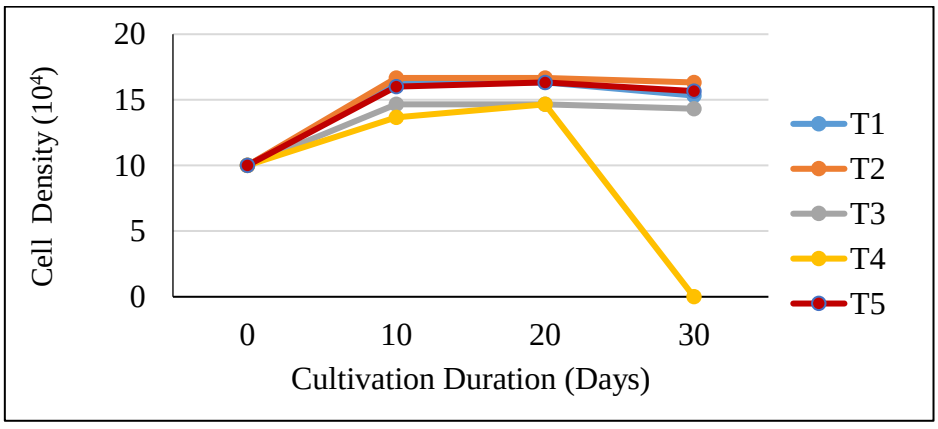

Figure 1: *Spirulina* cell growth in different media during cultivation period

Figure 1 shows that T2 had the highest cell concentration after one month. The study revealed that there is no significant difference between the cell concentrations of T1, T2 and T5 while T3 has a significant difference and the T4 has a significant deviation at the mass culture which resulted in no observable algae mass in the culture after the 30th day of observations. Because

of the unexpected environmental error. These findings were in agreement with the study done by Grover *et al.* (2019). The study discovered that vermiwash has positive growth-stimulating effects in freshwater microalgae in terms of growth rate and biomass.

Effect of vermiwash on the total dry weight of Spirulina

Table 1: Effect of vermiwash on *Spirulina* total dry weight

Treatment	Total number of observation	Mean ± SE
T1	16	0.39 ± 0.0002^{ab}
T2	16	0.43 ± 0.0002^{b}
T3	16	0.32 ± 0.0002^{ac}
T4	16	0.00 ± 0.0002^{c}
T5	16	0.38 ± 0.0002^{ab}

According to the Table 1, the different treatments have shown significant differences (P<.0001) in cell growth and dry weight. Treatment 2 showed the highest mean values among the other treatments.

Cost analysis for the vermiwash production

The total amount of vermiwash collected was 120 liters. The total operational cost for the vermiwash production was Rs. 4050.00. The cost for the production of 1liters vermiwash is Rs. 33.75. Therefore, the vermiwash can be made available for low price than commercially available chemical fertilizers.

Conclusion

The study revealed that among the treatments, the highest *Spirulina platensis* cell concentration was found in the concentration of 5 ml/L and also found to be the most effective concentration to increase in dry matter content of *Spirulina*. Consequently, it was seen that vermiwash fertilizers have the potential to replace commercially available medium in S. *platensis* mass cultures to decrease the costs of production. This formulated vermiwash can be an effective fertilizer for the mass cultivation of *Spirulina platensis.*

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References

Fishman, M.J. and Friedman, L.C. (1989). *Methods for Determination of Inorganic Substances in Water and Fluvial Sediments*. 3rd ed. Denver, Colo.: U.S. Dept. of the Interior, Geological Survey, pp.331–395.

Hosseini, S.M., Shahbazizadeh, S. and Khosravi-darani, K. (2013) 'Spirulina paltensis : Food and Function Spirulina paltensis : Food and Function', (July). doi:10.2174/1573401311309030003.

Grover, S., Sibi, G., Rubina, S. and Gowda, V.M. (2019). Utilization of Vermiwash to Promote Growth Rate and Biomass in Fresh Water Microalgae. *Trends in Applied Sciences Research*, 14(3), pp.205–209. doi:10.3923/tasr.2019.205.209.

Rekha, G.S., Valivittan, K. and Kaleena, P.K. (2013). Studies on the Influence of Vermicompost and Vermiwash on the Growth and Productivity of Black Gram (Vignamungo). *Advances in Biological Research*, 7(4), pp.114–121. doi:10.5829/idosi.abr.2013.7.4.73217.

Tulashie, S.K. and Salifu, S. (2017). Potential Production of Biodiesel from Green Microalgae. Biofuels, pp.1759–7277. doi:10.1080/17597269.2017.1348188.

DIFFERENT COMBINATIONS OF AMIRTHAKARAISAL AND COMPOST ON GROWTH AND YIELD OF *Vigna unguiculata* L.

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Abstract

This experiment was carried out at home garden in Ampara, Eastern province, Sri Lanka as a polybag experiment during the period of June to September, 2021 to investigate the different combinations of Amirthakaraisal and compost on growth and yield of *Vigna unguiculata*. The experiment was laid out in Completely Randomized Design (CRD) with six treatments and ten replications. The treatments were T1 (100% Amirthakaraisal), T2 (75% Amirthakaraisal +25% Compost), T3 (50% Amirthakaraisal + 50% Compost), T4 (25% Amirthakaraisal + 75% Compost), T5 (100% Compost), T6 (Control) and tested their performance on the growth and yield. In this investigation, the statistical analysis of data proved that 50% Amirthakaraisal liquid fertilizer and 50% compost gave the best performance when compared to other treatments. The 50% Amirthakaraisal and 50% compost (T3) increased plant height (9%), number of leaves per plant (18.29%), number of branches per plant (17.72%), fresh weight of shoot (14.02%), dry weight of shoot (28.33%), dry weight of roots (51.85%), root length (24.93%) total number of nodules per plant (20.62%), days for 50% flowering (15.36%), number of flowers per plant (52.38%), number of pods per plant (76.19%), fresh weight of pods (38.63%), dry weight of pods (61.41%), length of pods (39.28%), number of seeds per pod (57.44%), weight of seeds per pod (49.62%) , weight of 100 seeds (39.44%) and total yield per hectare (65.58%) compared to control. Therefore, the 50% of Amirthakaraisal and 50% of Compost (T3) fertilizer could be recommended to enhance the growth and yield of *Vigna unguiculata L.* which is environmentally friendly for sustainable agriculture.

Keywords: Amirthakaraisal, compost, *Vigna unguiculata,* organi*c* cultivation

Introduction

Cowpea is one of the important legume crops grown in Sri Lanka and mostly it is cultivated in dry zone and intermediate zone of the country. All cultivated cowpeas are grouped under the species *Vigna unguiculata.* Cowpea is high in protein, essential vitamins and minerals, unsaturated fatty acids, antioxidants, phenolic compounds, and soluble fiber and insoluble fiber (Liyanage *et al*., 2014). Chemical fertilizers improve crop productivity, but their excessive usage has harmed soil structure, polluted water and air and causing health and environmental risks. Inorganic fertilizers can improve crop yield and soil pH, total nutrient content, nutrient availability but their use is limited due to high cost, nutrient imbalance, scarcity and soil acidity. Use of organic manures as a means of maintaining and increasing soil fertility has been advocated.

Amirthakaraisal is organic manure that functions as a growth stimulant, growth promoter and immune booster. Amirthakaraisal proved its value by providing strength and great resistance to the crop. Some Macronutrients such as nitrogen, phosphorous, and potassium and Micronutrients such as Zinc, manganese, and copper along with reducing sugars are present in Amirthakaraisal. Composting has been defined as a biological process through which microorganisms convert organic materials into useful end products, which may be used as soil conditioners and/or organic fertilizers. Farm compost has 0.5% N, 0.15% P, and 0.5% K. The effective combination of Amirthakaraisal and compost is an essential step in harvesting high quality yield. However, the effect of different combinations of Amirthakaraisal and compost on

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cowpea growth and yield has not yet been reported. Therefore, the study was conducted to find the good combination of Amirthakaraisal and compost on cowpea growth and yield.

Materials and Method

Experimental site

A polybag experiment was carried out at the home garden in Ampara, Sri Lanka which is located in the Eastern Province of Sri Lanka during the period of June to September 2021. It is located in the latitude of 7° 18' 10.9" N, and longitude at 81° 40' 49.6" E at an elevation of 0 - 125 m above the mean sea level.

Climate and soil

It belongs to the agro-ecological region of low country dry zone of Sri Lanka. The average annual Temperature is 28 ± 2°C. The area receives a mean annual rainfall is less than 1750mm with a distinct dry season from May to September and long dry season (May to September) and a small rainy season (October to March). The predominant soil type of this area is non-classic brown.

Treatment codes and description

Table 1: Treatment Codes and Description

Treatment code	Description
T1	100% Amirthakaraisal
T2	75% Amirthakaraisal +25% Compost
T3	50% Amirthakaraisal + 50% Compost
T4	25% Amirthakaraisal + 75% Compost
T5	100% Compost
T6	Control

Preparation of polybags

This experiment was conducted by using polybags. The height and the diameter of the polybags were 30 cm and 30 cm respectively. The polybags were filled with topsoil and cow dung at the ratio of 1:1. A distance of one inch was left unfilled from the top of the soil to facilitate irrigation.

Preparation of Amirthakaraisal

Amirthakaraisal consists of two products from the cow (cow dung and cow urine) and jaggery. Materials used for the preparation of Amirthakaraisal are cow dung, cow urine, jaggery, and water. The steps involved in preparation of Amirthakaraisal are given in Figure 1.

Application

Once in two weeks different levels of Amirthakaraisal and compost organic fertilizer were applied to cowpea plants from two week after planting and their performances were recorded once at biweekly interval.

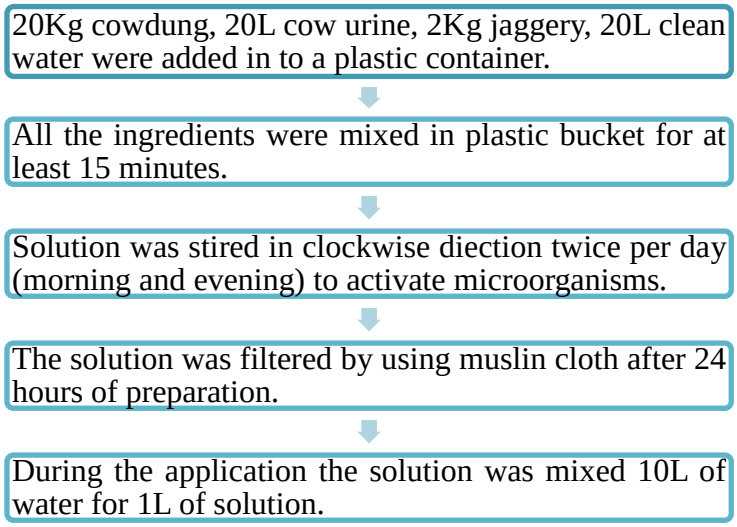

Figure 1: Steps involved with preparation of Amirthakaraisal

Results and Discussion

Dry weight of shoots

The dry weight of shoot of *Vigna unguiculata* L. is given below in Table 2. The results showed that changes in different levels of Amirthakaraisal and compost were significantly ($P<0.05$) affecting the dry weight of shoots of *Vigna unguiculata* L. This results in T3 treatment may be due to faster decomposition of organic manure, thereby increased availability of nitrogen which helps in protein synthesis and ultimately resulting in more dry matter production in plants (Ravisankar *et al.*, 2017). The cow dung and urine provide nitrogen which is essential for plant growth. The compost gives zinc (Zn) which influence the growth of shoots of plants (Karunarathna *et al.*, 2018)

Dry weight of roots

The dry weight of roots of *Vigna unguiculata* L. is given below in Table 2. This results of T3 might be due to the presence of microorganisms by combination of compost and Amirthakaraisal which increase the nutrient availability for cowpea production and thus increase the dry weight of roots as compared to the control. Amirthakaraisal increased the number of bacteria, fungi and soil invertebrates in soil. The use of compost can change plant-available micronutrients by changing both physical and biological characteristics of the soil.

Total number of nodules

The total number of nodules of *Vigna unguiculata* L. is given below in Table 2. This increased nodulation in T3 might be due to the increment of plant growth-promoting bacteria and other microorganisms by the combination of compost and Amirthakaraisal which encourage the nodulation of cowpea. Presence of plant growth-promoting bacteria and P-enriched compost is highly effective in improving the growth and nodulation of chickpea (Shahzad *et al.*, 2008). The effective microorganisms present in Amirthakaraisal improved soil quality, growth and yield of crops (Ketsiyal and Thatheyus, 2021).

Number of seeds per pod

The number of seeds per pod of *Vigna unguiculata* L. is given below in Table 2. This may be due to the high phosphorus content and high microbial population in Amirthakaraisal and compost. Amirthakaraisal contains a high amount of phosphorus due to cow dung and cow urine has increased microbial population in soil (Karunarathna *et al.*, 2018). Compost is known as a slow-release nutrient source of macro and micronutrients to the soil.

Weight of seeds per pod

The weight of seeds per pod of *Vigna unguiculata* L. is given below in Table 2. This treatment could be due to the presence of macro and micronutrients particularly Phosphorus in Amirthakaraisal and compost. Compost consists of nitrogen and phosphorous. Amirthakaraisal prepared by using cow dung. Cattle manure contains the three major plant nutrients such as nitrogen, phosphorus and potassium, as well as many essential nutrients such as Ca, Mg, S, Zn, B, Cu, Mn, etc.

Total yield (t/ha)

The total yield of *Vigna unguiculata* L. is given below in Table 2. This might be due to the increment of the microbial population by combination of compost and Amirthakaraisal which increase the nutrient availability in the soil helps to increase the yield. Effective microorganisms present in Amirthakaraisal improved soil quality, growth and yield (Ketsiyal and Thatheyus, 2021). The yield in the compost treatments increased compared to the unfertilized control in crops and crop quality was not affected by compost, but in some cases even improved.

Table 2: Effects of Different Combinations of Amirthakaraisal and Compost on Dry Weight of Shoots, Dry Weight of Roots, Total Number of Nodules, Number of Seeds Per Pod, Weight of Seeds Per Pod and Total Yield of *Vigna unguiculata* L. At 10 Weeks After Planting.

Treatments	Dry Weight of Shoot (g)	Dry Weight of Roots (g)	Total Number of Nodules	Number of Seeds Per Pod	Weight of Seeds Per Pod (g)	Total Yield (t/ha)
T1	18.80 ± 1.02^{b}	2.80 ± 0.32^{b}	39.50 ± 1.84^{b}	4.28 ± 0.62^{b}	1.29 ± 0.11^{b}	1.57 ± 0.19^{b}
T2	19.80 ± 0.92^{b}	3.10 ± 0.23^{b}	41.30 ± 0.68^{b}	6.00 ± 0.74^{ab}	1.59 ± 0.18^{b}	1.90 ± 0.16^{b}
T3	23.10 ± 1.67^{a}	4.10 ± 0.31^{a}	46.20 ± 1.84^{a}	7.40 ± 0.76^{a}	2.02 ± 0.14^{a}	2.55 ± 0.28^{a}
T4	18.10 ± 0.74^{b}	3.20 ± 0.19^{b}	40.70 ± 0.66^{b}	4.90 ± 0.70^{b}	1.46 ± 0.15^{b}	1.77 ± 0.27^{b}
T5	19.00 ± 0.96^{b}	3.00 ± 0.25^{b}	39.40 ± 1.35^{b}	5.20 ± 0.41^{b}	1.50 ± 0.12^{b}	1.87 ± 0.13^{b}
T6	18.00 ± 0.75^{b}	2.70 ± 0.36^{b}	38.30 ± 2.78^{b}	4.70 ± 0.57^{b}	1.35 ± 0.11^{b}	1.54 ± 0.21^{b}
F Test	*	*	*	*	*	*

Value represents mean ± standard error of 10 replicates.
** Represents significant at 5% level of probability.*
Mean values in a column having the dissimilar letter/letters indicates significant difference at 5% level of significance by Duncan's Multiple Range Test (DMRT).

Conclusion

In this investigation, the statistical analysis of data proved that application of 50% Amirthakaraisal and 50% compost in to soil increased the dry weight of shoot, dry weight of roots, total number of nodules per plant, fresh weight of pods, dry weight of pods, number of seeds per pod, weight of seeds per pod and total yield compared to the plants in other treatments. Therefore, the 50% Amirthakaraisal and 50% compost fertilizer could be recommended for the cultivation of *Vigna unguiculata L*. in order to enhance the growth and yield which is environmentally friendly for Sustainable Agriculture.

References

Abdelaziz, M.E., Pokluda, R. And Abdelwahab, M.M., 2007. Influence of compost, microorganisms and NPK fertilizer upon growth, chemical composition and essential oil production of Rosmarinus officinalis L. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, *35*(1), p.86.

Karunarathna, B., 2018. Effect of different concentration of organic liquid fertilizer 'Amirthakaraisal'on growth of Polyscias sp in Sandy Regosol. Effect of different concentration of organic liquid fertilizer 'Amirthakaraisal'on growth of Polyscias sp in Sandy Regosol, 15(1), pp.05-05.

Ketsiyal, J. and Thatheyus, A.J., 2021. Infleuence of Vermicompost, Amirthakaraisal and Abda Gold on the Growth of Capsicum annum. *Journal of Biotechnology Research*, 7(2), pp.18-26.

Liyanage, R., Perera, O. S., Weththasinghe, P., Jayawardana, B. C., Vidanaarachchi, J. K., & Sivakanesan, R. (2014). Nutritional properties and antioxidant content of commonly consumed cowpea cultivars in Sri Lanka. *Journal of Food Legumes*, 27(3), 215-217.

Ravisankar, N., Panwar, A. S., Prasad, K., Kumar, V., & Bhaskar, S. (2017). Organic Farming Crop Production Guide. Network Project on Organic Farming, ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut-250, 110, 586.

Shahzad, S. M., Khalid, A., Arshad, M., Khalid, M., & Mehboob, I. (2008). Integrated use of plant growth promoting bacteria and P-enriched compost for improving growth, yield and nodulation of chickpea. *Pakistan Journal of Botany*, 40(4), 1441-1735.

Swaminathan, C. and Nandhakumar, M.R., 2011. Vrkshayurvedic Farming-A Revisit and Review. *Madras Agriculture Journal*, 98(4-6), pp.99-108.

EFFECT OF SEED PELLETING TREATMENT WITH DIFFERENT LEAF POWDERS USING DIFFERENT BINDING MATERIALS ON GROWTH AND YIELD PERFORMANCE OF BLACK GRAM (*Vigna mungo* L.*)*

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Abstract

A field experiment was conducted at the Integrated Farm and Training Centre, Faculty of Agriculture, University of Jaffna, Puliyankulam, during the period from April to July 2022, to find out the effect of seed pelleting treatment with different leaf powders using different binding materials on the growth and yield performance of black gram (*Vigna mungo)* Anuradha variety. The study was carried out using six leaf powders (*Azadirachta indica* (Neem), *Prosopis juliflora*, *Pongamia pinnata* (Pungham), *Cassia auriculata*, *Annona squamosa* (Annona), and control) with three binding materials (Clay, Wheat flour, and *Aloe vera*). The experiment was carried out using a two factor factorial randomized complete block design with three replicates. Data were collected on nodulation, growth, and yield parameters and they were subjected to analysis of variance (ANOVA) to determine the effect and their interactions using SAS 9.1. Mean separation was done by using the Duncan test. Leaf powder treatment significantly ($p<0.05$) induced the nodulation in roots which led to the improvements on vegetative and yield parameters. Different binding materials has significantly ($p<0.05$) affected nodulation, and it influenced the number of nodules per plant and the growth and yield parameter of black gram. Considering all growth parameters (plant height, number of leaves, number of branches), yield parameters (number of pods, yield,) and number of nodules, Pungham leaf treatment was significantly ($p<0.05$) performed well among all six leaf powder treatments and *Aloe vera* binding material was significantly ($p<0.05$) performed well among all three-binding material. The interaction effect found to be non-significant. This experiment results revealed that Pungham leaf treatment and *Aloe vera* binding material improved the growth and yield performance of black gram. Further, the experiment indicated that without applying additional inorganic fertilizers, black gram can be cultivated. Therefore, the farmers could be advised to cultivate black gram effectively without applying inorganic fertilizers using leaf pelleting techniques using Pungham powder and *Aloe vera* gel as binding materials.

Keywords: Binding material, black gram, dry zone, leaf powder treatment, seed pelleting

Introduction

Worldwide, pulses are being a second most important group of crops (Anbarasan and Srimathi, 2015). Black gram (*Vigna mungo* L) is one of the most significant pulse crops and its belongs to Fabaceae family (Tandon and Chauhan, 2019). The average national productivity of black gram was recorded as 1.16 t/ha in 2020. However, the potential productivity of different black gram varieties; MI 1, Anuradha, MIBG3, MIBG4 is reported as 1.8 to 2 t/ha, 1.5 t/ha, 2.2 to 2.5 t/ha and 2 to 2.2 t/ha, respectively (Department of Census and Statistics, 2021). Anuradhapura, Vavuniya, Kurunegala, Kilinochchi, Batticaloa, and Jaffna are the major districts where black gram is primarily grown. The amount of black gram that is farmed and produced varies from year to year with a decreasing tendency (Economics division, DOA), according to the data that is currently available, and the overall production is insufficient to meet the demand. Population growth, lack of natural resource availability, and low agricultural production are some of the main issues in Sri Lanka in the recent past. Food scarcity is becoming a major issue, developing

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countries and must rely mostly on cereals, grains, starchy roots, and pulses for their protein needs (Kulasinghe,2019). Seed quality is regarded as a fundamental requirement to increase germination and uniform stand which can be improved through seed treatment, such as seed pelleting (Khatun *et al*., 2011). Pre-sowing seed treatments like seed pelleting aid to promote seed germination by overcoming challenging environmental factors like limited rainfall and dry soil (Vennila, 2018). Seed pelleting is the process of enclosing a seed in a little amount of inert material to create a globular unit of a standard size and deliver a modest amount of nutrients to young seedlings (Krishnasamy, 2003). A limited amount of growth-promoting chemicals given to the seed by seed pelleting. These compounds give new seedlings some nutrients during the early growth stage and improve the soil's ability to hold water near the area where roots emerge (Srimathi, 2013). The development of environmentally friendly crop production methods using natural resources is crucial in organic farming to minimize the dangers caused by the use of chemicals (Kavitha, 2009). Seed pelleting with different botanical leaf powders has been reported by several scientists, but there is a need to develop appropriate seed pelleting technology to increase the production of black gram. This study was conducted to study the effect of botanical seed pelleting by using different leaf powders with different binding materials on growth characters of black gram variety Anuradha.

Materials and Methods

A field experiment was carried out at the Integrated Farm and Training Centre, Faculty of Agriculture, University of Jaffna, Parasankulam, Puliyankulam during the period from April to July 2022. Vavuniya is located in the Northern Province of Sri Lanka, which is located at 8˚ 45’ 5.04” N latitude and 80˚ 29’ 49.56” E longitudes and belongs to DL1e agro-ecological region in the low country dry zone of Sri Lanka. The soil is well-drained well aerated reddish-brown soil. It consists of slightly sloppy topography and relatively flat land. The area receives a mean annual rainfall is about 1434mm.Anuradha variety was selected for this study. Due to the high demand from the consumers, this variety was chosen. A field experiment was conducted in two factor factorial randomized completed block design with three replicates. Black gram seeds were planted in the field at 30 cm × 10 cm. Three blocks were made and each block was further divided into eighteen plots with the size of 1.7 m x 1.8 m to accommodate the 18 treatment combinations. Three main blocks were separated by 1 m and every plot was separated by a ridge of 1 m. The furrows were made according to the row spacing.

Six different leaf powders were chosen for the pelleting experiment (T_1 - Neem leaf powder, T_2 - *Prosopis juliflora leaf powder*, T_3 - Pungham leaf powder, T_4 – *Cassia auriculata* leaf powder, T_5 – Annona leaf powder, T_6 – Control). The fresh leaves were collected separately and dried under shade conditions. The shade-dried leaves were powdered using a mixer grinder. A fine leaf powder was obtained by sieving through a 0.25mm sieve to remove unwanted material and leaf debris. Three different binding materials were taken (B_1 - Clay, B_2 – Wheat flour (Maida) and B_3 – *Aloe vera* gel). Wet clay was taken and allowed to dry fully for 2 days. Dried clay was ground and sieved to obtain fine clay powder. Maida and fresh *Aloe vera* gel were taken. The bulk seeds were cleaned manually to remove unwanted material from the seed lot. Pelleting was done by using 200 g/kg of the seed of leaf powder with 10% of the seed of binding material and water. Pelleted seeds were air dried for 2 days under shade to bring back to the normal moisture content.

Table 1: Treatment and their combination

Leaf powder	Binding material	Treatment code
Azadirachta indica	Clay	T_1B_1
	Wheat flour (Maida)	T_1B_2
	Aloe vera	T_1B_3
Prosopis juliflora	Clay	T_2B_1
	Wheat flour (Maida)	T_2B_2
	Aloe vera	T_2B_3
Pongamia pinnata	Clay	T_3B_1
	Wheat flour (Maida)	T_3B_2
	Aloe vera	T_3B_3
Cassia auriculata	Clay	T_4B_1
	Wheat flour (Maida)	T_4B_2
	Aloe vera	T_4B_3
Annona squamosa	*Clay*	T_5B_1
	Wheat flour (Maida)	T_5B_2
	Aloe vera	T_5B_3
Control	Clay	T_6B_1
	Wheat flour (Maida)	T_6B_2
	Aloe vera	T_6B_3

All agronomic practices were done as per the recommendation of the Department of Agriculture. Four plants were tagged in each plot to obtain the growth of and yield parameters such as plant height (cm), number of leaves, number of branches, number of pods per plant, seed yield (ton/ha). One plant was uprooted per plot weekly interval from four weeks after planting (WAP) to record the number of active nodules. The data were analyzed by using SAS 9.1 package. Mean separation was using Duncan Multiple Range Test.

Results and Discussion

Growth parameters

***Plant height (cm)*:** Plant height (Table 2) was significantly influenced by the different leaf powder treatments at any time of the growth stage except 4WAP. But control significantly differed from other leaf treatments. In 5WAP, 6WAP and 7WAP highest plant height was observed in Pungham Leaf treatment (78.26 cm) and followed by Annona leaf treatment. However, there were no significant differences observed among Annona, *Cassia*, *Prosopis* and Neem leaf powder treatment in 7WAP. Many researchers have reported the same finding that the increase in plant height by using Pungham leaf powder (Nadeem binzia, 1992). Plant height (Table 2) was significantly influenced by the different binding materials used for the pelleting at any time of the growth stage except 5WAP. The highest plant height was observed in *Aloe vera* binding material in 6WAP and 7WAP. It was significantly different from other binding materials such as Wheat flour (Maida) Maida and clay. Many researchers have reported that the natural *Aloe vera* gel has many hormones, Vitamins, minerals and enzymes. Maybe due to these substances *Aloe vera* gel enhances the growth and development of the plant (Hassan, 2021).

***Number of leaves*:** The number of leaves increased with the age of the crop. The average number of leaves (Table 2*)* were significantly influenced by the different leaf powder treatment at any time of the growth stage except 3WAP. In 7WAP higher number of leaves (63) was observed in Pungham leaf powder treatment. However, there were no significant differences observed among Annona, *Cassia*, *Prosopis*, Neem and control in 7WAP. Pushpakaran et al, (2018) stated the same finding that the Pungham leaf treatment increase the number of leaves

in black gram. The number of leaves was influenced by a different binding material. In 4WAP higher number of leaves were observed in *Aloe vera*. However, there were no significant differences between *Aloe vera*, wheat flour and clay in 4WAP. Even though there were no significant differences observed among different binding materials in 6WAP and 7WAP. A higher number of leaves were observed in Aloe vera. Many researchers stated that *Aloe vera* gel has vitamins, enzymes, and minerals (Raman *et al*., 2013). It may be due to the number of leaves being increased by *Aloe vera* gel.

Number of branches: The number of branches (Table 2) was influenced by the different leaf powder treatments. The highest number of branches (6.41) were observed in Pungham leaf treatment in 7WAP. The low number of branches (5.31) was observed in control in 7WAP. In 6WAP also higher number of branches were observed in Pungham treatment. However, there were no significant differences observed among Annona, *Cassia, Prosopis*, Neem and control in 6WAP and 7WAP. In 4WAP and 5WAP low number of branches were observed in control. However, there were no significant differences observed among other treatments in 4WAP and 5WAP. The number of branches (Table 2) was significantly influenced by different binding materials at any time of the growth stage except 4WAP and 5WAP. In 6WAP higher number of branches were observed in *Aloe vera*. It has significantly differed from clay and wheat flour (Maida). In 7WAP higher number of branches were observed in *Aloe vera*. Sharma *et al*. (2015) stated that *Aloe vera* contains Bioactive polysaccharides like acemannan and saponin, which enhance plant growth and development.

Total number of nodules per plant: Kevin Zaychuk (2006) reported that nodule formation begins approximately 14 days after crop emergence, but under certain conditions, formation may take 3-4 weeks. The total number of nodules per plant at the different growth stages of a black gram at different leaf powder treatments is given in Table 3. The number of nodules was significantly influenced by different leaf powder treatments in all growth periods. A significantly higher number of nodules were observed in Pungham leaf treatment in 4WAP,5WAP and 6WAP. A higher number of nodules (68.96) were observed in Pungham in 6WAP. There were no significant differences observed between Annona and Prosopis in 5WAP. However, a significant difference was observed between Annona and *Prosopis* in 6WAP. Previous researchers stated the same finding as Pungham leaf treatment increase the number of nodules (Pushpakaran et al., 2018). Several nodules were influenced by Different binding materials. *Table 3* shows that there were significant differences observed among binding materials in 4WAP and 5WAP. But there were no significant differences observed in 6WAP. In 4WAP higher number of nodules were observed in *Aloe vera*. But there was no significant difference between clay and *Aloe vera*. However, there were no significant differences observed between Wheat flour (Maida) and *Aloe vera* in 5WAP.

Number of clusters: The number of clusters (Table 3) was significantly influenced by different leaf powder treatments. A higher number of clusters (12.88) were observed in the Pungham leaf powder treatment. A low number of clusters (8.22) were observed in Neem leaf treatment. However, there were no significant differences observed among Annona, *Cassia, Prosopis* and control. Previous researchers stated the same finding that the Pungham leaf treatment increases the number of clusters (Vennila, 2018). Table 3 shows the number of clusters that were influenced by a different binding material. But there was no significant difference was observed among all binding materials. A higher number of clusters were observed in *Aloe vera*.

Table 2 Effect of leaf powder and binding material treatments on growth parameters of black gram.

Treatment	Plant height					Number of leaves per plant					Number of branches per plant			
	3WAP	4WAP	5WAP	6WAP	7WAP	3WAP	4WAP	5WAP	6WAP	7WAP	4WAP	5WAP	6WAP	7WAP
Leaf powder														
Neem (T1)	21.66^{a}	39.49^{a}	60.04^{ab}	64.29^{b}	72.06^{bc}	8.00^{a}	18.50^{a}	32.47^{a}	40.63^{ab}	53.05^{bc}	3.22^{a}	3.69^{a}	4.11^{b}	5.34^{b}
Prosopis (T2)	21.78^{a}	40.08^{a}	60.09^{ab}	65.91^{b}	72.53^{bc}	8.00^{a}	18.75^{a}	35.72^{a}	39.97^{ab}	54.38^{bc}	3.11^{a}	3.61^{a}	4.27^{b}	5.44^{b}
Pungham (T3)	22.30^{a}	40.04^{a}	62.84^{a}	70.47^{a}	78.26^{a}	8.00^{a}	19.91^{a}	37.11^{a}	43.58^{a}	63.02^{a}	3.41^{a}	3.75^{a}	4.83^{a}	6.41^{a}
Cassia (T4)	21.79^{a}	40.02^{a}	60.43^{ab}	64.33^{b}	73.08^{ab}	8.00^{a}	18.51^{a}	32.66^{a}	39.08^{b}	52.80^{bc}	3.16^{a}	3.66^{a}	4.11^{b}	5.25^{b}
Annona (T5)	22.13^{a}	40.33^{a}	62.19^{a}	68.15^{ab}	76.82^{ab}	8.00^{a}	18.61^{a}	34.00^{a}	41.00^{ab}	55.97^{b}	3.10^{a}	3.66^{a}	4.22^{q}	5.30^{b}
Control (T6)	20.35^{b}	38.71^{a}	56.84^{b}	60.37^{c}	67.18^{c}	8.00^{a}	15.59^{b}	27.40^{b}	35.60^{c}	50.51^{bc}	2.79^{b}	3.00^{b}	4.13^{b}	5.31^{b}
Binding material														
Clay (B1)	21.77^{a}	40.31^{a}	60.78^{a}	64.61^{b}	71.96^{b}	8.00^{a}	18.53^{ab}	31.95^{b}	39.37^{a}	54.40^{a}	3.20^{a}	3.56^{a}	4.27^{b}	5.43^{b}
Maida (B2)	20.75^{b}	38.52^{b}	59.09^{a}	64.25^{b}	72.34^{b}	8.00^{a}	17.59^{b}	34.71^{a}	39.91^{a}	53.86^{a}	3.13^{a}	3.54^{a}	3.97^{c}	5.36^{ab}
Aloe vera (B3)	22.48^{a}	40.51^{a}	61.35^{a}	67.90^{a}	75.66^{a}	8.00^{a}	18.75^{a}	34.83^{a}	40.65^{a}	55.11^{a}	3.08^{a}	3.59^{a}	4.60^{a}	5.57^{a}

Means with the same letter within a given treatment are not significantly different at p= 0.05
WAP indicates the Week After Planting.

Table 3: Effect of leaf powder and binding material treatments on number of clusters and nodule formation of black gram

Treatment	Number of root nodules per plant			Number of Clusters per pant
Leaf powder	4WAP	5WAP	6WAP	
Neem (T1)	30.11^{d}	45.63^{d}	58.57^{d}	9.22^{bc}
Prosopis (T2)	32.37^{c}	51.74^{bc}	61.05^{c}	8.22^{c}
Pungham (T3)	42.54^{a}	59.67^{a}	68.96^{a}	9.33^{b}
Cassia (T4)	32.70^{c}	49.82^{c}	62.85^{bc}	12.88^{a}
Annona (T5)	36.54^{b}	53.37^{b}	63.17^{b}	9.44^{b}
Control (T6)	30.41^{d}	41.90^{e}	56.28^{e}	9.88^{b}
Binding material				
Clay (B1)	34.14^{a}	48.13^{b}	61.23^{a}	9.83^{a}
Maida (B2)	31.38^{b}	51.20^{a}	61.43^{a}	9.66^{a}
Aloe vera (B3)	36.81^{a}	51.73^{a}	62.79^{a}	10.00^{a}

Means with the same letter within a given treatment are not significantly different at p= 0.05
WAP indicates the Week After Planting.

Yield Parameter: Shkolnik *et al*. (1975) stated that the leaves powders contain gibberellin-like substances and zinc which are synergistically activated to form indole acetic acid. Indole acetic acid regulates the growth and development processes such as cell division and elongation. Increased quality parameters in developing plants may be due to enlarged embryos, higher rate of metabolic activity and respiration, better utilization and mobilization of metabolites to growing points and higher activity of enzymes (Satiskumar *et al*., 2011). Anon, (2000) stated that botanicals contain growth-promoting substances and nutrients. Maybe due to these facts the leaf powder treatment increases the yield parameter like the number of pods and yield of black gram. *Table 4* shows that the number of pods was significantly influenced by different leaf powder treatments. A higher number of pods (41.25) were observed in Pungham leaf treatment. However, there were no significant differences observed among Pungham, Annona, *Prosopis* and *Cassia*. A lower number of pods (33.19) were observed in Neem leaf treatment. *Table 4* shows that there were no significant differences observed among different binding materials. A higher number of pods were observed in *Aloe vera*. The yield of black gram was significantly influenced by different leaf powder treatments. *Table 4* shows that a higher yield (2.15 ton/ha) was observed in Pungham leaf powder treatment and a lower yield (1.73 ton/ha) was observed in Neem leaf treatment. However, there were no significant differences observed among Pungham, Annona, *Cassia* and *Prosopis* leaf treatments. *Table 4* shows that there were no significant differences observed among all binding materials. The higher yield was observed in *Aloe vera*.

Table 4: Effect of leaf powder and binding material treatments on yield parameters of black gram

Treatment	Number of pods per plant	Seed yield(ton/ha)
Leaf powder		
Neem (T1)	33.19^{c}	1.73^{c}
Prosopis (T2)	39.77^{ab}	2.07^{ab}
Pungham (T3)	41.25^{a}	2.15^{a}
Cassia (T4)	38.94^{b}	2.03^{b}
Annona (T5)	40.08^{ab}	2.09^{ab}
Control (T6)	33.47^{c}	1.74^{c}
Binding material		
Clay (B1)	37.61^{a}	1.96^{a}
Maida (B2)	37.72^{a}	1.97^{a}
Aloe vera (B3)	38.02^{a}	1.98^{a}

Means with the same letter within a given treatment are not significantly different at p= 0.05

Conclusion

Considering all growth parameters (Plant height, Number of leaves, Number of clusters), yield parameters (Number of pods and yield) and other parameters (Number of nodules) Pungham leaf powder treatment was significantly performed well among all other leaf powder treatment. Considering growth parameters (Plant height and Number of leaves) *Aloe vera* significantly performed well among all other binding materials. Even though there were no significant differences observed in yield parameters (Number of pods and Yield) and other parameters (Number of nodules), a higher value was observed in *Aloe vera* than in other binding Materials.

Results revealed that Pungham leaf powder and *Aloe vera* improved the productivity of black gram.

References

Anbarasan, R. And Srimathi, P., 2015. 6. Influence of organic pelleting on seed quality characters in green gram by r. anbarasan1 and p. srimathi1. life sciences leaflets, 64, pp.41

Department of Agriculture (2021) *Black gram*, *Department of Agriculture*.

Department of Census and Statistics (2021) *Black Gram Extent (Hectares) & Production (MT), Agriculture and Environment statistics division*.

Khatun, A., G. Kabir, M.A.H. Bhuiyan and D. Khanam. (2011). Effect of preserved seeds using different botanicals on seed quality of lentil. Bangladesh J. Agric. Res., 36(3): 381-387.

Krishnasamy V.2013, Seed pelleting-Principles and Practices. ICAR Short Course on Seed Hardening and Pelleting Technologies for Rainfed/Garden Land Ecosystems, Tamil Nadu Agricultural University, Coimbatore, 96.

Kulasinghe.W.M.A.A,2019, Importance of compositional analysis of traditional agro bio diverse pulse species grown in Sri Lanka. *Journal of technology*, 1(2):41- 53

Nadeem Binzia,(1992) Investigation of the chemical constituents of Prosopis julifera and circular Dichroismic studies of cholestano Quinaxaliner. Ph.D Thesis, University of Karachi, Pakistan.

Pushpakaran, M., Vennila, S. And Palaniraja, K., 2018. Effect of seed pelleting on seed quality parameters in blackgrm (*Vigna mungo* L.) Hepper]. *Journal of Pharmacognosy and Phytochemistry*, 7(4), pp.2926-2928

Srimathi, P., N. Mariappan, L. Sundaramoorthy and M. Paramathma. (2013). Effect of organic seed pelleting on seed storability and quality seedling production in biofuel tree species. *J. of Horti. and Forestry*, 5(5): 68-73.

Tandon, M. and Chauhan, P. (2019) 'Bioassay of ZnO-SnO2 nano composite on black gram (*Vigna mungo*)', *Plant Cell Biotechnology and Molecular Biology*, 20(13–14), pp. 595–603.

RESPONSE OF DIFFERENT FORMULATIONS OF FISH TONIC FOLIAR SPRAYS ON GREEN CHILLI (*Capsicum annum* L.) YIELD

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Abstract

A research was conducted at Regional Agriculture Research and Development Centre, Kilinochchi from February 1st 2022 to May 20th 2022 to find out the responses of different formulations of fish tonic foliar sprays on *Capsicum annum* L. yield under organic system. Two major steps were involved in this research, which were preparations of different formulations of fish tonic and field experiment. The field experiment was laid out in a Randomized Complete Block Design, with 8 treatments and 3 replicates. Seven different formulations of fish tonics were prepared using fish, brown sugar, jaggery, bananas, sugarcane extract and dates at different ratios, while maintaining the total amount constant and applied on *Capsicum annuum* L. along with 10 ton/ha cow dung as basal fertilizer. The treatments tested were; Treatment 1 (control), Treatment 2 (fish+brown sugar), Treatment 3 (fish+jaggery), Treatment 4 (fish+bananas), Treatment 5 (fish+sugarcane extract), Treatment 6 (fish+jaggery+bananas), Treatment 7 (fish+jaggery+dates) and Treatment 8 (fish+jaggery+dates+bananas). The applications of fish tonic were done at weekly intervals. The results revealed that, significant nitrogen content was observed in T4 (1.41%) and T5 (1.34%) when compared to other treatments. Field results showed that, T4 significantly showed an excellent plant growth, higher leaf length as well as leaf width. Even, higher yield and yield attributes were experienced in crops. T4 produced significantly highest pod length (9.35 cm), pod diameter (9.93 mm) and yield per hectare (7.18 ton/ ha). Apart from T4, T5 also had a good response on chilli yield (6.99 ton/ha). It could be concluded that both T4 and T5 foliar applications have good impact on chilli yield. They can be used as promising alternatives for the reduction of inorganic fertilizers. Further research should be done to increase the yield with combined application of fish tonic with reduced amounts of organic, inorganic fertilizers.

Keywords: Chilli, fish tonic, foliar application, growth, yield

Introduction

Capsicum annum L. is a species of plant genus Capsicum which belongs to the family Solanaceae. Around the world, chillies are grown over an area of 1776 thousand hectares, yielding 7182 thousand tons (Hussain *et al*., 2019). The yield of chillies depends on adequate supply of the essential nutrients. The nitrogen application to green chilli shows a great increase on plant growth and yield (Stroehlein and Oebker, 1979).

Foliar feeding of organic liquid manures cures nutrient deficiencies and boosting crop performances at specific physiological stages (Ramesh *et al*., 2020). Fish tonic is a cost-effective fertilizer made from the by-products of fish industry. Fish tonic, being an organic fertilizer promotes higher growth and yield in crops, as well as a viable alternative to chemical fertilizers. Fish tonic foliar spray promotes seedlings for the growth of plants such as chilli, brinjal etc. Use of foliar spray is obtaining importance in yield development owing to its quick response in plant growth (Ramesh *et al*., 2020). It is revealed in literature that fish tonic is said

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to be an excellent nitrogen fertilizer, which improves the chilli yield during their vegetation period. It provides enough nitrogen to the plants for uptake and also plant is maintained by means of chlorophyll production (Weinert *et al*., 2014). Thereby, this experiment was aimed to study the responses of different formulations of fish tonic foliar sprays on green chilli yield under organic system.

Materials and Methods

The experiment was conducted at Regional Agriculture Research and Development Centre, Kilinochchi from February 1st 2022 to May 20th 2022. MI green chilli variety was selected for this study. The experiment was carried out in a Randomized Complete Block Design (RCBD) replicated thrice with eight treatments (Table 1). Seven different formulations of fish tonics were prepared with three replicates for each of the formulations and applied on *Capsicum annuum* L. along with cow dung basal application of 10 ton/ ha.

Table 1: The designed treatments are indicated here

Treatment	
Treatment 1	Control
Treatment 2	Fish (50%) + brown sugar (50%)
Treatment 3	Fish (50%) + jaggery (50%)
Treatment 4	Fish (50%) + bananas (50%)
Treatment 5	Fish (50%) + sugar cane extract (50%)
Treatment 6	Fish (45%) + jaggery (45%) + bananas (10%)
Treatment 7	Fish (45%) + jaggery (50%) + dates (5%)
Treatment 8	Fish (40%) + jaggery (48%) + dates (4%) + bananas (8%)

Fish tonic preparation and application

Low-cost fishes were collected from Katakaadu fish market, near Elephant pass. The fishes were chopped into pieces and added with different ingredients (brown sugar, jaggery, bananas, sugarcane extract, dates) for each treatment. The components were mixed thoroughly, sealed air tightly and allowed to ferment for 26 days in a cool shady site. Finally, the liquid portion of the fish tonic was filtered and stored in separate containers. 1% of fish tonic was applied on crops, in accordance with the findings of Priyanka *et al*., (2019). That means,10 ml of fish tonic was diluted with 1000 ml of water and sprayed at weekly intervals.

Data collection

Total nitrogen, available phosphorus, potassium, organic carbon, pH, EC of the different formulations of fish tonics were analyzed using standard procedures. Plant growth parameters such as plant height, leaf length and leaf width were recorded after 30 and 60 days of transplanting (DAT) and yield parameters like pod length, pod diameter and total yield per hectare were measured at the time of harvest. The data were statistically analyzed by single factor completely randomized design SAS 9.1 package and Duncan's multiple range test was used to compare means.

Results and Discussion

Nutrition analysis of the different formulations of fish tonics

Among the nutrition elements analyzed, there were significant differences ($p<0.05$) resulted in T4, T5 and T8 with acceptable range of SLSI standard (Table 2). When compared to SLSI standard, significant nitrogen content was observed in T4 (1.41%) and T5 (1.34%). T4 resulted with significant potassium content (1.19%) when compared to other treatments. Significant amount of phosphorus was registered under T8 (0.99%). No significant variations were resulted for NPK in other treatments. When considering EC, T4 and T5 had EC value (34.1 dS/m, 39.3 dS/m) even above the SLSI standard. This might be due to the higher presence of ions in

solution. But it didn't affect the plant growth and yield, as because only 1% of fish tonic application was done on crops. But in case of Organic carbon, all treatments were high in content, except T4 (4.09%) and T5 (3.85%).

Table 2: Nutrient analysis of fish tonic

Treatment	pH	EC(dS/m)	N%	P%	K%	Organic C%
SLSI standard	6.5-8.5	<20	>1%	>0.5%	>0.5%	-
1	Control application					
2	4.87^{c}	2.07^{c}	0.60^{e}	0.74^{c}	0.55^{c}	26.26^{b}
3	4.66^{c}	1.65^{c}	0.86^{b}	0.38^{d}	0.35^{d}	29.58^{a}
4	6.31^{b}	34.1^{b}	1.41^{a}	0.91^{ab}	1.19^{a}	4.09^{e}
5	7.41^{a}	39.3^{a}	1.34^{a}	0.70^{c}	0.55^{c}	3.85^{e}
6	4.34^{c}	2.97^{c}	0.82^{bc}	0.77^{bc}	0.68^{b}	18.28^{d}
7	4.78^{c}	2.91^{c}	0.78^{cd}	0.75^{bc}	0.65^{b}	18.95^{cd}
8	4.79^{c}	2.87^{c}	0.74^{d}	0.99^{a}	0.73^{b}	20.67^{c}
CV	7.4	20.0	3.8	11.6	7.9	7.3

Growth and yield parameters

Foliar application of fish tonic resulted in higher plant height, leaf length as well as leaf width when compared to T1 (control). Highest significant difference was observed under T4, when compared to other treatments at $p<0.05$ (Table 3). T4 application resulted in highest plant height (31.04 cm), leaf length (8.95 cm) and leaf width (2.75 cm) at 60 DAT, which is significant with other treatments. That is because T4 has the highest nitrogen (1.41%), potassium (1.19%) and relatively good phosphorus content (0.91%) when compared to other formulated fish tonics. Comparatively least results were registered under control (T1). FAA application had a great role in enhancing the metabolism processing due to the importance of nitrogen. Consequently, gained a promotion in vegetative plant growth i.e., plant length, number of branches and/ or leaves per plant of whole pumpkin plant. These results were in accordance with the findings of Shwe *et al*. (2018).

Table 3: Effect of fish tonic foliar sprays on growth and yield parameters

Trt	Plant height (cm)		Leaf length (cm)		Leaf width (cm)		Pod	Pod	Yield
	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	length (cm)	diameter (mm)	ton/ha
1	15.33^{d}	20.43^{e}	5.33^{c}	5.98^{e}	1.82^{b}	1.85^{d}	8.08^{c}	6.93^{c}	3.03^{d}
2	19.31^{c}	25.06^{d}	5.79^{bc}	7.03^{d}	2.02^{ab}	2.15^{bcd}	8.26^{c}	7.90^{bc}	3.87^{c}
3	20.49^{bc}	26.86^{c}	6.30^{abc}	7.96^{bc}	2.25^{ab}	2.50^{abc}	8.70^{abc}	8.56^{abc}	5.54^{b}
4	23.14^{a}	31.04^{a}	6.88^{a}	8.95^{a}	2.44^{a}	2.75^{a}	9.35^{a}	9.93^{a}	7.18^{a}
5	21.74^{ab}	28.64^{b}	6.59^{ab}	8.48^{ab}	2.33^{ab}	2.61^{ab}	9.17^{ab}	9.20^{ab}	6.99^{a}
6	19.43^{c}	24.76^{d}	5.59^{c}	6.71^{d}	1.98^{ab}	2.09^{cd}	8.13^{c}	7.66^{bc}	3.26^{d}
7	19.51^{c}	25.33^{cd}	5.91^{abc}	7.12^{d}	2.16^{ab}	2.35^{abc}	8.42^{bc}	8.37^{abc}	4.07^{c}
8	19.63^{c}	25.64^{cd}	6.16^{abc}	7.68^{c}	2.22^{ab}	2.46^{abc}	8.6^{abc}	8.40^{abc}	5.22^{b}
CV	5.2	3.4	8.4	4.2	13.1	11.2	5.1	10.5	3.8

The yield attributes were recorded with a better performance when compared to T1 (control). T4 application significantly resulted with the highest pod length (9.35 cm) and pod diameter (9.93 mm). A significant difference was observed in case of yield and the highest yield rate (7.18 ton/ ha) was recorded under T4 at $p<0.05$. Even T5 also recorded with a heavy yield (6.99 ton/ ha). In the year of 2018, the average chilli yield was 5.83 tons/ ha (AgStat,2019). Even though, T4 and T5 were resulted with a high yield when compared to the average yield, still the yield is not enough for other treatments. Combined application of fish tonic with reduced organic and inorganic fertilizer usage might increase the yield in future. Moreover, quick absorption and assimilate of more nitrogen, phosphorus, potassium and micro nutrients present in the fish amino acid through foliar spray would said to have improved the metabolic activity and cell division resulting in higher plant height, a greater number of leaves, more chlorophyll content which consequently increased the photosynthetic activity which in turn yield attributes and higher yield of green gram. These results are in accordance with the findings made by Abbasi *et al*. (2003), who reported that foliar spray of fish emulsion increases the total yield of tomato and peppers.

Conclusion

The study revealed that both T4 (fish+ bananas), T5 (fish+ sugarcane extract) fermented tonics had significant amounts of Nitrogen and resulted comparatively higher yield on green chilli when compared to other treatments.

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References

Hussain, F. and Abid, M., 2011. Pest and diseases of chilli crop in Pakistan: A review. *Int. J. Biol. Biotech*, *8*(2), pp.325-332.

Priyanka, B., Anoob, D., Gowsika, M., Kavin, A., Sri, S.K., Kumar, R.V.K., Gomathi, R.S., Sivamonica, B., Devi, G. and Theradimani, M., 2019. Effect of fish amino acid and egg amino acid as foliar application to increase the growth and yield of green gram. *The Pharma Innovation Journal*, 8, pp.684-686.

Ramesh, T., Rathika, S., Murugan, A., Soniya, R.R., Mohanta, K.K. and Prabharani, B., 2020. Foliar spray of fish amino acid as liquid organic manure on the growth and yield of Amaranthus. *Chemical Science Review and Letters*, 9, pp.511-515.

Weinert, E.J., Miller, S.A., Ikeda, D.M., Chang, K.S., McGinn, J.M. and DuPonte, M.W., 2014. Natural farming: Fish amino acid. Sustainable Agriculture, SA-12, College of Tropical Agriculture and Human Resources.

INHOUSE CULTIVATION OF *Withania somnifera* (ASHAWANGHA) USING HYDROPONICS

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Abstract

There is an annual demand for medicinal plant based raw materials in the world. To fulfill the increasing demands, the medicinal plants are harvested excessively from their natural habitants causing loss of biodiversity. The hydroponics technologies have proven its benefits in increasing yields of many medicinal plants. Ashwagandha is widely used herb due to its anti-microbial, anti- inflammatory, anti-tumor, anti-stress, neuroprotective, cardioprotective, and anti-diabetic properties. The objective of the present study was to investigate effect of substrate moisture level and salicylic acid concentrations on the growth and yield of *W.somnifera*. The plants were grown in an open top coir dust grow bags inside a protected house. Four moisture stress levels 100% CC (container capacity)-M_1, 80% of CC-M_2, 60% of CC-M_3, 50% of (CC)-M_0 and four strengths (10^{-2}M-S_1,10^{-3}M-S_2,10^{-4}M-S_3 and control-S_0) of Salicylic acid as a foliar spray was applied to induce the root yield. The experiment was designed based on split plot design. There were 16 treatment combinations and 3 replicates for each treatment combination of moisture and salicylic acid. Plant height, number of leaves, and internodal length were taken as growth parameters and fresh weight and dry weight of the root was taken as the yield parameter. The data was analyzed by using one way ANOVA and means were separated by Duncan Multiple Range Test (DMRT) in SAS® software. The highest plant height (76.79cm) was recorded under treatment M_0 and the salicylic acid stress level S_3. The highest number of leaves were shown under the moisture stress level M_0 and the Salicylic acid stress level S_3 which were 117 and 86 leaves per plant respectively. There was no significant influence by treatments on internodal length. Root is the main plant part harvested from *W.somnifera* due to its rejuvenate properties. Highest fresh root weight was given under the interaction effect of treatments M_2 and S_3. Highest dry root weight was given under the interaction effect of treatments M_4 and S_3. According to the results of the experiment, it can be concluded that moisture stress level 50% of container capacity and a foliar spray concentration of 10^{-4}M Salicylic acid could be applied to increase root yield of *W.somnifera.*

Keywords: Coir dust, foliar spray, moisture stress, polytunnel, root yield, salicylic acid

Introduction

Demand for herbal products accounts for a significant portion of medicinal use in Europe, United States, Asian region, and other emerging regions and the growth of medicinal herb market is expected to expand with high profit margins in next decades (Mugundhan *et al*., 2011). Due to the excessive demand, most of the medicinal plants species and their population diminishing in alarming rate and in danger of extinction due to over exploitation of plant resources and deforestation (Xego *et al*., 2016). It is a timely requirement to develop of sustainable methodologies for the cultivation of medicinal plants in order to ensure consistent supply of quality raw materials for the wellbeing of present and future of medical care.

Withania somnifera (Ashawagandha) is a medicinal plant which has higher demand in both local and foreign market. The phytochemicals in *W.somnifera* contains many medicinal properties including anti-microbial, anti- inflammatory, anti-tumor, anti-stress,

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neuroprotective, cardioprotective, and anti-diabetic properties (Dar et al., 2015). The open field cultivation results in large year-to-year variability, as both biomass production and synthesis of secondary metabolites are affected by many factors such as genotype, climatic conditions, soil type, growing practices and the presence of pests and diseases. Hydroponic technology can be applied to produce high- standard plant material all year-round in consideration of the possibility to control growing conditions and to stimulate secondary metabolism by appropriate manipulation of mineral nutrition (Maggini *et al.*, 2012). Secondary metabolite production of plants depends on stress conditions, nutrient availability, drought stress, saline stress *etc.* (Teklic *et al*., 2020). Salicylic acid, well known for systemic acquired resistance, induces in the plant response to many pathogens, can also elicit the production of secondary metabolites in plants (Singh and Dwivedi, 2018).

LC1 and FR1 are the two local varieties present in Sri Lanka (Siriwardane *et al*., 2013). The usage of the local varieties of Ashwagandha in herbal medicine has been limited due to the lower content of Withanolides and higher fibre content compared to the Indian variety. The Indian varieties of Ashawagandha cultivated in Sri Lanka, does not show similar growth and yield performance levels compared to that of grown in India. The Indian variety of Ashwagandha is imported to Sri Lanka in large scale to fulfil the requirements in herbal medicine industries. In Sri Lanka, a proper agronomic practices have not been developed to grow Indian variety of *W.somnifera* to give maximum Withanolides content. The objective of the study was to investigate the growth and yield of *W.somnifera* as affected by different moisture stress levels and Salicylic acid concentrations.

Materials and Methods

Location of the Study

The experiment was carried out in a 1500ft^2 protected house in Faculty of Technology, University of Ruhuna, Sri Lanka. The experimental area is located in the WL2B climate zone, which is a low-lying wet zone.

Cultivation of Ashwagandha

W. somnifera was grown in an open top coir dust grow bags. The plants were established in the protected house after a nursery period of one month. Same fertilizer schedule was applied for all plants. A common fungicide, insecticide and other chemical application schedule were practiced for both crop species as an initial prevention method of pests and diseases. The treatments were started to apply one month after transplanting.

Application of Moisture stress

Four moisture stress levels as 100% container capacity (CC) (M_0), 80% of CC (M_1), 60 % of CC (M_2) and 50 % of CC (M_3) was maintained. The moisture stress was applied one month after transplanting. The specific moisture stress levels were maintained using XH-M214 humidity controller soil sensor modules. Emitters of drip irrigation line was buried in each grow bag.

Application of Salicylic acid stress

There were four Salicylic acid stress levels as without Salicylic acid (S_0) ,10^{-2} M (S_1),10^{-3}M (S_2), 10^{-4}M (S_3) under each moisture level. Salicylic acid was applied as foliar spray once in two weeks.

Experimental design

There were three replicates for each treatment combination and 16 treatment combinations for whole experiment. One grow bag was considered as one experimental unit and two plants were grown in each grow bag. The treatments were arranged in a split plot design.

Data collection

Growth parameters of the plant (plant height, internodal length, number of leaves in main stem/plant) were measured at two weeks interval after commencement of application of treatments. Fresh weight of root/plant and dry weight of root/plant were measured as yield parameters at harvesting.

Data analysis

Collected data was analyzed using one way ANOVA and the means were separated using Duncan Multiple Range test (DMRT). The test was carried out using SAS software.

Results and Discussion

The Salicylic acid levels and the moisture stress levels had a significant additive effect on the plant height of *W.somnifera* as given in Figure 1. The highest plant height (80.33cm) was recorded under treatment M_0 (substrate moisture equals to field capacity). The lowest average plant height of 62.79cm was recorded in the treatment of M_3 (substrate moisture equals 50% of field capacity). The highest plant height (76.79cm) was shown under the Salicylic acid stress level of S_3 while the lowest plant height (63.42cm) was given under the treatment S_0.

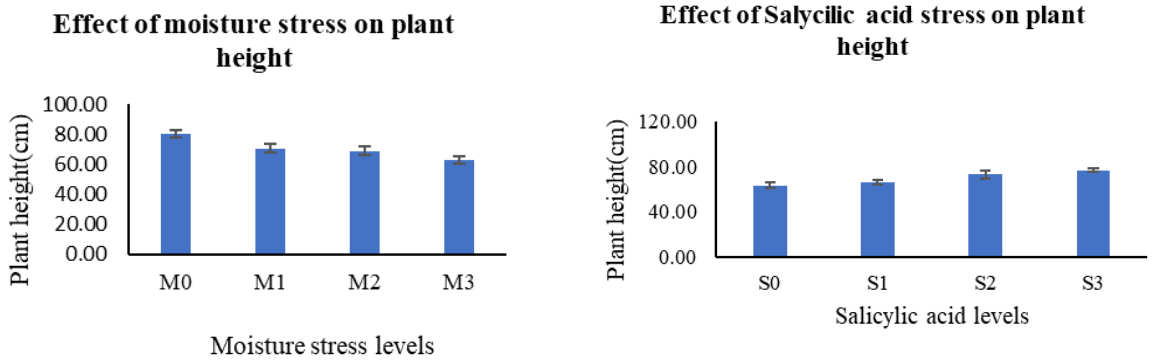

Figure 1: Plant height

There was a significant effect on number of leaves of *W.somnifera* from the applied moisture stress and Salicylic acid stress. The highest number of leaves was shown under the moisture stress level M_0 and the Salicylic acid stress level S_3 which were 117 and 86 leaves per plant respectively (Figure 2).

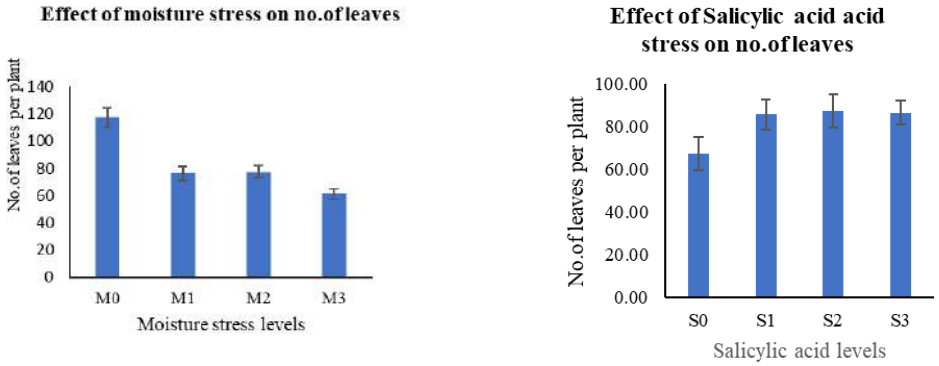

Figure 2: No. of leaves per plant

Root is the main plant part harvested from *W.somnifera* cause of its rejuvenative properties. Highest dry root weight was given under the interaction effect of treatments M_4 and S_3 as shown in Figure 3. The metabolic changes mediated by drought stress results in accumulation of higher natural products in medicinal plants (Kleinwachter and Selmar 2014). This can be the reason for the increment of dry weight observed in our study.

Similar results of decreased plant height with the application of drought stress have already been shown in *Satureja hortensis L* (Baher *et al*.,2002) and *Trachyspermum ammi l* (Azhar *et al*., 2011). Adequate water supply is one of the key factors which, determines the growth of a plant. The drought stress conditions created by the restricted water supply causes huge damage to physiology of the plant. The damages occurred to the plant physiology will be indicated by the degradation of morphological characteristics of plant including plant height, number of leaves and number of branches and number of fruits (Pradhan *et al*.,2017).

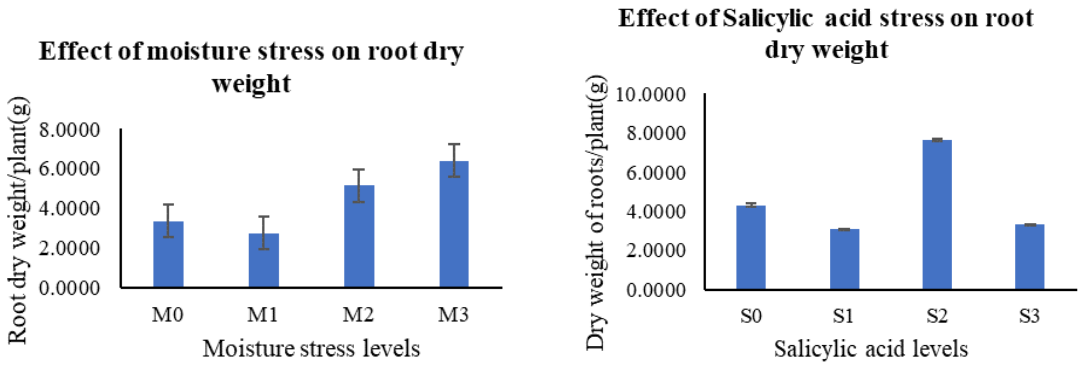

Figure 3: Dry weight

The Salicylic acid concentration 10^{-2}M (S_1) cannot be recommended for foliar spray since it was not shown any significant difference with that of control. Similar results were obtained during the study of "Salicylic acid-induced modulation of growth and metabolism of medicinal plant; *Mentha spicata*. That study has recommended 200 µg ml^{-1} concentration of Salicylic acid for the increment of shoot length, branch number per plant, leaf area, leaf number, and plant biomass, when compared with control plants (Kundu *et al*., 2018).

Conclusion

Results can be concluded that the *W.somnifera* plants have to be grown in moisture stress level -50% of container capacity with a foliar spray of Salicylic acid concentration 10^{-4}M. The recommended Salicylic acid level and the moisture stress level showed a root yield increment of 24.12% and 46.18% respectively related to the control.

Reference

Azhar, N., Hussain, B., Ashraf, M.Y. and Abbasi, K.Y., 2011. Water stress mediated changes in growth, physiology and secondary metabolites of desi ajwain (*Trachyspermum ammi* L.). *Pak. J. Bot*, 43(1), pp.15-19.

Baher, Z.F., Mirza, M., Ghorbanli, M. and Bagher Rezaii, M., 2002. The influence of water stress on plant height, herbal and essential oil yield and composition in Satureja hortensis L. *Flavour and Fragrance Journal*, 17(4), pp.275-277.

Dar, N.J., Hamid, A. and Ahmad, M., 2015. Pharmacologic overview of Withania somnifera, the Indian Ginseng. Cellular and molecular life sciences, 72(23), pp.4445-4460.

Kleinwachter, M. and Selmar, D., 2014. Influencing the product quality by applying drought stress during the cultivation of medicinal plants. In Physiological mechanisms and adaptation strategies in plants under changing environment (pp. 57-73). Springer, New York, NY.

Maggini, R., Kiferle, C., Guidi, L., Pardossi, A., Raffaelli, A., 2012. Growing medicinal plants in hydroponic culture. Acta Hortic. 952, 697–704. https://doi.org/10.17660/ActaHortic.2012.952.88

Mugundhan, R.M., Soundaria, M., Maheswari, V., Santhakumari, P. and Gopal, V., 2011. " Hydroponics"-a novel alternative for geoponic cultivation of medicinal plants and food crops. *International Journal of Pharma and Bio Sciences*, 2(2)

Pradhan, J., Sahoo, S.K., Lalotra, S. and Sarma, R.S., 2017. Positive impact of abiotic stress on medicinal and aromatic plants. *International Journal of Plant Sciences* (Muzaffarnagar), 12(2), pp.309-313.

Singh, A., Dwivedi, P., 2018. Methyl-jasmonate and salicylic acid as potent elicitors for secondary metabolite production in medicinal plants : A review 7, 750–757.

Siriwardane, A.S., Dharmadasa, R.M. and Samarasinghe, K., 2013. Distribution of withaferin A, an anticancer potential agent, in different parts of two varieties of Withania somnifera (L.) Dunal. grown in Sri Lanka. *Pakistan journal of biological sciences*, 16(3), pp.141-144.

Teklic, T., Parađikovic, N., Spoljarevic, M., Zeljkovic, S., Loncaric, Z., Lisjak, M., 2020. Linking abiotic stress, plant metabolites, biostimulants and functional food. *Ann. Appl. Biol*. https://doi.org/10.1111/aab.12651

Xego, S., Kambizi, L. and Nchu, F., 2016. Threatened medicinal plants of South Africa: case of the family Hyacinthaceae. African Journal of traditional, complementary and alternative medicines, 13(3), pp.169-180.

IMPACT OF DIFFERENT LEVELS OF GAMMA IRRADIATION ON GROWTH OF *Arachis hypogaea*

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Abstract

Agriculture plays an important role in eradicating poverty and ensuring food security throughout the world. This study investigated the impact of different levels of gamma irradiation on growth of *Arachis hypogaea.* This experiment was conducted in the Crop farm, Eastern university of Sri Lanka as field experiment during July 2022 to October 2022. Groundnut seeds were exposed to Gamma irradiation using "Gamma chamber 1200 Cobalt-60" research irradiator. In the experiment was conducted as treatments T1 (0 Gy), T2 (100 Gy), T3 (200 Gy), T4 (300 Gy), T5 (400 Gy) and T6 (500 Gy).Treated seeds were planted in poly bags with rooting media thereafter seedlings were transplanted in open field. The experiment was laid out in Randomized Complete Block Design with five replications. Growth parameters such as number of leaves, leaf area, and shoot dry weight were collected. Collected data were statistically analyzed by using SAS 9.1 software and the mean comparison within treatments was performed by Duncan Multiple Range Test (DMRT) at 5 % significant level. The study revealed that, there was significant difference among the different levels of gamma irradiation and treatment T3 (200Gy) showed that significantly increased number of leaves (102%), leaf area (66%), shoot dry weight (118.9%). Therefore, according to this present study, treatment T3 (200 Gy) is more suitable to create desirable characteristic in *Arachis hypogaea* especially in Indi variety.

Keywords: *Arachis hypogaea,* gamma irradiation, mutation and plant mutation breeding

Introduction

Agriculture plays an important role in eradicating poverty and ensuring food security throughout the world. In 2050, the human population is expected to attain 9-11 billion (Frona *et al*., 2019). Due to climate change and limited land crop production is decreasing continuously therefore, a 60% increase in crop production would be needed to compensate for the food requirement of the human population (Stagnari *et al.*, 2017). Plant mutation breeding is an important approach in crop improvement which produces a large germplasm pool for selection and crop improvement.

Mutation is the process of genes being altered permanently in the environmental conditions and altered genes being transferred to the next generation. The mutation is the major source of genetic variation in any organism including plants (Oladosu *et al*., 2016). By using chemical and physical mutagens high amount of genetic variability is induced in plants and which takes part in modern plant breeding (Beyaz and Yildiz, 2017). Mutation breeding plays an important role in new crop varieties development in the entire world. Plant breeding by using different induced mutants have resulted in to production of 3222 plant varieties by using 170 different species of plants (Oladosu *et al.,* 2016). This induced mutation plant breeding is practiced in more than 60 countries throughout the world (Raina *et al*., 2016).

Groundnut (*Arachis hypogaea*) is an important oil seed crop belonging to the family Fabaceae. Groundnut has little diversity and self-pollinates. Therefore, standard breeding techniques can only improve groundnut cultivars to a certain point. As a source of growing diversity that

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complements traditional plant breeding, mutation breeding has the potential to offer specific improvements without drastically changing a plant's phenotype (Chopra, 2005). Gamma rays have been successfully used in plant breeding to create genetic diversity in economically important crops (Oladosu *et al*., 2016).Numerous studies have shown that genetic diversity for several desired traits may be successfully created by mutations, and its usefulness in plant development programs has been well established. The fundamental benefit of mutation breeding is the ability to enhance one or two traits without altering the genotype as a whole (Chopra, 2005). Therefore, this present study was undertaken with the following objective: To evaluate the impacts of gamma irradiation on the growth of *Arachis hypogaea* cv. Indi.

Materials and Methods

The field experiment was conducted in crop farm of Eastern University, Sri Lanka, in Vantharumoolai during the period of July to October in 2022. Groundnut seeds of Indi variety were irradiated with different levels of gamma irradiations (0, 100, 200, 300, 400 and 500 Gy) with a cobalt 60 source using gamma chamber 1200 research irradiator at Horticultural Crop Research and Development Institute (HORDI), Gannoruva, Sri Lanka. Treated seeds were planted in poly bags with rooting media with equal part of top soil, sand and compost. Poly bags were kept under 40% of shade house to reduce the irradiation shock. Thereafter seedlings were transplanted with the spacing of 45cm×15cm in open field. The experiment was laid out in Randomized Complete Block Design with five replications. Agronomic practices such as irrigation, fertilizer application, weeding and pest and disease control were done according to the recommendation of Department of Agriculture. In addition, gypsum was applied at the rate of 400kg/ha, 3 weeks after transplanting along with the earthing up. Growth parameters such as number of leaves, leaf area, and shoot dry weight were taken at 12 weeks after planting. Collected data were statistically analyzed by using SAS 9.1 software and the mean comparison within treatments was performed by Duncan Multiple Range Test (DMRT) at 5 % significant level.

Results and Discussion

Number of leaves

Table 1 revealed that there were significant differences between the applied gamma irradiation levels on number of leaves of *Arachis hypogaea*. Significantly ($P<0.05$) increased number of leaves was recorded in treatment T3 (200 Gy) by 102% compared with the control. Followed by T4 (300 Gy), T5 (400 Gy) and T2 (100 Gy) were shown 34.6%, 32.9% and 5.4% of increased number of leaves, respectively.

Table 1. Impacts of Gamma irradiation on number of leaves of *Arachis hypogaea*

Treatments	Number of leaves
T1 (0 Gy)	62.0 ± 5.88^{bc}
T2 (100 Gy)	65.4 ± 5.19^{bc}
T3 (200 Gy)	125.8 ± 8.43^{a}
T4 (300 Gy)	83.6 ± 9.70^{b}
T5 (400 Gy)	82.4 ± 10.92^{b}
T6 (500 Gy)	48.6 ± 3.58^{c}
F- Test	*

Value represents means ± standard error of 5 replicates. '' represents significant difference at 0.05 level of probability. Mean value in a column having the dissimilar letter or letters indicates significant difference at 0.05 level of significance by Duncan's Multiple Range Test.*

It is noticeable that the number *Arachis hypogaea* leaves were reduced with the high dose of the gamma radiation seed treatment. Treatment T6 (500 Gy) showed that 21.6% of reduced number of leaves which is in agreement with Ganesan *et al*. (2022).

Leaf area

According to the results of Figure 1, there were significant differences (P<0.05) among the different levels of gamma irradiation on leaf area of *Arachis hypogaea*. It was revealed that, 66.0% of significantly (P<0.05) increased leaf area was recorded in treatment T3 (200 Gy) compared with the control. Followed by T4 (300 Gy), T5 (400 Gy), T2 (100Gy) were shown increased leaf area by 21.3%, 18.24% and 13.38%, respectively. Further, it is obvious that the leaf area was reduced by 32.0% in T6 (500 Gy).

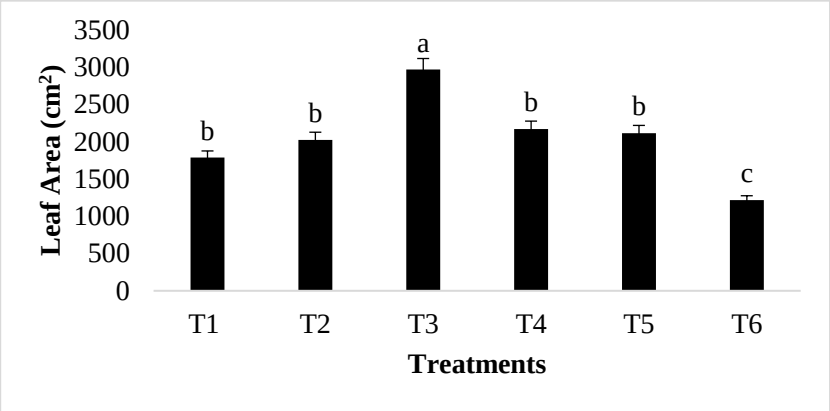

Figure 1: Impact of Gamma irradiation on leaf area of *Arachis hypogaea*

Error bar denotes a standard error. Mean value in a bar between the parameters having the dissimilar letter or letters indicates significant difference at 0.05 level of significance by Duncan's Multiple Range Test.

This results obtained due to lower levels might enhance antioxidant potentials and improve growth hormone interactions in exposed cells, which might promote faster growth (Majeed *et al*., 2018) These results are in agreement with results obtained on cowpea by Olasupo *et al*. (2016) who stated that, leaf area of cowpea continuously decreases with increasing doses of gamma radiation.

Shoot dry weight

According to the Table 2, there were significant difference among the applied levels of gamma irradiation. It was found that 118.9% of significantly (P<0.05) increased shoot dry weight was noted in T3 (200 Gy) when compared with the control. Other treatments such as T4 (300 Gy), T5 (400 Gy) and T2 (100 Gy) were noted increased shoot dry weight by 27.3%, 11.8% and 15.9% respectively. Furthermore, treatment T6 (500 Gy) was shown reduced shoot dry weight by 29.4%. These results are in agreement with results obtained on groundnut by Tshilenge (2012), who stated that, shoot growth was slowed while increasing the gamma radiation doses in different species of *Arachis hypogaea.*

Similar reduction in shoot dry weight of groundnut was observed while increasing the doses of gamma radiation by Gunesekaran and Pavadai (2015). Furthermore, Badr *et al.* (2014) stated that increasing the gamma radiation dose to 300 Gy dose, caused the inhibition of shoot growth and severely reduced the measured vegetative characteristics and yield components.

Table 2. Impacts of Gamma irradiation on shoot dry weight of *Arachis hypogaea*

Treatments	Shoot dry weight (g)
T1 (0 Gy)	23.8 ± 3.09^{bc}
T2 (100 Gy)	27.6 ± 2.01^{b}
T3 (200 Gy)	52.1 ± 6.66^{a}
T4 (300 Gy)	30.3 ± 3.58^{b}
T5 (400 Gy)	26.6 ± 2.54^{b}
T6 (500 Gy)	16.8 ± 2.74^{c}
F- Test	*

Value represents means ± standard error of 5 replicates. '' represents significant difference at 0.05 level of probability. Mean value in a column having the dissimilar letter or letters indicates significant difference at 0.05 level of significance by Duncan's Multiple Range Test.*

Conclusion

It could be concluded from this study various levels of gamma irradiation were significantly influenced the growth characteristics of *Arachis hypogaea* in Indi variety. Among the various treatments, treatment T3 (200Gy) showed significantly increased values in growth characteristics of number of leaves (102%), leaf area (66%), shoot dry weight (118.9%). Furthermore, higher levels of gamma irradiation showed the reduction in growth of *Arachis hypogaea.* Therefore, according to this present study, treatment T3 (200Gy) is more suitable to create desirable characteristic in *Arachis hypogaea* especially in Indi variety.

Acknowledgment

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References

Badr, A., Ahmed, H. I. S., Hamouda, M., Halawa, M. and Elhiti, M. A. (2014). Variation in growth, yield and molecular genetic diversity of M2 plants of cowpea following exposure to gamma radiation. *Life Science Journal*, *11*(8), 10–19.

Beyaz, R. and Yildiz, M. (2017). The Use of Gamma Irradiation in Plant Mutation Breeding. Plant Engineering.

Chopra, V. L. (2005). Mutagenesis: Investigating the process and processing the outcome for crop improvement. *Current Science*, 89(2), 353–359.

Frona, D., Janos, S. and Harangi-Rakos, M. (2019). The challenge of feeding the poor. MDPI Journal for Sustainability, 2017, 3–4.

Ganesan, A., Dhanarajan, A., Sellapillai, L. and Gurunathan, S. (2022). e - Publishing Group Improvement of oil content in groundnut (Arachis hypogaea L .) by the impacts of gamma irradiation. x(x).

Gunasekaran, A. and Pavadai, P. (2015). Effect of Gamma Rays on Germination, Morphology, Yield and Biochemical Studies in Groundnut (Arachis hypogaea L.). World Scientific News, 23, 13–23.

Majeed, A., Muhammad, Z., Ullah, R. and Ali, H. (2018). Gamma irradiation i: Effect on germination and general growth characteristics of plants–a review. *Pakistan Journal of Botany*, 50(6), 2449–2453.

Oladosu, Y., Rafii, M. Y., Abdullah, N., Hussin, G., Ramli, A., Rahim, H. A., Miah, G. and Usman, M. (2016). Principle and application of plant mutagenesis in crop improvement: A review. *Biotechnology and Biotechnological Equipment*, 30(1), 1–16.

Olasupo, F. O., Olumuyiwa Ilori, C., Forster, B. P. and Bado, S. (2016). Mutagenic Effects of Gamma Radiation on Eight Accessions of Cowpea (Vigna unguiculata L. Walp.). *American Journal of Plant Sciences*, 7(2), 339–351.

Raina, A., Laskar, R., Khursheed, S., Amin, R., Tantray, Y., Parveen, K. and Khan, S. (2016). Role of Mutation Breeding in Crop Improvement- Past, Present and Future. *Asian Research Journal of Agriculture*, 2(2), 1–13.

Stagnari, F., Maggio, A., Galieni, A. and Pisante, M. (2017). Multiple benefits of legumes for agriculture sustainability: an overview. *Chemical and Biological Technologies in Agriculture*, 4(1), 1–13.

Tshilenge-Lukanda, L. (2012). Radio-Sensitivity of Some Groundnut (Arachis hypogaea L.) Genotypes to Gamma Irradiation: Indices for Use as Improvement. *British Biotechnology Journal*, 2(3), 169–178.

EFFICACY OF WILD SUNFLOWER (*Tithonia diversifolia* (Hemsl.) A.Gray) AND SORGHUM (*Sorghum bicolor* (L.) Moench) AQUEOUS EXTRACTS ON WEED CONTROL IN COWPEA CULTIVATION (*Vigna unguiculata* (L.) Walp)

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Abstract

Cowpea is an important annual grain legume in Sri Lanka and other countries. Weeds cause roughly about 53 to 60% of the yield losses in cowpea cultivation. One method for controlling weeds in cowpea is chemical weed control (herbicide). Herbicide importation has been restricted since recent past due to the country's economic crises and government policy. Therefore, the identification of alternate substitutes for herbicides are important. Accordingly, the study investigated the effect of aqueous extracts of wild sunflower and sorghum on weed parameters of cowpea cultivation. This experiment was carried out in the Crop farm of Eastern University, Sri Lanka from September to November 2022. The field experiment was laid out in a Randomized Complete Block Design (RCBD) with five treatments and four replications. The treatments were T1(Wild sunflower aqueous extract - 12 L ha^{-1}), T2 (Sorghum aqueous extract -12 L ha^{-1}), T3 (Combined application of wild sunflower and sorghum aqueous extract with the ratio of 1:1 - 6+6 L ha^{-1}), T4 (Hand weeding) and T5 (Unweeded check-control). Cowpea variety Waruni was sown in 1.125 m^2 size of 20 beds with a spacing of 30cm×15cm. Aqueous extracts were applied 2,21 and 35 DAS and hand weeding was done 21 and 42 DAS. Weed parameters such as weed dry weight at 50 DAS and weed control index at 35 and 50 DAS were collected. Collected data were statistically analyzed by using Mini tab software and the mean comparison within treatments was performed by Turkey's test at α=0.05. The experiment revealed that weed dry weight and weed control index were significantly ($P<0.05$) influenced by different weed control methods. Among the treatments, hand weeding proved to be more effective than the other treatments when compared with the control (unweeded check). After hand weeding, a combined application of wild sunflower and sorghum aqueous extracts was more effective at controlling weeds than the control (an unweeded check). The study concluded that the combined application of wild sunflower and sorghum aqueous extract could be substituted for hand weeding in cowpea cultivation to suppress the emergence of weeds in cowpea which is environmentally friendly for Sustainable Agriculture in Sri Lanka.

Keywords: Allelochemicals, aqueous extract, cowpea, hand weeding, sorghum and wild sunflower

Introduction

Cowpea (*Vigna unguiculata* L. Walp) is a major annual grain legume crop belonging to the family Fabaceae. One of Sri Lanka's most significant crops is cowpea. Weeds are the most significant biotic constraint to worldwide agricultural production. In Nigeria, weeds reduced crop yields of legumes like cowpea by 53 to 60% (Madukwe *et al*., 2012). The primary weeds in cowpea fields are *Dactyloctenium aegyptium*, *Eleusine indica*, *Gnaphalium indicum*, *Cyperus rotundus*, *Echinochloa crusgalli* and *Sorghum halepense* (Tripathi and Singh, 2001). Weed control methods are necessary to manage weeds in cowpea cultivation. The five categories of weed control are preventive, physical, cultural, biological and chemical. The use of herbicide proved the most practical, effective and economical means of controlling even unapproachable or inaccessible weeds or noxious weeds. However, there is ample proof that

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exposure to specific herbicides increases the risk of many chronic diseases and environmental problems.

Allelopathy, which is the direct or indirect impact of one plant species on another via the release of chemical substances into the root environment, may offer an alternate method of weed control (Duke, 2015). Under field conditions, allelopathic potentiality can be used to manage weeds in a variety of ways, including combination application with reduced herbicide dosages, incorporation into the soil, mix cropping/intercropping, surface mulching and aqueous extracts (Cheema *et al*., 2013). Allelochemicals are substances that have an allelopathic effect. Alkaloids, benzoxazinones, cinnamic acid derivatives, cyanogenic compounds, ethylene, other seed germination stimulants and flavonoids are some examples of allelochemicals (Putnam, 1988). Wild sunflower (*Tithonia diversifolia* A. Gray) is an aggressive weed with high invasive capacity because it is known to exhibit allelopathy. Methanolic and water extracts of wild sunflower consist of flavonoids, tannins, glycosides, terpenoids saponins, alkaloids and phenols. Weed control by using wild sunflower allelochemical *Tridax procumbens*, *Amaranthus cruentus* and *Cleome gynandra* (Musyimi *et al*., 2012*).*

Sorghum (*Sorghum bicolor* L. Moench) is an allelopathic species that suppresses the growth of weeds. Allelochemicals found in *sorghum bicolor*, including benzoic acid, p-hydroxy benzoic acid, vanillic acid, m-coumaric acid, p-coumaric acid, gallic acid, caffeic acid, ferulic acid and chlorogenic acid, may be utilized to manage some significant weeds, including *Cyperus rotundus*, *Phalaris minor* Retz, *Chenopodium album* L, *Rumex dentatus* L and *Convolvulus arvensis* L (Mahmood and Cheema, 2004). Therefore, this present study was undertaken with the following objective to find the effect of wild sunflower and sorghum aqueous extract on weed control of cowpea cultivation.

Materials and Methods

The field experiment was carried out in the Crop farm of Eastern University, Sri Lanka from September to November 2022. Aqueous extracts were prepared by soaking chopped dry wild sunflower and sorghum herbage separately in water for twenty-four hours at a ratio of one kilogram of dry herbage to ten liters of water (weight/volume or w/v). Aqueous extracts were filtered and the volume of the respective filtrate was reduced twenty times by continuously boiling it (Awan *et al*., 2012). Cowpea variety Waruni was sown in 1.125 m^2 size of 20 beds with a spacing of 30cm×15cm. The experiment was laid out in Randomized Complete Block Design with five treatments and four replications. Agronomic practices such as irrigation, fertilizer application and pest and disease control were done according to the recommendation of the Department of Agriculture. The treatments were as follows.

Table 1: Treatments Code and its Description

Treatment code	Description
T1	Wild sunflower aqueous extract @ 12 L ha^{-1} at 2, 21, and 35 days after sowing
T2	Sorghum aqueous extract @ 12 L ha^{-1} at 2, 21, and 35 days after sowing
T3	Wild sunflower + Sorghum aqueous extract (combined) @ 6+6 L ha^{-1} at 2, 21 and 35 days after sowing
T4	Hand weeding at 21 and 42 days after sowing
T5	Control (Unweeded check)

Measurement

Weed dry weight (g) - Weeds were collected by uprooting the weeds from each plot after harvesting the cowpea pods and packed in separate polybags (50 days after sowing). Weeds were cut into small pieces and placed in paper trays, where they were dried at 70°C in the oven until a constant weight was achieved, and their dry weight was measured using an electronic balance.

Calculation

Weed control index (%) - Weed control index (WCI) was measured by taking the reduction in weed population in the treated plot over the weed population in an unweeded check (control). It was expressed in percentage.

$$\text{Weed control index} = \frac{\text{WPC} - \text{WPT}}{\text{WPC}} \times 100$$

WPC - Weed population in control (unweeded) plot.

WPT- Weed population in the treated plot

Results and Discussion

Weed dry weight (g)

Table 2. shows the effect of an aqueous extract of wild sunflower and sorghum on the dry weight of weeds at 50 days after sowing. The results revealed that the dry weight of weeds was significantly ($P<0.05$) influenced when compared with the control (unweeded check). The lowest weed dry weight was recorded in hand weeding (4.14 g) when compared with the control (unweeded check). Sorghum extract (53.77 g) had the highest dry weight among applications of aqueous extracts, while the combined application of extracts had the lowest dry weight (31.84 g).

Table 2: The Effect of the Aqueous Extract of Wild Sunflower and Sorghum on the Dry Weight of Weeds at 50 DAS.

Treatments	Weed dry weight (g)
Wild Sunflower extract	52.13 ± 2.61^{b}
Sorghum extract	53.77 ± 1.41^{b}
Wild Sunflower + Sorghum extract	31.84 ± 1.30^{c}
Hand weeding	4.14 ± 0.28^{d}
Control (unweeded check)	92.13 ± 8.82^{a}

Mean values in a column having dissimilar letter/letters indicate significant differences at a 5% level of significance by Tukey's test.

These results were obtained due to hand weeding, which gets rid of weeds before they mature and produce seeds. Additionally, hand weeding aids in the removal of all weeds, including their roots, rhizomes, and other underground parts like tubers or stolons. Further aqueous extract contains allelochemicals. These allelochemicals inhibit weed seed germination and weed growth by changing the cell membrane's permeability, altering the weeds' photosynthetic process, respiration, and the concentrations of metabolites needed to build the cellular machinery (Ghimire *et al*., 2020). Further, compared to sorghum, wild sunflower's aqueous extract has more allelochemicals that hinder the growth of weeds (Mubeen *et al*., 2012). This finding was also reported by Ajayi *et al*. (2017). who reported hand weeding had lower weed dry weight when compared with the unweeded plot in cowpea cultivation.

Weed control index (%)

Figure 1 depicts the effect of an aqueous extract of wild sunflower and sorghum on the weed control index. It was measured at 35 and 50 days after sowing. There were significant differences ($P < 0.05$) in the weed control index when compared with the control (unweeded check) at 35 and 50 days after sowing. The highest weed control index was reported in hand weeding than other treatments when compared with the control (unweeded check). Among the aqueous extract application, the combined application of wild sunflower and sorghum recorded more weed control index when compared with control (unweeded check). The treatments of wild sunflower extract, sorghum extract, combined application of wild sunflower and sorghum aqueous extract and hand weeding enhanced the weed control index by 39.37%, 37.79%, 54.39% and 82.98% at 50 days after sowing compared with the control (unweeded check).

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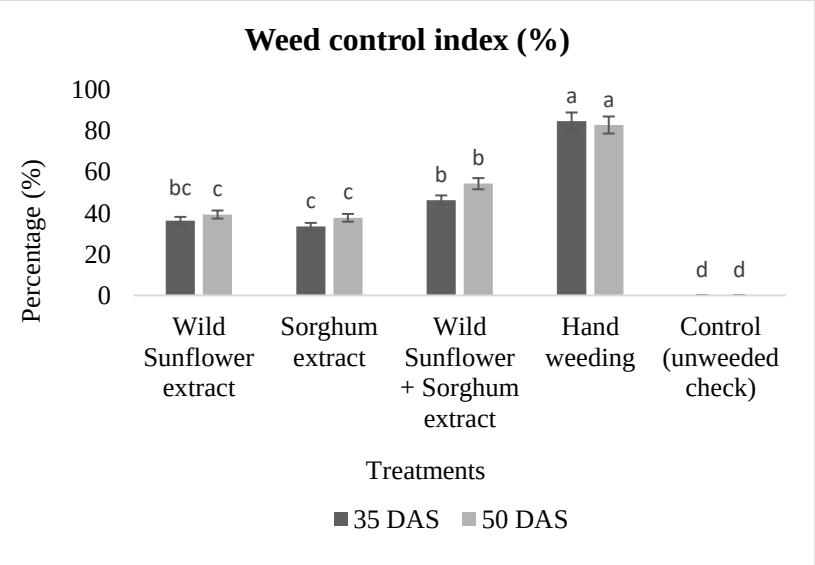

DAS- Days After Sowing; Error bar denotes a standard error. Mean values in a bar with dissimilar letter/letters indicate significant differences at a 5% significance level by Tukey's test.

Figure 1: The effect of aqueous extract of wild sunflower and sorghum on weed control index at 35 DAS and 50 DAS

It might be due to that a larger concentration of the allelochemicals interfered with membrane permeability, photosynthesis, respiration, protein metabolism, and plant/water relationships, which significantly reduced weed growth (Ghimire *et al*., 2020).

Conclusion

Different weed control methods significantly controlled the weeds when compared with the control (unweeded check). Among the various treatments hand weeding showed more effective in comparison with control (unweeded check). Further Among the aqueous extract application combined application of wild sunflower and sorghum extract had more ability to control the weeds in comparison with control (unweeded check). Further Hand weeding and combined application of extract significantly controlled the weeds population by 82.98%. and 54.39% respectively at the end of cowpea cultivation compared with control (unweeded check). On the large-scale hand weeding is a difficult, cost-effective and time-consuming method. In that case, aqueous extract application is an alternate substitute for weed control. The finding will be helpful to add knowledge of the aqueous extract of wild sunflower and sorghum could be an organic alternative to synthetic herbicides on weed control in cowpea cultivation since they are less labor-intensive and have fewer negative impacts on the environment and human health.

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The authors would like to thank the Department of Crop Science, Faculty of Agriculture, Eastern University, Sri Lanka for the field, laboratory and other support.

References

Ajayi, O. A., Akinola, M. O. and Rasheed, O. A. (2017). Allelopathic potentials of aqueous extracts of *Tithonia Diversifolia* (Hemsley) A. Gray in biological control of weeds in cowpea cropping system. *International Journal of Agriculture and Economic Development*, 5(1), 11 - 28.

Awan, F. K., Rasheed, M., Ashraf, M. and Khurshid, M. Y. (2012). Efficacy of brassica, sorghum and sunflower aqueous extracts to control wheat weeds under rainfed conditions of Pothwar, Pakistan. *The Journal of Animal and Plant Sciences*, 22(3), 715-721.

Cheema, Z. A., Farooq, M. and Khaliq, A. (2013). Application of allelopathy in crop production: success story from Pakistan. In Cheema, Z. A., Farooq, M., & Wahid, A(Eds.), Allelopathy (pp. 113-143). Springer, Berlin, Heidelberg, Germany.

Duke, S. O. (2015). Proving allelopathy in crop–weed interactions. *Weed Science*, 63(SP1), 121-132.

Ghimire, B. K., Hwang, M. H., Sacks, E. J., Yu, C. Y., Kim, S. H. and Chung, I. M. (2020). Screening of Allelochemicals in *Miscanthus sacchariflorus* Extracts and assessment of their effects on germination and seedling growth of common weeds. *Plants*, 9(10), 1313.

Madukwe, D. K., Ogbuehi, H. C. and Onuh, M. O. (2012). Effect of weed control method on the growth and yield of cowpea (*Vigna unguiculata* (L) Walp) under Rain- fed condition Owerri. *American-Eurasian Journal of Agriculture and Environment Sciences*, 12(11), 1426-1430.

Mahmood, A. R. I. F. and Cheema, Z. A. (2004). Influence of sorghum mulch on purple nutsedge (*Cyperus rotundus* L.). *International journal of agriculture & biology*, 6(1), 86-88.

Mubeen, K., Nadeem, M. A., Tanveer, A. and Zahir, Z. A. (2012). Allelopathic effects of sorghum and sunflower water extracts on germination and seedling growth of rice (*Oryza sativa* L.) and three weed species. *The Journal of Animal and Plant Sciences*, 22(3), 738-746.

Musyimi, D. M., Kahihu, S. W., Buyela, D. K. and Sikuku, P. A. (2012). Allelopathic effects of Mexican sunflower [*Tithonia diversifolia* (Hemsl) A. Gray] on germination and growth of spiderplant (*Cleome gynandra* L.). *Journal of Biodeversity and Environmental Sciences*, 2(8), 26-35.

Putnam, A. R. (1988). Allelochemicals from plants as herbicides. *Weed technology*, 2(4), 510-518.

Tripathi, S. S. and Singh, G. (2001). Critical period of weed competition in summer cowpea (*Vigna unguiculata* L. Walp.). *Indian Journal of Weed Science*, 33(1&2), 67-68.

DRY MATTER YIELD OF *Vigna unguiculata* AS AFFECTED BY APPLICATION OF *Allium cepa* PEEL EXTRACT

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Abstract

This study was carried out to maximize dry matter yield of *Vigna unguiculata* L. (cowpea) by application of *Allium cepa* peel extract. The experiment was conducted at a home garden, Mailapitiya, Kandy in May to September 2021 in a Randomized Complete Block Design. There were six treatments in six replications comprised of different percentages of *Allium cepa* peel extract expressed as, T1 was control treatment by using normal water and T2 - 20%, T3 - 40%, T4 - 60%, T5 - 80% and T6 - 100% extract concentrations. The peel extract was prepared by soaking 100 g of peels in one-liter water for 48 hours at the room temperature then extract was diluted according to the treatments. The application of *Allium cepa* peel extract was started at two weeks after seeding and the plant performance was recorded in vegetative phase and in harvesting phase. The results were confirmed that application of *Allium cepa* peel extract had significant ($P<0.05$) effects on tested parameters over the control. The application of 40% (v/v) concentration *Allium cepa* peel extract increased the number of trifoliate leaves, root length, dry weights of stem, leaves, root and crop residue after harvesting pods. But the application of 100% (v/v) concentration of *Allium cepa* peel extract was significantly increased pod weight per plant among the treatments. The maximum mean value of dry matter yield was recorded in T6 (782.44 g/m^2) and the minimum mean value was recorded in T1 (327.11 g/ m^2). According to the statistically analyzed results, 100% of *Allium cepa* peel extract gave a higher dry matter yield of *Vigna unguiculata* (L) but there was no significant variation on pod weight and dry matter yield between T5 and T6. Therefore, *Allium cepa* (onion) peel at 80% could be used for increasing the pod and dry matter yield of *Vigna unguiculata* (L).

Keywords: Cowpea, foliar application, onion peel extract, pod weight

Introduction

Vigna unguiculata L. Walp. is one of the most significant grain legumes in developing countries. It is an essential crop in many impoverished regions of the globe because of its drought tolerance and fixes atmospheric nitrogen and contributes to soil fertility. Cowpea supplies food for humans and livestock. In crop cultivation, liquid fertilizer is used directly to leaves of plants. Basavaraj (2018) stated that the foliar spray technique is suitable for application of small quantities of fertilizers, particularly micronutrients. On the other hand, under certain circumstances, foliar fertilization is particularly practiced, more economic and effective when it is necessary to supply micronutrients to plants (Niewiadomska *et al*., 2020). Mallarino (2001) noted that at early growth stages, foliar fertilization could increase P and K supplies at a time when the root system is not well developed. Onion is one of the important condiments widely used in all household. Throughout the year, onions are used in curries, as spices, salads or cooked with other vegetables (Griffiths *et al.*, 2002). Onion peel wastes are good sources of minerals such as potassium, calcium, magnesium, iron, zinc and manganese (Benítez *et al.*, 2011). Onion skins are also excellent in flavonoids, including quercetin, a powerful antioxidant and anti-inflammatory. Onion peel is a source of potassium and other nutrients**.** The onion peel can be used as main component for making organic liquid fertilizer**.** Therefore, this study was done to perform the *Allium cepa* (red onion) peel extract as liquid application on dry matter yield of *Vigna unguiculate*.

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Materials and Methods

This study was done at home garden in Mailapitiya, in Kandy, Central province, Sri Lanka in 2021. The climate of the experimental site receives a significant amount of rainfall throughout the year and the reddish brown lateritic soil is the foremost soil of the Kandy district. For the experiment, *Vigna unguiculata* (Cowpea) variety Dhawala seeds were used in this experiment which was designed in Randomized Complete Block Design with six treatments and six replicates. The treatments were application rates (0%, 20%, 40%, 60%, 80% and 100%) of *Allium cepa* (red onion) peel extract to plants. For extract preparation, 100 g of *Allium cepa* peels collected from kitchen waste in household level were placed in a plastic container containing one-liter water. The top lid of plastic container was covered and left at room temperature for 48 hours and then the extract was filtered (1 mm size mesh sieve) as described by Chiew *et al*. (2014), After that, it was kept separately for preparation of extract according to treatments. In this experiment polybags were filled with soil and compost and then two seeds of dhawala were planted in each polybag. After two weeks of seeding, one plant was thinned out from each bag. As basal application of fertilizer, 0.157 g urea and 0.45 g Triple superphosphate (TSP) were added while 0.135 g urea was applied as a top dressing for each polybag and other cultural practices were done according to the recommendation of the Department of Agriculture, Sri Lanka. During the experimental period, the *Allium cepa* peel extract (50 ml) was spray on each plant four times at two-week intervals. Data was collected from 3rd weeks after planting at two weeks intervals upto harvesting. Harvesting was done at 64 days after planting then plants were uprooted at 86 days. Number of trifoliate leaves per plant, length of root (cm), dry weights of leaves, stem, root, crop residue and pods per plant were taken. The collected data was analyzed using statistical software, SAS 9.1 version. Tukey's HSD Test was used to compare the treatments at a 5% significant level were used for data analyzing.

Results and Discussion

Number of trifoliate leaves per plant

The number of trifoliate leaves per plant was significantly ($P<0.05$) varied among the treatment at 9th week and treatments did not significantly influence ($P>0.05$) in numbers of trifoliate leaves in cowpea plants at 3rd, 5th and 7th weeks after planting. Due to the application of 40% (v/v) *Allium cepa* peel extract, the maximum mean number (8.3) of trifoliate leaves was recorded in T3 and the minimum mean number (6.5) in control (T1) at 9th week after planting (Figure 1).

Length of root

The different concentrations of *Allium cepa* peel extract application significantly influenced ($P<0.01$) the length of tap root. According to this result, peel extract significantly showed longest taproot in T3 (24.4 cm) among the treatments except T5 (20.9 cm) while shortest length of 14.9 cm observed in T1. Hayyawi *et al*. (2018) noted that the foliar application of tri Nano mixed fertilizer of N, P and K significantly increased plant height, root length and leaves with all treatments except the control treatment.

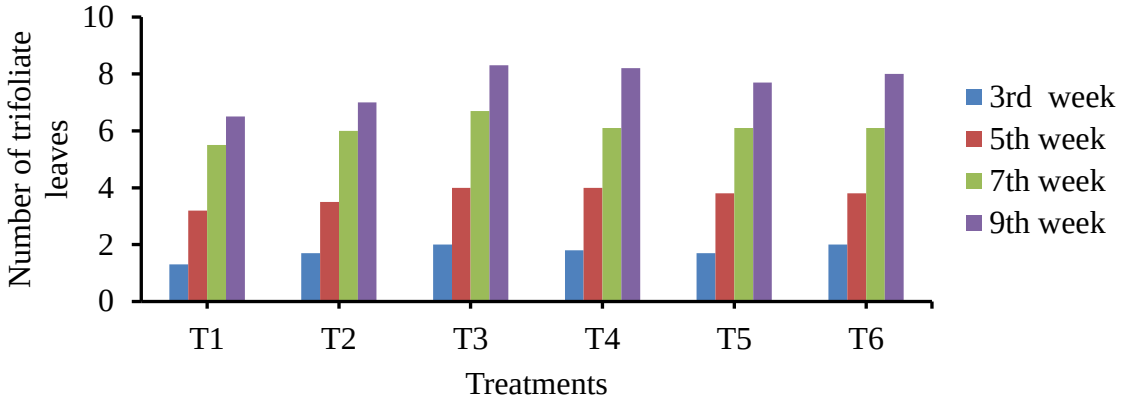

Figure 1: Effects of different concentrations of *Allium cepa* peel extract on number of trifoliate leaves of *Vigna unguiculata* at different weeks.

Stem weight

The result showed that dry weight of stem was significantly influenced (P<0.05) with the application of *Allium cepa* peel extract (Table 1). The maximum dry weight of stems was recorded in T3 (8.01 g) and the lowest dry weight of cowpea stems was recorded in T1 (4.46 g). Ebrahimian *et al*., (2011) stated that iron foliar application significantly increased in sunflower stem dry weight and this increase can be due to increase photosynthesis and growth

Table 1: Effects of different concentrations of *Allium cepa* peel extract on dry weights of stem, leaves, roots, crop residue and pod weight of *Vigna unguiculata* plant after harvesting.

Treatments	Dry weights (g)				
	Stem	Leaves	Root	Crop residue	Mature pods
T1	4.46^{b}	2.84^{c}	0.96^{c}	8.25^{c}	6.47^{b}
T2	7.03^{a}	4.57^{b}	1.96^{bc}	13.56^{b}	8.68^{b}
T3	8.01^{a}	6.45^{a}	3.86^{a}	18.31^{a}	11.58^{b}
T4	6.33^{ab}	4.28^{bc}	2.26^{b}	12.87^{b}	14.82^{b}
T5	5.99^{ab}	3.67^{bc}	2.79^{ab}	12.44^{b}	18.43^{ab}
T6	6.92^{a}	3.78^{bc}	2.51^{b}	13.21^{b}	22.00^{a}
F test	P<0.05	P<0.001	P<0.01	P<0.001	P<0.001

Mean values in a column having the dissimilar letter/letters indicate significant differences at 5% level of significance according to Tukey's HSD Test.

Leaf weight

Effect of *Allium cepa* peel extract application on dry weight of leaves is presented in Table 1. It was significantly influenced (P<0.001) the dry weight of leaves among the tested treatments. The significantly maximum dry weight of leaves was observed in T3 (6.45 g) while minimum dry weight (2.84 g) of leaves was observed in the control treatment. Increased dry matter production is due to the foliar fertilization which resulted in better crop growth and photosynthetic activity which has led to better supply of photosynthates ultimately resulted in higher dry matter production of leaves per plant.

Root weight

A significant difference (P<0.01) was noted on dry weight of root in cowpea plant (Table 1). Among the tested treatments, T3 (3.86 g) recorded the maximum dry weight of roots and T1

(0.96 g) was recorded the minimum dry weight of roots. Sharifi *et al.* (2018) noted that the increased dry matter production of soybean plant due to foliar application of water-soluble fertilizer and that gave significantly difference result of higher dry weight of roots among treatments than the control. In all cases, the increments in growth parameters were often highly significant in comparison with untreated ones.

Crop residue weight

There was a significant difference (P<0.001) in dry weight of crop residue per plant (Table 1). Significantly highest dry weight was observed in T3 (18.31 g) while minimum weight was observed in T1 (8.25 g). This result suggested that the dry weight of crop residue of the foliar fed with 40% concentration of *Allium cepa* peel extract was increased in comparison with the control treatment.

Pod weight

Table 1 represents the different concentration of *Allium cepa* peel extract application on dry weight of mature pods per plant. All treatments significantly influenced (P<0.001) the dry weight of mature pods of cowpea. Average maximum dry weight of pods was observed in T6 (22 g) followed by T5 while minimum dry weight of pod was observed in T1 (6.47 g). There was no remarkable variation (P<0.05) on pod weight between T5 and T6. Thus, the application of *Allium cepa* peel extract at the rate of 100% concentration at two weeks interval increased the dry weight per pod per plant. This increase in pod weight is due to the presence of high level of potassium content in *Allium cepa* peel extract. Ramezani *et al.*, (2011) reported that potassium has the ability to improve the fruit quality by improving the formation and translocation of carbohydrates from the shoot to storage organs (pods) and carbohydrate enzymes.

Dry matter yield

Application of different rates of *Allium cepa* peel extract significantly influenced (P<0.01) the dry matter yield (g/m^2) per plant which is confirmed with Tukey's HSD Test (Figure 2). Maximum dry matter yield (782.44 g/ m^2) per plant was observed in T6 and minimum was observed in T1 (327.11 g/ m^2). According to the analyzed results, the foliar application of *Allium cepa* peel extract at the rate of 100% concentration at two weeks interval increased the Dry matter yield when compared to control treatment. According to Rouphael *et al.*, (2020), the application of plant extracts increases the growth of different crops and can be have a positive impact of yield of plants.

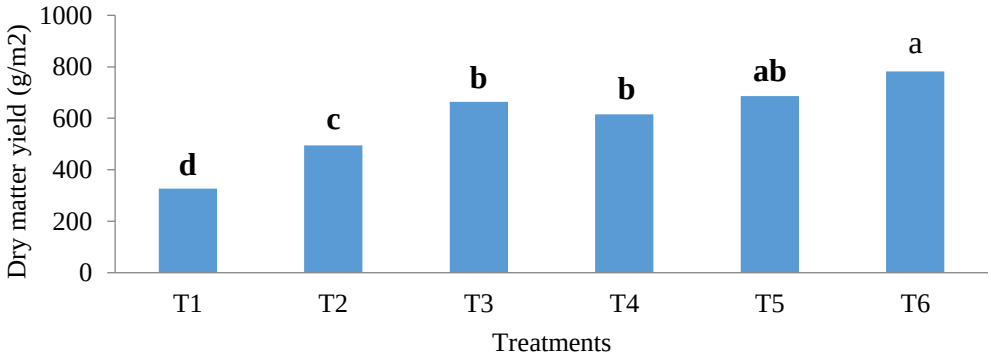

Figure 2: Effects of different concentrations of *Allium cepa* peel extract on dry matter yield *Vigna unguiculata* plant after harvest

Mean values in a bar having the dissimilar letter/letters indicate significant differences at 5% level of significance according to Tukey's HSD Test

Conclusion

The results revealed that significant variations were noted on the measured paramerets due to the application of different concentration of *Allium cepa* peel extract. There was a significant difference in dry weight of the mature pods. According to statistically analyzed results, application of *Allium cepa* peel extract had a significant influence on biological yield of *Vigna unguiculata* L. Walp. The maximum mean value of dry matter yield was recorded in T6 and the minimum mean value of dry matter yield was recorded in T1. There was no remarkable variation ($P<0.05$) on dry matter yield between T5 and T6. Therefore, 80% (v/v) of *Allium cepa* peel extract could be applied to increase dry matter yield of *Vigna unguiculata.*

References

Basavaraj, P. and Chetan, H. T. (2018). Foliar fertilization of nutrients. (Available online: www.marumegh.com) 3(1): 49 - 53. (December 12, 2022)

Benítez, V., Mollá, E., Martín-Cabrejas, M. A., Aguilera, Y., López-Andréu, F. J., Cools, K., Terry, L. A. and Esteban, R. M. (2011). Characterization of industrial onion wastes (*Allium cepa L.*): dietary fibre and bioactive compounds. *Plant Foods Human Nutrition*, 66 (1): 48–57.

Chiew, S. P., Thong O.M, and Yin, K. B. (2014). Phytochemical composition, and cytotoxic activities of red onion peel extracts prepared using different methods. *International Journal of Integrative Biology*, 15(2): 49-54.

Ebrahimian, E. and Bybordi, A. (2011). Effect of iron foliar fertilization on growth, seed and oil yield of sunflower grown under different irrigation regimes. *Middle East Journal of Scientific Research*, 9(5): 621- 627.

Griffiths, G., Laurence, T., Timothy, C., Brian, T., and Smith, B. (2002). Onions a global benefit to health. *Phytotherapy Research* 16(7): 603-615.

Hayyawi, W. A., Al-Juthery., Kahraman, H., Habeeb., Altaee, F. J. K., Taey, D. K. A. A. L., Rahman, M. A. and Al-Tawaha. (2018). Effect of foliar application of different sources of nano-fertilizers on growth and yield of wheat. *Bioscience Research*, 15(4): 3988-3997.

Mallarino, A. P., Haq, M.U., Agron. J., Wittry, D. and Bermudez, M. (2001). Variation in soybean response to early season foliar fertilization among and within fields. 93, 1220–1226.

Niewiadomska, A., Hanna, S., Agnieszka, W. M., Karolina, R., Zyta, W. and Anna, B. (2020). The Influence of Bio-Stimulants and Foliar Fertilizers on Yield, Plant Features, and the Level of Soil Biochemical Activity in White Lupine (*Lupinus albus* L.) *Cultivation Agronomy*, 10: 150.

Ramezani, S. and Shekafandeh, A. (2011) Influence of Zn and K sprays on fruit and pulp growth in olive (*Olea europaea* L. cv. 'Amygdalifolia'). *Iran Agriculture Research*, 30(1-2): 1-10.

Rouphael, Y. and Colla, G. (2020) Biostimulants in agriculture. *Frontiers in plant science*, 11, 40.

Sharifi, S. K., Lalitha, B. S., Qasimullah, R., Kumar, G. K. P. and Manjanagoud, S. S. (2018). Effect of foliar application of water-soluble fertilizer on growth and yield of soybean (*Glycine max* L. Merrill). *International Journal of Pure and Applied Bioscience*, 6(5): 766-770.

CROP PROTECTION TECHNOLOGY

ANALYSIS OF PHYTOCHEMICALS PRESENT IN SELECTED PLANTS USING WATER AND METHANOL BASED EXTRACTION

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Abstract

Several botanical pesticides exhibit extensive activity against grain insects and are considered as attractive alternative to chemical pesticides toward food and environmental safety. Further the reference in Sri Lanka evidenced that the botanical pesticides are efficacious in minimizing these problems, owing to the anti-insecticidal properties. Moreover, the reference studies stated that the distinct components of secondary metabolites, which are responsible for the insecticidal activities, confirmed its efficacy individually. Therefore the present study was undertaken to analyze the secondary metabolites, like alkaloid, flavonoid, phenol, tannin, steroids, cardiac glycosides, terpenoid, saponine, anthraquinone and reducing sugar present in water and methanol extract of some indigenous plants, *Capsicum annuum* (chilli), *Citrus aurantiifolia* (lime), *Pepper nigrum* (pepper), *Azadiracta indica* (neem), *Moringa oleifera* (moringa), *Eucalyptus globules* (eucalyptus), *Justicia adhatoda* (adhathodai), *Annona reticulate* (annona), *Cymbopogan citratus* (lemon grass), *Vitex trifolia* (nochchi), *Ocimum tenuiflorium* (thulsi), *Lantenna camera* (nayunni), *Eichhornia crassipes* (water hayasinth), *Tagetes erecta* (marigold), *Piper longum* (thipilli) *and Achyranthes aspera* (nayuruvi) in the Batticaloa district, Sri Lanka. Ten grams dried leaf powder of each selected plants were used to get the methanol and water extraction using Electro Thermal Soxhelt apparatus and then the extracts were individually concentrated by using rotary evaporator. The qualitative analysis for plant secondary metabolites was performed through standard protocols. The results showed the presence of flavonoids in all the tested crops except *P. longum* in the both extracts which contained only phenol and tannin in the water extract with additionally alkaloid, steroid and cardiac glycoside in methanol extracts. Leaves extracts of *A. indica* contained all analyzed phytochemicals in methanol extract but water extract of *A. indica* did not show anthraquinone. Further the presence of alkaloids was not observed in *C. annum, P nigrum, A. reticulate, C. citratus, L. camera E. crassipes* in both extracts whereas *E. globules, V. trifolia* and *O. tenuiflorium* contain alkaloids in methanol extract. Methanol extraction projected the presence of most phytochemicals in all the tested crops than the water extraction. The study evidenced the presence of various groups of phytochemical in selected crops, which could be used as botanical pesticide. Therefore, the study is useful in selecting the plants with desired component of secondary metabolites, which will be extracted individually using standard methods to be tested against insect pests.

Keywords: Alkaloids, aqueous, extract, grains, methanol and phytochemical

Introduction

Plants naturally contain a variety of biologically active compounds, and most of them are gaining eco-friendly insecticidal activity, which can significantly reduce the use of synthetic chemical insecticides (Geraldin *et al*., 2019). Traditionally, farmers have used selected botanicals in developing countries like Sri Lanka and other Asian countries in post-harvest pest management that exhibits varied actions on target pests such as repellence, toxicity and have growth inhibitory effect of insect development causing reduction of adult survival and rate of new emergence of next generations. Several studies emphasized in Sri Lanka that the plant leaf extract or leaf powders could minimize or control insect damage specially focused preservation

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of grains during storage. Gunarathna and Karunaratna (2009), they evaluated thirty seven Sri Lankan plants for their repellent properties against rice weevil *Sitophillus oriezea* , considering twenty plants caused significant repellency of the weevil as well as Karunakaran and Arulnandhy (2018) and Perera *et al* carried out the same period in SriLanka that, locally available selected plants for controlling maiz weevil *Sitophillus zeamais* on maize seeds during storage, neem leaf showed 86% adult mortality and 60% repellency respectively and also projected reduction of new emergency in both findings. Further Niranjana *et al* (2021) stated cow urine based indigenous plant leaf extracts of neem and annona significantly highest protection against the above weevil on different pulse grains. Another study revealed in Sri Lanka by Karunaratne (2012) extracts of *Mentha viridis* strongest and highest repellent against cowpea weevil *Callosobruchid maculatus.*

Alkaloids, terpenoids, steroids, tannin, and phenolic compounds are the most significant phytochemicals that are bioactive in nature and have anti-pathogen, antioxidant, or anti-insecticidal properties. They are much safer, eco-friendly, and effective at competing with synthetic chemicals to control target organisms. They are also widely available, inexpensive, easily biodegradable, and have low toxicity to non-target organisms. Amaninder and Shiva (2018). Amongst phytochemical constituents, alkaloids, flavonoids, and glycosides are the most important group of natural substances that play an important role in insecticidal activity, especially they are effective as fumigants against stored insects. Wachira *et al.* (2014) concluded that pyridine alkaloids extracted from castor bean plant against malaria vectors, and Acheuk *et al*. (2013) also indicated that flavonoids play an important role in protecting plants from herbivorous insects.

Therefore, this study reveals the presence of phytochemicals in water and methanol extracts of Sixteen (16) species of insecticidally active native plants were found in the Batticaloa region of Sri Lanka for pest control.

Materials and Methods

Collection of samples

Botanically conformed fresh and healthy leaves of *Capsicum annuum* (chilli), *Citrus aurantiifolia* (lime) *Pepper nigrum* (pepper), *Azadiracta indica* (neem), *Moringa oleifera* (moringa) *Eucalyptus globules* (eucalyptus), *Justicia adhatoda* (adhathodai) *Annona reticulate* (annona), *Cymbopogan citratus* (lemon grass) *Vitex trifolia* (nochchi), *Ocimum tenuiflorium* (thulsi), *Lantenna camera* (nayunni), *Eichhornia crassipes* (water hayasinth), *Tagetes erecta* (marigold) *piper longum* (thipilli) and *Achyranthes aspera* (nayuruvi) were collected from their natural habitats in Batticaloa district, Sri Lanka and brought to the Laboratory of the Department of Agricultural Biology, Faculty of Agriculture and washed separately. Afterwards shade dried until attain constant weight at room temperature and ground each dried leave in to fine powder using domestic electric grinder.

Preparation of extracts

10 g of each leaf powder were extracted separately with 200 ml of the solvents that, water and methanol at a temperature not exceeding the boiling points of the above solvents using Electro Thermal Soxhelt for 36 hours approximately 10 cycles and then extracts were individually concentrated by using rotary evaporator and stored in reagent bottles for further analysis.

Qualitative phytochemical analysis

The tests were performed following standard protocols used by Trease and Evans (1996).

Alkaloids*:* 1 ml of 1% HCl mixed with 3 ml of test sample extract in a test tube and added few drops of Mayer's reagent along the side of the test tube, appearance of creamy white precipitate indicated the presence of alkaloids.

Phenols, Flavonoids and Tannins: 5 to 6 drops of 10% lead acetate solution added to 1 ml of each extract appearance of white colour precipitate indicated the presence of phenols and if yellow precipitate appeared for 12 to 15 drops of above same solution indicated presence of flavonoids. As well as if formation of cream gelatinous obtained for 3 drops of the same solution confirmed the presence of tannins.

Steroids: 2 ml of chloroform and 2 ml of sulphuric acid was carefully added along the side wall of the test tube which contains 2 ml test extract and gently shaken formation of red colour in the lower chloroform layer confirmed the presence of steroids.

Cardiac glycosides: 2 ml test sample extracts mixed with 2 ml of glacial acetic acid containing 1-2 drops of 2% $FeCl_3$ and the mixture poured along the sidewall of another test tube contain 2 ml of con.H_2SO_4 presence of cardiac glycosides conformed by the appearance of a brown ring at the interface.

Terpenoid: 5 ml of extract mixed with 2 ml of chloroform and 3 ml of con.H_2SO_4formation of reddish –brown coloration at the junction of two liquid indicated presence of terpenoids.

Saponine: confirmed the presence of saposines by shaken 5 ml of extract for 5 to 10 minutes the formation stable foam.

Anthracquinone: 5 ml of extract taken in a dry test tube and shake with 5 ml of chloroform for 5 minutes then filtered the extract and filtrate had shaken with an equal volume of 10% ammonium solution. The appearance of pink, red or violet coloration in the ammonical phase indicated the presence of anthraquinone.

Reducing sugars: 0.5 ml extract mixed with 1ml of dihydrogen monoxide and 5-8 drops of Fehling"s solution was integrated at boiling and observed brick red precipitate.

Results and Discussion

Presence of phytochemicals in sixteen plants leaves in Batticaloa district, Sri Lanka is given in the Table 1. The qualitative results were expressed as (✓) for presence and (×) for absence of phytochemicals. The results indicated the presence of flavonoids in all the tested crops except thipilli in both extracts which contained only phenol and tannin in the water extract with additionally alkaloid, steroid and cardiac glycoside in methanol extracts. Apart from that, leaves extract of neem contained all analyzed phytochemicals in methanol extract but water extract of neem did not show only anthraquinone. Further the chilli, pepper, annona, lemon grass, nayunni and water hyasinth abstained the results for the alkaloids in both extracts whereas eucalyptus, nochchi and thulsi obtained alkaloid in methanol extract as well as steroids also were observed only seven plants in water extract where the above said phytochemical presence in ten plants with methanol extract out of sixteen.

Moreover, the study revealed the presence of biologically active components like flavonoids, phenols, tannin and steroids in many of the tested leaves. Further, it was also clearly noted from the qualitative analysis that the methanol as a solvent performed well to extract most of the tested phytochemicals from the selected leaves than the water. Engwa *et al*., (2013) in Nigeria stated that among the solvents like, water, methanol, ethyl acetate and hexane, used to extract phytochemicals, water and methanol did well to extract tannin, flavonoids, cardiac glycosides, phenolics, steroids, terpenes, saponin, carbohydrate, phlobatannin and alkaloids. In addition, Prakash *et al.*, (2012) revealed that the presence of secondary metabolites in plants is very important to protect themselves from the attack of phytophagous insects. The findings of Wafaa

et al., (2017) and Geraldin *et al.*, (2021) was also par with the findings of Prakash *et al.*, (2012) and explored that the phytochemical compositions like essential oils, flavonoids, alkaloids, glycosides, esters and fatty acids having anti insect effects and such mechanisms against pest is very important in agriculture productions.

Table 1: Presence of Phytochemical in 10 g of dried leaf powder using water and Methanol extraction

Leaf of selected Plants	**Water Extract**										**Methanol Extract**									
	al	fl	ph	ta	st	cgl	ter	sap	anq	rsg	al	fl	ph	ta	st	Cgl	ter	sap	anq	rsg
Capsicum annuum (chilli)	×	✓	×	✓	✓	✓	×	✓	×	✓	×	✓	×	✓	✓	✓	✓	✓	×	✓
Citrus aurantiifolia (lime)	✓	✓	✓	✓	×	×	×	×	×	×	✓	✓	✓	✓	×	×	×	✓	×	×
Pepper nigrum (pepper)	×	✓	✓	×	×	×	×	✓	✓	×	×	✓	✓	✓	×	×	×	×	✓	×
Azadiracta indica (neem)	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Moringa oleifera (moringa)	✓	✓	✓	✓	×	×	×	×	×	×	✓	✓	✓	✓	×	×	×	✓	✓	×
Eucalyptus globules (eucalyptus)	×	✓	✓	✓	✓	×	×	×	×	×	✓	✓	✓	✓	✓	✓	×	×	×	×
Justicia adhatoda (adhathodai)	✓	✓	×	✓	×	✓	×	×	×	×	✓	✓	×	✓	✓	✓	✓	×	×	×
Annona reticulate (annona)	×	✓	✓	✓	×	×	×	×	×	✓	×	✓	✓	✓	×	✓	×	✓	✓	✓
Cymbopogan citratus (lemon grass)	×	✓	✓	✓	×	×	×	×	×	×	×	✓	✓	✓	✓	✓	×	×	×	×
Vitex trifolia (nochchi)	×	✓	✓	✓	✓	×	×	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	×
Ocimum tenuiflorium (thulsi)	×	✓	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	✓	×
Lantenna camera (nayunni)	×	✓	×	×	✓	×	×	×	×	×	×	✓	×	×	✓	✓	✓	×	✓	×
Eichhornia crassipes (water hyasinth)	×	✓	✓	✓	×	×	×	×	×	×	×	✓	✓	✓	×	✓	×	✓	×	×
Tagetes erecta (marigold)	✓	✓	✓	✓	✓	✓	×	×	×	✓	✓	✓	✓	✓	✓	×	×	×	×	×
piper longum (thipilli)	✓	×	✓	✓	×	×	×	×	×	×	×	×	✓	✓	✓	✓	×	×	×	×
Achyranthes aspera (nayuruvi)	✓	✓	×	✓	×	×	✓	×	✓	×	✓	✓	×	✓	×	✓	✓	×	×	×

al-alkaloid, **fl**- flavonoid, **ph**-phenol, **ta**-tannin, **st**-steroids, **cgl**-cardiac glycosides, **te**-terpenoid, **sa**-saponine, **anq**-anthraqunone and **rsg**-redusing sugar.

Conclusion

The study evidenced the presence of various secondary metabolites in the methanol and water extract of tested plants. The findings will direct to choose proper plants for further studies, which aiming to test the efficacy of specific component of secondary metabolites against insect pests.

References

Amaninder, K.R. and Shiva, O. (2018): A review of Effect of phytochemicals against different pest: *International Journal of Advanced Research* (IJAR). Vol 6 (6),999 -1003.

Engawa, A.G., Nnamdi., P., Nnadi.,J.C., Offor., T.I. and Eze.,B.C. (2013). *International journal of Pharmacognosy and Phytochemical Research*, 5(3); 164-167.

Geraldin, M.W. Lengai., James,W.Muthomi. and Ernest, R. Mbega. (2019). Phytochemical activity and role of botanical pesticides in pest management for sustainable agricultural crop production: *Scientific African Journal*,7 (2020): home page: www.elsevier.com/locate/sciaf.

Gunarathna, T.V.N.M. and Karunaratne. (2009). Laboratory evaluation of some Sri Lankan plants as post-harvest grain protectants for the control of rice weevil *Sitophilus oryzea*: *Vidyodaya J. of Sci*, vol 14. (11): pp. 69-83.

Karunakaran, S. and Arulnandhy. V. (2018). Insecticidal activity of selected Botanicals on maize weevil, *Sitophilus zeamais* L., in stored maize grains: Journal of Agricultural Sciences, Volume 12(1): pp. 1-6.

Karunaratne, U.K.P.R. and Karunaratne, M.M.S.C. (2012): Evaluation of Methanol, Ethanol and Acetone extracts of four plant species as repelents against Callosobruchus maculatus (Fab.): *Vidyodaya J. of Sci*. (2012). Vol, 17. Pp 1-8.

Niranjana R.F, Karunakaran., S. and Nifflah, M.R.F. (2021): Effect of Cow urine based plant extracts against maize weevil, (*Sitophilus zeamais*) on different pulse grains: Abstract of the Proceedings of 8th Ruhuna International Science & Technology Conference, RISTCON-2021), University of Ruhuna, Matara, Sri Lanka

Perera, A.G.W.U., Karunaratne.,M.M.S.C. and Chinthaka, S.D.M. (2018): Bioactivity and Volatile Profiling of *Azadiracta indica* leaves for the management of maize weevil, *Sitophilus zeamais* (Motsch.) Infestations: *Journal of Tropical Forestry and Environment*, vol.8 (1): pp.10-24.

Prakash, D, Gupta., C. and Sharma, G. Importance of phytochemicals in Nutraceuticals. *Journal of Chines Medicine Research and Development (JCMRD*). (2012); 1 (3): 70-78.

Trease, G.E. and Evans, W.C. (1996): Pharmacognosy. In:WB (4th Edition), New York Scientific Press, USA, 1996: 243-283.

Wachira, S.W., Omar., S., Jacob., J.W., Wahome.,M., Alborn.,H.T., Spring., D.R. and Torto, B. (2014) : Toxicity of six plant extracts and two pyridine alkaloids from *Ricinus communis* against the malaria vector *Anopheles gambiae* Parasites & Vector, 7, 312.

Wafaa, M.H., Rowida., S.B. and Hussein, A.H.S. (2017). Botanical insecticide as a simple extractives for pest control, *Journal of Cogent Biology*, 3: 1404274; 1-16.

INVESTIGATION OF MICROBIAL QUANTITY AND DIVERSITY IN PROCESSED CINNAMON KEPT UNDER DIFFERENT POST-HARVEST TREATMENTS

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Abstract

Ceylon cinnamon is one of the most popular spices throughout the world. Yet, Sri Lanka has not been able to create a significant market niche in developed countries mainly due to the perishing of the product by fungal contaminations. Therefore, a research was conducted to study the fungal quantity and diversity of processed cinnamon under different post-harvest treatments. Cinnamon quills kept in the drying room (28 ± 2 °C) for 14 days after processing were selected for the study. Fungal contaminants of cinnamon quills were cultured by inoculating them in sterile PDA plates with selected samples and incubating for 3-days under room temperature (28 ± 2°C). Emerging fungal colonies were isolated and identified using microscopic and culture characteristics. To study the fungal quantity and diversity, control treatment (T_1: cinnamon quills stored in a regular storehouse 28 ± 2 °C, RH 88% ± 4) was compared with five different treatments as follows;-T_2) SO_2 fumigation (3 ppm) and storing in storehouse, T_3) placing in sealed polythene bags and storing in storehouse, T_4) SO_2 fumigation, placing in sealed polythene bag and storing in storehouse, T_5) storing in controlled environment (25 °C, RH<65%), and T_6) SO_2 fumigation and storing in controlled environment (25 °C and RH<65%). Data were recorded once in two weeks. Results revealed that *Rhizopus* spp., *Penicillium* spp., and *Aspergillus* spp. are the common fungal contaminants of processes cinnamon quills. Further, both T_4 and T_6 showed significantly ($p < 0.05$) low fungal contaminations throughout the observation period compared to the control treatment. Highest fungal diversity was observed in T_1 (T_1: cinnamon quills stored in a regular storehouse 28 ± 2 °C, RH 88% ± 4). Thus, SO_2 fumigation followed by controlled environment storage can be recommended to reduce the fungal contaminants and improve the post-harvest quality of processed cinnamon.

Keywords: Cinnamon quills, fungal contaminants, fungal diversity, post-harvest quality, sulphur dioxide fumigation

Introduction

Ceylon cinnamon, (*Cinnamomum zeylanicum* Blume) is one of the major spice products exported from Sri Lanka (Jayasinghe *et al.*, 2017). Cinnamon quill is the prime commodity of Ceylon cinnamon. Higher post-harvest losses can be resulted due to inappropriate storage conditions. Emergence and the number of fungal colonies are varied under different moisture levels, relative humidity conditions and locations. Sulphur Dioxide (SO_2) fumigation may improve the hygienic quality of cinnamon quills. Therefore, we aimed to study the fungal quantity and diversity of processed cinnamon under different post-harvest treatments.

Materials and Methods

C-grade cinnamon quills (7.2 Kg) kept in the drying room (28±2 °C) for 14 days after processing were obtained from National Cinnamon Research and Training Centre. Samples were tested in triplicates, 200g of cinnamon quills were used for each treatment. Sterile PDA plates were inoculated with the cinnamon samples and incubated for 3-days under room

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temperature for culturing fungal contaminants. Sulphur dioxide fumigation (3ppm) was done using 45 g sulphur/15 Kg cinnamon quills. Cinnamon quills were kept in a regular storehouse (28±2 °C, 88%±4 RH) for the control treatment (T_1). And other five treatments were as follows T_2) fumigation with SO_2 (3 ppm) and storing in the storehouse; T_3) placing in sealed polythene bags and storing in the storehouse; T_4) fumigation with SO_2 (3 ppm), placing in sealed polythene bags and storing in the storehouse; T_5) storing in a controlled environment (25 °C and RH<65%); and T_6) SO_2 fumigation (3 ppm) and storing in controlled environment (25 °C and RH<65%). In each treatment Colony Forming Units (CFU) and fungal diversity were recorded once in two weeks up to 8 weeks. The number of colony forming units (CFU) of fungi were counted using a colony counter equipment (Julianti, Rajah and Fidrianny, 2017). The Simpson's diversity index (1949) was used (Gaur *et al*., 2021) to determine the fungal diversity of each sample.

Results and Discussion

Rhizopus spp., *Penicillium* spp., and *Aspergillus* spp. were found to be most common fungal contaminants of processed cinnamon. The lowest number of CFUs were observed (Table.1) in cinnamon quills stored in controlled conditions (25 °C and RH<65%) after SO_2 fumigation (T_6) and SO_2 fumigated cinnamon stored in sealed polythene bags (T_4) respectively. Number of CFUs was significantly lower in T_6 than in the control treatment. Cinnamon quills placed in sealed polythene bags and stored in storehouse (T_3) showed a higher number of fungal contaminations compared to the control (T_1). Out of all treatments the lowest number of CFUs were observed in T_6.

Table 1. Mean CFUs under different post-harvest treatments at 0.05 significance level

Treatments	CFU/ml 2 weeks	CFU/ml 4 weeks	CFU/ml 6 weeks	CFU/ml 8 weeks
T1	$44333^{a} \pm 4041$	$246667^{a} \pm 2157$	$49333^{a} \pm 1528$	$37000^{a} \pm 1127$
T2	$35333^{ab} \pm 1528$	$31667^{a} \pm 1528$	$5566^{a} \pm 2797$	$32666^{ab} \pm 1528$
T3	$44000^{a} \pm 2000$	$67000^{a} \pm 2000$	$32866^{a} \pm 1531$	$48666^{a} \pm 6506$
T4	$31233^{ab} \pm 2116$	$31833^{a} \pm 1796$	$7133^{a} \pm 3863$	$6000^{b} \pm 1000$
T5	$28533^{ab} \pm 2141$	$50000^{a} \pm 1803$	$33233^{a} \pm 2626$	$47666^{a} \pm 2286$
T6	$3333^{b} \pm 152.8$	$39333^{a} \pm 1528$	$8200^{a} \pm 2443$	$6866^{b} \pm 2303$
p- value	0.016	0.075	0.069	0.001

(Note: T_1: cinnamon quills stored in a regular storehouse 28 ± 2 °C, RH 88% ± 4, T_2: SO_2 fumigation (3 ppm) and storing in storehouse, T_3: placing in sealed polythene bags and storing in storehouse, T_4: SO_2 fumigation, placing in a sealed polythene bag and storing in storehouse, T_5: storing in a controlled environment (25 °C, RH<65%), and T_6: SO_2 fumigation and stored in controlled environment. The mean of fungal CFUs ± Standard deviation)

The lowest fungal diversity (Figure.1) was observed when the cinnamon quills were fumigated with SO_2 and stored in a controlled environment (25 °C and RH<65%) (T_6) followed by cinnamon quills stored in sealed polythene bags (T_3). Highest fungal diversity was recorded in the cinnamon quills stored in the storehouse (T_1) and in the cinnamon quills stored in controlled conditions (T_5).

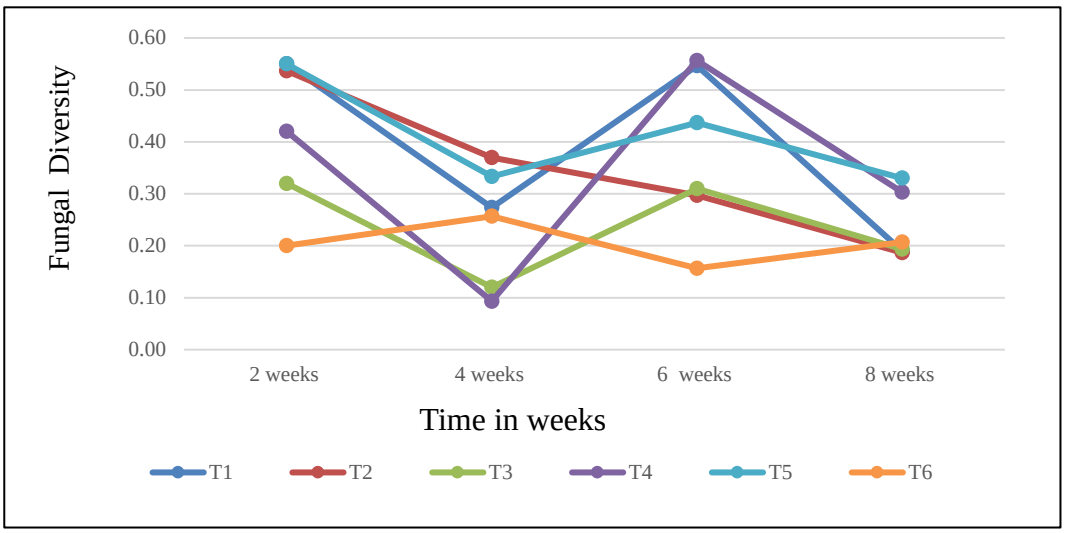

Figure 1: Fungal Diversity of cinnamon quills in different storage conditions

Conclusion

Sulphur dioxide fumigation followed by storing under low moisture and RH conditions (RH<65%) can significantly reduce the fungal contamination in processed cinnamon quills and increase their shelf life.

References

Gaur, A., Parkash, V., Kumar, V. and Thakur, A. (2021) 'Endophytic fungal diversity associated with roots of Angelica glauca : An endangered medicinal plant of Northwest Himalaya', 4(December), pp. 144–158. doi: 10.5943/ajom/4/2/10.

Jayasinghe, G. G., Kumara, K.L.W., Wijayawardana, M.W.G.C., Wijesinghe, K.G.G., Samaraweera, D.N. and Priyangika, K.M.M. (2017) 'Rough bark disease on cinnamon (*Cinnamomum zeylanicum*): Disease symptoms develpoment and the causal agent with special reference to ITS morphology', *Proceedings of the symposium on minor export crops*, (March), pp. 63–72.

Julianti, E., Rajah, K. K. and Fidrianny, I. (2017) 'Antibacterial activity of ethanolic extract of Cinnamon bark, honey, and their combination effects against acne-causing bacteria', *Scientia Pharmaceutica*, 85(2). doi: 10.3390/scipharm85020019.

POTENTIAL OF SWEET FLAG (*Acorus calamus*) AND LONG PEPPER (*Piper longum*) POWDERY FORMULATIONS AGAINST COWPEA BEETLE (*Callosobruchus maculatus*) ON STORED GREEN GRAM

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Abstract

The present study was conducted to evaluate the potential of *Acorus calamus* rhizome powder and *Piper longum* fruit powder against *Callosobruchus maculatus* to protect one of the nutrient rich sources, green gram, which is vulnerable for the *C. maculatus* attack, under the laboratory condition (30±2°C and 70±5%). As the green gram is highly consumed by humans, the insecticides, which are used to protect such grains from the infestation of pests, should be formulated in a manner easily pick up out from the grains before cooking. Thus, the powdery formulations were selected for this study, as it is easy for packing in a finely perforated cloths and picking up out before cooking. For preparing powdery formulations, selected plant parts were pulverized into fine powder and combined along with an adjuvant based on weight basis. Green gram seed lots were separately treated with different powdery pesticide formulations, 100, 90 and, 80% of *A. calamus* and *P. longum,* and 100% of adjuvant, along with untreated control were laid out in a Completely Randomized Design (CRD) after the introduction of 5 pairs of unsexed *C. maculatus* adult beetles in the all tested eight treatments and three replications. This experiment was setup to evaluate adult mortality, ovipositional ability and seed weight loss, under the no choice condition for the selection of best green gram seed protectant. Data were subjected to the analysis of variance aided by the SAS 9.1 version and means were separated by using DMRT. The statistical analysis revealed the no significant difference between the treatments treated with 100 and 90% of *A. calamus* powdery pesticides, in giving maximum percent mortality in two days after the treatment with least number of eggs. Meanwhile the lowest weight loss percentage was observed in 80, 90 and 100% of *A. calamus* treated green grams. By comparing the above results, it was concluded that 90 and 100% of *A. calamus* powdery pesticides had the potency in protecting the green gram from the infestation of *C. maculatus*.

Keywords: *Acorus calamus,* Adjuvant, *Callosobruchus maculatus* Green gram, *Piper longum*

Introduction

Green gram (*Vigna radiata*) is widely farmed in India, Thailand, South China, Malaysia, Vietnam, Pakistan, Cambodia, Indonesia and Sri Lanka (Yewle *et al*., 2020). Green gram is a seasonal crop but is utilized throughout the year. Therefore, it needs to be stored until the next consumption, selling and planting. While storing, the larvae of *C. maculatus* bore into green gram and feed the entire content of the seed. Though the control of *C. maculatus* is possible through cultural, physical, biological, botanical insecticides and chemical techniques. The botanical insecticides are safe for both people and animals, do not destroy natural enemies, affordable to local farmers as it has a simple preparation process, and contain multiple active ingredients that work together to prevent pests from developing resistance (Kareru *et al*., 2013). *A. calamus* and *P. longum* are the medicinal plants, showed efficacy against various insects (Kumar *et al.,* 2015; Sharmah *et al*., 2018). By considering these facts the present study has been conducted to formulate an organic insecticide using *A. calamus* and *P. longum* as the formulation of insecticide may further enhance the efficiency and easy handling of insecticides.

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Materials and Methods

The experiment was conducted in the laboratory of the Department of Agricultural Biology, Eastern University, Sri Lanka, Kaluwankerny, from September to November 2022. Cowpea beetles collected for mass culturing from the culture at the laboratory of the Department of Agricultural Biology and Rhizome of *A. calamus* and fruit part of *P. longum* were purchased from Ayuevedhic shops at Batticaloa.

Separation and purification of an adjuvant used for the formulation of botanical insecticide

As the neem gum has the binding capacity and is secreted for the purpose to protect the plants from the abiotic and biotic stresses, it was chosen to use as the adjuvant for this study. Neem plant (*Azadirachta indica* A.) gum were dissolved by deionized water at room temperature (25–30°C) and filtrated through muslin cloth. Then, it was centrifuged at 4500 rpm for 15 minutes at 10°C temperature. Afterward, a clear polysaccharide solution was obtained. Thereafter 100 ml of methanol was added to 50 ml of polysaccharide solution and allowed 72 hours get gum precipitation. Consequently, precipitation was washed with deionized water, dried under sunlight and ground to acquire pure powder of gum (Figure 1) (Hamdani *et al*., 2019).

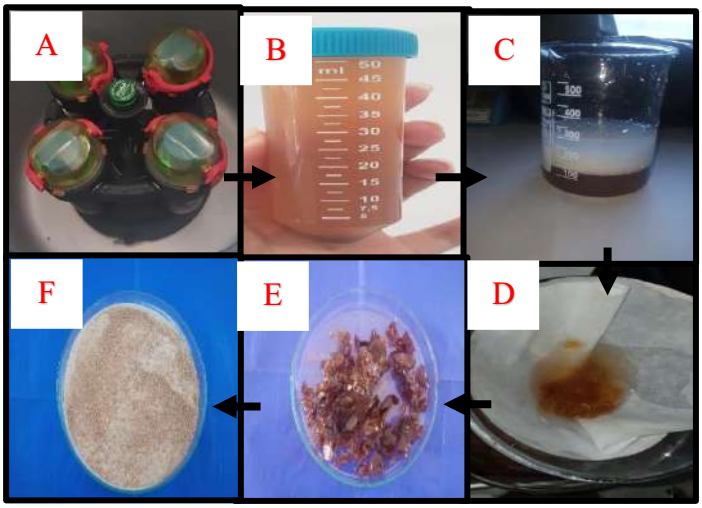

Figure 1: Purification of an Adjuvant used for the formulation of botanical insecticide; (A)- Centrifugation, (B)- Polysaccharide solution, (C)- Precipitation, (D)- Washing, (E)- Drying, (F)- Grinding

Pesticide formulation

Ten gram of purified neem gum powder were weighed and mixed thoroughly with 90 g of *A. calamus* rhizome powder to formulate 90% *A. calamus.* Likewise, 90% *P. longum* pesticide was also formulated. A sufficient amount of water was added to each mixture and mixed well until a well-formed mixture was obtained. The mixtures were kept under shade dry for 48 hours to remove the moisture content, sequentially ground and sieved through a 500 µm mesh to get a homogenous formulated pesticide. Similarly, 80% *A. calamus* and *P. longum* pesticides were formulated by the addition of 20 g of purified adjuvant powder into each of 80 g of *A. calamus* and *P. longum.* Further 100% of *A. calamus* and *P. longum* were also prepared without the addition of any adjuvants.

Experimental setup to find the efficacy of botanical pesticides

Eight hundred grams of oven dried green gram was taken and put it into 8 sterilized gunny bags as 100 g in each. Thereafter 5 g from each of the formulated pesticides, 100, 90 and 80% *A. calamus*, and 100, 90 and 80% *P. longum*, were taken and put each slot into 5 minutely perforated 5 x 5 cm^2 sized bags as 1 g of botanical pesticide in each. In addition, 5 g of adjuvant

powder was also taken and put it into 5 minutely perforated 5 x 5 cm^2 sized bags as 1 g of adjuvant in each. The perforated 5 x 5 cm^2 sized bags consisting botanical pesticides and adjuvants were tied by thread to make small packets. Five packets each containing similar botanical pesticide formulations and adjuvant were introduced into each of the gunny bags containing 100 g of green gram separately and shaken well to ensure the even distribution. The unsexed five pairs of newly emerged, matured and aggressive *C. maculatus* were collected from mass culture and introduced to each bag containing 100 g of green gram and 5 g of botanical pesticides and adjuvants, and tied with rubber band. Similarly, the procedure was repeated thrice for all the treatments. All the treatments and replicates were kept in an undisturbed place in the laboratory by following Completely Randomized Design (CRD) to monitor the development of *C. maculatus* daily.

Parameters measured

The mortality percentage of cowpea beetle, cumulative number of eggs laid and percentage of seed weight loss were analyzed.

Statistical analysis

Data were subjected to the analysis of variance aided by SAS 9.1 version and means were separated by using Duncan Multiple Range Test (DMRT) at 5% significance level

Results and Discussion

Table 1 illustrates the mortality percentage of *C. maculatus* concerning different treatments at 1 day and 2 days after treatment. It was found that there were significant ($p<0.05$) differences between treatments. According to these data, green gram treated with 90% and 100% *A. calamus* had the highest mortality percentage against C. *maculatus* at 2 days after treatment, which was statistically equivalent at 5% significant level with the mean values of 96.67 and 100.00 % of mortality respectively.

Table 1: Mortality percentage of *C. Maculatus* in different treatments

	Mortality Percentage	
Treatments	*1 DAT	*2 DAT
Green gram treated with 90% *Acorus calamus*	56.67 ± 5.77^{a}	96.67 ± 5.77^{a}
Green gram treated with 80% *Acorus calamus*	16.67 ± 5.77^{cd}	26.67 ± 5.77^{c}
Green gram treated with 90% *Piper longum*	26.67 ± 5.77^{bc}	53.33 ± 5.77^{b}
Green gram treated with 80% *Piper longum*	16.67 ± 5.77^{cd}	26.67 ± 5.77^{c}
Green gram treated with 100% adjuvant	10.00 ± 0.00^{d}	20.00 ± 0.00^{c}
Green gram treated with 100% Acorus *calamus*	63.33 ± 5.77^{a}	100.00 ± 0.0^{a}
Green gram treated with 100% Piper *longum*	36.67 ± 5.77^{b}	56.67 ± 5.77^{b}
Untreated green gram (control)	0.00 ± 0.00^{d}	20.00 ± 0.00^{c}

**Each value represents the mean of three replicates ± standard deviation.*
Means followed by the same letter in each column do not differ statistically at $p<0.05$ based on DMRT at a 5% significant level.
Duncan grouping was done for arcsine square root transformed data. 1 DAT- One day after treatment
2 DAT- Two days after treatment.

A possible explanation for these results might be that *A. calamus* rhizome powder has insect-killing properties and it is capable as a pesticide. This finding was also supported by Saranya *et al*., (2019) who stated that *A. calamus* extract showed an insecticidal effect against *C. maculatus*.

Table 2: The efficacy of formulated pesticides against ovipositional ability of *C. Maculatus* and weight loss percentage in green gram due to *C. Maculatus* infestation

Treatments	*Cumulative number of eggs	*Weight loss percentage
Green gram treated with 90% *Acorus calamus*	11.00± 4.00^{d}	0.63± 0.85^{c}
Green gram treated with 80% *Acorus calamus*	15.00± 3.00^{c}	0.87± 0.90^{c}
Green gram treated with 90% *Piper longum*	24.00± 1.00^{b}	9.93± 1.63^{b}
Green gram treated with 80% *Piper longum*	36.67 ± 4.73^{a}	17.67 ± 2.91a
Green gram treated with 100% adjuvant	44.67± 5.69^{a}	24.83± 3.56^{a}
Green gram treated with 100% Acorus *calamus*	9.67± 2.082^{d}	0.43± 0.45^{c}
Green gram treated with 100% Piper *longum*	18.33 ± 3.52^{bc}	7.73 ± 2.35^{b}
Untreated green gram (control)	37.00 ± 2.65^{a}	24.93 ± 4.10^{a}

**Each value represents the mean of three replicates ± standard deviation.*
Means followed by the same letter in each column do not differ statistically at p<0.05 based on DMRT at a 5% significant level. Duncan grouping was performed on arcsine square root transformed and log10 transformed values of weight loss percentage and cumulative number of eggs laid.

The cumulative number of eggs laid on seeds in each treatment and the percentage of weight loss due to *C. maculatus* in each treatment are shown in Table 2. The cumulative number of eggs laid on seeds was measured on the 6th day of experiment when all the introduced *C. maculatus* died in all treatments. A significant variance ($p<0.05$) between treatments was observed. The maximum number of eggs was observed in green gram treated with 100% adjuvant, control and green gram treated with 80% *P. longum*. Interestingly the minimum number of eggs was seen on green gram treated with 90% and 100% *A. calamus*. The result of this study indicated that *A. calamus* has the oviposition deterrent ability thus; minimize the egg laying of *C. maculatus*. Referring to the views of Hafez *et al*. (2014), it was noted that *A. calamus* has a considerable influence on the ovipositional period of adult females of *C. maculatus* through quickly caused mortality thus limiting the number of egg-laying. The results of the current study seem to be consistent with other research, which stated *A.* calamus extremely effective in reducing egg laying of *C. maculatus* (Govindan *et al*., 2020; Anvesh *et al*., 2022). The percentage of weight loss due to *C. maculatus* was shown to be significantly different ($p<0.05$) between treatments. The results of the study showed that the minimum seed weight loss percentage was observed in green gram treated with 80%, 90% and 100% of *A. calamus*. It is due to the potential of *A. calamus* in reducing the infestation of *C. maculatus* and thus reduced weight loss. Manju *et al*. (2019) declared maximum seed viability in *A. calamus*-treated green gram seeds, which was because of the zero-weight loss in green gram seed.

Conclusion

The study evidenced the efficacy of powdery pesticides, 90% *Acorus calamus* and 100% *A. calamus* against *C. maculatus* along with maximum mortality percentage, minimum number of eggs laid and least weight loss percentage on green gram. However, the study confirmed that no pesticidal effect was imposed by the adjuvant used for the formulation of pesticide as the records on mortality percentage, numbers of eggs laid and seed weight loss were equivalent to untreated control when the adjuvant was applied alone as the seed protectant.

References

Anvesh, A., Nelson, S. J., Suganthi, A., Uma, D., Anusooriya, P. and Kousika, J. (2022). Toxicity of sweet flag, *Acorus calamus* L. extracts on pulse beetle, *Callosobruchus maculatus* L. *The Pharma innovation on Journal*, 11(7), 121–126.

Govindan, K., Geethanjali, S., Brundha, G. and Pandiyan, M. (2020). Effect of plant powders

on pulse beetle, *Callosobruchus maculatus* (F.) and seed weight loss in stored black gram. *Journal of Entomology and Zoology studies*, 8(6), 61–66.

Hafez, M., Dimetry, N. D. and Abbass, M. H. (2014). Insecticidal and biological efficacy of two vegetable oils against *Callosobruchus maculatus* (Fabricius) (Coleoptera: Bruchidae) under laboratory conditions. *Archives of Phytopathology and Plant Protection*, 47(16), 1942–1955.

Hamdani, A. M., Wani, I. A. and Bhat, N. A. (2019). Sources, structure, properties and health benefits of plant gums: a review. *International Journal of Biological Macromolecules*, 135, 46–61.

Kareru, P., Rotich, Z. K. and Maina, E. W. (2013). Use of botanical and safer insecticides designed in controlling insects: The African case. In S. Tradan (Ed.), Insecticides–Development of Safer and More Effective Technologies (pp. 297–309). London: Intech open.

Kumar, A., Sharma, S. and Verma, G. (2015). Insecticidal and genotoxic potential of *Acorus calamus* rhizome extract against *Drosophila melanogaster. Asian Journal of Pharmaceutical and Clinical Research,* 8(4), 113–116.

Manju, K., Jayaraj, J. and Shanthi, M. (2019). Efficacy of botanicals against pulse beetle *Callosobruchus maculatus* (F.) in green gram. *Indian Journal of Entomology*, 81(1), 144–147.

Saranya, M., Nelson, S. J., Paramasivam, M. and Mahalingam, C. A. (2019). Evaluation of different solvent extracts of sweet flag rhizomes, *Acorus calamus* (L.) on pulse beetle, *Callosobruchus Maculatus* (F.). *Indian Journal of Agricultural Research*, 53(4), 373–382.

Sharmah, D., Sharmah., A. K. and Rahman, S. (2018). Phytochemicals derived from *Piper longum* in insect and mite pests management: A review. *Journal of Applied and Natural Science*, 10(2), 553–556.

Yewle, N., Charpe, A. M., Gupta, S., Patil, B., Tushir, S. and Mann, S. (2020). Impact of hermetic packaging on green gram (*Vigna radiata*) insect and microbial damage under environmental condition. *Journal of Entomology and Zoology Studies*, 8(5)1883–1887.

EFFICACY OF GRAS COMPOUNDS IN CONTROLLING FOLIAR DISEASES IN EGGPLANT (*Solanum melongena* L.)

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Abstract

Foliar diseases are prominent in eggplant (*Solanum melongena* L.) that cause enormous economic losses to eggplant cultivation. Non-fungicidal approaches are increasingly being employed to control foliar diseases due to the environmental and human health risks caused by the use of synthetic fungicides. The present study evaluated the efficacy of Generally Recognized as Safe (GRAS) compounds in controlling foliar diseases of eggplant. The selected GRAS compounds such as sodium bicarbonate (0.1%), salicylic acid (400 µM) and three plant extracts, namely neem leaf extract (200 ppm), eucalyptus leaf extract (200 ppm) and garlic clove extract (200 ppm) were evaluated for their efficacy in this study. The experiment was laid out in completely randomized design with six treatments and four replicates. Natural infection of foliar diseases was considered in this study. Data on disease incidence and disease severity were recorded seven weeks after transplanting (WAT). The significance of treatment effects on the measured variables was determined by analysis of variance and the treatment means were compared using Tukey's test at α=0.05. The findings showed that the disease incidence and severity were significantly ($P<0.05$) reduced by the foliar application of salicylic acid and garlic clove extract, and the effectiveness of both compounds was statistically similar. Foliar application of salicylic acid and garlic clove extract reduced the disease incidence by 88.7% and 63.8%, respectively and the disease severity by 92.4% and 77.7%, respectively, over the control treatment. Hence, salicylic acid and garlic clove extract could be ecologically feasible options for controlling foliar diseases of eggplant during its vegetative growth period.

Keywords: Disease incidence, disease severity, foliar diseases, garlic clove extract, salicylic acid

Introduction

Eggplant (*Solanum melongena* L.) is an important vegetable in tropical and subtropical regions in the world (Gürbüz *et al*., 2018). Several diseases occur in eggplant cultivation, of which fungal foliar diseases are more severe in tropical countries like Sri Lanka, where congenial humidity and uniform warm temperatures are the norms (DOA, 2022). Systemic foliar diseases such as leaf spots and leaf blight are the primary causes of crop losses and yield reductions (Iqbal *et al*., 2018). They affect the crop photosynthetic and transpiration rates, which therefore have an indirect impact on the production of pod quality (Ponmurugan *et al*., 2007). Usually, agrochemicals are primarily used to combat those foliar diseases. However, synthetic fungicides use on plant materials, especially on food crops, has been brought into question, as the usage of these substances may result in residual toxicity posing risk to human health, as well as they are a source of environmental contamination and have long degradation period (Kalupahana *et al*., 2020). Therefore, it is crucial to develop alternatives to chemical fungicides. In recent years, synthetic fungicide replacement with Generally Recognized as Safe (GRAS) compounds has drawn increased attention. These natural antimicrobial compounds are renewable, toxic-free and non-persisting additives. The antimicrobial properties of GRAS and natural aromatic compounds are efficient and elicit plant defenses against many plant diseases without causing any threat to the environment or to human health (Elsalam *et al.,* 2017).

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Therefore, the objective of this study was to investigate the efficacy of different GRAS compounds to control the foliar diseases of eggplant under *in vivo* condition.

Materials and Methods

The experiment was conducted at the crop farm, Faculty of Agriculture, Palachcholai, Eastern University, Sri Lanka during the period of August to November, 2022. Healthy seedlings of eggplant variety 'Thinnaveli purple' were used for the study. The seedlings were grown in the media of topsoil and cow dung mixture at the ratio of 1:1 (DOA, 2022) in polybags under *in vivo* condition. The experiment was laid out in completely randomized design with six treatments and four replicates. The seedlings were allowed for natural leaf disease infections.

Treatment structure

T_1 – Sodium bicarbonate (0.1%)
T_2 – Salicylic acid (400 µM)
T_3 – Neem (*Azadirachta indica)* leaf extract (200 ppm)
T_4 – Eucalyptus (*Eucalyptus globulus)* leaf extract (200 ppm)
T_5 – Garlic (*Allium sativum)* clove extract (200 ppm)
T_6 – Control (No application)

Preparation of methanolic plant extracts and their stock solutions

The required amount of respective healthy parts of each plant was taken for the preparation of plant extracts. Plant parts were sun-dried, cut and ground to make dry powders. A quantity of 25 g of dry powder of each plant material was taken and extracted with 300 ml of methanol (99.8%) using a Soxhlet extractor for 6 hours. The methanolic plant extracts were subjected to rotary evaporation and subsequently concentrated under reduced pressure (in a vacuum at 40°C). The extracts were further evaporated to dryness by shade dry and stored at room temperature in airtight bottles (Gopalasatheeskumar, 2018). Dried solid portions of plant extracts were weighed and diluted to appropriate volumes according to their amounts by adding distilled water. For spraying, 200 ppm of each plant extract was used, and it was obtained by adding the appropriate amount of stock solution with distilled water.

Preparation of sodium bicarbonate solution

For spraying, 0.1% of 240 ml of sodium bicarbonate solution was prepared. Around 0.24 g of sodium bicarbonate was weighed and brought into a volume of 240 ml with distilled water.

Preparation of salicylic acid

For spraying, 400 µM of 240 ml of salicylic acid was prepared. A quantity of 13.259 mg of salicylic acid powder was taken and dissolved in 240 ml of distilled water. Prior to the addition of distilled water, the salicylic acid powder was dissolved in a few drops of absolute ethanol for better dissolving.

Data collection

Data on the disease incidence and disease severity were collected from the eggplant leaves with foliar disease symptoms from each replicate of each treatment. Based on the characteristic symptoms, the spots and blights observed were confirmed to be fungal diseases. Data were recorded seven weeks after transplanting. Number of leaves of each plant showing typical foliar disease symptoms was recorded as percentage disease incidence of foliar diseases in eggplant. The disease incidence was calculated using the following formula.

$$\text{Disease Incidence} = \frac{(\text{Number of infected leaves})}{(\text{Total number of leaves})} \times 100\%$$

For the disease severity, percentage of leaf area affected was determined by using the mobile application called Leaf Doctor (Pethybridge and Nelson, 2015). Disease severity was evaluated using the following disease rating scale (Table 1) (Tipu *et al*., 2021).

Table 1. Disease rating scale for assessment of disease severity

Rating scale	Disease percentage (leaf area affected)
0	No infection (healthy leaves)
1	1 – 5
2	6 – 25
3	26 – 50
4	51 – 75
5	76 – 100

Disease severity was determined as disease severity index (DSI) using the following formula.

$$\text{Disease Severity Index} = \frac{[\text{Sum (class frequency} \times \text{score rating)}]}{(\text{Total number of leaves} \times \text{maximum disease rating})} \times 100\%$$

Statistical analysis

Data on percentage disease incidence and disease severity were arcsine square root transformed in order to stabilize variance. Significance of treatment effects on the measured variables was determined by analysis of variance (ANOVA) using Minitab 19 statistical software. Treatment means were compared with control using Tukey's test at α=0.05.

Results and Discussion

Evaluation of different treatments against foliar disease incidence of eggplant

The effects of different treatments on foliar disease incidence and disease severity of naturally infected eggplant leaves at seven weeks after transplanting (WAT) were summarized in Table 2. As per the results on disease incidence and disease severity, there was a significant difference ($P<0.05$) observed among the treatments. The finding on disease incidence revealed that applying salicylic acid and garlic clove extract significantly ($P<0.05$) reduced the incidence of foliar diseases compared to the control. Besides, there was no significant ($P>0.05$) difference observed between these two treatments. Compared with the control, salicylic acid and garlic clove extract reduced the disease incidence in leaves by 88.7% and 63.8%, respectively. On the other hand, sodium bicarbonate, neem leaf extract and eucalyptus leaf extract showed statistically similar disease incidence in comparison to the control. The results on disease severity presented that sodium bicarbonate, salicylic acid and garlic clove extract applications significantly ($P<0.05$) reduced the disease severity compared to the control and those applications brought down the disease severity by 92.4%, 62.1% and 77.7% than the control, respectively. It was found that neem leaf extract and eucalyptus leaf extract did not significantly ($P>0.05$) reduce the disease severity as they both exhibited similar results as control.

Table 2. Effect of treatments against foliar disease incidence and disease severity of Eggplant at 7th WAT

Treatments	Disease incidence ± SE (%)	Disease severity ± SE (%)
T_1 – Sodium bicarbonate (0.1%)	16.97 ± 1.85^{ab}	3.15 ± 0.31^{bc}
T_2 – Salicylic acid (400µM)	3.33 ± 2.04^{c}	0.63 ± 0.38^{d}
T_3 – Neem leaf extract (200 ppm)	21.42 ± 3.84^{ab}	6.19 ± 0.53^{ab}
T_4 – Eucalyptus leaf extract (200 ppm)	20.42 ± 4.89^{ab}	6.53 ± 1.18^{ab}
T_5 – Garlic clove extract (200 ppm)	10.56 ± 3.44^{bc}	1.85 ± 0.26^{cd}
T_6 – Control	29.14 ± 4.03^{a}	8.30 ± 0.98^{a}

Values with the same letter within a column are not significant (p>0.05) according to Tukey's test at 5% significant level. Values represent means ± standard error of four replications.

Based on the current investigation, both salicylic acid and garlic clove extract showed a significant effect in reducing the foliar disease incidence and disease severity when compared to the control. Hence, it was evident that salicylic acid treatment effectively decreased the disease incidence and disease severity in foliage of eggplant and these findings were supported by Spletzer and Enyedi (1999) in tomato against Alternaria leaf spot. They found that salicylic acid application decreased the susceptibility to *A. solani*, perhaps in part. Salicylic acid is capable of inducing pathogenesis-related (PR) protein synthesis and systemic acquired resistance (SAR) when it is injected into or sprayed onto the leaves (Van-Loon and Antoniw, 1982).

The findings on garlic clove extract are concordant with those of Nashwa and Elyousr (2012) in tomato against early blight, and Asaduzzaman *et al*. (2008) in chilli against Cercospora leaf spot as garlic extract contains the organosulfur compounds such as allicin, diallyl disulfide, diallyl trisulfide, etc. Many studies have proven that garlic clove extract has excellent antifungal properties (Yousuf *et al*., 2010; Martins *et al.,* 2016). Sodium bicarbonate was also found to express effectiveness against the disease severity, and it was supported by El-Mougy and Abdel-Kader (2009) in potato against early blight disease. However, a significant effect of foliar application of sodium bicarbonate on disease incidence was not found in this study. Meanwhile, neem extract and eucalyptus extract failed to control the foliar diseases in contrast to the findings of Nashwa and Elyousr (2012). Possible reasons for this contrary may be the less effectiveness of these leaf extracts to control the diseases and variations in the host plant factors.

Conclusions

The overall results revealed that the foliar applications of salicylic acid and garlic clove extract were effective for minimizing the foliar disease incidence and severity in eggplant. Meanwhile, these two treatments were equally capable of reducing the foliar disease incidence and disease severity. However, their efficacy should be further tested in extensive field trials and farmers level adaption trials.

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References

Asaduzzaman, M., Hossain, M. M., Parvez, M. N., Islam, M. A. and Meah, M. B. (2008). Effect of dose and frequency of garlic tablet spray on the incidence of Cercospora leaf spot of chilli. *J. Agrofor. Environ*, 7(1), 119–122.

DOA (Department of Agriculture, Sri Lanka). (2022), Brinjal- *Solanum melongena.* Available: https://doa.gov.lk/hordi-crop-brinjal/, (November 17, 2022).

El-Mougy, N. S. and Abdel-Kader, M. M. (2009). Salts application for suppressing potato early blight disease. *Journal of Plant Protection Research*, 49(4), 354–361.

Elsalam, A. K. A., Hashim, A. F., Alghuthaymi, M. A. and Said-Galiev, E. (2017). Nano biotechnological strategies for toxigenic fungi and mycotoxin control. In: Grumezescu, A. M. (Ed.), Food preservation (pp. 337–364). Romania: Academic Press.

Gopalasatheeskumar, K. (2018). Significant role of soxhlet extraction process in phytochemical research. *Mintage Journal of Pharmaceutical and Medical Sciences*, 7(1), 43–7.

Gürbüz, N., Uluişik, S., Frary, A., Frary, A. and Doğanlar, S. (2018). Health benefits and bioactive compounds of eggplant. *Food Chemistry*, 268, 602–610.

Iqbal, Z., Khan, M. A., Sharif, M., Shah, J. H., Rehman, M. H. and Javed, K. (2018). An automated detection and classification of citrus plant diseases using image processing techniques: a review. *Computers and Electronics in Agriculture*, 153, 12–32.

Kalupahana, K. I. M., Kuruppu, M. and Dissanayake, P. K. (2020). Effect of essential oils and GRAS compounds on postharvest disease control in mango (*Mangifera indica* L.cv Tom EJC). *Journal of Agricultural Sciences – Sri Lanka*, 15(2), 207–221.

Pethybridge, S. J. and Nelson, S. C. (2015). Leaf Doctor – a new application for assessing disease severity. *Plant Disease*, 99, 1310–1316.

Ponmurugan, P., Baby, U. I. and Rajkumar, R. (2007). Growth, photosynthetic and biochemical responses of tea cultivars infected with various diseases. *Photosynthetica*, 45(1), 143–146.

Martins, N., Petropoulos, S. and Ferreira, I. C. (2016). Chemical composition and bioactive compounds of garlic (*Allium sativum* L.) as affected by pre-and post-harvest conditions: a review. *Food Chemistry*, 211, 41–50.

Nashwa S. M. A. and Elyousr K. A. M. (2012). Evaluation of various plant extracts against the early blight disease of tomato plants under greenhouse and field conditions. *Plant Protect. Sci*, 48, 74–79.

Spletzer, M. E. and Enyedi, A. J. (1999). Salicylic acid induces resistance to *Alternaria solani* in hydroponically grown tomato. *Phytopathology*, 89(9), 722–727.

Tipu, M. M. H., Jahan, R., Rahman, J., Riad, M. I., Rahman, M. M. and Nabi, K. E. (2021). Status of major diseases of brinjal and tomato in charland of Jamalpur and Sherpur districts of Bangladesh. *Plant Science Today*, 8(1), 161–165.

Van-Loon, L. C. and Antoniw, J. F. (1982). Comparison of the effects of salicylic acid and ethephon with virus-induced hypersensitivity and acquired resistance in tobacco. *Neth. J. Plant Pathol*, 88, 237–256.

Yousuf, S., Ahmad, A., Khan, A., Manzoor, N. and Khan, L. A. (2010). Effect of diallyldisulphide on an antioxidant enzyme system in Candida species. *Canadian Journal of Microbiology*, 56(10), 816–821.

CONTROL OF *Fusarium oxysporum* CAUSING PANAMA WILT IN BANANA USING PLANT EXTRACTS

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Abstract

Banana is one of the highest marketing fruits in the global market. It is a nutrient-rich and widely grown tropical fruit crop. Fusarium wilt is considered one of the most important diseases of bananas caused by *Fusarium oxysporum*. To date, no effective chemical control method has been found to control Panama disease in bananas. In most studies, it was proposed to use new resistant cultivars. Therefore, this research aimed to use twelve different plant extracts [cinnamon (*Cinnamomum verum*), clove (*Syzygium aromaticum*), nutmeg (*Myristica fragrans* Houtt.), neem (*Azadirachta indica*), gliricidia (*Gliricidia sepium*), moringa (*Moringa oleifera*), malabar nut (*Justicia adhatoda*), castor plant (*Ricinus communis*), tithonia (*Tithonia diversifolia*), bitter vine (*Mikania micrantha*), teppaddi (*Aleurites laccifer*), and soursop (*Annona muricata*)] to control banana Panama disease by organic suppression of *F. oxysporum*. This experiment was laid out on a Completely Randomized Design with twelve treatments and three replicates. The effects of these extracts were compared with the control. In this *in vitro* experiment, the mycelial growth diameter of the *F. oxysporum* in the culture plate was measured. According to the results, clove and cinnamon were the best inhibitors and completely inhibited mycelia growth. Gliricidia and nutmeg extracts slightly inhibited (30%) the mycelia growth followed by the neem extract (10%). Following the results, the effective treatments could be used against Panama-infected banana plants. In the future, more efforts should be taken to validate the results to improve their efficacy by setting up effective formulations, application protocols, and integrated strategies.

Keywords: Banana*, Fusarium oxysporum*, plant extract, panama wilt

Introduction

One of the most severe diseases of bananas, Fusarium wilt produced by *F. oxysporum*, is thought to be reducing banana production globally (Ploetz and Pegg, 2000; Dita *et al*., 2018). The disease's heterocyclic nature ensures that over time, the repeated cycles of infection it produces in bananas are leading to significant losses. Fusarium produces a variety of toxins that have a role in the pathogenesis and progression of disease (Buddenhagen, 2009). After 5–6 months from planting, the symptoms begin to appear and exhibit both within and outwardly. The disease results in considerable yield losses later on by causing splitting of the pseudo-stem, hanging down of leaves surrounding the pseudo-stem, and yellowing of the leaf margins on the oldest leaves. Generally, plants with the wilt pathogen produce unprofitable bunch, and the disease eventually destroys the entire plant (Akila *et al*., 2011). Fungicide use to combat wilt disease is not practicable and harmful to both humans and animals and the environment. The goal of the current study was to decrease the use of pesticides while promoting organic banana growing through eco-friendly management.

Materials and Methods

Isolation and morphological confirmation of pathogen

Banana leaf and pseudo stem samples that had been affected by the wilt were used to isolate *F. oxysporum*. Small portions of brown, discoloured vascular tissue were removed, and contaminated tissue was surface sterilized with sodium hypochlorite (0.1%). The tissues were

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sterilized before being placed on Potato Dextrose Agar (PDA) medium and allowed to develop at a temperature of 25±2 ^{0}C. For further investigation, the pathogen's pure culture was kept on a PDA medium. Using microscopic observations, the morphological confirmation of *F. oxysporum* was characterized. The pathogen was identified under microscopic examination by the detection of macroconidia and microconidia.

Preparation of plant extracts

From the Fruit Research and Development Institute in Kananwila, Horana, the plant leaves of cinnamon, clove, nutmeg, neem, gliricidia, moringa, malabar nut, castor plant, tithonia, bitter vine, teppaddi, and soursop were collected. They were washed with running water and left to dry in the shade. Finally, 25 g of each sample was made into aqueous crude extracts in 100 ml of sterilized distilled water, which were then sealed in containers and kept in the refrigerator for further investigation.

In vitro* screening of plant extracts against *F. oxysporum

The flask was filled with the previously stored 100 ml aqueous plant extracts, 4 g of agar, and 2 g of glucose before being well mixed. The samples were heated thoroughly by shaking them on a hot plate. The medium was then sterilized in an autoclave for 20 minutes at 121 ^{0}C and 15 psi. The isolated fungus was then maintained on a plant extract culture medium at a temperature of 25 ^{0}C. All of the samples were kept in the culture room, and the untreated control cultures were retained without the addition of plant extract.

The formula shown below was used to determine the percentage of fungal growth inhibition (Wonglom *et al*., 2019).

Reduction in growth (%) = [(Diameter C – Diameter F) / Diameter C] x 100

Where, Diameter C = Growth zone diameter mean of the control plate
Diameter F = Growth zone diameter mean of the sample plate

Data analysis

The data were analyzed to determine whether there were significant differences using SAS computer software. Means were separated using Duncan's Multiple Range Test and all the significances were tested at $P<0.05$.

Results and Discussion

According to the results, among the examined plant extracts, cinnamon and clove extracts completely (100%) inhibited mycelial development (Figure 1). The mycelial growth was modestly reduced by extracts from the gliricidia and nutmeg plants. Among the significant effects observed, neem plant extract showed the lower percentage of mycelial growth inhibition after the eighth day of inoculation.

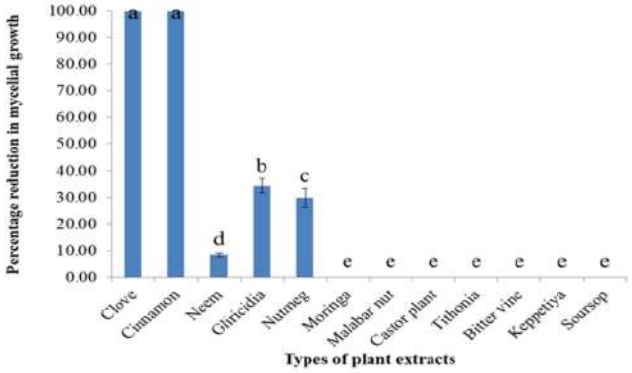

Figure 1: Percentage growth inhibition of *Fusarium oxysporum* after eight days of inoculation

The presence of antifungal chemicals in these plant extracts may be the cause of the inhibitory impact of the extracts. One of the key areas of research worldwide is natural chemicals and their application for integrated protection. The findings of this study revealed a definite indication of the ability of plant extracts to suppress fungi infections, and these substances can be exploited.

Conclusion

The results revealed that the extracts prepared from clove and cinnamon were the most effective inhibitors for *F. oxysporum*. An affordable, risk-free management strategy for reducing the Panama wilt of bananas would be to employ these widely available plant extracts.

References

Akila, R., Rajendran, L., Harish, S., Saveetha, K., Raguchander, T. and Samiyappan, R. (2011). Combined application of botanical formulations and biocontrol agents for the management of *Fusarium oxysporum* f. sp. cubense (Foc) causing Fusarium wilt in banana. *Biological control*. 57, 175-183.

Buddenhagen, I. (2009). Understanding strain diversity in *Fusarium oxysporum* f. sp. cubense and history of introduction of 'tropical race 4' to better manage banana production. Acta Hortic. 828, 193–204. DOI: 10.17660/ActaHortic.2009.828.19.

Dita, M., Barquero, M., Heck, D., Mizubuti, E. S. G. and Staver, C. P. (2018). Fusarium wilt of Banana: current knowledge on epidemiology and research needs toward sustainable disease management. *Front. Plant Sci*., 9, 1468. DOI: 10.3389/fpls.2018.01468.

Ploetz, R. C. and Pegg, K. G. (2000). Fusarium wilt. In: Diseases of Banana, Abacá and Enset [ed. by Jones, D. R.]. Wallingford, UK: CABI Publishing, 143-159.

Wonglom, P., Daengsuwan, W., Ito, S. and Sunpapao, A. (2019). Biological control of *Sclerotium* fruit rot of snake fruit and stem rot of lettuce by *Trichoderma* sp. T76-12/2 and the mechanisms involved. Physiological and Molecular Plant Pathology, 107, 1-7.

RELATIVE EFFECTIVENESS OF VERMIWASH ON PHYTOPHAGOUS INSECTS OF YARDLONG BEAN (*Vigna unguiculata*), VARIETY BUSHITA

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Abstract

The extension and production of yardlong beans have been decreasing over the past few years in Sri Lanka, owing to the extreme pest infestation. This experiment was conducted to examine the efficacy of different vermiwash sprays against phytophagous insect pests and the yield of yardlong bean. The investigation was carried out during the period of June to November 2022 at the laboratory and farm of the Department of Agricultural Biology, Faculty of Agriculture, Eastern University, Sri Lanka. The study was initiated with the mass-culturing of exotic (*Eudrilus euginea*) and indigenous varieties of earthworms using cow dung. Ten different types of vermiwash were prepared by feeding each earthworm species with each of the selected botanicals like onion and, garlic peel, marigold and neem leaves, and without feeding any botanical. The field experiment was laid out in the Randomized Complete Block Design with eleven treatments and three blocks. Vermiwashes were applied at weekly intervals to the respective plots since the third week of planting. The total number of insects in each treated and untreated plot were counted manually before each of treatment application. The statistically lowest number of epilachna beetles was observed in plots treated with vermiwash prepared using indigenous variety of earthworm with garlic peel, exotic variety with onion peel, and indigenous variety with onion peel. However, significantly less population of epilachna beetles was recorded in the plots treated with vermiwash of indigenous variety with neem leaves, where highest yield of yardlong bean was also found. Further, the statistical analysis stated that almost all the treatments except the vermiwash of exotic species with onion peel were safer to ladybird beetle. Therefore, by comparing these measured parameters, the vermiwash prepared from the combination of an indigenous variety of earthworm with neem leaves could be recommended for yardlong bean cultivation among the applied different types of vermiwash, as it was economically and environmentally sound.

Keywords: Earthworm, exotic, garlic, indigenous, neem, vermiwash

Introduction

The vegetable crop known as the yardlong bean (*Vigna unguiculata*), is a key vegetable in Sri Lankan cooking. The extreme infestation of several insect pests is a significant issue for the production of yardlong beans cultivation (Benchasri and Bairaman, 2010). Apart from that, the increased use of chemical pesticides and fertilizers in Sri Lanka over the past few decades has resulted in extremely high concentrations of heavy metals and hazardous chemicals in the environment, which ultimately has a negative influence on cultivated crops and watershed. In light of all of these issues, it is necessary to boost yardlong bean production while implementing an effective organic pest control strategy. This study was conducted to examine the efficacy of different vermiwash spray against phytophagous pests on yardlong bean.

Materials and Methods

Collection and mass culture of earthworms

Two types of earthworms were used for the preparation of vermiwash. According to that the exotic type of earthworm known as *Eudrilus eugeniae* was bought from Ottusuttan District Agriculture Training Center. Locally available earthworms (indigenous) were gathered from the premises of Eastern University, Sri Lanka. Both exotic and local varieties were mass

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cultured in the laboratory using the standard method (Hitinayake *et al.*, 2018).

Vermiwash preparation

Table 1: Method of vermiwash preparation

Earthworm variety	Plant material	Different types of vermiwash
Exotic variety *Eudrilus eugeniae*	Onion peel	T1
	Garlic peel	T2
	Marigold leaves	T3
	Neem leaves	T4
	Control (No any plant materials)	T5
Indigenous earthworm variety	Onion peel	T6
	Garlic peel	T7
	Marigold leaves	T8
	Neem leaves	T9
	Control (No any plant materials)	T10

Ten plastic buckets of 20 L capacity along with tap at the bottom were used to prepare and collect the liquid worm extract. Among them, five plastic buckets were used to get the vermiwash from each of the earthworm species. The buckets were layered in succession with various materials as recommended by Harsita *et al.* (2019). Medium-sized clay bricks were loaded to a height of 15 cm at the bottom of each bucket. Up to 15 cm of gritty sand were sprinkled over the foundation layer. Then, 75 of earthworms from each earthworm species were collected from mass culture and introduced 15 into each of the container in accordance with the treatments. Among the five buckets used for the indigenous species, each of the buckets separately added with chopped onion peel, garlic peel, marigold leaves, and neem leaves for the height of 10 cm and one of the buckets was used as control. Likewise, the buckets allocated for exotic species also individually filled with selected above-mentioned plant materials (Table 1). After that, an organic residual and a layer of partially decomposed cow dung for the height of 20 cm were added to induce the growth of earthworms. Approximately half a litre of water was sprayed daily into each bucket to moisturise whole structure. Vermiwash collection from each set-up was started after 30 days of initiation. It is essential to assess the viability of earthworms for plant materials before introducing them to a compost bin. In order to examine their behaviour, plant materials were gradually introduced to an earthworm colony and their behaviour was observed closely. The botanicals such as marigold leaves, neem leaves, onion peel, and garlic peel were utilized to produce vermiwash in the absence of any anomalous behaviour of earthworms. Prior to the collection of vermiwash, 2 L of water were added in to each bucket and permitted for overnight. The vermiwash gathered on the following day was kept at room temperature in airtight containers for future use. After the collection of vermiwash, the plant materials were frequently added in to the respective buckets to ensure the next collection.

Yardlong bean cultivation

The cultivation of yardlong bean variety, bushita (Local) was carried out at the field of the Department of Agriculture Biology, Faculty of Agriculture, Eastern University Sri Lanka, Palacholai, located in the Batticaloa district during the period from June to September 2022. All the agronomic practices except nutrient and pest management recommended by the

Department of Agriculture, Sri Lanka were followed to cultivate the bushita. Randomized Complete Block Design (RCBD) was used to setup 11 treatments in 03 blocks.

Efficacy of vermiwash

Three weeks after the planting, the vermiwash was sprayed to the respective plots. The collected and preserved vermiwash was diluted with water to a ratio of 1:10. A separate hand sprayer was used to each vermiwash for the application of diluted solution at a rate of 300 ml per experimental plot. The vermiwash was applied in a weekly interval during the late evening until the harvesting.

Data collection and analysis

Number of pests per plot, number of natural enemies per plot and total yield per plot were calculated. By eliminating the border effect the effectiveness of data was maintained. The log $_{10}(n+1)$ data transformation was done for number of pest, and number of natural enemy. Treatment effects were determined by Analysis of variance (ANOVA) and mean separation values were compared by using Duncan's Multiple Range Test (DMRT) at 5% significant level by using SAS software.

Results and Discussion

Number of Epilachna beetle on yardlong bean

It was discovered that the effects of 10 different varieties of vermiwash on the pest population were varied significantly ($p<0.05$). The lowest pest number was observed on plots treated with the vermiwash of indigenous variety of earthworm with garlic peel with a mean value of 1.33. It has been demonstrated that garlic peel is remarkably efficient in pest control. According to Andersen (1997) phenolic chemicals found in garlic make it effective against pests. However statistically, the same results were observed among the treatments like indigenous variety of earthworm with garlic peel, exotic variety of earthworm with onion peel, and indigenous variety of earthworm with onion peel, followed by indigenous variety of earthworm with neem leaves and exotic variety of earthworm with garlic peel. Onion peel and neem leaves also showed considerable effectiveness in pest control, which also stated by Podder *et al*. (2013) through previous studies. According to the Table 2, plants treated without any vermiwash, had the highest pest number. It may be due to the absence of any repellent or pesticidal properties. However, treatments like an exotic variety of earthworm and an indigenous variety of earthworm were not significantly different with control revealed that the pest population was high in these treatments due to the absence of botanicals. Furthermore, the usage of different earthworm varieties (exotic and indigenous) revealed that there were no remarkable differences between them in decomposing the plant materials and that indigenous variety of earthworm could also be employed to produce effective vermiwash.

Effectiveness of vermiwash on ladybird beetle

It was observed that the numbers of ladybird beetles significantly ($P<0.05$) differed between treatments (Table 2). The maximum numbers of ladybird beetles were observed in treatments like indigenous variety of earthworm with neem leaves and indigenous variety of earthworm without botanicals treated plants. It showed that indigenous variety of earthworm with neem leaves treatment highly encouraged the occurrence of ladybird beetle. Hwang-In-Cheon *et al.* (2007) stated that the neem based pesticide expressed a negligible range of toxicity against natural enemies. However, statistically equal result was found in all other treatments except exotic variety of earthworm with onion peel, which stated the least toxicity of the selected plant materials against ladybird beetle. Generally, the use of synthetic chemical pesticides significantly affected the prevalence of diseases, pests, and especially natural enemies.

Table 2: Cumulative Pest Number, Ladybird Beetle, and Yield

Treatment	Pest number / plot	Number of ladybird beetles / plot	Total Yield (g) / plot
Exotic variety of earthworm + onion peel	02.33 ± 2.30 ^{cd}	2.00 ± 0.00 ^{b}	1131.67 ± 35.47 ^{a}
Exotic variety of earthworm + garlic peel	04.33 ± 2.51 ^{bc}	5.00 ± 1.73 ^{ab}	983.33 ± 115.47 ^{abc}
Exotic variety of earthworm + marigold leaves	10.33 ± 5.50 ^{b}	6.00 ± 1.00 ^{ab}	866.67 ± 137.68 ^{bcd}
Exotic variety of earthworm + neem leaves	10.00 ± 1.00 ^{b}	8.00 ± 7.00 ^{ab}	970.00 ± 18.00 ^{abc}
Exotic variety of earthworm	25.66 ± 3.78 ^{a}	7.66 ± 1.52 ^{a}	841.67 ± 38.18 ^{cd}
Indigenous variety of earthworm + onion peel	03.00 ± 1.73 ^{cd}	8.00 ± 4.35 ^{a}	1008.33 ± 87.79 ^{abc}
Indigenous variety of earthworm + garlic peel	01.33 ± 1.52 ^{d}	5.66 ± 2.08 ^{ab}	925.00 ± 90.13 ^{bc}
Indigenous variety of earthworm + marigold leaves	11.66 ± 7.09 ^{b}	6.00 ± 1.73 ^{ab}	891.67 ± 101.03 ^{bcd}
Indigenous variety of earthworm + neem leaves	05.00 ± 2.00 ^{bc}	9.33 ± 0.57 ^{a}	1041.67 ± 76.37 ^{ab}
Indigenous variety of earthworm	32.33 ± 8.62 ^{a}	9.33 ± 6.02 ^{a}	883.33 ± 142.15 ^{bcd}
Control	35.33 ± 5.50 ^{a}	7.66 ± 3.51 ^{a}	725.00 ± 156.12 ^{d}

Each value represents the mean value of three replicates ± standard deviation. Means followed by same alphabet don't vary significantly at $p<0.05$ based on DMRT.

Even though the exotic variety of earthworm with onion peel demonstrated excellent pesticide effectiveness, it could not be recommended as a suitable pesticide as it was harmful to ladybird beetles. According to the present findings, it was observed that the indigenous variety of earthworm with neem leaves treatment, promotes ladybird beetles while also being effective against pests. As a result, indigenous variety of earthworm with neem leaves can be recommended as a safe and effective insecticide against the pests of yardlong bean.

Yield

The average yield of exotic variety of earthworm with onion peel treated plants was higher, with a mean value of 1131.67 g based on Table 2. However, the study revealed that there was no significant difference among the treatments like exotic variety of earthworm with onion peel, indigenous variety of earthworm with neem leaves, indigenous variety of earthworm with onion peel, exotic variety of earthworm with garlic peel, and exotic variety of earthworm with neem leaves. It clearly showed that the statistically equal amount of yield in these treatments except for the exotic variety of earthworm with neem leaves due to the minimum number of pests. Baba *et al.* (2019) who found that onion extract increases cowpea yield by reducing pest infestation in their investigation on the effectiveness of onion extract against cowpea pests, which finding is par with the results of present study. It was also confirmed through the correlation analysis, where a negative correlation ($r = -0.55$) was observed between pest infestation and yield.

Conclusion

The study confirmed the efficacy of vermiwashes prepared using indigenous variety of earthworm with garlic peel, exotic variety with onion peel, and indigenous variety with onion

peel in lowering the number of epilachna beetles followed by indigenous earthworm variety with neem leaves and exotic variety with garlic peel. Though the vermiwash of indigenous earthworm variety with neem leaves was statistically categorized into second group in lowering the number of epilachna beetle, the higher yield in yard long bean cultivation with maximum numbers of ladybird beetles were recorded in such treatment treated plots. Therefore, the vermiwash prepared using indigenous earthworm variety with neem leaves could be recommended to the yardlong bean cultivation. Further, the study evidenced the comparable effectiveness of native earthworm species with indigenous earthworm variety in producing vermiwash, which enables farmers to create biopesticides at comparatively lower cost using domestic waste.

References

Andersen, T. F. A. O. M. (1997). Malonated anthocyanins of garlic *Allium sativum* L. *Food Chem*, 58, 215–217.

Baba, S., Ayaaba, A. A. and Samuel, Y. (2019). Efficacy of spring onion (*Allium fistulosum*) leaf extract for controlling major field insect pests of cowpea (*Vigna unguiculata* L.) in the guinea savannah Agro ecological zone of Ghana. *Journal of Entomology and Zoology Studies*, 07(1), 730–733.

Benchasri, S. and Bairaman, C. (2010). Evaluation of yield components and consumers satisfaction towards yard long bean and cowpea in agricultural organic system. *Bulgerian Journal of Agricultural sciences*, 06,705–712.

Harsita, N., Sumit, R., Rakhi, M., Priyanka, R., Shivpoojan, Y., Saroj, K. P. and Rajesh, K. S. (2019). Vermiwash: A potential tool for sustainable agriculture. *Journal of Pharmacognosy and Phytochemistry*, 05(5), 308–312.

Hitinayake, H. M. G. S. B., Ubayapala, K. G. K. C., Samaranayake, J. K. S. and Weerasekera, W. A. T. H. (2018). Evaluation of earthworm species and bedding material collected from tea plantations for vermicomposting in Sri Lanka. *International of Journal of Environment, Agriculture and Biotechnology*, 03(5), 1935–1939.

Hwang In Cheon, Kim-Jin, Kim-Hyeong-Min, Kim-Do-Ik, Kim-Seon-Gon, KimSang-Su and Jang, C. (2009). Evaluation of Toxicity of Plant Extract Made by Neem and Matrine against Main Pests and Natural Enemies. *Korean Journal of Applied Entomology*, 48(1), 87–94.

Podder, S., Uddin, M. M. and Adnan, S. M. (2013). Assessment of the effectiveness of different botanicals and chemical insecticide in managing Epilachna beetle. *International Reserach Journal of Agricultural Science*, 01(4), 52–59.

STUDY ON SEED SETTING PERFORMANCE OF SELECTED CLUSTER ONION (*Allium cepa* L.) CULTIVARS UNDER VERNALIZATION AND NON-VERNALIZATION CONDITIONS

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Abstract

Cluster onion is popular among the growers of northern province and preferred by consumers throughout the state for its size, storability and palatability. This research presents an overview of the study of floral biology associated with cluster onion germplasms to improve cluster onion seed setting for hybridization. This was conducted at Regional Agricultural Research and Development Centre, Killinochchi using a Factorial Randomized Complete Block Design with three replicates. One standard variety (MICLO 1) with four selected cultivars (TVM 1, TVM 6, MH 4 & *Kundu vallarai)* of red onion were used. Five cultivars of onion with different methods taken as treatments *viz,* vernalization and non – vernalization. The research period from March 2022 to May 2022 to evaluate the floral behavior and hybridization of different onion germplasms under rainfed and irrigation conditions in Dry zone. Observations were analyzed in ANOVA using SAS software. This study shows that the vernalization process had a substantial impact on floral behavior and was helpful for the developing hybridization program. Significant differences were found between the vernalization and non-vernalization conditions. Overall, the study found that vernalization improves flowering ability, flower presence in umbels, umbel size, and seed quantity and quality. The most flowering onions were MH4 and MICLO 1 showed the highest number of flower count, umbel diameter, flower stalk and flower stalk width. TVM 6 and TVM 1 showed the intermediate responses with two treatments. But during the research period TVM 1 was most affected by fungal attack and the TVM 6 was field tolerant to major fungal disease and *Kundu vallarai* had the lowest responses with these two treatments because of this non-flowering ability.

Keywords: Cluster onion, cultivar, floral biology, germplasm, vernalization

Introduction

Onion production is important in the Sri Lankan economy, helping to ensure rural empowerment opportunities. In Sri Lanka, Jaffna district is primarily an agricultural area with enormous potential for commercial agriculture production. In Valikamam-East and Vadamarachchi area in Jaffna, red onions are cultivated and farmers use seed onion for their cultivation (Thayaparan and Kajendeni, 2020). Onion is thought to have been carried to Sri Lanka by ancient traders from Tamil Nadu, particularly to northern areas, and then spread to other parts of the country.

Floral biology study is highly concerned with flower function in order to promote pollination and hybridization. Floral biology of a cluster onion is an essential for developing an effective program of genetic improvement through hybridization. It is the most important member of the family Alliaceae with monocotyledonous and cross-pollinated behavior (Sathiyamurthy and Harish, 2017). Onion production sometimes fall down due to scarcity of seeds. Huge differences are observed on the average seed yield as it depends on genotype, locality and method of seed production. Therefore, the objective of the study was to investigate floral behavior of different cultivars/ variety with vernalization and non- vernalization conditions to select good parents to improve the hybridization in cluster onions.

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Materials and Methods

An experiment was carried out among five germplasms planted with two different treatments T_1:(Vernalization) and T_2 (Non-vernalization). Experimental design was Factorial Randomized Complete Block Design with three replicates. MH 4, MICLO 1, TVM 6, TVM 1 and *Kundu vallarai* bulbs were planted in each plot. Bulbs were planted in raised beds, Maha season (march 2022 to May 2022) at Regional Agricultural Research and Development Centre, Killinochchi, Sri Lanka. The area fall under Low country Dry Zone (DL3) agro-ecological region. All cultural practices were followed as recommended by the Department of Agriculture, Sri Lanka. The study of floral biology and selection for the best parental line for the hybridization program observed from: Number of days for bud formation, Number days for first flowering, Number of days for fifty percent flowering, Anthesis time, Anther colour, Stigma colour, Anther dehiscence, Number of umbels per plot, Umbel diameter. Flowers per umbel, Flower stalk height, Flower stalk width, Seed set percentage through self and cross pollination, total seeds per plot were analyzed using analysis of variance (ANOVA) with SAS-9.1 package.

Results and Discussion

Number of days taken to first and fifty percent flowering

It was observed that flowering of cluster onion was significantly ($p<0.05$) influenced by the treatments. MH4 and MICLO1 showed earliest flowering without significant differences between them. *Kundu vallarai* obviously showed the non- flowering in both treatments. The highest days were recorded in TVM 1 and TVM 6.

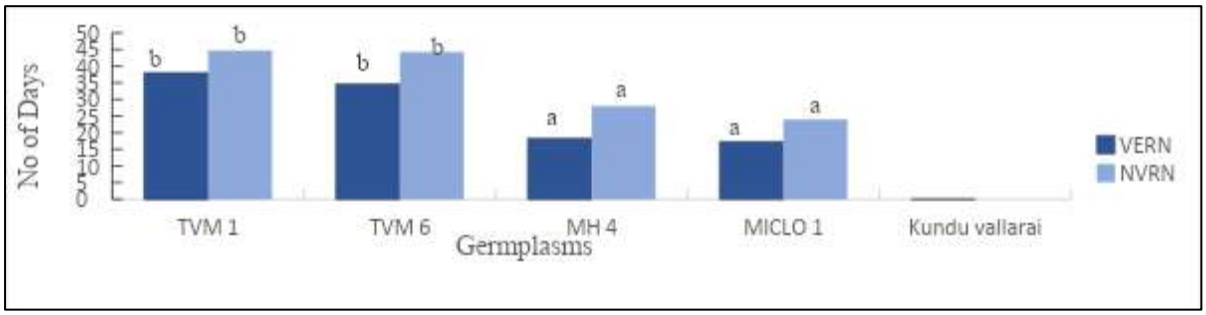

Figure 1: Mean number of days for first flowering of five onion germplasm under different treatments

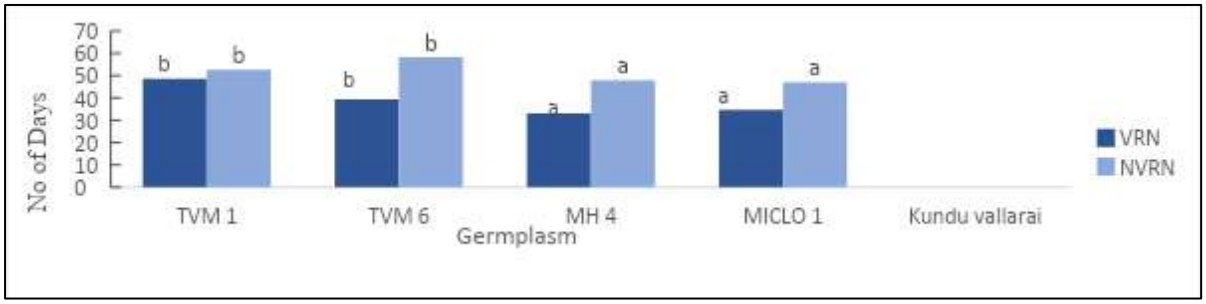

Figure 2: Mean number of days for fifty percent flowering of selected cultivars under different treatments

This study might reflect the effect of vernalization and non-vernalization on flowering of cluster onion. Within treatment, Vernalization treatment was most effective which stimulated early flowering of onion bulbs.

Anthesis and Anther dehiscence

In Onion anthesis occurred between 11.00 a.m. to 1.00 p.m. The peak level of flower opening was seen during this time period. After anthesis, the anther dehiscence was observed in the evening. The next day of anthesis, however, the peak level of anther dehiscence was seen between morning 9.30am and evening 5pm.

Anther colour

Table 1*:* Anther color in different stages (RHS value)

Color Group	Number
Yellow green group	N144- B
Yellow green group	N144-A
Yellow green	147-C
Greyed -orange group	164-B

Number of umbels per plot

There were significant differences($p<0.05$) among treatments. There was no any significance difference between MH 4 and MICLO1 germplasms. However, these two germplasms differ greatly from the other three. When compared to TVM 1, TVM 6, and *Kundu vallarai*, MH 4 and MICLO 1 exhibited greater flowering ability. In vernalized condition umbels mean value this was the higher number value than non-vernalization condition.

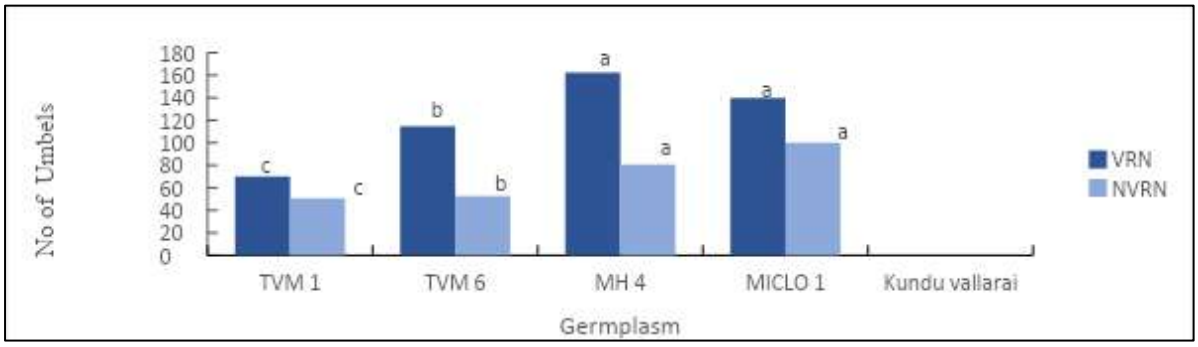

Figure 3: Mean Number of Umbels of selected onion germplasms under different treatments.

Umbel width of selected cultivars

Umbel diameter is an important growth parameter that has a direct impact on seed yield. When the umbel diameter increases, it may hold more seeds, resulting in an increase in seed yield. There was an interaction between the vernalization and non-vernalization conditions, as well as distinct five germplasm and umbel diameters. *Among* the treatments with germplasms MH4 and MICLO1 had highest umbel width than other treatment. When compared to non-vernalized bulbs, vernalized bulbs have a higher number of flowers in the umbel and wide umbel. Therefore, there was a significance effect on umbel width by vernalization.

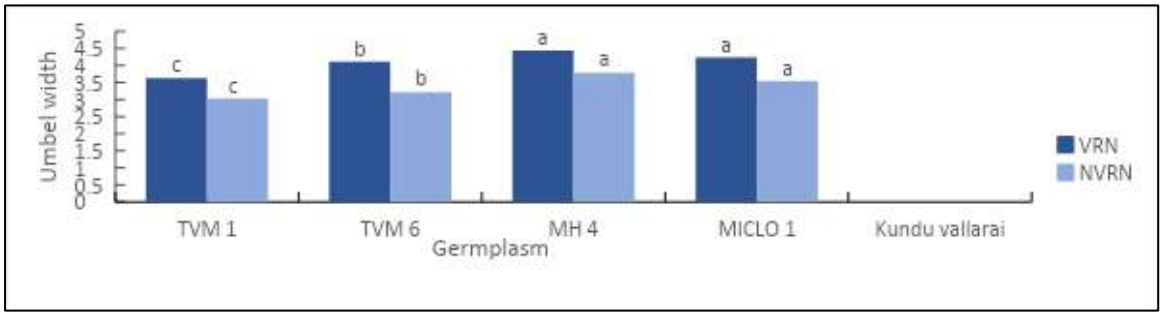

Figure 4: Mean value of umbel width of onion cultivars under different treatments.

Table 1: Means values of growth parameters and floral parameters with different treatments

Parameter	Vernalization					Non- vernalization				
	V1	V2	V3	V4	V5	V1	V2	V3	V4	V5
Establishment%	99.00 ±1.73[a]	99.33 ±0.58[a]	100 [a]	97.67 ±2.52[a]	99.33 ±1.15[a]	92.33 ±0.58[a]	96.67 ±2.08[a]	95 ±2.65[a]	93.67 ±3.21[a]	92 ±4.36[a]
Bud formation (Days)	21.67 ±0.58[b]	13.00[c]	7.33 ±0.58[d]	7.00±. 1.00[d]	0	28.33 ±2.52[b]	15.33 ±1.53[c]	9.67 ±0.58[d]	10.00 ±1.00[d]	0
1st Flowering (Days)	38 ±1.00[b]	34.67 ±3.79[b]	18.33 ±4.51[c]	17.33 ±3.21[c]	0	44.67 ±5.51[b]	44.33 ±1.51[b]	28.00 ±2.65[c]	24.00 ±1[c]	0
Umbels per plot	70 ±11.36[c]	114.67 ±22.37[b]	162.33 ±26.54[a]	140 ±3.61[a]	0	50.67 ±1.53[c]	52.67 ±3.21[b]	60.67 ±1.53[a]	100[a]	0
No.of flowers per umbel	87.43 ±2.88[c]	82.60 ±10.04[c]	117.53 ±2.27[b]	126.53 ±3.00[a]	0	55.2 ±2.88[c]	66.4 ±2.98[c]	99.5 ±1.99[b]	110.17 ±7.78[a]	0
Flowerstalk per plant	4.13 ±0.23[a]	2.63 ±0.06[b]	3.83 ±0.40[a]	3.6 ±0.2[a]	0	3.27 ±0.50[a]	2.1 ±0.1[b]	3.37 ±0.05[a]	3.6 ±0.1[a]	0
Umbel width (cm)	3.63 ±0.09[c]	4.11 ±0.14[b]	4.44 ±0.42[a]	4.24 ±0.43[a]	0	3.02 ±0.04[c]	3.22 ±0.07[b]	3.79 ±0.18[a]	4.22 ±0.09[a]	0
Flowerstalk height	31.5 ±1.54[ab]	36.42 ±2.91[a]	35.54 ±4.79[a]	35.94 ±2.62[a]	0	36.59 ±1.13[ab]	36.93 ±4.54[a]	37.63 ±2.29[a]	36.33 ±5.92[a]	0
Flowerstalk width	9.35 ±0.34[b]	7.47 ±0.12[c]	8.07 ±0.72[b]	9.58 ±0.47[a]	0	5.08 ±0.09[b]	4.46 ±0.05[c]	6.15 ±1.00[b]	7.70 ±0.72[a]	0

Conclusion

Based on the results, vernalization is one of the most effective treatments for increasing seed setting on onion crops. According to the results showed that MH4, MICLO 1, and TVM 6 are the best for the hybridization process. Using these three verities/cultivars can increase the success of hybrid seed production.

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References

Arasakesari, S.J., Bowleeswran, B. Atputhachandran, P. Herath S. and Balasoorya, B.G.R.C.A (2017). Promising multiplier onion (Allium cepa) line with field Resistance to majour fungal diseases and possessing moderate flowering efficiency, *Topical Agriculturist*, Vol.165:Part1,2017

Bashir, M. A. *et al.* (2021) 'Onion flowers anthesis and insect pollinators preferences on onion flowers anthesis and insect pollinators preferences on onion (*Allium cepa*) crop', (february).

Sathiyamurthy, V.A., T. S. and S. Harish, N. A. T. (2017) 'Review on Aggregatum Onion (*Allium cepa* L. var. aggregatum Don.)', *International Journal of Current Microbiology and Applied Sciences*, 6(4), pp. 1649–1667. doi: 10.20546/ijcmas.2017.604.201.

Thayaparan, A. and Kajendeni, S. (2020) 'Socio-economic Characteristics and Its Impact on Onion Cultivation in Jaffna District of Sri Lanka', *Journal of Finance and Accounting*, 8(5), p. 212. doi: 10.11648/j.jfa.20200805.11.

Yalamalle, V. (2018) 'Vernalization Responses in Onion (Allium cepa) Pre-flowering and Reproductive Phases Vernalization Responses in Onion (Allium cepa) Pre-flowering and Reproductive Phases', (January 2016).

IN VITRO EVALUATION OF ANTIFUNGAL ACTIVITY OF DIFFERENT SEAWEED EXTRACTS ON *Colletotrichum musae* IN BANANA

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Abstract

Bananas are one of the most important fruits of human dessert. However, due to their susceptibility to anthracnose and the use of hazardous substances to control such post–harvest diseases, the marketability of bananas has been questioned. Hence, natural plant substances are being explored as a sustainable alternative to synthetic fungicides. In this regard, a research study was conducted to evaluate the effects of different seaweed extracts (SEs) of *Halimeda opuntia*, *Kappaphycus alvarezii*, *Padina minor*, and *Sargassum polycystum* on *Colletotrichum musae* in banana fruits (variety–Kathali). First, seaweeds were dried, extracts were prepared with 50% methanol (v/v), followed by the removal of residual methanol from the extracts. Second, the availability of phytochemicals was checked qualitatively. Finally, an *in vitro* experiment was conducted to check the antifungal activity of the selected SEs by using poison food medium and agar disc diffusion methods at 25 °C and 70% RH. The treatments, *S. polycystum*, *K. alvarezii*, *P. minor*, a combination of the three SEs, mancozeb fungicide (2µg/µl) and control (sterile distilled water) were carried out with three replicates. The study evidenced the presence of flavonoids, phenol, tannins and saponins in *K. alvarezii* and *S. polycystum*. In the poison food medium and agar disc diffusion methods, the *in vitro* analysis revealed that *K. alvarezii* extract had a significant ($P<0.05$) effect on suppressing mycelial growth (100%) and inhibition zone (1.47 cm) compare to the control, followed by mancozeb fungicides and the combination of SEs after 7 days of incubation. It confirmed the antifungal effects of *K. alvarezii* on anthracnose in banana fruits, and the results were comparable to the conventional fungicide. Therefore, it could be concluded that the *K. alvarezii* extract might be an ecologically friendly, chemical–free, consumable option to manage post–harvest anthracnose in bananas, and more experiments are needed to validate the efficacy in the field.

Keywords: Anthracnose, antifungal activity, banana, post–harvest, phytochemicals, seaweed extract

Introduction

Banana (*Musa acuminata* L.) belongs to the family *Musaceae* and is the most widely produced and consumed tropical fruit in the world including Sri Lanka (Debabandya *et al*., 2010). Numerous post–harvest diseases including anthracnose disease affect banana quality of fresh products and reduce consumer preferences. Anthracnose in bananas is caused by *C. musae* (Cannon *et al*., 2012). In Sri Lanka, banana annual production reduces by 20% (around 80,964 metric tons) due to anthracnose and crown rot disease (Anthony *et al*., 2004). Most commercial banana varieties are sensitive to anthracnose including 'Puli kathali' or 'Ambul kesel' (Abayasekara *et al*., 2013). When banana fruits are wounded by scratches during handling and transportation, anthracnose worsens and the fruit becomes unmarketable. The post–harvest disease of fruits is commonly managed by the application of chemical fungicides by dipping or spraying (Jinasena *et al*., 2011). They have the potential of negative consequences on humans and the environment. Therefore, an innovative plan of action to lower the incidence of diseases using safe substances that don't pose any risks to human health, safety or the environment is needed.

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Among the various viable options, natural marine products, including seaweeds that are biodegradable and eco–friendly are attracting the interest of scientists all around the world. Seaweeds are having a wide range of biological activities, including antiviral (Damonte *et al*., 2004), antiprotozoal (Senecheau *et al*., 2011), anti–fungicidal (Machado *et al*., 2014), anti–nematocidal (Gharee, 2022) and anti–bactericidal (Shanmughapriya *et al*., 2008) activities hold a significant position among marine organisms. Therefore, the present study aims to investigate the antifungal activity of four different seaweed species *H. opuntia*, *K. alvarezii*, *P. minor* and *S. polycystum* collected from Batticaloa and Jaffna districts, Sri Lanka against the *C. musae* associated banana anthracnose disease in the Kathali variety.

Materials and Methods

Collection and identification of seaweeds

Plate 1: (A) – Morphology of *P. minor*; (B) – Morphology of *K. alvarezii*, (C) – Morphology of *S. polycystum*, (D) – Morphology of *H. opuntia*

The seaweed species such as *H. opuntia*, *P. minor* collected from Batticaloa, Passikudah (Latitude 7° 43' 0.00" N and Longitude 81° 42' 0.00" E and *K. alvarezii*, *S. polycystum* were collected (Plate 1) from Jaffna, Point Pedro (Latitude 9° 40' 0.00" N and Longitude 80° 0' 0.00" E) district coastal areas in Sri Lanka in the period of May–June 2022. The collected seaweeds were washed with seawater to remove soil at the site. The samples were stored in a few styrofoam cold boxes and transported to the laboratory, Department of Agricultural Biology, Eastern University, Sri Lanka. The collected seaweed species were identified using a taxonomic identification guide (Coppejans *et al*., 2009). The morphology of the seaweed was examined through the stereo microscope (Optika microscope, Italy).

Preparation of seaweed liquid extract and qualitative analysis of phytochemical

The seaweeds were cleaned, dried under the shade, powdered by using an electric mixer grinder (Panasonic, MX–AC 400, Japan), and sieved through a screen with a mesh size of 0.01 mm, 20 g of seaweed powder was successively extracted with 400 ml, 50 % methanol (v/v) at room temperature for 6 hours by using a soxhlet apparatus (500 ml, 6 Recess, Electrothermal, United Kingdom) and methanolic extracts were evaporated by using a rotary evaporator (Witegvapor diagonal or vertical 180 ºC, 20–280 rpm, 500 ml, Germany). The phytochemicals of alkaloids, flavonoids, phenol, tannins, steroids, cardiac glycosides, terpenoids, saponins, and anthraquinone were qualitatively analyzed (Ushie *et al*., 2016).

Isolation and purification of Colletotrichum musae from diseased banana fruit specimens

Banana fruits with conspicuous symptoms of the anthracnose disease caused by *C. musae* such as sunken dark lesions were obtained from the local market of Chenkalady, Batticaloa District of Sri Lanka. The fruits came from nearby towns and thus are locally produced. A 1×1 cm section of the banana peel was excised aseptically using a scalpel from the diseased specimen containing half infected and half healthy tissue. The tissue portions were surface sterilized using 3% sodium hypochlorite solution for 3 minutes, rinsed with serial washing in sterile distilled water for 1 minute, and then blot in a sterile Whatman No 1 filter paper and air dried in a laminar flow hood (ESCO, United Kingdom). The tissue portion was placed on PDA media and incubated in a growth chamber at 25 ºC and 70 % RH. Potential pathogens were transferred to new PDA plates in order to obtain pure cultures. The fungal pathogens were identified by

microscopic observation according to the appropriate taxonomic key and related literature description (Lim *et al*., 2002) using slide cultures. The isolated fungi were maintained on slant culture at 4 °C until future use.

Antifungal effect of seaweed extract on mycelial radial growth under in vitro condition

Poison food medium method

An aliquot amount of 5 ml from each of 100% *S. polycystum*, 100% *K. alvarezii*, 100% *P. minor*, a combination of seaweed extracts (100% *S. polycystum*, 100% *K. alvarezii* and 100% *P. minor*), sterile distilled water, mancozeb fungicide (2 µg/µl) were aseptically added to 20 ml of sterile cooled PDA medium (45 °C) separately into sterilized petri plates. Then a 5 mm disc of *C. musae* mycelium was placed on the center of the PDA medium in each petri dish. The treated media with 6 treatments were incubated in the growth chamber (Memmert, Schwabach) with suitable conditions (25 °C, 70% RH) in a Completely Randomized Design (CRD) with 3 replicates, and mycelial growth was measured daily. The formula MGI = [(dc – dt)/dc] × 100 was used to calculate the mycelial growth inhibition (MGI), where dc represents the mycelium diameter in the control petri dish and dt represents the mycelium diameter in the seaweeds–treated petri dish (Mishra and Dudey, 1994).

Agar disc–diffusion method

In this procedure, the center of PDA plate was inoculated with a standardized inoculum of the test microorganism *C. musae*. Then, Whatman No 1 filter paper 6 mm diameter discs, amended for three hours under the laminar air flow hood with the test 6 treatment as mentioned above poison food medium method were placed on the PDA surface. The Petri dishes were incubated under suitable conditions (25º C, 70% RH) in the growth chamber. Finally, the diameters of the inhibition growth zones were measured (Balouiri *et al*., 2016).

Statistical analysis

Analysis of variance was performed using SAS 9.1 version statistical software package and mean comparison was performed within treatments using Duncan Multiple Range Test (DMRT) at a 5% significant level for precise and easy interpretation of the results of this experiment. Data on mycelial growth inhibition (%) was arcsine square root transformed in order to stabilize variance.

Results and Discussion

Qualitative analysis of phytochemicals

Among qualitatively analyzed phytochemicals, *H. opuntia* extract had no phytochemicals. Flavonoids and saponins were present in the *P. minor* extract. The *K. alvarezii* and *S. polycystum* extracts had flavonoids, phenol, tannins, and saponins (Table 1).

Effect of seaweed extract on mycelial radial growth and mycelial inhibition zone

The results of the poison food medium and the agar disc–diffusion method revealed that the *K. alvarezii* extract has the highest antifungal activity against the *C. musae* with 100% mycelial growth inhibition and 1.47 cm inhibition zone respectively (Table 2). In the *K. alvarezii* and *S. polycystum* same phytochemicals were observed. Moreover, the carrageenan present in *K. alvarezii* induced antioxidant defense and antifungal in banana, thereby offering resistance against anthracnose disease caused by *C. musae*. The present study's finding agrees with earlier findings made by Machado *et al* (2014) who revealed that *Padina gymnospora*, *Hypnea musciformis*, *Laurencia dendroidea*, *Ochtodes secundiramea* and *Pterocladiella capillacea* extracts highly inhibited the mycelial growth of *C. musae*. Further, *K. alvarezii* was reported to be fungicidal to *Aspergillus niger*, *A. flavus*, *A. fumigatous*, *Saccharomyces cervisiae* and *Mucor indicus* (Aruna *et al*., 2010).

Table 1: Details of Phytochemical Availability of SEs

Name of the phytochemicals	*H. opuntia*	*K. alvarezii*	*P. minor*	*S. polycystum*
Alkaloids	–	–	–	–
Flavonoids	–	+++	+++	+++
Phenol	–	++	–	+++
Tannins	–	+++	–	+++
Steroids	–	–	–	–
Cardiac glycosides	–	–	–	–
Terpenoid	–	–	–	–
Saponins	–	++	+	++
Anthraquinone	–	–	–	–

– = absent, + = present, ++ = moderately abundant, +++ = highly abundant

Table 2: Effects of the SEs of *C. musae* Mycelium Growth and Inhibition Zone on PDA Media

Treatments	Poison food medium method	Agar disc–diffusion method
	Mycelial growth inhibition (%)	Inhibition zone (cm)
S. polycystum SEs	49.98 ± 10.48^{cd}	0.10 ± 0.10^{c}
K. alvarezii SEs	100.00 ± 0.00^{a}	1.47 ± 0.31^{a}
P. minor SEs	45.98 ± 13.78^{d}	0.10 ± 0.17^{c}
A combination of the three SEs	72.71 ± 26.00^{bc}	1.33 ± 0.15^{a}
Mancozeb fungicide	95.90 ± 7.11^{ab}	0.57 ± 0.21^{b}
Control (sterile distilled water)	0.00 ± 0.00^{e}	0.13 ± 0.15^{c}
F–test	*	*

*The value represents the mean ± standard error of three replicates. * represents significant difference at 5% level of probability.*
Mean values in a column having dissimilar letter/letters indicate significant differences at 5% level of significance by DMRT.

Conclusions

According to the findings obtained from the poison food medium and the agar disc diffusion techniques, the *K. alvarezii* extract possessed the strongest antifungal activity against the *C. musae in vitro*, which was comparable to the effect of mancozeb fungicide. Therefore, the extract of *K. alvarezii* might be an environmentally safe and appropriate alternative to synthetic fungicides for the management of the post–harvest anthracnose disease that affects banana fruits.

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References

Abayasekara, C. L., Adikaram, N. K., Wanigasekara, U. W. and Bandara, B. M. (2013). *Phyllosticta musarum* infection–induced defences suppress anthracnose disease caused by *Colletotrichum musae* in banana fruits cv 'Embul'. *The Plant Pathology Journal*, 29(1): 77–86.

Anthony, S., Abeywickrama, K., Dayananda, R., Wijeratnam, W. S. and Arambewela, L. (2004). Fungal pathogens associated with banana fruit in Sri Lanka, and their treatment with

essential oils. *Mycopathologia*, 157(1): 91–97.

Aruna, P., Mansuya, P., Sridhar, S., Kumar, J. S. and Babu, S. (2010). Pharmacognostical and antifungal activity of selected seaweeds from Gulf of Mannar region. *Recent Research in Science and Technology*, 2(1): 115–119.

Balouiri, M., Sadiki, M. and Ibnsouda, S. K. (2016). Methods for *in vitro* evaluating antimicrobial activity: A review. *Journal of Pharmaceutical Analysis*, 6(2): 71–79.

Cannon, P., Damm, U., Johnston, P. and Weir, B. (2012). *Colletotrichum* – Current status and future directions. *Studies in Mycology*, 73(5): 181–213.

Coppejans, E., Leliaert, F., Dargent, O., Gunasekara, R. and Clerck, O. D. (2009). Sri Lankan seaweeds methodologies and field guide to the dominant species. In: Y. Samyn, D. V. Spiegel & J. Degreef, (Eds.), Abc taxa (pp. 1–275). Sri Lanka: Belgion Development Cooperation.be.

Damonte, E., Matulewicz, M. and Cerezo, A. (2004). Sulfated seaweed polysaccharides as antiviral agents. *Current Medicinal Chemistry*, 11(2): 2399–2419.

Debabandya, M., Mishra, S. and Sutar, N. (2010). Banana and its by–product utilization: an overview. *Journal of Scientific and Industrial Research*, 69(4): 323–329.

Gharee, R. Y. (2022). Nematicidal activity of seaweed–synthesized silver nanoparticles and extracts against Meloidogyne incognita on tomato plants. *Scientific Reports*, 3841(12): 1–12.

Jinasena, D., Pathirathna, P., Wickramarachchi, S. and Marasinghe, E. (2011). Use of chitosan to control anthracnose on "Embul" banana. *International Conference on Asia Agriculture and Animal*, 13(3): 56–60.

Lim, J., Lim, T. H. and Cha, B. (2002). Isolation and identification of *Colletotrichum musae* from imported bananas. *Plant Pathology Journal*, 18(3): 161–164.

Machado, L. P., Matsumoto, S. T., Jamal, C. M., Silva, M. B., Centeno, D. D., Neto, P. C. and Carvalho, L. R. (2014). Chemical analysis and toxicity of seaweed extracts with inhibitory activity against tropical fruit anthracnose fungi. *Science and Food Agriculture*, 94(3): 1739–1744.

Mishra, A. K. and Dudey, N. K. (1994). Evaluation of some essential oil for their toxicity against fungi causing deterioration of stored food commodities. *Applied and Environmental Microbiology*, 60(2): 1101–1105.

Senecheau, C. V., Kaiser, M., Devambez, I., Vastel, A., Mussio, I. and Rusig, A. M. (2011). Antiprotozoal activities of organic extracts from French marine seaweeds. *Marine Drugs*, 9(6): 922–933.

Shanmughapriya, S., Manilal, A., Sujith, S., Selvin, J., Kiran, G. S. and Natarajaseenivasan, K. (2008). Antimicrobial activity of seaweeds extracts against multiresistant pathogens. *Annals of Microbiology volume*, 58(2): 535–541.

Ushie, O. A., Onen, A. I., Ugbogu, O. C., Neji, P. A. and Olumide, V. B. (2016). Phytochemical screening and antimicrobial activities of leaf extracts of *Swietenia macrophylla*. *ChemSearch Journal,* 7(2): 64–69.

OPTIMIZATION OF ARTIFICIAL GROWTH CONDITION OF *Fusarium oxyporum* AND SCREENING THE RESISTANT BEAN (*Phaseolus vulgaris L.*) GERMPLASM AGAINST FUSARIUM WILT

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Abstract

Common beans (*Phaseolus vulgaris*) are very nutritious and popular vegetable around the world that belongs to the family Fabaceae. It is widely cultivated in the upcountry intermediate zone in Sri Lanka. Many diseases reduce the yield and quality of beans. Fusarium wilt is an economically important fungal disease of the common bean. It is important to screen the resistant varieties against Fusarium wilt. This research aimed to select the resistant germplasm and suitable conditions of growing media, temperature, and pH of media to inoculate the *Fusarium oxysporum* into various bean germplasm. For this experiment, six types of bean germplasm were tested. To optimize the artificial growth condition of *F. oxysporum*, two growth media (nutrient agar, potato dextrose agar), two temperature levels (room temperature-37 ^{o}C, 30 ^{o}C), and five pH levels (5, 5.5, 6, 6.5, 7) were employed. Altogether 20 treatments were tested with three replicates. This experiment was laid out using Completely Randomized Design. During this study, the observations of foliage symptoms and vascular discoloration were recorded and the mycelial growth diameter and number of spores of *F. oxysporum* were documented. Based on the observations, the resistant cultivars were selected. From the screening, the germplasm BWB 1, 4, and 5 were identified with prominent resistant characteristics. For optimization of growth conditions, the best combination of nutrient agar, a pH level 5 or 5.5, and a temperature level of 30 °C was selected. In the future, the identified resistant accessions can be used as the source of resistance in breeding programs to develop resistant cultivars.

Keywords: *Fusarium oxysporum,* growth condition, *Phaseolus vulgaris,* resistance variety

Introduction

Grain legumes are an important part of the human diet because they are a rich source of dietary proteins and necessary minerals (Bohra *et al*., 2015). Numerous fungal infections create a significant threat to the global output of legumes (Kaiser *et al*., 2000). It is abundantly grown in the intermediate highland region, particularly in the Badulla district of Sri Lanka. The Badulla area experiences a large number of diseases that lower bean quality and output. The main factor limiting the output of grain legumes is the Fusarium wilt (FW) disease. The anticipated climate change will probably make the existing situation worse. Following colonization in the vascular system, the Fusarium wilt (FW) pathogen interrupts the root-water continuity of the plant, causing wilting symptoms and plant mortality (Schäfer, 1994). The most practical, cost-effective, and environmentally benign method of risk reduction among the different plant protection strategies is genetic modification of agricultural cultivars' disease resistance. The primary goal of the study was to screen bean germplasm for resistance to Fusarium wilt and to improve the artificial growing conditions for *F. oxyporum*.

Materials and Methods

This experiment was carried out at the Regional Agriculture Research and Development Center in Bandarawela. An experiment with 20 different treatments and three repetitions was carried out in a Completely Randomized Design (CRD) to determine the best artificial growing conditions for *F. oxysporum*. To optimize the artificial growth condition, five pH levels (pH 5, pH 5.5, pH 6, pH 6.5, and pH 7), as well as two temperature settings (30 and 37 °C) and two growth media (nutrient Agar and

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potato dextrose agar), were employed. The selected combinations of treatment were

T1 - NA 30 °C pH 5
T2 - NA 30 °C pH 5.5
T3 - NA 30 °C pH 6
T4 - NA 30 °C pH 6.5
T5 - NA 30 °C pH 7
T6 - NA Room temperature pH 5
T7 - NA Room temperature pH 5.5
T8 - NA Room temperature pH 6
T9 - NA Room temperature pH 6.5
T10 - NA Room temperature pH 7
T11 - PDA 30 °C pH 5
T12 - PDA 30 °C pH 5.5
T13 - PDA 30 °C pH 6
T14 - PDA 30 °C pH 6.5
T15 - PDA 30 °C pH 7
T16 - PDA Room temperature pH 5
T17 - PDA Room temperature pH 5.5
T18 - PDA Room temperature pH 6
T19 - PDA Room temperature pH 6.5
T20 - PDA Room temperature pH 7

Using a cork borer and forceps, the *F. oxysporum* colony was transferred from the mother plate to the center of the culture plate (Plate 1). The sealed cultured plates were kept aside for further observation. The diameter of the colony was recorded at 3, 6, 9, 12, 15, 18, and 21 days after incubation. After 21 days of incubation, the number of spore counts was taken using a haemocytometer.

Plate 1: Culturing *F. oxysporum*

Another experiment was done in the greenhouse to explore the resistant germplasm. For this purpose, 120 plants of 14-day seedlings from the six germplasm were selected. It was done by inoculating *F. oxysporum* spore suspension. Bean plants that were two weeks old had their roots removed using a sterile blade. The root zone was then given 15 ml of *F. oxysporum* spore suspension. After a month, the symptoms of foliage and vascular discoloration were recorded, and the diseased plants' stems were chopped. Bean varieties' stem sections underwent a 20-minute detergent wash to determine the presence of the disease. The stem pieces were then rinsed with a Clorox solution for 10 minutes. The stem pieces were then soaked in a 70% ethanol solution for 10 minutes of washing. Finally, the stem sections were sliced into small pieces after being rinsed with distilled water. The components were PDA cultivated. The cultivated sample was examined under a microscope after three days. The disease severity was recorded by using symptoms of foliage.

Data analysis

The collected data were subjected to ANOVA using SAS software for any significant differences.

Results and Discussion

The *F. oxysporum* subculture plate that had the most macrospores was chosen as the best treatment combination after 21 days. T2 was identified with the highest number of macrospores with the combination of Nutrient Agar pH 5.5 at 30 °C. There were no significant differences between the treatments T1, T2, and T5. T15, potato dextrose agar media pH 7 at 30 °C, was identified with a lower amount of macrospores (Figure 1).

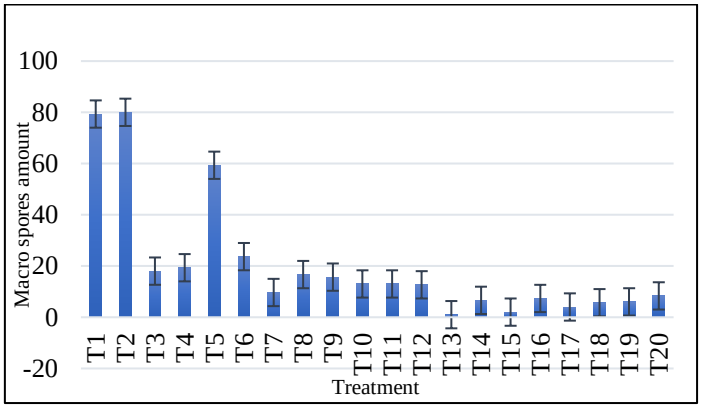

Figure 1: Macro spore count after 21 days of sub-culturing

The root-cutting method was used for the pathogenicity screening. Following the inoculation after 21 days, disease responses were assessed by internal inspection of vascular tissue discoloration and a disease severity grading based on foliar symptoms. According to Fall *et al.* (2001), the plants with a score of 1-3 are classed as resistant, 4-6 as intermediate, and 7-9 as vulnerable. When compared to un-inoculated control plants 5-9 days after inoculation, the treated plants displayed stunted development.

According to the findings of Perera *et al*. (2016), the primary leaves showed epinasty symptoms and chlorotic areas appeared on leaves followed by necrosis at their margins. Transient wilting was the first symptom on plants about 12 days of inoculation. After 15 days from inoculation, three cultivars displayed yellowing signs on the primary leaves and chlorotic regions emerged on the leaves (Plate 2).

Plate 2: Foliage symptoms in BWB 2

Disease reactions ranged from extremely resistant to extremely vulnerable. The variable reactions among the accessions could be due to the heterogeneous nature of the seed source, population, and disease severity. The germplasm identified with yellow colour was categorized as susceptible accessions according to this. Based on the disease symptoms, BWB 1, 4, and 5 germplasm were identified as resistant to this disease and meantime, the other three were susceptible.

Conclusion

The study revealed that the suitable combination of artificial growing conditions for *F. oxysporum* was nutrient agar media at 30 °C with pH 5 or 5.5 and it was confirmed that the bean germplasm BWB 1, BWB 4, and BWB 5 were resistant to Fusarium wilt disease. Further, the identified resistant germplasm can be used in future breeding programs for developing resistant bean varieties.

References

Bohra, A., Sahrawat, K. L., Kumar, S., Joshi, R., Parihar, A. K. and Singh, U. (2015). Genetics- and genomics-based interventions for nutritional enhancement of grain legume crops: status and outlook. *J. Appl. Genet*. 56, 151–161. doi: 10.1007/s13353-014-0268-z

Fall, A. L., Byrne, P. F., Jung, G., Coyne, D. P., Brick, M. A. and Schwarts, H. F. (2001). Detection and mapping of a major locus for Fusarium wilt resistance in common bean. *Crop science*, 41(5), 1494-1498.

Kaiser, W. J., Ramsay, M. D., Makkouk, K. M., Bretag, T. W., Acikgoz, N. and Kumar, J. (2000). "Foliar diseases of cool season food legumes and their control," in Linking Research and Marketing Opportunities for Pulses in the 21st Century, ed. R. Knight (Dordrecht: Kluwer Academic Publishers), 437–455. doi: 10.1007/978-94-011-4385-1_41

Perera G. Y. A. D. D., Chandrasena, G., Silva P. D. P. M. D. and Somachandra, K. P. (2016). Screening a Bean Germplasm for Fusarium Wilt Disease, Caused by Fusarium oxysporum f. sp. Phaseoli. Proceedings of the 6th Research Symposium of Uva Wellassa University January 28-29, 75

Schäfer, W. (1994). Molecular mechanisms of fungal pathogenicity to plants. Annu. Rev. Phytopathol., 32, 461–477. doi: 10.1146/annurev.py.32.090194.002333

INTEGRATION OF FUNGICIDES AND CULTIVARS FOR THE MANAGEMENT OF COWPEA ROOT ROT IN BATTICALOA

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Abstract

Cowpea (*Vigna unguiculata*) is one of the primary grain legumes utilized in dry zone of Sri Lanka. The production of cowpea plant stand and yield are significantly impacted by root infections caused by soil-borne pathogenic fungi. Experiments were conducted at the Agricultural Biology Laboratory and the crop farm, Faculty of Agriculture, Eastern University, Sri Lanka, to evaluate the integration of fungicides and crop cultivars in managing cowpea root rot caused by *Fusarium solani*. Four different cultivars of cowpea and three different fungicides were used for this study. The experiment was laid out in factorial Randomized Complete Block Design (RCBD). Conidial suspension (10^5 conidia/mL) of *F. solani* was introduced to the four different cultivars of cowpea as a soil drench. The fungicides were applied after the inoculation to evaluate the interaction effects between cultivars and fungicides to control Fusarium root rot. Results based on rot lesions developed on taproot revealed that, in general, the interaction effect of each cultivar with homai or topsin fungicide showed significantly ($P<0.05$) lower disease severity. Furthermore, Wijaya cultivar exhibited minimum disease severity with maximum grain yield among the cultivars tested, whereas topsin fungicide showed a significant reduction in disease severity. Therefore, the present study suggested Wijaya as the relatively resistant cultivar to Fusarium root rot and topsin as an effective fungicide for controlling this disease in cowpea in Batticaloa district, Sri Lanka.

Keywords: Cowpea, fungicides, fusarium root rot, *Fusarium solani*, host resistance

Introduction

In Sri Lanka, cowpea is regarded as one of the vegetable crops that is significant for domestic use. One of the main grain legumes used in Sri Lanka's drier regions' farming methods is cowpea. The popularity of suggested varieties among conventional cowpea growers is very low, and most farmers grow their own variety collections (Hewavitharana *et al.,* 2010). Therefore, adopting farmer-preferred varieties with improved adaptability would meet the actual demands of the farmers in Sri Lanka's rain-fed region. Root infections caused by soil-borne pathogenic fungi have a significant impact on cowpea plant stand and yield production. Numerous researchers observed that the most active fungi attacking cowpea plants throughout the growing season were *Fusarium solani* and *Rhizoctonia solani* (Elsayed *et al*., 2011). In the growing season, root rot disease manifests at both pre- and post-emergence stages of plant development (Ajayi *et al.,* 2013). Therefore, the aim of the current research was to assess the effect of integrating fungicides and crop cultivars on the control of cowpea root rot and determine the relatively resistant cultivars and effective fungicides for the management of this disease in Batticaloa district, Sri Lanka.

Materials and Methods

Diseased sample collection

Based on the symptoms such as yellowing lower leaves, dwarfed growth, sunken reddish-brown lesions on roots and stems under the soil line, and wilting of the infected plants, the diseased samples were collected from the crop farm, Eastern University, Sri Lanka and nearby farmers' fields in the Batticaloa district.

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Preparation of Fusarium solani conidial suspension

Twenty-five milliliter of sterile water was added to a well-sporulating desired stock culture (seven days old culture). A sterile spatula was used to scrape the mycelia in order to release spores. A pipette was used to collect the solution from the top of the culture plate and transfer it into a sterile test tube. The mixture was vigorously agitated on a vortex mixer for one minute. To remove agar and mycelial particles, the vortexed solution was filtered through a muslin cloth and placed in a 250 mL volumetric flask. Conidial concentration was determined using a haemocytometer and was adjusted to 10^5 conidia/mL (Stankovic *et al*., 2015) by adding sterile water.

Inoculation of fungal root rot pathogen to the plants

Three-week-old seedlings cultivated in the research field were inoculated by soil drenching with conidial suspension (5 mL/plant).

Preparation of fungicide solutions and applications

Based on the application rate and application interval recommended by the manufacturers, 36.45 g of homai (Thiophanate-methyl + thiram), 21.87 g of topsin (Thiophanate-methyl 70% WP), and captan (N-trichloromethylthio-4-cyclohexane-1,2-dicarboximide) fungicides were dissolved in 36.45 L of water separately. They were applied as soil drenching thrice at 10 days intervals. The first application was done seven days after the soil inoculation.

Disease severity assessment

The plants were uprooted 14 days after the third application of fungicides. Each plant in an experimental unit was assessed for disease severity as the ratio of the length of the sunken, reddish-brown lesions on the taproot to the total length of the taproot of the plant. The disease severity of each experimental unit was then calculated using the following formula.

$$\text{Disease severity} = \frac{\varepsilon \text{ Disease severity of infected plants in the experimental unit}}{\text{Total number of plants in the experimental unit}} \times 100\%$$

Total weight of seeds at harvest

The pods were harvested at the time of uprooting the plants (i.e.14 days after the third application of fungicides). The total seed weight of each plot was measured using an electronic balance after sun drying, removing seeds from dried pods and cleaning.

Statistical analysis

Data on percentage disease severity was subjected to arcsine square root transformed in order to stabilize variance. Interaction and significance of treatment effects on the measured variables were determined by analysis of variance (ANOVA) using MINITAB 19 statistical software. Treatment means were compared using Turkey's test at 5% significant level.

Results and Discussion

Table 1 indicates the disease severity 14 days after the third application of fungicides. There was a significant difference ($P<0.05$) in the interaction between cultivars and fungicides. Additionally, the main effects of cultivars and fungicides were also found to significantly ($P<0.05$) affect the severity of plant disease. In general, the interaction of each cultivar with homai or topsin fungicide significantly reduced the disease severity in cowpea. Therefore, it could be stated without ambiguity that cultivar × fungicide interaction was more beneficial for disease control in cowpea. Wegulo *et al.* (2013) demonstrated that combining cultivar resistance with fungicide application was a more effective strategy for managing Fusarium head blight than using a single approach.

Table 1 indicates that there was a significant difference in disease severity among the cultivars utilized in the experiment. The cultivars Bombay and Wijaya recorded significantly the lowest

disease severity among the cultivars. In many agricultural systems, cultivar resistance is a crucial component of disease control programs. Utilizing resistant cultivars increases stress on pathogen populations and thus reduces disease (Carolan *et al.*, 2017). Statistically, the minimum disease severity was attained with topsin among the fungicides tested. The high effectiveness of topsin application was also proven by Vatchev and Maneva (2012) for the control of root rot complex and stem rot of greenhouse cucumber in straw-bale culture.

Table 1. Disease severity 14 Days after the third application of fungicides

		Disease severity%
Main effects		
Cultivars (C)	Bombay	4.57367 ± 1.343^{b}
	Dhawala	7.86385 ± 4.17^{a}
	Waruni	6.84375 ± 2.730^{a}
	Wijaya	3.93525 ± 1.097^{b}
		*
Fungicides (F)	Homai	4.95958 ± 2.651^{c}
	Topsin	3.06035 ± 0.904^{d}
	Captan	6.9726 ± 1.872^{ab}
	Non-fungicidal	8.19185 ± 4.14^{a}
		*
Interaction (C×F)		
Cultivars (C)	Fungicides (F)	
Bombay	Homai	4.7163 ± 0.443^{cde}
	Topsin	3.3897 ± 0.271^{de}
	Captan	4.7163 ± 1.409^{cde}
	Non-fungicidal	5.3437 ± 2.13^{cde}
Dhawala	Homai	6.4247 ± 0.757^{cd}
	Topsin	2.1597 ± 0.963^{e}
	Captan	10.7884 ± 0.492^{ab}
	Non-fungicidal	12.0827 ± 1.76^{a}
Waruni	Homai	5.1183 ± 1.457^{cde}
	Topsin	4.0910 ± 0.585^{de}
	Captan	8.1050 ± 1.626^{bc}
	Non-fungicidal	10.0607 ± 1.465^{ab}
Wijaya	Homai	3.5790 ± 0.365^{de}
	Topsin	2.6010 ± 0.250^{e}
	Captan	4.2807 ± 0.569^{de}
	Non-fungicidal	5.2803 ± 0.586^{cde}
		*

**Significant difference between means at 5% significant level. Means followed by different letters indicate a significant difference between means according to Turkey's test at α=0.05.*

The results of total seed weight at harvesting (Table 2) showed that the main effects of cultivars and fungicides significantly ($P<0.05$) affected the total grain weight. The cultivars Wijaya and Bombay yielded significantly ($P<0.05$) the highest and lowest seed weight, respectively. Even though Bombay cultivar seemed to be relatively resistant to Fusarium root rot, its lowest total seed weight may be owing to other varietal characteristics. The fungicides topsin, captan, and homai were statistically non-significant among them in terms of total seed weight. The

minimum seed weight was resulted in by the non-fungicidal application. This could be due to the impact of high disease severity by the non-fungicidal treatment. Fungicides are chemical substances that prevent or eliminate the growth of fungus, pathogens with fungal-like characteristics, and their spores (Carmona *et al*., 2020). A significant interaction effect between cultivars and fungicides on the total seed weight was not observed.

Table 2. Total seed weight at harvesting

		Total seed weight (g)
Cultivars	Bombay	129.993 ± 19.29^{c}
	Dhawala	216.508 ± 23.39^{b}
	Waruni	211.145 ± 38.4^{b}
	Wijaya	265.091 ± 29.68^{a}
		*
Fungicides	Homai	213.609 ± 55.9^{a}
	Topsin	219.533 ± 23.39^{a}
	Captan	214.229 ± 38.4^{a}
	Non- fungicidal	175.365 ± 46.7^{b}
		*

**Significant difference between means at 5% significant level. Means followed by different letters indicate a significant difference between means according to Turkey's test at α=0.05*

Conclusion

The severity of the Fusarium root rot disease was significantly highly reduced following the application of topsin or homai fungicide on each cultivar. The Wijaya cultivar could be considered relatively resistant to Fusarium root rot as it exhibited the lowest disease severity and increased seed weight. Topsin-treated plants showed the lowest disease severity among the fungicides tested. Therefore, the Wijaya cultivar and topsin fungicide would be the potential candidates for mitigating the Fusarium root rot disease of cowpea in the Batticaloa district, Sri Lanka.

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References

Ajayi, O. O., Paulitz, T. C., Campbell, K., Murphy, K. M. and Ullrich, S. E. (2013). Identification of resistance to Rhizoctonia root rot in mutant and wild barley (*Hordeum vulgare* subsp. *spontaneum*). *Phytopathology,* 103, S2- S3.

Carmona, M., Sautua, F., Perez-Hernandez, O. and Reis, E. M. (2020). Role of fungicide applications on the integrated management of wheat stripe rust. *Frontiers in Plant Science*, 11, 733.

Carolan, K., Helps, J., van den Berg, F., Bain, R., Paveley, N. and van den Bosch, F. (2017). Extending the durability of cultivar resistance by limiting epidemic growth rates. *Proceedings of the Royal Society B: Biological Sciences*, 284(1863), 20170828.

Elsayed, F. A. A., Abeer, H., Ali, H. B. and AL-Huqail, A. (2011). First report of black root rot disease (*Thielaviopsis basicola*) of carrot in Saudi Arabia. *African Journal of Microbiology Research,* 5(18), 2867-2869.

Hewavitharane, H. V. C., Warnakulasooriya, H. U. and Wajira Kumara, G. B. S. (2010). Constraints to expansion of cowpea and mungbean under rain-fed farming in Anuradhapura District (No. 138-2016-1916).

Stankovic, I., Milojevic, K., Vucurovic, A., Nikolic, D., Krstić, B. and Bulajic, A. (2015). First report of Fusarium root rot of stored carrot caused by Fusarium avenaceum in Serbia. *Plant disease*, *99*(2), 286-286.

Vatchev, T. and Maneva, S. (2012). Chemical control of root rot complex and stem rot of greenhouse cucumber in straw-bale culture. *Crop Protection*, 42, 16-23.

Wegulo, S. N., Bockus, W. W., Nopsa, J. F. H., Peiris, K. H. and Dowell, F. E. (2013). Integration of fungicide application and cultivar resistance to manage Fusarium head blight in wheat. *Fungicides-Showcases of Integrated Plant Disease Management from Around the World*, pp.35-54.

FOOD, NUTRITION, PRESERVATION, VALUE ADDITION AND POSTHARVEST TECHNOLOGY

DEVELOPMENT OF PICKLE FROM YELLOW FIN TUNA (*Thunnus albacares*) MUSCLE AND CHANGES OF NUTRITIONAL CONTENT DURING STORAGE

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Abstract

Fishery products' nutritional quality changes as a result of processing and preservation. Fish protection is a critical aspect of fisheries. Pickle has a long shelf life and a minimal risk of food poisoning. The aim of this investigation was to see the effect of fish preservation by vinegar on sensory and nutritional qualities of yellow fin tuna pickle at room temperature (32^0 C). In this study, fish pickle was made from Yellow fin tuna (Thunnus albacares) fish chunks by varying the amount of vinegar and other condiments. According to standard procedures, the pickle samples were evaluated for variations in proximate including moisture and ash content, chemical such as titrable acidity and pH, and sensory attributes such as color, appearance, texture, aroma, sourness, saltiness, and overall acceptability throughout fifteen days of storing period at room temperature (32°C).The results revealed that proximate, chemical, and sensory parameters changed significantly ($p < 0.05$) during storage. With storage, moisture content and pH decreased, while titratable acidity and ash content increased. Microbiological amount and sensory value attributes didn't differ significantly after 15 days of storage and remained acceptable during the storage period. This research is critical to meet consumer demand for nutritional composition and shelf life of fish pickle at ambient temperature.

Keywords: Fish pickle, nutritional quality, room temperature, vinegar

Introduction

Fish intake is considered to be important to human wellbeing, particularly like these species high in omega-3 fatty acids, due to healthy effects on the elderly public's heart, lower risk of cardiovascular disease and lower blood triglyceride levels (Siriwardhana *et al*., 2012). Yellow fin tuna (YFT) (*Thunnus albacares*) is a large pelagic marine fish in the Scombridae family. The YFT is the one of the world's most important profitably traded species. YFT is popular in both domestic and export markets in Sri Lanka, and it is the most sought-after commercial tuna species. Sri Lanka is also one of the largest tuna exporters and one of the earliest known tuna production nations in the Indian Ocean (Jinadasa *et al*., 2015).However, due to the distinctive fishy flavor and taste, many people, particularly young people, are unwilling to consume fish. Furthermore, because fish is perishable in nature, it is critical after harvesting, keep it in order to share it with the entire consumer base. To reap the nutritional and health gains of harvested fish, appropriate collecting, preparation, ability to handle, and preservation are required(Mazrouh, 2015).

Developing countries are finding it increasingly difficult to protect fish and other marine harvests during large capture periods in order to satisfy consumer requirement when the grab is insufficient. As a result, it is critical to develop low-cost new processing techniques that make use of inexpensive and readily available fish to deliver them all year. Pickling fish is considered as the lowest, simple, and secure method of quick storage inside this context. Fish pickling are made from inexpensive fish and enhanced with ingredients such as acetate, chili, ginger, and so on (Renitta & Patterson, 2013). Pickles not just to add flavor and also assist digestive process

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by boosting the exudation of gastric juices (Isra *et al*., 2021). Pickle storage ability is primarily determined by adding acetate, decreasing moisture content, and adding salt, spices and additional condiments. In order to avoid spoilage of abundant fishes the inexpensive protecting procedure should be followed. Taking these facts into account, the current study aimed to create pickle utilizing Yellow fin tuna and decide the shelf-life of pickle after incorporating various levels of acetic acid and kept in ambient temperatures.

Materials and Method

Healthy Yellow fin tuna (YFT) fishes with an average body weight of 2.5 kg were collected from the piliyandala local fish market in Sri Lanka and transferred to the chemistry lab in an insulated box with ice. The experiment was performed at Department of Post-Harvest Technology in NARA (National Aquatic Resource and Development Agency).The fish pickle was made in the manner described by (Shikha *et al*., 2019) with a few alterations. The fishes were immediately gutted and processed. After that, cut into small pieces and washed. The large pieces were cooked and deboned. The fleshes were marinated without the bones for 30 minutes at room temperature with the adequate level of turmeric, red chili powder, and salt. The marinated tuna tissue was fried for 15 minutes in mustard oil before being stored at room temperature. After frying the garlic and onion in oil until golden brown in color, the necessary amount of cloves, cumin, salt, sugar and vinegar were mixed. The pre-fried fish tissue was combined and heated until the vinegar had been absorbed. Then, using a hand spoon, spice-mixed roasted fish flesh was mixed with tamarind extract. After that, the pickles were left to cool completely before being kept in a sterilized glass bottle.

Table 1. Experimental designs

Ingredients	Formulations			
	T1	T2	T3	T4
Vinegar	10 ml	30 ml	50 ml	70 ml
Black pepper	3g	3g	3g	3g
Mustard oil	25 ml	25 ml	25 ml	25 ml
Whole cloves	1g	1g	1g	1g
Onion	5 g	5 g	5 g	5 g
Cumin	3g	3g	3g	3g
Tamarind flesh	4 g	4 g	4 g	4 g
Sugar	5 g	5 g	5 g	5 g
Garlic	3 g	3 g	3 g	3 g

Proximate and Chemical evaluation

Proximate properties, such as moisture estimation, was measured using the oven drying method, and ash was measured using the AOAC methods(Horwitz & Latimer, 2006). A digital pH meter was used to measure the pH. (Model HANNA HI 98130). Titratable acidity was found by measuring with standard NaOH and expressed in terms of citric acid. All fish pickle determinations were done in triplicate, and the average values were reported.

Organoleptic Evaluation

Sensory evaluation of YFT pickle samples was performed by a panel of 10 untrained participants. A 7-point hedonic scale was used to assess the color, aroma, texture, appearance, sourness, saltiness, and overall acceptability.

Statistical evaluation

Experiments were conducted in triplicate for each formulation, using a Complete Randomized

Design. One-way analysis of variance (ANOVA) ($\alpha = 0.05$) was utilized to analyze data from proximate and chemical parameters, and mean separation was performed using Ducan's Multiple Range Test (DMRT). The Turkey Test was used to analyze sensory evaluation data at a 95 percent significant level. All analyses were done by means of the Statistical Analysis System (SAS) software.

Results and Discussion

Fresh Fish Biochemical Composition

The fish gathered from Sri Lanka's piliyandala local fish market were fresh and most of them were alive. Table 2 shows the initial chemical properties of fresh fish samples. (Jinadasa et al., 2015) reported that the proximate composition of YFT was in the range of pH 5.74± 0.15 and histamine 11± 3 mg/kg. This finding lends support to the current study's findings.

Table 2: Proximate-chemical properties of fresh yellow fin tuna fish

Proximate-chemical parameters	Value
Moisture (%)	67.8±0.21
Ash (%)	2.3±0.36
PH	5.3±0.56
Titratable Acidity (%)	5.4±0.48
Histamine content (mg/kg)	10.6±0.85

The Values are means of triplicates ± standard error

Variations in the Moisture Content of Pickled Fish

Table 3 shows the variations in moisture level (percentage) of fish pickle primed with YFT muscle over a 15-day storage period at room temperature (32°C). Fresh fish's moisture content was found to be lower quickly after frying and preparing food(Ayinsa and Maalekuu, 2013). Fresh fish had an initial moisture content of 62.8%. The maximum moisture of tuna pickle was 65.53% on 0 day, which gradually decreased to 63.02% within a week of 7 days of storing, and 59.43 % after 15 days of storage.10ml of vinegar affected the moisture content lesser than other vinegar concentration. The moisture content (percentage) of tuna pickle stored at room temperature decreased as the storage period lengthened. The similar finding was made in mola fish pickle (Ismail *et al*., 2019).

Table 3: Variations in moisture content of pickled fish during storage

Duration (Days)	Moisture Content %			
	T1	T2	T3	T4
0	62.27 ± 0.04^{d}	64.07 ± 0.30^{c}	64.90 ± 0.10^{b}	65.53 ± 0.05^{a}
7	60.87 ± 0.24^{a}	61.03 ± 0.21^{a}	61.93 ± 0.36^{a}	63.02 ± 0.10^{c}
15	58.23 ± 0.41^{a}	56.23 ± 0.84^{b}	57.89 ± 0.23^{b}	59.43 ± 0.19^{a}

The Values are means of triplicates ± standard error
The means with the same letters in each rows are not significantly different at 5% level

Variations in the Level of Ash in Pickled Fish

Table 4 shows the change in ash content of YFT vinegar pickle over a 15-day period of storage at ambient temperature (32 °C). The ash content differed significantly between treatments. On 0 day, the pickle with the maximum ash content was 5.23% (T4). Even as fish muscle liquefied, the ash content gradually increased. It reached 6.75% within a week of 7 days period of storage and 8.18% after 15 days period of storage. The ash content was increased as vinegar concentration and storage time increased. The current study found that fish pickle had a higher ash content quickly compared to fresh fish after processing. This is attributable to loss of

moisture in the produced fish pickle throughout cooking and frying (Kocatepe *et al*., 2011) and another possible explanation is the inclusion of additives all through pickle processing (Shikha et al., 2018). This ash content is associated to moisture loss during storing (Pawar *et al*., 2013).

Table 4. Variation in ash content of pickled fish during storage

Duration (days)	Ash Content (%)			
	T1	T2	T3	T4
0	3.17 ±0.04^{a}	3.57 ±0.50^{a}	4.23 ±0.32^{b}	5.20 ±0.02^{c}
7	4.01±0.08^{a}	5.23±0.07^{b}	6.13±0.03^{c}	6.75±0.05^{c}
15	5.21±0.14^{a}	6.54±0.10^{b}	7.48±0.12^{c}	8.18±0.23^{c}

The Values are means of triplicates ± standard error
The means with the same letters are not significantly different at 5% level

Variation in the pH of Pickled Fish

Table 5 depicts the pH level of YFT pickle over a 15-days period of storage at ambient temperature (32°C). On 0 day, the maximum pH value of 3.55 was acquired in T1 tuna pickle processed with vinegar; as time passed, it reduced. It reached 3.47 within a week of 7 days period of storage and 3.13 upon 15 days period of storage. The pH decrease in the current study could be attributed to the mixing of tamarind and vinegar throughout treating, as well as its progressive absorption by fish pickle (Rahman *et al*., 2019). Similarly (Ismail *et al*., 2019) found that pH decreased during pickle preservation.

Table 5. Variation in pH of pickled fish during Storage

Duration (Days)	pH			
	T1	T2	T3	T4
0	3.55 ±0.10^{a}	3.51±0.02^{b}	3.48±0.01^{b}	3.33 ±0.04^{a}
7	3.47±0.24^{a}	3.45±0.08^{a}	3.32±0.04^{b}	3.12±0.10^{c}
15	3.13±0.41^{a}	3.18±0.15^{b}	3.13±0.03^{a}	3.05±0.19^{c}

The Values are means of triplicates ± standard error
The means with the same letters are not significantly different at 5% level

Variation in the titratable acidity of pickled fish

Table 6 shows the variations in the titratable acidity value of YFT tuna pickle over a 15-days period of storage at ambient temperature (32°C). On the first day, the maximum titratable acidity value (6.12%) was acquired in T4 tuna pickle prepared with vinegar; as time went on, it enlarged. 7 days after, it had extended 6.5%, and after 15 days, it had reached 7.05%. The titratable acidity increased as the storage period lengthened. The enhanced titratable acidity can be attributed to increased moisture loss and the impact of condiments combination. A comparable observation was made in low acid mural pickle (Sahu et al., 2012).

Table 6. Variation in titratable acidity of pickled fish during storage

Duration (Days)	Titratable acidity (%)			
	T1	T2	T3	T4
0	4.2 ±0.02^{a}	4.9 ±0.10^{b}	5.4 ±0.07^{c}	6.12 ±0.30^{d}
7	4.47±0.24^{a}	5.1±0.02^{b}	5.9±0.08^{b}	6.50±0.10^{c}
15	5.13±0.41^{a}	5.5±0.12^{a}	6.4±0.05^{b}	7.05±0.19^{c}

The Values are means of triplicates ± standard error
The means with the same letters are not significantly different at 5% level

Sensory analysis

Variations in organoleptic quality features of pickled fish held at ambient temperature (32°C)

Table 07: Variations in sensory parameters of pickled fish during storage period

Treatments	T1			T2			T3			T4		
	0 day	7 days	15 days	0 Days	7 days	15 days	0 day	7 days	15 days	0 days	7 days	15 days
Colour	3.4 ±0.51^{a}	3.0±0.11^{a}	2.4±0.23^{a}	5.6±0.51^{b}	5.5±0.03^{b}	5.4±0.03^{b}	6.2 ±0.78^{c}	6.1 ±0.58^{c}	6.1±0.23^{c}	4.0 ±0.94^{b}	3.8 ±0.94^{a}	3.0 ±0.94^{a}
Appearance	4.8 ±0.78^{a}	4.5±0.70^{a}	2.5±0.70^{d}	5.5±0.52^{b}	5.4 ±0.03^{b}	5.3±0.12^{b}	6.5 ±0.70^{c}	6.4 ±0.25^{c}	6.3±0.15^{c}	4.0 ±0.81^{a}	3.0±0.31^{d}	2.0±0.12^{d}
Texture	3.1 ±0.99^{d}	2.5±0.10^{d}	2.0±0.47^{d}	5.5±0.52^{b}	5.4 ±0.12^{b}	5.3±0.45^{b}	6.4 ±0.69^{a}	6.3 ±0.14^{a}	6.0±0.25^{a}	3.9 ±0.87^{c}	3.0±0.53^{d}	2.6±0.71^{d}
Aroma	3.9 ±0.87^{c}	3.8±0.83^{c}	3.0±0.81^{c}	5.4±0.51^{b}	5.4 ±0.48^{b}	5.3±0.21^{b}	6.2 ±0.78^{a}	6.1 ±0.45^{a}	6.1±0.24^{a}	3.8 ±0.78^{c}	3.5±0.51^{c}	2.5±0.28^{c}
Sourness	2.9 ±0.82^{d}	2.7±0.94^{d}	2.0±0.48^{d}	5.5±0.52^{b}	5.5 ±0.25^{a}	5.5±0.03^{a}	6.2 ±0.78^{a}	6.2 ±0.41^{a}	6.0±0.47^{b}	4.0 ±0.81^{b}	3.7±0.43^{c}	3.5±0.11^{c}
Saltiness	2.4 ±0.51^{c}	2.4±0.20^{c}	2.2±0.54^{c}	5.7 ±0.48^{a}	5.6 ±2.36^{a}	5.5±0.21^{b}	6.5 ±0.52^{a}	6.5 ±0.36^{a}	6.4±0.34^{b}	3.7 ±0.67^{d}	3.5±0.41^{d}	3.0±0.81^{c}
Overall acceptability	2.6 ±0.51^{c}	2.5±0.32^{c}	2.0±0.20^{c}	5.7±0.48^{a}	5.6±0.45^{a}	5.4±0.42^{a}	6.8 ±0.42^{a}	6.7 ±0.48^{a}	6.6±0.38^{a}	3.7 ±0.94^{b}	3.5±0.51^{b}	3.3±0.54^{b}

The Values are means of nine replicates ± standard error
Means in a column preceded by various superscript letters differ significantly at the 5% level.

are shown in Table 7. Sensory properties of the products, including appearance, color, texture, aroma, saltiness, and overall acceptability, differed significantly between YFT pickle treatments. The sensory characteristics changed as the storage period progressed. The organoleptic properties differed and displayed a low grade for the processed product as the storage duration was extended in the current experiment, which corresponds with prawn pickle(Kumar and Basu, 2001). They found that the overall acceptability value for shrimp pickle had been falling due to an increase in peroxide as the storage time progressed. (Ninan *et al*., 2008) Found that sensory parameters of minced products from Tilapia were decreased significantly. The quality of all goods stored at room temperature was deemed adequate for consumption afterward 15 days.

Conclusion

The nutritional composition of YFT fish pickle did not deteriorate during storage at room temperature. It can be concluded that choosing a procedure that links fish cooking and the addition of salt, tamarind, spices and vinegar to low moisture pre-cooked fish chunks allows for the preparation of YFT fish pickle with considerable sensory value, and a better shelf life of 15 days at room temperature (32 ^{0}C). YFT fish pickle has the possibility to become an indigenous fish product that is ready to eat and extremely acceptable. Based on overall acceptability, T3 was the best.

References

Ayinsa, K. and Maalekuu, B. K. (2013). Effect of traditional fish processing methods on the proximate composition of red fish stored under ambient room conditions. *American Journal of Food and Nutrition*, *3*(3), 73–82. https://doi.org/10.5251/ajfn.2013.3.2.73.82

Horwitz, W. and Latimer, G. (2006). Official Methods of Analysis of AOAC International. In W. Horwitz and G. W. Latimer (Eds.), *AOAC International* (18 th edit). AOAC International.

Ismail, H., Hoque, S., and Sanjida, S. (2019). Changes in biochemical and microbiological parameters of Mola (Amblypharyngodon mola) fish pickle during storage at room temperature. *Fundamental and Applied Agriculture*, *4*(0), 1. https://doi.org/10.5455/faa.35406

Isra, L., Suraiya, S., Salma, U. and Haq, M. (2021). Nutritional Evaluation and Shelf-Life Study of Mackerel Tuna (Euthynnus affinis) Fish Pickle. *Agricultural Research*, 1–9. https://doi.org/10.1007/s40003-021-00559-7

Jinadasa, B. K. K. K., Galhena, C. K. and Liyanage, N. P. P. (2015). Histamine formation and the freshness of yellowfin tuna (Thunnus albacares) stored at different temperatures. *Cogent Food and Agriculture*, *1*(1), 1–11. https://doi.org/10.1080/23311932.2015.1028735

Kocatepe, D., Turan, H., Taşkaya, G. and Kaya, Y. (2011). Effects of Cooking Methods on the Proximate Composition of Black Sea Anchovy. *GIDA*, *36*(2), 71–75.

Kumar, S., & Basu, S. (2001). Preparation of prawn pickle and its storage. *Journal of the Indian Fisheries Association*, *28*, 105–111.

Mazrouh, M. (2015). Effects of freezing storage on the biochemical composition in muscles of Saurida undosquamis (Richardson, 1848) comparing with imported frozen. *Fisheriesjournal.Com*, *3*(2), 295–299. https://www.fisheriesjournal.com/archives/2015/vol3issue2/PartD/3-2-35-960.pdf

Ninan, G., Bindu, J. and Joseph, J. (2008). Frozen storage studies of mince based products developed from tilapia(Oreochromis mossambicus, Peters 1852). *Fishery Technology*, *45*(1), 35–42.

Pawar, P. P., Pagarkar, A. U., Rathod, N. B., Patil, S. S. and Mahakal, B. V. (2013). Effect of frozen storage on biochemical and sensory quality changes of fish cutlets, made from fresh water fish catla (Catla catla). *International Jornal of Bioassays*, *2*(5), 789–793.

Rahman, M., Hossain, M. and Shikha, F. (2019). Changes in the Nutritional Composition of

Fish Pickle Prepared from Thai Pangus (Pangasianodon hypophthalmus) during Longer Storage at Low Temperature. *Journal of Food Science and Nutrition Research*, *02*(03), 299–308. https://doi.org/10.26502/jfsnr.2642-11000028

Renitta, R. E. and Patterson, J. (2013). Quality and shelf-life assessment of underutilized marine gastropod pickle. *Journal of Food Processing and Preservation*, *37*(5), 589–595. https://doi.org/10.1111/j.1745-4549.2012.00679.x

Sahu, B. B., Kumar, K., Sahu, A. K., Kumar, R., Mohanty, U. L., Maji, U. J., Noor Jahan, S. M., Samal, R. and Jayasankar, P. (2012). Quality and storage stability of low acid murrel (Channa striatus) fish pickle at room temperature. *International Food Research Journal*, *19*(4), 1629–1632.

Shikha, F. ., Hossain, M. I., Akter, K. and Rahman, A. (2018). Changes in the nutritional composition of Thai pangus (Pangasianodon hypophthalamus) pickle during storage at refrigeration temperature. *Journal of the Bangladesh Agricultural University*, *16*(3), 553–559. https://doi.org/10.3329/jbau.v16i3.39455

Shikha, F. H., Hossain, M. I. and Shohan, S. (2019). Effect of low temperature on quality of Mola (Amblypharyngodon mola) fish pickle during storage and consumer preference towards. *Bangladesh Journal of Fisheries*, *31*(August), 125–135.

Siriwardhana, N., Kalupahana, N. S. and Moustaid-Moussa, N. (2012). Health Benefits of n-3 Polyunsaturated Fatty Acids. Eicosapentaenoic Acid and Docosahexaenoic Acid. In *Advances in Food and Nutrition Research* (1st ed., Vol. 65). Elsevier Inc. https://doi.org/10.1016/B978-0-12-416003-3.00013-5.

EFFECT OF LEAF MATURITY STAGE ON THE ANTIOXIDANT ACTIVITY OF *Moringa oleifera* GROWN IN DRY ZONE OF SRI LANKA

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Abstract

Antioxidants play an essential role in inhibiting and scavenging free radicals, thus providing protection to humans against infections and degenerative diseases. *Moringa oleifera* is a common plant known for its various medicinal properties, and further, it is commonly cultivated all along the part of the country at the home garden level. In the present study, the antioxidant capabilities of the *Moringa oleifera* leaf extracts collected from the dry zone area (DL_{2a}) were investigated in three stages of maturity using conventional in vitro models to comprehend the mechanism of pharmacological actions and to be used in future industrial purposes. The antioxidant activities of different concentrations of methanol extracts of the leaves were determined by DPPH radical scavenging assay method. The scavenging assay was expressed as inhibition percentage and IC_{50} µg/ml values. Results showed significantly lowest IC_{50} µg/ml values from over-matured (17.38 µg/ml) and mature leaves (17.34 µg/ml) compared to tender leaves (22.05 µg/ml). The free radical scavenging effect of *Moringa oleifera* leaf extract was comparable to that of the Gallic acid reference antioxidants. The data obtained in the present study suggests that the extracts of *Moringa oleifera* in all over-mature, mature, and tender leaves have potent antioxidant activity against free radicals, prevent oxidative damage to major biomolecules and afford significant protection against oxidative damage. Further study suggested that mature and over-mature leaves have significant antioxidant activity over tender leaves that could be useful in future industrial activities.

Keywords: Antioxidant activity, leaf maturity stage, *Moringa oleifer*

Introduction

According to epidemiological research, meals high in antioxidants offer protection against degenerative illnesses such as cancer, coronary heart disorders, and Alzheimer's disease (Ames *et al*., 1993). For this reason, it is essential to significantly boost the consumption of antioxidants derived from food sources (Soong and Barlow, 2004). In the past, synthetic antioxidants such as BHA and BHT were used as food additives; however, recent investigations have raised safety concerns regarding their application, and natural antioxidants have become the subject of considerable study (Iqbal *et al*., 2006). The present emphasis of the study is on the commercial development of plants as sources of antioxidants to benefit health and food preservation. Tocopherols, flavonoids, vitamin C, and other phenolic compounds are some of the most well-known natural antioxidants found in plants, which are major sources of antioxidants. Sources of antioxidants have been found in various herbs, fruits, vegetables, spices, and legumes (Iqbal *et al*., 2006).

One of the 14 species that make up the genus *Moringa*, which is native to India, Africa, Arabia, Southeast Asia, the Pacific and Caribbean islands, and South America, *Moringa oleifera*, Lam. (Moringaceae) is cultivated all over the world in the tropics and sub-tropics of Asia and Africa. It is part of the family Moringaceae. It is also frequently referred to as the horse-radish tree, which comes from the flavour of its roots, or the drumstick tree (describing the shape of its pods). The plant can survive in a variety of soil types and can adapt to a large number of different precipitation levels. Both the blooms and the fruits occur twice yearly, and although seeds and cuttings can be used to grow the tree, cuttings are the more successful method (Asma

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et al., 2005).

Moringa oleifera is known as the "wonder vegetable" because to the fact that it is not only a food but also medicine, and as a result, it has the potential to be a functional food (Fuglie 1999). The flowers, roots, fruits, and seeds have been shown to contain phytochemicals such as vanillin, omega fatty acids, carotenoids, ascorbates, tocopherols, beta-sitosterol, kaempferol, and quercetin. The leaves contain considerable amounts of beta-carotene, vitamin C, protein, iron, and potassium, making them a very healthy food source (Kumar *et al*., 2012). The hypolipidemic, antiatherosclerotic, immune-boosting, and tumour-suppressive actions of the plant's leaves have been the subject of substantial research. The plant's leaves are the part of the plant that is used for medicinal purposes. According to Fuglie (1999), the numerous applications for Moringa include alley cropping (biomass production), animal forage (leaves and treated seed cake), biogas (from leaves), a domestic cleaning agent (crushed leaves), blue dye (wood), fencing (living trees), fertilizer (seed-cake), foliar nutrient (juice expressed from the leaves), green manure (from leaves), gum (from tree trunks), honey (flower nectar), medicine (all plant parts), and gum (from (powdered seeds). In particular, this plant family has a high concentration of molecules, including the simple sugar rhamnose. Additionally, it has a high concentration of a very unusual group of chemicals known as glucosinolates and isothiocyanates. For instance, specific components of Moringa preparations have been reported to have hypotensive, anticancer, and antibacterial activity. These components include niazimicin, pterygospermin, benzyl isothiocyanate, and 4-(-L-rhamnopyranosyloxy) benzyl glucosinolate13. Other components include benzyl isothiocyanate and benzyl isothio (Fuglie 1999).

The present study examined the antioxidant activity of *Moringa oleifera* leaves at three different phases of maturation. Due to the numerous applications of *Moringa oleifera* and its medical and pharmacological features, the present study may be useful to expanding industries. Since the crop has multiple uses in addition to its pharmacological characteristics, identifying the correct maturation stage for the antioxidant property will improve its utilization.

Materials and Methods

Plant Material

The *Moringa oleifera* leaves were collected from the dry zone area of Sri Lanka (Sevenagala - Agro-ecological zone – DL2a). Three biological replicates were selected for the study.

Preparation of the Extract

The leaves were dried under shade and chopped into small pieces. The dried leaves were powdered and passed through sieve no. 20 and extracted (100 g) was subjected to extraction with 200 mL of methanol for 24 hours in a shaking water bath at 50 °C. The collected methanol extract was filtered using Whatman's No. 1 filter paper, and methanol was evaporated using a rotary evaporator at 50 °C under a vacuum. These leaf-crude extracts were kept in a refrigerator (4 °C) until use.

Determination of Antioxidant Activity

Antioxidant activity of the leaves extracts was determined using 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity method (Marxen et al., 2007) with minor modifications. Exactly 0.5 ml of crude extract was mixed with 2.5 mL of 100% (v/v) methanolic 0.1 mM DPPH and kept at room temperature for 10 minutes in the dark. The absorbance was recorded at 517 nm using a UV visible spectrophotometer against the control (Methanol 0.5 mL + DPPH 2.5 mL). Three different concentrations of extracts were used as 20.0, 50.0 and 100.0 µg/ml. The antioxidant activity was calculated as inhibition percentage and IC_{50} µg/ml. Moreover, the values were compared with µg Gallic Acid Equivalents (GAE) per gram of dry weight leaves

using a gallic acid standards curve.
Inhibition (%) = [($A_{DPPH} - A_{sample}$) / A_{DPPH}] * 100
A_{sample} is the absorbance of the solution containing the extract after 10 minutes, and A_{DPPH} is the absorbance of the DPPH solution devoid of extract.

Statistical Analysis
The AOX analysis was carried out in triplicate, considering technical replicates and three biological replicates. The analysis was fitted into the ANOVA, and means were compared using the Dunnett method at 95% confidence intervals. The statistical analyses were performed using the statistical package Minitab 18 version.

Results and Discussion

DPPH radical scavenging capacity of different stages of Moringa leaves
DPPH scavenging activity has become routine in establishing the antioxidant activity of herbal extracts and phytochemicals. The antioxidants react with the stable free radical DPPH (deep violet colour) and convert it to 1,1-diphenyl-2-picryl hydrazine with discolouration. The scavenging effects of extract increased with their concentrations to similar extents. The percentage inhibitions of concentrations 20, 50 and 100 µg/ml are gradually increased, as shown in Table 1. The standard gallic acid presented a scavenging effect of 94.0% at 100 µg/ml concentration. So increased scavenging of DPPH radicals was a dose-dependent manner due to the scavenging ability of the *Moringa oleifera* methanolic extract and comparable to gallic acid (Table 1). The highest inhibition percentage was shown by gallic acid, followed by mature and over-mature leaves, and the lowest was observed from tender leaves. There was a significant difference between tender and mature leaves, while no significant difference between mature and over mature leaves. The results obtained in the current study were compatible with the previous study conducted on moringa leaf extracts (Kumar *et al*., 2012).

Table 1: Antioxidant profiles of *Moringa oleifera* extracted from different leaf maturity stages

Maturity stage	Inhibition percentage value			IC 50 (µg/ml) extract/standard Average ± SD (µg/ml)
	20 µg/ml	50 µg/ml	100 µg/ml	
Standard (GAE)	57.0 ± 2.6 [a]	70.7 ± 3.2	94.0 ± 2.9	13.77 ± 0.57 [a]
Over mature leaf	51.8 ± 2.5 [b]	68.0 ± 4,0	87.7 ± 4.4	17.38 ± 0.20 [b]
Mature leaf	52.7 ± 3.0 [b]	66.3 ± 3.5	84.3 ± 4.5	17.34 ± 0.30 [b]
Tender leaf	37.3 ± 3.1 [c]	57.0 ± 3.6	76.0 ± 3.8	22.05 ± 0.89 [c]

Note: difference letters indicate significantly different groups ($p < 0.05$)

IC 50 (µg/ml) values of different stages of Moringa leaves
DPPH scavenging activity has become routine in establishing the antioxidant activity of herbal extracts and phytochemicals. The amount of sample needed to decrease the initial DPPH concentration by 50% is a parameter widely used to measure antioxidant activity. The scavenging effects of over-mature, mature and tender leaf extracts on the DPPH radical are illustrated in figure 4.1. *Moringa oleifera* leaf extract significantly reduced DPPH radicals. In comparison, the standard gallic acid had an IC_{50} of 13.77±0.57 µg/ml. The DPPH scavenging ability of the extract may be attributed to its hydrogen donating ability, and mature leaf extract showed significant scavenging activity (Table 1).

Plant extracts and antioxidants derived from plants are capable of causing a variety of in vivo effects, including the stimulation of an increase in the production of the body's endogenous antioxidant defences or the stimulation of the body's direct production of antioxidants (Sen, and Chakraborty, 2011)). It has also been found that the composition of antioxidants can change

drastically depending on many factors, such as the stage of maturation, variety, climatic conditions, part of the plant that was analyzed, post-harvest processing, and storage (Rodriguez-Amaya, 2003). The current research findings indicate that the levels of antioxidants in *Moringa oleifera* leaves change in accordance with their stages of maturation. The effects of senescence and ageing on the expression of antioxidant gene products have been studied in many plants, which report the variation in levels of antioxidants as a result of these studies (Wang et al., 2001).

Conclusion

There is considerable, and compatible antioxidant activity in Moring leaves compared to gallic acid. The antioxidant activity of Moringa leaves changes with the maturity stage, and the highest value is shown at the mature and over-mature stages. Furthermore, there was no significant difference between mature and over-mature leaves regarding antioxidant activity.

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References

Ames, B. N., Shigenaga, M. K. and Hagen, T. M. (1993). Oxidants, antioxidants, and the degenerative diseases of aging. *Proceedings of the National Academy of Sciences*, *90*(17), 7915-7922.

Asma, B. M. and Ozturk, K. (2005). Analysis of morphological, pomological and yield characteristics of some apricot germplasm in Turkey. *Genetic Resources and Crop Evolution*, *52*(3), 305-313.

Fuglie, L. J. (1999). The miracle tree: *Moringa oleifera*, natural nutrition for the tropics.

Iqbal, M., Ashraf, M. and Jamil, A. (2006). Seed enhancement with cytokinins: changes in growth and grain yield in salt stressed wheat plants. *Plant growth regulation*, *50*(1), 29-39.

Kimura, M., & Rodriguez-Amaya, D. B. (2003). Carotenoid composition of hydroponic leafy vegetables. *Journal of Agricultural and Food Chemistry*, *51*(9), 2603-2607.

Kumar, V. V., Kumar, M. P., Thiruvenkadaravi, K. V., Baskaralingam, P., Kumar, P. S. and Sivanesan, S. (2012). Preparation and characterization of porous cross linked laccase aggregates for the decolorization of triphenyl methane and reactive dyes. *Bioresource technology*, *119*, 28-34.

Marxen, K., Vanselow, K. H., Lippemeier, S., Hintze, R., Ruser, A. and Hansen, U. P. (2007). Determination of DPPH radical oxidation caused by methanolic extracts of some microalgal species by linear regression analysis of spectrophotometric measurements. *Sensors*, *7*(10), 2080-2095.

Sen, S., & Chakraborty, R. (2011). The role of antioxidants in human health. In *Oxidative stress: diagnostics, prevention, and therapy* (pp. 1-37). American Chemical Society.

Soong, Y. Y., & Barlow, P. J. (2004). Antioxidant activity and phenolic content of selected fruit seeds. *Food chemistry*, *88*(3), 411-417.

Wang, J. (2001). Glucose biosensors: 40 years of advances and challenges. *Electroanalysis: An International Journal Devoted to Fundamental and Practical Aspects of Electroanalysis*, *13*(12), 983-988.

IDENTIFICATION OF ACETIC ACID BACTERIA FROM NATURALLY FERMENTED BANANA VINEGAR

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Abstract

Vinegar is a commonly used food condiment in Sri Lanka, and is commonly developed either from coconut sap or coconut water through the fermentation of acetic acid bacteria (AAB). Acetic acid bacteria are gram-negative α-Proteobacteria that require oxygen as the terminal electron acceptor, and are found commonly in products such as vinegar, fruits, flowers, rotten fruits or flowers. They are famous for their capability to oxidize sugars and alcohols, to useful organic acids as their final product. The current study was done to isolate, identify and characterize AAB that was responsible for the natural fermentation of banana vinegar developed at room temperature, 27 °C, at the laboratory level. Four strains of AAB that formed yellow-colored colonies were isolated by spreading the developed banana vinegar in Yeast extract, polypeptone and glucose media (YPG) and Yeast extract polypeptone and mannitol media (YPM), and the isolated strains were identified using morphological, physiological and biochemical methods. All strains were gram-negative rod shape and catalase-positive bacteria. Moreover, the isolated strains were confirmed as acetic acid bacteria from the capability of producing acetic acid from ethanol. As it did not give any brown color pigmentation on YPG media and the ability to oxidize only acetate, the isolated strain was confirmed as *Acetobacter* or *Gluconoacetobacter* and there were no *Gluconobacter* strains. Further, the isolated strains did not show the production of dihydroxyacetone from glycerol. All four strains showed over-oxidation of ethanol which is a characteristic of *Acetobacter* and Gluconoacetobacter. None of the strains showed acid production from glycerol, and it confirmed that the isolated strains belong only to the genus *Acetobacter*. Since all four strains showed growth only in the presence of D-glucose as the carbon source, all the isolated strains were identified as *Acetobacter pasteurianus*. All four isolates showed good growth at 30 °C and 37 °C in potato agar medium, while showing poor growth at 40 °C. The obtained results confirmed that the AAB strains isolated from banana vinegar were *Acetobacter pasteurianus* and they can grow at a temperature of 37 °C, and further characterization of the identified strains is needed.

Keywords: Acetic acid bacteria, *Acetobacter pasteurianus,* banana vinegar, natural fermentation

Introduction

Acetic acid bacteria (AAB) are gram-negative and obligate aerobic bacteria. They have the capability of oxidizing alcohols and sugar to organic acids such as acetic acid. This unique characteristic has made them use in vinegar production (Buddhika *et al*., 2021). The AAB, is presently classified into ten genera and is accommodated to the family *Acetobacteraceae*, the *Alphaproteobacteria: Acetobacteer, Gluconobacter, Acidomonas, Gluconacetobacter, Asaia, Kozakia, Swaminathania, Saccharibacter, Neoasaia* and *Granulibacter* (Yamada and Yukphan, 2008). Vinegar is a result of fermentation of alcoholic liquids or sugar-containing liquids by AAB. Vinegar fermentation is a two-step process, alcoholic fermentation of sugar- containing liquids by *Saccharomyces cerevisiae* and acetic acid fermentation by AAB. During the natural fermentation of vinegar, the starter culture of the mother vinegar will not be added to the fermentation media, fermentation will take place as a result of a mixture of AAB strains or a

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single strain that lives in the atmosphere. The current study was conducted to isolate and identify the AAB that are responsible for the natural fermentation of banana vinegar.

Materials and Method

YPG and Yeast extract polypeptone sugar media (YPS) were used to culture *Acetobacter* and *Gluconobacter* strains respectively (Buddhika *et al*., 2021). To isolate AAB bacteria, 25 µL of previously prepared banana vinegar was streaked separately on YPG and YPS medium and incubated at 30°C. The AAB cultures were streaked onto YPG and YPS agar plates until a pure culture with yellow colonies was obtained.

Identification and characterization of isolated Acetic Acid bacteria strains

The identification of the isolated strains was made using their morphological, biochemical and physiological characteristics as mentioned by Asai *et al*., (1964); Yamada *et al*., (1976); Katsura *et al*. (2002) and Brenner *et al*. (2005). Gram staining of the isolates was done as described by Hucker and Conn (1923). To observe the catalase production, the isolated strains were observed under microscope, with few drops of 3% hydrogen peroxide (Brenner *et al*., 2005).To observe the acetic acid production from isolated colonies, they were inoculated on agar plates containing 3 mL ethanol, 3 g yeast extract, 2 g $CaCO_3$ and 2 g agar per 100 mL (Perumpuli *et al*., 2014). The medium comprising 0.5 g of yeast extract, 1 g of each sugar source in 100 mL distilled water supplemented with 0.003% bromocresol purple (pH 6.8) was used to examine the acid production from various sugar sources and the inoculated agar plates were incubated at 30 °C to observe acid formation from different sugar sources. Production of dihydroxyacetone (DHA) from glycerol was observed as described by Yamada *et al*. (1999). The complete oxidation of acetate and lactate to CO_2 and H_2O, was studied according to Brenner *et al*. (2005). Yeast extract polypeptone glucose dextrose (YPGD) medium was used to observe the acetate over oxidation and incubated at 30 °C (Saeki *et al*., 1997). The carbon source utilization pattern of the isolated *Acetobacter* strains was examined using a salt agar medium as described by Sokollek *et al*. (1998). The growth characteristics of isolates were monitored by incubating at 30 °C, 37 °C and 40 °C in YPG medium.

Results and Discussion

Four different strains were isolated from two different banana kinds of vinegar, and they were identified as acetic acid bacteria based on the formation of yellow colour zones around the colonies (Diba *et al*., 2015). All the isolated strains were identified as gram-negative and catalase-positive bacteria and it was further confirmed as AAB by the capability to produce acetic acid from ethanol, which is the major characteristic of AAB (Table 1).

Table 1: Physiochemical identification of isolated strains

Strain	Formation of the yellow colour zone around colonies	Gram staining	Catalase test	Production of acetic acid from ethanol
SBV1	+	-	+	+
SBV2	+	-	+	+
ABV1	+	-	+	+
ABV2	+	-	+	+

According to the biochemical identification, all four strains were identified either as *Acetobacter* or *Gluconacetobacter* due to the positive results given for acetate and lactate oxidation. On the other hand, since the isolated strains gave negative results for DHA formation from glycerol, it was confirmed that any of the isolated strains do not belong to the genus

Gluconobacter. The ability to oxidize acetate and lactate and over oxidation of acetate cannot be observed in *Gluconobacter* strains due to the lacking of a functional Tri Carboxylic Acid cycle (TCA cycle), and the absence of a functional TCA cycle in *Gluconobacter* is due to the deficiency of alpha-ketoglutarate dehydrogenase and succinate dehydrogenase enzymes. The results of acid production from various sugar sources are summarized in the Table 2, indicating that none of the isolated strains produced acid from lactose, sucrose, D-Sorbitol, D-Mannitol, maltose, fructose, galactose, n- propanol and glycerol, therefore it was confirmed that all four isolates are capable of utilizing D-glucose and ethanol in acid production. Further this confirms that all the isolates belong to the genus *Acetobacter,* and these result confirm the findings of Buddhika *et al*. (2021) and Kadere *et al*. (2008).

Table 2: Acid production of isolated acetic acid bacteria strains.

Strain no.	D- Glucose	Lactose	Sucrose	D- Mannitol	D- Sorbitol	Maltose	Fructose	Galactose	Ethanol	n- Propanol	Glycerol
SBV1	++	-	-	-	-	-	-	-	++	-	-
SBV2	++	-	-	-	-	-	-	-	+	-	-
ABV1	+++	-	-	-	-	-	-	-	++	-	-
ABV2	+++	-	-	-	-	-	-	-	++	-	-

+++ Good acid production; ++ moderate acid production; + slight acid production; - no acid production

Species level identification of the isolated *Acetobacter* strains was done by observing the carbon source utilization pattern of the isolates (Table 3). As per the results, except for the strain SBV2, all other three strains showed good growth in salt agar media supplemented with glucose. Moreover, none of the isolated showed their growth in any type of carbon source used in the experiment. Since, they are showing good growth in salt agar medium supplemented only with glucose, the isolates were identified as *Acetobacter pasteurianus*.

Table 3: Carbon source utilization pattern of isolate strains

strain	Glucose	Lactose	Sucrose	D-Mannitol	D-Sorbitol	Fructose	Galactose	Ethanol	n-Propanol	Glycerin	Maltose
SBV1	+++	-	-	-	-	-	-	-	-	-	-
SBV2	-	-	-	-	-	-	-	-	-	-	-
ABV1	++	-	-	-	-	-	-	-	-	-	-
ABV2	+++	-	-	-	-	-	-	-	-	-	-

+++ Good growth; - no growth; ++ moderate growth

The growth characteristics of isolated strains were observed under 30 °C, 37 °C and 40 °C in YPG media, where all the isolated strains gave good growth at both 30 °C and 37 °C. The isolated AAB didn't show any growth at 40 °C. According to Brenner *et al*., (2005), the optimum temperature for the growth of AAB was found to be in the range of 25 to 35 °C. But, during the examination of growth characteristics, almost all the *Acetobacter pasteurianus* strains were found to be able to grow up to 37 °C. Thus, *Acetobacter pasteurianus* is considered as a thermotolerant bacteria species.

Conclusion

Four different AAB strains were separately isolated from naturally fermented *Ambul* and *Seeni* banana vinegar separately, and the morphological, and biochemical identifications, identified them as *Acetobacter pasteurianus.* Further, studies on growth at different temperatures, showed that the isolates exhibit thermotolerant properties.

References

Asai, T., Iizuka, H. and Komagata, K. (1964). The flagellation and taxonomy of genera Gluconobacterand Acetobacter with reference to the existence of intermediate strains. Journal of General and Applied Microbiology 10(2), 95 - 126.

Brenner, D.J., Krieg, N.R. and Staley, J.T. (2005). In: G.M. Garrity, Bergy's Manual of Systematic Bacteriology,New York, NY: Springer-Verlag Pp. 51 - 54.

Buddhika, M.A.A., Perumpuli, P.A.B.N., Kaumal, M.N., 2021. Identification and characterization of acetic acid bacteria species isolated from various sources in Sri Lanka. Ceylon Journal of Science 50, 521. https://doi.org/10.4038/cjs.v50i4.7951

Diba, F., Alam, F. and Talukder, A.A. (2015). Screening of acetic acid producing microorganisms from decomposed fruits for vinegar production. Advances in Microbiology 5(5), 291 - 297.

Du Toit, W.J. and Pretorius, I.S. (2002). The occurrence, control and esoteric effect of acetic acid bacteria in winemaking. Annals of Microbiology 52(2), 155 - 179.

Hucker, G.J. and Conn, H.C. (1923). Method of Gram Staining. Technical Bulletin 93. New York State Agricultural Experiment Station, Ithaca.

Kadere, T.T., Miyamotoo, T., Oniango, R.K., Kutima, P.M. and Njoroge, S.M. (2008). Isolation and identification of the genera Acetobacter and Gluconobacter in coconut toddy (mnazi). African Journal of Biotechnology 7(16), 2963 - 2971.

Katsura, K., Yamada, Y., Uchimura, T. and Komagata, K. (2002). Gluconobacter asaii Mason and Claus 1989 is a junior subjective synonym of Gluconobacter cerinusYamada and Akita 1984. International Journal of Systematic and Evolutionary Microbiology52(5): 1635 - 1640. Mamlouk, D., Gullo, M., 2013. Acetic Acid Bacteria: Physiology and Carbon Sources Oxidation. Indian Journal of Microbiology 53, 377–384.https://doi.org

Mamlouk, D. and Gullo, M. (2013). Acetic acid bacteria: physiology and carbon source oxidation. Indian Journal of Microbiology53(4): 377 - 384. Matsushita, K., Toyama, H. and Adachi, O. (2004). Respiratory chains in acetic acid bacteria: membrane bond periplasmic sugar and alcohol respirations. In: D. Zannoni (Eds.), Respiration in Archea and Bacteria, Advances in Photosynthesis and Respiration, Springer, Dordrecht Pp. 81 - 99.

Perumpuli, P.A.B.N., Watanabe, T. and Toyama, H. (2014). Identification and characterization of thermotolerant acetic acid bacteria strains isolated from coconut water vinegar in Sri Lanka. Bioscience, Biotechnology, and Biochemistry 78, 533 - 541.

Sengun, I.Y., Karabiyikli, S., 2011. Importance of acetic acid bacteria in food industry. Food Control 22, 647–656.

Yamada, Y., Yukphan, P., 2008. Genera and species in acetic acid bacteria. International Journal of Food Microbiology 125, 15–24.

DEVELOPMENT OF INSTANT *KOLA KENDA* MIXTURE UTILIZING HERBAL PLANT LEAVES,MUNG BEAN FLOUR, AND UNRIPE BANANA FLOUR

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Abstract

Child malnutrition in Sri Lanka is one of the most serious problems to be considered where Sri Lanka is among the top ten countries with the highest number of malnourished children. The introduction of indigenous foods with better nutritional quality such as *kola kenda* will support ensuring food security among the rural population. This study was aimed to develop an instant *kola kenda* mixture composed of curry leaves (*Murraya koenigii*), *gotu kola* (*Centella asiatica*), drumstick leaves (*Moringa oleifera* L.), mung bean flour, and unripe banana flour and characterizing the physicochemical, nutritional and sensory attributes of the *kola kenda* mixture. Accordingly, five different product formulations were prepared. The best formulation was selected based on the physicochemical and sensory characteristics. The sensory evaluation was carried out by ranking test based on color, taste, odor, consistency, and overall acceptability with 40 semi trained panelists. Physical properties did not show any significant difference among formulations. However, higher total phenolic content [87.98±2.75mg gallic acid equivalents (GAE) per gram of sample in dry weight (mg/g)] and significantly higher ($p<0.05$) overall preference in the sensory analysis (Friedman test) was observed for the formulation which containes, *gotu kola* 4%, curry leaves 1.5%, drumstick leaves 1.5%, coconut flour 28.5%, mung bean flour 21.4%, banana flour 21.4%, garlic powder 7%, ginger powder 5%, and salt 8.5%. The nutritional quality of the selected formulation E was analyzed using the Association of Official Analytical Chemists (AOAC) methods and it resulted, crude protein 16.0%, crude fat 0.5%, ash 4.3% moisture 9.4%, crude fiber 4.8%, and carbohydrates 65%. This study reveals that the developed instant *Kola Kenda* mixture has the potential to be used as a convenient food source toaid food security among Sri Lankan communities.

Keywords: Flour base, instant, leaf powder, *Kola Kenda*

Introduction

Sri Lanka is fortunate to have numerous herbs with established therapeutic values which are freely available in home gardens. *Kola kenda* is one of the oldest methods that utilize these valuable herbs that are made from the fresh juice of leaves, coconut milk, raw rice, and a pinch of salt(Kanthi *et al.*, 2017). Herbal porridge or *kola kenda* is a unique breakfast food popular among Sri Lankans and used as a reputed remedy for treating different diseases. In most rural areas *kola kenda* is consumed with a piece of "Jaggery", a crystallized sugary secretion of *Caryota urens* (Kitul) palm inflorescences as a breakfast or as an appetizer. However, consumption of *kola kenda* is decreasing due to difficulties in obtaining suitable leaves and inconveniences associated with traditional preparation methods. The main objective of this study was to formulate a nutritious instant *kola kenda* mixture utilizing curry leaves (*Murraya koenigii*), *gotu kola* (*Centella asiatica*), and drumstick leaves (*Moringa oleifera* L.) powder with pregelatinized mung bean flour, pregelatinized unripe banana flour and coconut flour by dehydration, simple mixing and grinding techniques and determine the physicochemical, sensory, and nutritional characteristics.

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Materials and Methodology

Materials

Curry leaves, *gotu kola*, and drumstick leaves were harvested from Mawanella, Sri Lanka, and transported to the laboratory facilities. Unripe *ambul banana* at the 2nd stage of ripening was purchased from the local market in Peradeniya, Sri Lanka. Mung beans, coconut flour, garlic powder, ginger powder, and salt were purchased from the local market in Peradeniya, Sri Lanka.

Preparation of Kola Kenda mixture

Freshly harvested leaves were cleaned and processed by the method described by Zhao *et al.*, (2019). Pregelatinized unripe banana flour was produced according to the method described by Loypimai and Moongngarm, (2015) and pregelatinized mung bean flour was produced according to the method in Sirikong, Weerawatanakorn and Chittrakorn, (2016).

Leaf powder, pregelatinized mung bean flour, pregelatinized banana flour, coconut flour, ginger powder, garlic powder, and salt were triturated by mortar and pestle. The appropriate combinations were determined by the trial and error method. Each formulation contains coconut flour 28.5%, mung bean flour 21.4%, banana flour 21.4%, garlic powder 7%, ginger powder 5% and salt 8.5% and different combinations of leaf powder as Formulation A: curry leaves 7%, formulation B: *gotu kola* 7%, formulation C:*gotu kola* 3% and curry leaves 3%, formulation D: curry leaves 5% and drumstick leaves 2%, formulation E: *gotu kola* 4%, curry leaves 1.5%, anddrumstick leaves 1.5%.

Total phenolic content

The conventional total phenolic content (TPC) method is based on the Folin–Ciocalteu European Commission Regulation method. Total phenol content was calculated using a standard curve of gallic acid.

Physical properties

Water absorption index (WAI) and water solubility index (WSI) were determined by the method Yousf *et al.* (2017). Reconstitution time (RT), swelling index (SI), and water holding capasity (WHC) were determined by the method of Musundire, Dhlakama and Serere (2021). Viscosity was measured by a viscometer (Tokimec, BL, Japan) at 60rpm and 30rpm with rotor no.2. Conversion factor table given with the machine was applied to calculate the viscosity.

Sensory evaluation

The sensory evaluations of the *kola kenda* mixtures were carried out after the reconstitution of the herbal porridge. Color, taste, odor, consistency, and overall acceptability of the samples wereevaluated using the ranking test with 40 semi-trained panelists.

Proximate analysis

Proximate analysis was carried out according to the procedure of the Association of Official Analytical Chemists (AOAC., 2000) for moisture, ash, crude fiber, crude fat, and crude protein content. The carbohydrate was calculated by the difference method (AOAC., 2000).

Statistical Analysis

All the data collected and results obtained from the various tests were computed and calculated into means with standard deviations and compared and interpreted by post hoc Tukey's HSD testusing Minitab 19 software. Data on sensory evaluation were analyzed by Friedman test using IBM SPSS Statistics version 26 software.

Result and Discussion

Total Phenolic Content

The total phenolic content is higher in formulation E at 87.98±2.75 mg GAE/g and it was recorded as the highest total phenolic content among formulations. However, there was no

significant difference (p>0.05) among formulation C,D, and E. When considering the properties of leaf powder drumstick leaves and curry leaves contain a higher amount of phenolic compounds than *gotu kola* (Nascimento, 2017).

Table 1: Total Phenolic Content in different product formulations

Formulations	mg GAE/g
A	76.74 ± 2.95^{b}
B	49.51 ± 3.07^{c}
C	84.29 ± 6.18^{ab}
D	79.37 ± 4.45^{ab}
E	87.98 ± 2.75^{a}

Values are presented as means ± standard deviation. Values with the same superscript are not significantly different
(P >0.05) based on the post hoc Tukey's HSD test.

Physical characteristics

Most of the physical characteristics are identical to all 5 different formulations (Table 2). The physical properties of the food are highly dependent on its starch and protein content (Egharevba, 2016; Luther, Suter and Technology, 2005). In the developed formulations, unripe banana flour is rich in carbohydrates and mung bean flour contains a high amount of proteins. Therefore, the physical properties are approximately identical in all formulations.

Table 2: Physical characteristics of formulations

	WSI	WAI	RT (seconds)	SI	WHC	Viscosity (Pas)
A	0.23 ± 0.01^{c}	3.15 ± 0.04^{b}	119.33 ± 2.52^{c}	2.74 ± 0.41^{a}	214.52 ± 4.03^{b}	7.92 ± 0.722^{a}
B	0.45 ± 0.01^{a}	3.32 ± 0.06^{a}	98.33 ± 3.51^{d}	2.57 ± 0.16^{a}	232.17 ± 5.97^{b}	10.0 ± 0.00^{a}
C	0.24 ± 0.23^{c}	3.28 ± 0.01^{ab}	114.00 ± 5.29^{c}	1.98 ± 0.06^{b}	227.80 ± 1.16^{ab}	8.54 ± 0.361^{a}
D	0.27 ± 0.01^{b}	3.23 ± 0.10^{ab}	155.00 ± 3.00^{b}	2.40 ± 0.01^{ab}	222.82 ± 10.06^{ab}	9.38 ± 1.88^{a}
E	0.458 ± 0.01^{a}	3.22 ± 0.04^{ab}	172.67 ± 2.52^{a}	2.50 ± 0.07^{ab}	222.15 ± 4.01^{ab}	10.42 ± 0.72^{a}

Values are presented as means ± standard deviation. Values with the same alphabet along the same columns are not significantly different (P >0.05) based on the post hoc Tukey's HSD test.

Sensory evaluation

The results of the sensory study showed that formulation E had the highest overall (Figure 1) preference over the others. When considering the color, consistency, aroma, and taste, there was no significant difference (p>0.05) among the formulations. According to the overall preference of sensory evaluation and the physicochemical properties formulation E was selected for thefinal proximate analysis.

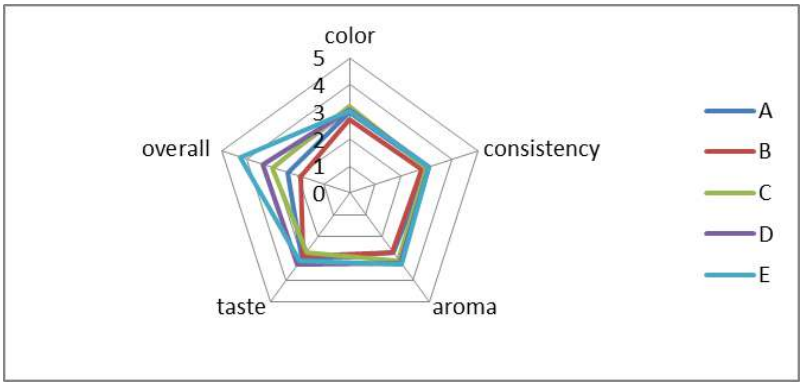

Figure 1: Radar graph of ranking test sensory evaluation based on appearance, color, flavor, taste, crispiness, overallacceptability by the untrained panel

Proximate Analysis

According to the proximate analysis, Formulation E contains 16% of crude protein (Table 4). Since the protein content is between 10% - 19%, this product can be categorized as a good sourceof protein (FAO and WHO, 2004). In addition, it contains only 0.5% of crude fat content. Thus, itcan be considered a fat-free food (FAO and WHO, 2004). It contains a considerable amount of crude fiber, however, not exceeding 10% to be considered a good source of dietary fiber (FAO and WHO, 2004).

Table 4: Nutrient content in Formulation E

Nutrient	%
Moisture	9.4%
Crude protein	16.0%
Crude fat	0.5%
Crude fiber	4.3%
Ash	4.8%
Carbohydrates	65%

Conclusion

Dehydrated leaf powder, pregelatinized unripe banana flour, and pregelatinized mung bean flour can effectively be used to develop a nutritious instant *kola kenda* mixture with acceptable physicochemical and sensory properties. This study is proved that the instant *kola kenda* mixture can be a significant solution to the food insecurity among Sri Lankan community.

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References

AOAC (2000) Official Methods of Analysis. 17th Edition, The Association of Official Analytical Chemists, Gaithersburg, MD, USA. Methods 925.10, 65.17, 974.24, 992.16.

Egharevba, H.O. (2016) 'Chemical Properties of Starch and Its Application in the Food Industry Henry', in IntechOpen, p. 13. Available at: https://www.intechopen.com/books/advanced-biometric-technologies/liveness-detection-in-biometrics.

FAO and WHO (2004) Codex guideline for use of nutrition and health claims - CAC/GL 23-1997, Codex Alimentarius Commission. Available at:

http://www.fao.org/ag/humannutrition/32444-09f5545b8abe9a0c3baf01a4502ac36e4.pdf.

Kanthi, N. et al. (2017) 'Development of Calcium Rich Instant Herbal Porridge mix by Incorporating Drumstick Leaves (Moringa oleifera L .)', 9(2), pp. 278–282.

Loypimai, P. and Moongngarm, A. (2015) 'Utilization of pregelatinized banana flour as a functional ingredient in instant porridge', Journal of Food Science and Technology, 52(1), pp. 311–318. Available at: https://doi.org/10.1007/s13197-013-0970- 6.

Luther, R., Suter, D.A. and Technology, P.E. (2005) 'Selections_From_Food_Proc._Eng._Tech.Pdf', pp. 23–52.

Musundire, R., Dhlakama, R.B. and Serere, J.H. (2021) 'Physico-chemical and sensory quality evaluation of an extruded nutrient-dense termite (Macrotermes natalensis) and millet (Eleusine coracana) instant porridge', International Journal of Tropical Insect Science, 41(3), pp. 2059–2070. Available at: https://doi.org/10.1007/s42690-021-00488-6.

Nascimento, K. (2017) 'Total phenolic and antioxidant capacity of flower, leaf and seed of Moringa oleifera Probiotic cheese and effects on the health View project Total phenolic and antioxidant capacity of flower, leaf and seed of Moringa oleifera', International Journal of Food and Nutrition Research, 1(1), p. 1.

Sirikong, P., Weerawatanakorn, M. and Chittrakorn, S. (2016) 'Physico-Chemical Properties of Pregelatinized Mung Bean Flour by Drum and Extrusion Process, Proceedings of The IRES 30th International Conference, 18 february,2016, Tokyo, 55-60s.', in IRES 30th International Conference, Tokyo, Japan. Tokyo, pp. 55–60.

Yousf, N. et al. (2017) 'Water solubility index and water absorption index of extruded product from rice and carrot blend', Journal of Pharmacognosy and Phytochemistry, 6(6), pp. 2165–2168. Available at: https://www.phytojournal.com/archives/2017/vol6issue6/PartAD/6-6-326-909.pdf.

Zhao, D. et al. (2019) 'Effect of sodium carbonate solution pretreatment on drying kinetics, antioxidant capacity changes, and final quality of wolfberry (*Lycium barbarum*) during drying', Lwt, 99(April 2018), pp. 254–261. Available at: https://doi.org/10.1016/j.lwt.2018.09.06.

INFLUENCE OF DIFFERENT CONCENTRATIONS OF *Aloe vera* LEAF GEL ON THE SHELF LIFE OF BANANA PEPPER (*Capsicum annuum*) IN DIFFERENT STORAGE TEMPERATURE

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Abstract

The application of edible coating is a technique that used to increase the shelf life of vegetables. This experiment was conducted from February to May 2022 at Department of Agronomy, Faculty of Agriculture, University of Jaffna, Kilinochchi to study the influence of different concentration of *Aloe vera* gel on increasing the shelf life of *Capsicum annuum*. Two factor factorial laboratory experiment was carried out in Complete Randomized Design (CRD) with six replicates. First factor was different storage conditions use up to 16 days (C1- room temperature 32 °C, C2–refrigerator temperature10 °C) and second factor was different concentration of *Aloe vera* coating (T1- 100% of *Aloe vera* gel, T2- 80% of *Aloe vera* coating, T3- 60% of *Aloe vera* coating, T4 - Control). Physical and chemical parameters such as moisture content, firmness rate, weight loss, pH and titratable acidity were measured for capsicum. All the date was analyzed in ANOVA using SAS software version 9.4. The means were compared by using Duncan's multiple range test to identify the best treatment combination. The result revealed that the highest moisture content (90%), firmness rate (75%), low level of weight loss (15%), and pH (6.28 pH) were found in T1 at refrigerator temperature in 16th day. These processes being more intense during the storage periods. According to this study, it can be concluded that different ratios of *Aloe vera* gel and different storage conditions have impact on banana pepper shelf life. Among the different ratio of *Aloe vera* solution, 100% of *Aloe vera* solution can be recommended as best coating at the refrigerator temperature (10 °C), due to good quality of vegetables.

Keywords: *Aloe vera* gel, edible coating, storage condition, shelf life, physicochemical parameters

Introduction

Banana pepper (Capsicum annuum L) belongs to the family Solanaceae, it is the most economically important plant in Sri Lanka (Ruhunuge *et al*., 2021). It could be a highly perishable in nature having low shelf life period and is additionally prone to fungal infections (Barkai-Golan, 1981). *Aloe vera* gel is one of the natural and environmentally friendly preservative materials. It is used to minimize the rate of respiration, water loss and maintaining the quality attributes of vegetables and fruits (Misir *et al*., 2014). Therefore, research is carried out to study the effect of different concentrations of *Aloe vera* gel coating to increase the shelf life of banana pepper and reduce the moisture and other losses.

Materials and Methods

Experimental design

Experiment was conducted in two factor factorial method in complete randomized design (CRD) with six replicates. The treatment combinations with water are 100 % (T1), 80 % (T2), 60 % (T3) of coating solution and control method (T4). And used two storage conditions are 10 ℃ (C1), (30±2) ℃ (C2).

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Selection of vegetables
Banana sweet pepper was selected with uniform size and thoroughly washed in water to lose the dirt particles.

Preparation and application of *Aloe vera* gel edible coating
Aloe vera leaf was collected and washed with tap water to remove the mucus. It was homogenized in a blender and filtered through Whatman filter paper. It was pasteurized at 70℃ for 45 min. Then 4.5g of citric acid was added to regulate PH at 4. *Aloe vera* gel solution was prepared by diluted with distilled water. Dipped the banana pepper in *Aloe vera* coating. It was kept at two different temperature 10℃ and (30±2) ℃. Shelf life of samples were compared with the control samples.

Analysis of coated banana pepper
Weight loss, firmness, moisture content, pH, Titratable acidity, Total Soluble Solid was analyzed in 4 days intervals. pH, Titratable acidity, Total Soluble Solid of banana pepper was analyzed using standard procedures. Weight loss were calculated by following equation:

$$\text{Weight loss\%} = \frac{\text{Initial weight} - \text{Weight in storage}}{\text{Initial weight}} \times 100$$

Moisture content were determined by gravimetrically method. it was calculated by following equation.

$$\text{Moisture content\%} = \frac{\text{Initial weight} - \text{oven dried weight}}{\text{Initial weight}} \times 100$$

Statistical analysis
Using ANOVA SAS 9.4 software and Duncan's multiple range test was used for comparing difference among mean value.

Results and Discussion

Weight loss
The effect of coating and different temperature effect on weight loss % of capsicum. The weight loss % of T1 is lower than T4 (Figure 1) Stored at 10 °C was significantly lower weight loss than that stored at 30±2 ℃ (Figure 2). This was supported by Misir *et al*. (2014) who estimated that Aloe gel based edible coating act as barrier, thereby restricting water transfer and protecting fruit skin from mechanical injuries.

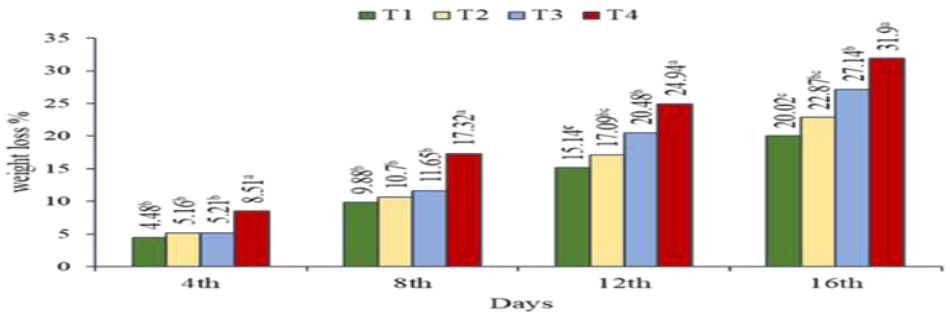

Figure 1: Weight loss percentage in different ratio of *Aloe vera* gel coating.

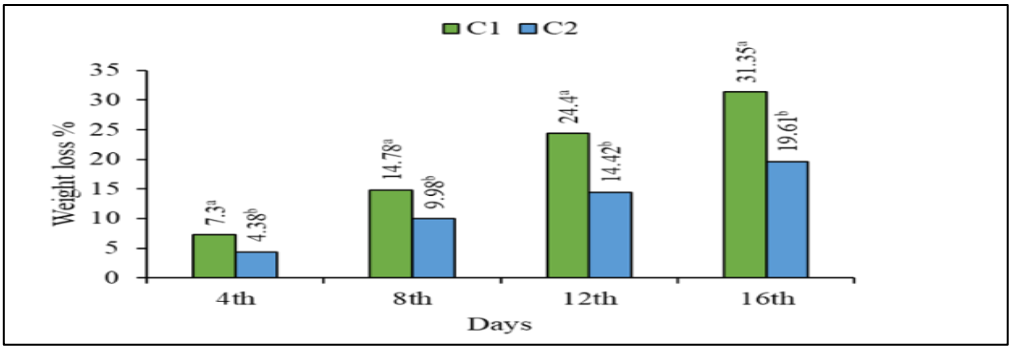

Figure 2: Weight loss percentage in different storage condition.

Moisture content

The moisture content in capsicum was significantly differed with different ratio of *Aloe vera* gel coating. The highest moisture content was recorded in T1. Morillon *et al.* (2002) stated that of *Aloe vera* gel has proved to be highly effective as a moisture barrier which allowed the formation of a barrier to the diffusion of water between the fruit and environment.

Firmness

The rate of firmness gradually reduces with time. Highest firmness percentage value was recorded in T1 than other treatment (Figure 3). The firmness of coated capsicum at 10℃ was significantly higher than that stored at room temperature (Figure 4). *Aloe vera* coating delays softening of fruits and maintains its texture. This result is in conformity with Hameed *et al.* (2013) who indicated that fruit stored at 10℃ were firmer than fruit store at high temperature. It may be due to lower metabolic activities at 10℃ which retained fruit firmness.

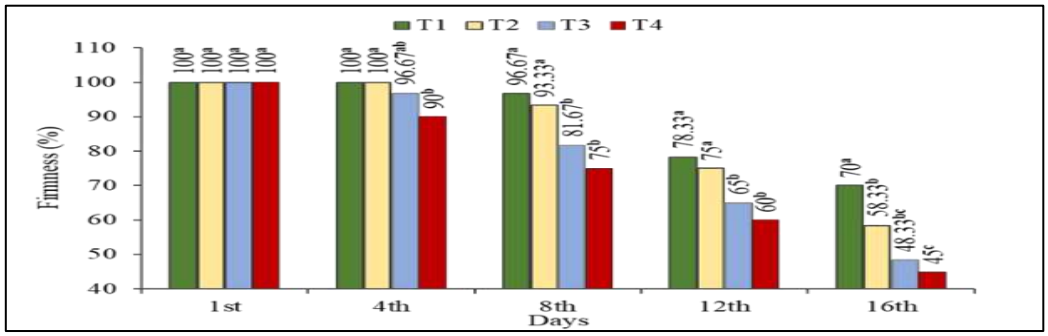

Figure 4: Firmness (%) in different ratio of *Aloe vera* gel coating

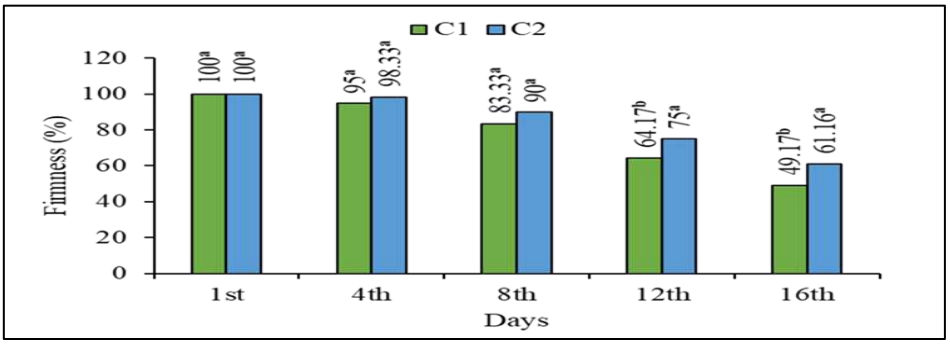

Figure 5: Firmness (%) in different storage condition

pH

Aloe vera coating delayed the changes in pH of capsicum. pH of T1 stored at 10 °C was significantly less increased than that of coated capsicum stored at (30±2) °C (Table 2). This result was supported by Firdous *et al*, (2020). (Firdous et al, 2015) who said that biochemical reactions leading towards ripening and decay are slowed by *Aloe vera* gel-based coating.

Titratable acidity

The acidity (%) reduces in high level at T4, but titratable content was not changed in T1 (Table 1). There was no significant different in acidity (%) among different storage condition. This was supported by Sharmin *et al*, (2015) who estimated that retention of TA by coated papaya was due to the protective effect of aloe gel coating as barrier to O_2 from surrounding atmosphere.

Total soluble solid

Total soluble solid content from the initial value increased up to 8th day of storage followed by decrement at end of storage (Table 1). The highest total soluble solid content was recorded in T1 stored at 10 °C. This result was further supported by previous finding of Kalauni *et al.* (2020) where they found that higher total soluble solid and sugar contents in coated fruits can be ascribed to the lower rate of metabolic changes due to reduced respiration.

Table 1: Total soluble solid, pH, Titratable acidity (%) in different ratio of *Aloe vera* gel coating

	TSS				pH				Titratable acidity			
	4th day	8th day	12th day	16th day	4th day	8th day	12th day	16th day	4th day	8th day	12th day	16th day
T1	4.05^{a}	4.38^{a}	3.3^{a}	3.3^{a}	6.2^{a}	6.27^{ab}	6.27^{b}	6.28^{b}	0.01^{a}	0.01^{b}	0.01^{b}	0.01^{a}
T2	4.07^{a}	4.2^{b}	3.33^{a}	3.33^{a}	6.14^{a}	6.28^{ab}	6.31^{ab}	6.33^{b}	0.02^{a}	0.01^{ab}	0.01^{ab}	0.01^{ab}
T3	4.06^{a}	4.63^{a}	3.46^{a}	3.11^{b}	6.15^{a}	6.22^{b}	6.24^{b}	6.31^{b}	0.02^{a}	0.01^{ab}	0.01^{ab}	0.01^{ab}
T4	3.96^{a}	4.21^{b}	3.28^{a}	3.02^{b}	6.28^{a}	6.38^{a}	6.42^{a}	6.55^{a}	0.02^{a}	0.02^{a}	0.01^{a}	0^{b}

Table 2: Total soluble solid, pH, Titratable acidity % in different storage condition

	TSS				pH				Titratable acidity			
	4th day	8th day	12th day	16th day	4th day	8th day	12th day	16th day	4th day	8th day	12th day	16th day
C1	3.94^{a}	4.79^{a}	3.38^{a}	3.28^{b}	6.22^{a}	6.31^{a}	6.34^{a}	6.39^{a}	0.02^{a}	0.01^{a}	0.01^{a}	0.01^{a}
C2	3.83^{a}	4.32^{a}	3.32^{a}	4.1^{a}	6.17^{a}	6.26^{a}	6.28^{a}	6.34^{a}	0.02^{a}	0.01^{a}	0.01^{a}	0.01^{a}

Conclusion

Shelf life of capsicum in different concentration of *Aloe vera* gel have great influenced on its physicochemical properties. Coated capsicum showed lower weight loss and color changes, reduce softening and ripening. The result of this study indicate that capsicum coated with 100 % of *Aloe vera* gel showed a significant increase of storage life during storage at 10 °C.

References

Barkai-Golan, R., 1981. Annotated check-list of fungi causing postharvest diseases of fruits and vegetables in Israel.

Firdous, N., Khan, M.R., Butt, M.S. and Shahid, M., 2020. Application of *Aloe vera* gel based edible coating to maintain postharvest quality of tomatoes. *Pakistan Journal of Agricultural Sciences*, *57*(1).

Hameed, R., Malik, A.U., Khan, A.S., Imran, M., Umar, M. and Riaz, R., 2013. Evaluating the effect of different storage conditions on quality of green chillies (*Capsicum annuum* L.).

Kalauni, S., Tripathi, K.M., Shrestha, A.K. and Shrestha, B., 2020. Effectiveness of Different Storage Conditions and Sanitizers of the Post-Harvest Performance of Sweet Pepper (*Capsicum annum* L.) in Chitwan District, Nepal. *Nepalese Horticulture*, *14*(1), pp.21-3.

Misir, J., Brishti, F.H. and Hoque, M.M., 2014. Aloe vera gel as a novel edible coating for fresh fruits: A review. *American Journal of Food Science and Technology*, *2*(3), pp.93-97.

Morillon, V., Debeaufort, F., Blond, G., Capelle, M. and Voilley, A., 2002. Factors affecting the moisture permeability of lipid-based edible films: a review. *Critical reviews in food science and nutrition*, *42*(1), pp.67-89.

Ruhunuge, I.J.A., Wijeratne, A.W. and Wimalasiri, E.M. (2021). Growth and Yield Response of Chilli (*Capsicum annum* L) for the Combined Organic and Inorganic Fertilizer Application. *ATRS Journal*, 1(1), p.18.

Sharmin, M.R., Islam, M.N. and Alim, M.A., 2015. Shelf-life enhancement of papaya with Aloe vera gel coating at ambient temperature. *Journal of the Bangladesh Agricultural University*, *13*(1), pp.131-136.

EFFECT OF SUGAR REPLACEMENT WITH NATURAL SWEETENER (*Stevia rebaudiana*) ON QUALITY OF VANILLA FLAVOURED *Aloe vera* ICE-CREAM

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Abstract

Ice-cream incorporated with herbs gives more benefits for healthy life. *Stevia rebaudiana* is the plant used as a natural sweetener which is having a potential to be used as an alternative replacer for sugar to sweetened dairy products. The current study aimed to investigate the effect of sugar replacement with stevia on quality of vanilla flavoured *Aloe vera* ice-cream. Commercially available pure stevia extract was used to replace the sugar at the rate of 0% (T_0), 20% (T_1), 40% (T_2), 60% (T_3), 80% (T_4) and 100% (T_5). Samples were evaluated for physicochemical and organoleptic attributes using standard procedures. Percentage of total solid, carbohydrate and calorie were shown as decreasing trend while protein and ash content were shown as increasing trend with increasing level of sugar replacement with stevia extract. There were no significant differences in fat content among all treatments. The pH shown non-significant differences while titratable acidity shown significant (p<0.05) difference between T_1 and other treatments. Low calorie ice-creams are most popular because people are more concerned about their health and wellbeing. The treatment (T_5) resulted in 53.99% reduction in calorie content in fresh ice-cream and based on the organoleptic evaluation, the overall acceptability was high in 20% stevia added ice-cram. It can be concluded that replacement of 100% sugar is possible with the commercially available stevia extract used in the current experiment for the production of vanilla flavoured *Aloe vera* ice-cream.

Keywords: *Aloe vera*, calorie content, ice-cream, stevia, sugar replacement

Introduction

Ice-cream is one of the oldest delicious fat-rich dairy products enjoyed by people of all ages all over the world (Manoharan and Ramasamy, 2013). People are more aware about their health status and thus conscious of their diet as a result of the high prevalence of obesity and type 2 diabetes among children and adolescents. The ice-cream industry faces a formidable challenge as a result of this health-conscious decision. As a result, the ice cream market is shifting toward low-calorie, low-sugar ice-cream with excellent texture and sensory properties (Pon *et al*., 2015). *Aloe vera* is one of the oldest medicinal plants, it is also known as the miracle plant. It has been reported to cure eczema, diabetes, and arthritis, as well as to prevent infection (Manoharan and Ramasamy, 2013). Products made with alternative sweeteners have recently become more popular as consumer demand for low calorie foods has increased. The prevalence of metabolic disorders such as diabetes, cardiovascular disease, and obesity is increasing as a result of excessive sugar consumption. Stevia can be used as a sugar substitute in a variety of foods (Ozdemir *et al.*, 2015). Stevia is known as the sugar plant. Stevia's active matter is the sugar rebaudioside A (Reb A) (stevia l glycoside). It has 250-300 times sweetness of sucrose. Stevia does not contain any energy. Stevia is appealing to people on carbohydrate-controlled diets because it has no effect on blood glucose levels (Ozdemir *et al.*, 2015). Therefore, this study on herbal ice cream with Aloe Vera and natural sweetener substitution was carried out. The objectives of this study were to determine optimum level of *Aloe vera* gel to prepare an ice-cream, determine optimum level of stevia sweetener to achieve the consumer acceptance of *Aloe vera* ice-cream and make an ice-cream by using herbs for diabetic patients and patients who need low calories.

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Materials and Methods

This research study was conducted at Department of Animal Science Laboratory, Faculty of Agriculture, Eastern University, Sri Lanka. Cow milk was collected at Eastern University, Sri Lanka Livestock Farm. *Aloe vera* was purchased from one of the home gardens at Karaitivu. Stevia liquid extract was purchased from SWLG (Pvt) Ltd, Minuwangoda. Other ingredients were purchased from local shop at Periya kallar. Preliminary study was conducted to select the optimum concentration of *Aloe vera* gel to prepare an ice-cream. Based on this 5% (w/w) of *Aloe vera* gel was finalized for further study. *Aloe vera* gel was prepared by using the method of Ahlawat *et al*. (2013).

Treatment frame works and preparation of sugar replaced Aloe vera ice-cream

Following treatments were done. T_0- *Aloe vera* ice-cream prepared with 100% sugar as a control, T_1- 80% sugar and 20% stevia extract, T_2- 60% sugar and 40% stevia extract, T_3- 40% sugar and 60% stevia extract, T_4- 20% sugar and 80% stevia extract and T_5- 100% stevia extract. (Three tea spoon of sugar is equal to 0.05g of stevia extract according to the label in stevia package) from each treatment, three replicates were carried out. Ice-cream was prepared as per the method of Mason and Nottingham (2002).

Physicochemical analysis

Total solid content, ash content, crude protein and carbohydrate content were determined by the standard methods of AOAC (1990), The fat content of the ice cream was determined by the Gerber method as described by AOAC (2001). Titratable acidity was determined by AOAC (1995) and determination of pH was done by using the pH meter (OHAUS®, Model ST 3100) as described by Owolabi *et al*. (2021). Calorie content of ice-cream samples were calculated by using the following equation Giri and Rao (2014).

Total Calorie content (%) = {(% Carbohydrate×3.87) +(% Fat×8.79) +(% Protein ×4.27)}

Sensory analysis

30 untrained panelists were used for organoleptic evaluations like texture, flavor, colour, taste and overall acceptability. Seven-point hedonic scale, ranging from (score = 1) to (score = 7) where, 7 indicates like very much while 1 indicates dislike very much, was used for evaluation. Questionnaires were used for the sensory assessment (Mason and Nottingham, 2002).

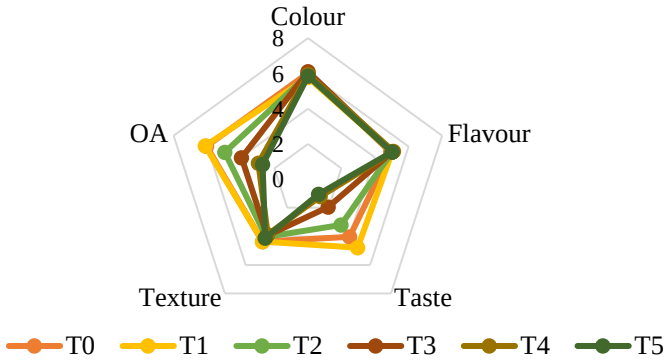
Statistical analysis

All observations were analyzed by using Minitab version 17. ANOVA was done to test the significant difference of different stevia concentrations and mean comparison of quantitative and qualitative observations were done by Tukey test and Freidman test, respectively.

Results and Discussion

Preliminary study to finding the best percentage of Aloe vera gel for manufacture of ice-cream

Figure 1 indicated that among all treatments 5% *Aloe vera* gel used ice-cream sample gave good characteristics in taste, aroma, texture, colour and overall acceptability to the ice-cream. Deviation in the results of taste is due to the bitterness of the ice-cream was increased along with *Aloe vera* gel concentration as reported by Manoharan and Ramasamy (2013). Therefore, 5% (w/w) concentration of *Aloe vera* gel was selected as the best level for preparation of sugar replaced *Aloe vera* ice-cream.



T_0= 100% sugar, T_1= 80% sugar + 20% stevia, T_2= 60% sugar + 40% stevia, T_3= 40% sugar + 60% stevia, T_4= 20% sugar + 80% stevia, T_5= 100% stevia

Figure 1: Variation of sensory attributes in ice-cream samples made from different concentration of *Aloe vera* gel

Effect of sugar replacement with stevia on composition of Aloe vera ice-cream

Table 1 shown that total solid content of sugar replaced *Aloe vera* ice-cream was showing decreasing trend with increasing stevia level. According to that T_5 had the lowest TSS content while T_0 had the highest TSS content. It has been reported that total solid content was decreased with increasing stevia extract level of milk products such as ice-milk and milk shake (Ali *et al*., 2015). When increasing the percentage of stevia level, proportionally sucrose level was going down. It causes the reduction of total solid content. Also when we consider the total solid content of all the treatments, T_5 was significantly (p<0.05) different from other treatments. Also clear decreasing trend could be observed in carbohydrate content as shown in the Table 1. The treatment T_0 had the highest carbohydrate content while T_5 sample had the lowest carbohydrate content. T_0 is significantly (p<0.05) different from the other treatments. And also protein content took increasing trend with increasing stevia level. Protein content of T_0 is significantly (p<0.05) different from T_3, T_4 and T_5. According to that T_5 had the highest protein content while T_0 had the lowest protein content (Giri and Rao, 2014). There were no significant differences in ash content among the all treatments observed. But ash content is non significantly increasing from T_0 to T_5. These results of this present study were found to be similar to the study of (Giri and Rao, 2014). Fat content of all treatments shown non- significant differences among the all treatments as per the findings of Robins *et al*. (2019). There were significant (p<0.05) differences in calorie content among treatments. The highest mean value of calorie content was observed at T_0 (109.13±2.33) and lowest mean value of calorie content was observed at T_5 (55.14±2.25). Calorie content was decreased from T_0 to T_5. These results were due to carbohydrate content is indirectly affect the percentage of total calorie content. Similar results were found in Giri and Rao (2014) in kulfi by adding stevia as a natural sweetener. There was no significant difference in pH among the treatments. Similar results were observed in Robins *et al*. (2019). There were significant (p<0.05) difference in titratable acidity between the T_0 and other all treatments due to 100% of sugar, the lactic acid formation might be occurred (Singh *et al*., 2014). Results of other treatments almost similar with findings of Robins *et al*. (2019).

Table 1: Physico-chemical attributes of sugar replaced *Aloe vera* ice-cream

Parameters	T_0	T_1	T_2	T_3	T_4	T_5
TS (%)	25.71±0.60^a	21.16±0.92^b	20.68±0.19^b	16.54±0.16^c	13.43±0.01^d	12.47±0.46^d
Ash (%)	0.53±0.07^a	0.55±0.11^a	0.62±0.10^a	0.62±0.21^a	0.74±0.12^a	0.74±0.15^a
Protein (%)	2.60±0.07^c	2.78±0.23^{bc}	3.25±0.10^{abc}	3.32±0.39^{ab}	3.60±0.27^a	3.56±0.24^a
Fat (%)	2.33±0.15^a	2.26±0.11^a	2.16±0.05^a	2.33±0.05^a	2.16±0.11^a	2.23±0.05^a
CHO (%)	18.07±0.12^a	15.37±0.92^b	14.57±0.20^b	10.21±0.41^c	6.84±1.03^d	5.77±0.51^d
Calorie (%)	109.13±2.33^a	91.63±3.47^b	89.31±0.71^b	74.24±0.80^c	60.05±5.59^d	55.14±2.25^d
pH	6.53±0.11^a	6.43±0.05^a	6.46±0.05^a	6.70±0.2^a	6.56±0.05^a	6.46±0.05^a
TA	0.35±0.03^a	0.22±0.00^b	0.26±0.02^b	0.24±0.01^b	0.23±0.01^b	0.24±0.01^b

T_0= 100% sugar, T_1= 80% sugar + 20% stevia, T_2= 60% sugar + 40% stevia, T_3= 40% sugar + 60% stevia, T_4= 20% sugar + 80% stevia, T_5= 100% stevia. The values are means of replicates ± standard deviation. Means with the same letters in a row are not significantly different at ($p<0.05$)

Sensory evaluation of sugar replaced Aloe vera ice-cream

Figure 2 revealed that there were no any significant differences in flavor and colour among the all treatments. Taste was similar range in T_0 and T_1 but other attributes were high in T_1. and overall acceptability was T_2=T_3=T_4<T_0<T_5<T_1 in order. And some of the treatments are similar in some other sensory attributes. Giri and Rao (2014) found that above 50% sugar replacement with stevia powder resulted in bitterness, lack of brownish appearance and presence of icy texture. Gheybi *et al*. (2017) found that substitution of stevia increases the hardness, and lower score for intensity of crystalline. Based on the organoleptic point of view compared with other treatments, T_1 had the highest preference of overall acceptability Characteristics.

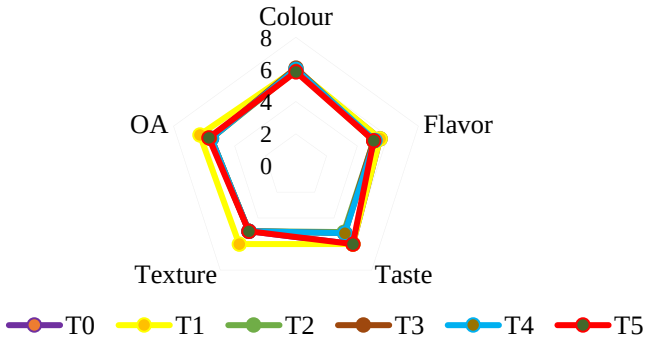


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Figure 2: Sensory attributes variation fresh sugar replaced *Aloe vera* ice-cream

Conclusion

In this present study, sugar replaced *Aloe vera* ice-cream was prepared with stevia natural sweetener by partially added stevia extract. Based on the organoleptic evaluation, the overall acceptability was high for T_1. Next to that T_5 had high score in attributes of taste, colour and overall acceptability according to the sensory evaluation. And also stevia added Aloe Vera ice-cream were high protein (due to less total weight), high ash content (but values are not significantly different) and low level of total solid, carbohydrate and total calorie content when compare with T_0. It can be stated that the replacement of 100% sugar also possible with the commercially available stevia extract used in the current experiment for the production of vanilla flavoured *Aloe vera* ice-cream as a low calorie herbal ice-cream specially for diabetic patients and patients who need low calories.

References

Ahlawat, K.S., Khatkar, B.S. and Neelam, G. (2013). Effect of processing and storage on sensory properties and acemannan content of aloe vera gel. *Annals of Agri Bio Research*, *18*(1), pp.70-73.

Ahlawat, K.S., Khatkar, B.S. and Neelam, G. (2014). Development and storage studies of aloe vera ice-cream. *Annals of Agri Bio Research*, *19*(4), pp.780-784.

Ali, H.M., Ahmed, E.A. and Adel, K.H.M. (2015). Production of healthy ice milk using Stevia extract as a sweetener. *World Journal of Dairy & Food Sciences*, *10*(2), pp.154-158.

AOAC. (1990). Official Methods of Analysis. 15th Edition, Association of Official Analytical Chemist, Washington DC.

AOAC. (1995). Official Methods of Analysis. 16th Edition, Association of Official Analytical Chemists. Washington DC, USA.

Department of Animal Production and Health. (2022). Key statistics of Dairy Industry 2021-2022. Department of census and statistics, 26th on July.

Gheybi, N., RaftaniAmiri, Z. and Kasaai, M.R. (2017). Effect of stevia and inulin on the structure, physicochemical and sensory properties of dietetic ice cream.

Giri, A. and Rao, H.G. (2014). Effect of partial replacement of sugar with stevia on the quality of kulfi. *Journal of food science and technology*, 51(8), pp.1612-1616.

International trade administration. (2021). Sri Lanka – country commercial guide, *data.worldbank.org*, 2021.09.28.

Kleyn D. H., Lynch J. M., Barbano D. M., Bloom M. J. and Mitchell M. W. (2001). "Determination of fat in raw and processed milks by the Gerber method: Collaborative Study," *Journal of AOAC International*, 84 (5): 1499-1508.

Manoharan, A.P. and Ramasamy, D. (2013). Physico-chemical, microbial and sensory analysis of Aloe vera (pulp) ice cream with natural colour in different artificial sweeteners. *Indian Journal of Fundamental and Applied Life Sciences*, *3*(2): 114-121.

Mason, R.L. and Nottingham, S.M. (2002). Sensory evaluation manual. *Brisbane: University of Queensland*.

Owolabi, I.O., Songsamoe, S., Khunjan, K. and Matan, N. (2021). Effect of tapioca starch coated-rubberwood box incorporated with essential oils on the postharvest ripening and quality control of mangosteen during transportation. *Food Control*, *126*, p.108007.

Ozdemir, C., Arslaner, A., Ozdemir, S. and Allahyari, M. (2015). The production of ice cream using stevia as a sweetener. *Journal of Food Science and Technology*, *52*(11): 7545-7548.

Pon, S.Y., Lee, W.J. and Chong, G.H. (2015). Textural and rheological properties of stevia ice cream. *International Food Research Journal*, *22*(4).

Robins, A., Radha, K., Sathian, C.T., Geetha, R. and Beena, A.K. (2019). Development of low-calorie goat milk ice cream by using stevia leaf powder. *The Pharma Innovation Journal*, *8*(1):296-299.

Singh, A., Bajwa, U. and Goraya, R.K. (2014). Effect of storage period on the physicochemical, sensory and microbiological quality of bakery flavoured ice cream. *Int J Eng Res Appl*, *4*:80-90.

DEVELOPMENT OF SNACK USING CASSAVA (*Manihot esculenta*) AND WHEAT (*Triticum aestivum*) FLOUR MIXTURE

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Abstract

The importation cost of wheat flour increased due to the higher popularity of the snack industry. Finding a possible alternative for wheat flour is a timely requirement. Thus, this experiment was conducted with the objective of evaluating the applicability of cassava flour as an alternative to wheat flour for the development of snacks. There were five treatments according to the dry weight basis ratios of cassava: wheat flour was used as treatments such as T1-100:0; T2-75:25; T3-50:50; T4-25:75; T5-0: 100 (control). The snack was prepared by using cassava and wheat flour mixtures by adding turmeric powder, curry powder, salt, pepper, garlic, ginger, water and vegetable oil as the raw materials. The sensory properties (aroma, taste, appearance, color, mouthfeel and overall acceptability) were evaluated using 50 trained panelists in 5 -point hedonic scale of 1 (dislike a lot) to 5 (like a lot). Proximate analysis was performed for moisture, ash, color and texture. The sensory evaluation data were analyzed using the Friedman test. Based on the results found, it was observed that, mixture of cassava: wheat flour at the ratio of 25:75 (T4) was the most acceptable sample for all sensory properties (the average value of response for appearance: 4.80, smell: 4.66, taste: 4.74, mouth feel: 4.76 and overall acceptability: 4.70). Further, T4 contained 7.84% moisture and 3.37% total ash. Hence, it can be recommended that mixture of 25% cassava flour with 75% wheat flour can be used to prepare a snack. Further studies need to be done to find the shelf life of the products.

Keywords: Cassava, *Manihot esculenta, snack, Triticum aestivum, wheat flour*

Introduction

Wheat flour is the most used ingredient for the production of snack products. Sri Lanka spent a large cost on the importation of wheat flour. Therefore, finding possible alternatives for wheat flour is a timely requirement. Cassava is an important staple food in developing countries, feeding almost half a billion people a basic diet (Freitas *et al*, 2015; FAO, 2006). It is a perennial crop that originated in Brazil and spread throughout Central America before being introduced to Sri Lanka during the Dutch colonial period (Palaniswami and Peter, 2008). It is one of the drought-resistant crops, capable of growing on marginal soils (Uthpala *et al.*, 2021). Cassava can be used to make flour which can be used to produce food products. Thus, this study was designed to find out the applicability of using cassava flour as an alternative to wheat flour.

Materials and Methods

Raw materials

Cassava tubers, wheat flour, turmeric powder, curry powder, salt, pepper, garlic, ginger, vegetable oil

Raw material collection

Well-matured cassava tubers were collected from cassava cultivation in Dambadeniya, Kurunegala District, Sri Lanka.

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Preliminary Studies
Based on the literature review, preliminary studies were conducted to select suitable ratios of other raw materials to incorporate into the snack.

Treatments
Cassava flour and wheat flour were mixed in the following ratio on a dry weight basis as treatments in the experiment (Table 1).

Table 1: Treatments

Treatment Number	Cassava flour	Wheat flour
01	100%	0%
02	75%	25%
03	50%	50%
04	25%	75%
05	0%	100%

Preparation of snack
The harvested tubers were peeled and washed thoroughly. Then, cleaned tubers were sliced into small pieces. The small pieces were oven-dried in 55 ^{o}C to 16-18 hours and grinded using electrical grinder. The cassava flour was sieved (250 µm) through a mesh. Wheat flour and cassava flour were mixed according to the treatments. According to the literature, turmeric powder, curry powder, salt, pepper, garlic, ginger, water, vegetable oil as the raw material (same amount of mixture for all treatment) were added to all cassava and wheat flour mixtures (all treatments).

Data Collection

Sensory evaluation
Sensory evaluation was carried out to determine the suitable ratio of cassava flour and wheat flour to develop the snack. The acceptability of the five treatments was tested by using sensory analysis (appearance, smell, taste, mouthfeel, and overall acceptability) of a five-point hedonic scale and a sensory panel consisting of 50 trained panelists.

Proximate analysis
Proximate composition analysis (moisture, color, total ash and texture) was done in the laboratory of the National Institute of Post-Harvest Management, Anuradhapura Sri Lanka.

Data analysis
Data gathered from the sensory evaluation was analyzed according to Friedman non-parametric test at 95% level of significance using Mini tab statistical software.

Results and Discussion

Sensory Evaluation
Five treatments were used for sensory evaluation. Considered parameters were appearance, smell, taste, mouth feel, and overall acceptability (Table 2).

Appearance
The results show that there was a significant ($P<0.05$) difference between the five treatments with respect to appearance. Treatment 04 that combination of cassava and wheat flour with the ratio of 25: 75 has shown the highest median value (4.70) and the highest sum of rank (233.0). Thus, it was the most preferred sample among the treatment for appearance (Figure 1)

Table 2*:* Friedman test results for sensory evaluation

Variable	Cassava and Wheat flour 100:0	Cassava and Wheat flour 75:25	Cassava and Wheat flour 50:50	Cassava and Wheat flour 25:75	Cassava and Wheat flour 0:100	Highest Sum of Rank	P – value
Appearance	1.00	4.20	2.10	4.70	1.00	233.0	0.000*
Smell	2.00	4.40	1.60	4.80	1.20	233.5	0.000*
Taste	1.80	4.80	1.80	5.00	1.60	232.5	0.000*
Mouth feel	1.10	4.40	2.00	4.90	1.10	234.0	0.000*
Overall acceptability	2.00	5.00	2.00	5.00	2.00	232.5	0.000*

*Values are medians of each response *values are significantly differs at 0.05 significance level according to the Friedman test*

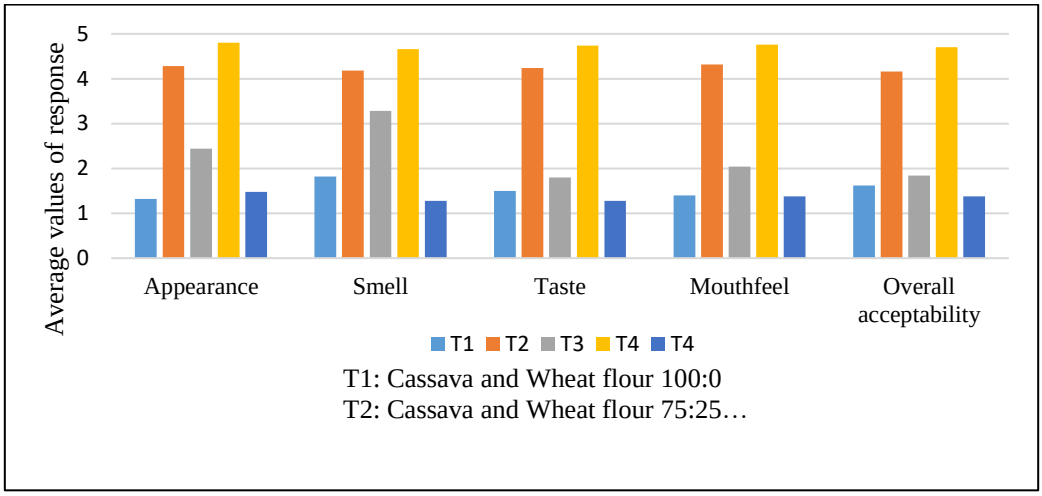

Figure 1: Sensory properties of snack of different treatments according to the sensory evaluation (Values are means of each response; (Response; 1-Dislike a lot, 2- Dislike a little, 3-Neither like nor dislike, 4-Like a little, 5-Like a lot; P value- 0.0000)

Smell

There is a significant difference (P<0.05) between the five treatments with respect to the smell. Treatment 04 that combination of cassava and wheat flour with a ratio of 25: 75 has shown the highest median value (4.80) and the highest sum of rank (233.5). Thus, it was the most preferred sample among the treatment for the smell (Figure 1).

Taste

There was a significant (P<0.05) difference between the five treatments with respect to taste. Treatment 04 that combination of cassava and wheat flour with a ratio of 25: 75 has shown the highest median value (5.00) and the highest sum of rank (232.5). Thus, it was the highest preferred sample (Figure 1).

Mouth feel

In terms of mouthfeel there is a significant (P<0.05) difference between five treatments with respect to the mouthfeel and the treatment 04 that combination of cassava and wheat flour with the ratio of 25: 75 has shown the highest median value (4.90) and highest sum of rank (234.00). Thus, it was the highest preferred sample among the treatment for mouthfeel (Figure 1).

Overall acceptability

According to the results, there is a significant difference between the treatments with respect to the overall acceptability. Treatment 04 has shown the highest median value (5.00) and highest sum of rank (232.5). Thus, it was the highest preferred sample among all treatments for overall acceptability (Figure 1).

According to the results T4 (snack produce using Cassava and Wheat flour 25:75) obtained the highest score for appearance, smell, taste, mouth feel and overall acceptability followed by T2 (snack produce using Cassava and Wheat flour 75: 25)

Proximate analysis of the snack

Table 1: Proximate analysis of the snack

Parameters	Units	Result
Moisture	g/100 g	7.48
Colour	L*, A* and B*	51.61, 6.80, 28.78 48.47, 6.37, 26.06 46.61, 7.73, 27.18
Total ash	g/100 g	3.37
Texture	N	7.50

According to the proximate analysis, moisture content of the T4 (snack produce using Cassava and Wheat flour 25:75) is 7.48 g/100 g of sample (7.48%). Further the colour also reported as 51.61, 6.80, 28.78, 48.47, 6.37, 26.06, 46.61, 7.73 and 27.18 L*, a* and b*. The color difference between the raw (Lo*, ao*, bo*) and fried (L*, a*, b*) snack was determined by taking the Euclidean distance between them, according to Mariscal and Bouchon (2008). The total ash content of T4 (snack produce using cassava and wheat flour 25:75) was recorded as 3.37g/100g of sample and which was 3.37%. The texture of the sample was recorded as the 7.50 N.

Conclusion

Mixing the cassava flour with wheat flour; 25: 75 (T4) showed higher significant values in all the sensory parameters. Further addition T4 showed acceptable values in proximate properties. Hence it can be concluded that, the mixture of cassava flour can be used as an alternative for wheat flour to produce snacks. Future studies should be needed for further development of the snack.

References

FAO. Food and Agricultural Organization of the UN. FAO: Rome, (2006). [Online] Available: http://faostat.fao.org/site.339/default.aspx. (January 12, 2008).

Freitas, M.A., Medeiros, F.H., Carvalho, S.P., Guilherme, L.R., Teixeira, W.D., Zhang, H. and Paré, P.W., (2015). Augmenting iron accumulation in cassava by the beneficial soil bacterium Bacillus subtilis (GBO3). *Frontiers in Plant Science*, *6*, p.596

Mariscal, M. and Bouchon, P., 2008. Comparison between atmospheric and vacuum frying of apple slices. Food chemistry, 107(4), pp.1561-1569.

Palaniswami, M. S., & Peter, K. V. (2008). Tuber & root crops. K.S. Peter, (Ed.), Introduction (Pp 5-8). New India Publishing.

Uthpala, T. G. G., Navaratne, S. B., & Thibbotuwawa, A. (2020). Review on low-temperature heat pump drying applications in food industry: Cooling with dehumidification drying method. *Journal of Food Process Engineering*, *43*(10), p.e 13502.

DETERMINANTS AND IMPACT OF NEW TECHNOLOGY ADOPTION FOR PEPPER POST-HARVEST PROCESSING ON FAMERS' WELLBEING: A CASE OF PEPPER FARMERS IN KEGALLE DISTRICT

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Abstract

Sri Lankan pepper is famous for its inherent pungent quality. Even though the Department of Export Agriculture, introduced Post Harvest Processing Technologies like drying, threshing and blanching to the farmers, they aren't much popular among them. The use of those technologies and adoption rates seems to be low. Due to lower-level practices pepper post-harvest quality is reducing rapidly. As quality is a critical parameter in the global pepper trade, most of the high-end European markets refuse our low-quality pepper. Also, the production rates are far below the international demand and there is a higher post-harvest loss. As a result, pepper export and farmer household incomes have been reduced dramatically. The use of appropriate post-harvest processing technologies is one of the major ways to mitigate those issues. So, popularizing those technologies among the farmers and increasing the technological diffusion rates are crucial. Thus, this study aims to investigate the factors affecting the adoption of post-harvest technologies and their impact on pepper farmers' well-being in the Kegalle district. The data used for the study were obtained from 100 purposively selected pepper farmers in the study area. Binary logistic model was employed to analyze the determinants for farmers' decisions to adopt post-harvest technologies. Mann-Whitney U test was used to determine the impact of adoption on household incomes and expenditure. As per the findings, having credit and internet accessibility, distance to the market and cost of production are the factors that have significant positive impacts on technology adoption. Moreover, technology adoption can improve the farmers' well-being as incomes and consumption expenditures were higher in adopters than that of non-adopters. Having a proper understanding about the determinants that highly contribute for farmers' technology adoption would help decision-makers to formulate necessary strategies to increase the adoption rates of technologies and thereby upgrade the quality of Sri Lankan pepper.

Keywords: Farmers' wellbeing, quality, post-harvest processing, pepper, technology adoption

Introduction

Black pepper is ranked the second in terms of volume of the exports and value while this industry has provided the livelihood for a large number of peasant farmers. (Disna & Ranawaka, 2018). Hence, practicing Post-harvest Processing Technologies (PhPT) in pepper processing can create a huge impact on pepper farmers' livelihood. Pepper quality is primarily dependent on the harvesting and post-harvest processing practices of the farmers. Traditionally, pepper processing is done mainly on the farm, and it consists of soaking, peeling, washing, and drying (Wulandari, 2022). Traditional processing impacts pepper quality and raises issues concerning time efficiency, labor efficiency, and the potential for environmental pollution. Therefore, the adaption of new technologies in post-harvest processing has become a new trend currently throughout the world to enhance the quality of agricultural products. So, the technology adoption can increase the quality and production efficiency of many agricultural products. For that the technologies should be popular among the pepper farmers. Before popularizing, knowing about the factors that drive for their decision-making process and the

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impact of using those technologies for the farmers' wellbeing are crucial. As there is a dearth of studies in Sri Lanka, the broad aim of this study was to assess the determinants and the impact of new technology adoption on post-harvest processing of pepper for farmers' wellbeing in the Kegalle district and specific objectives were to identify the factors affecting for new technology adoption on post-harvest processing of pepper and assess the impact of new technology adoption on farmers' wellbeing.

Materials and Method

The research approach was deductive and descriptive. The research strategy was the survey strategy. Kegalle district was selected as the location of the study. The sampling frame was the smallholder farmers who engaged in pepper cultivation in the Kegalle district. However, the study considered two groups of farmers including PhPT adopters and technology non-adopters. Based on the number of technology-adopting pepper farmers in the Kegalle district, 4 Divisional Secretariate (DS) divisions were selected by using the purposive sampling technique. 100 pepper farmers (47 technology-adopted farmers and 53 technology non adopted farmers) were taken as the sample size. Primary data was collected through a pre-tested questionnaire. Binary logistic regression was employed to test the determinants of new technology adoption and Mann Whitney U test was used to explore the impact of technology adoption on farmers' wellbeing.

Results and Discussion

Factors affecting the adoption of post-harvest technologies by the farmers

Omnibus test for the model coefficients

According to the omnibus tests for the model coefficient showed a parameter estimate value of 0.000 and it is greater than the 0.05 significant level. Hence, the model is a good fit (Table 1).

Table 1. Omnibus results for the model coefficients.

	Chi square	df	Sig
Step	20.274	4	.000
Block	20.274	4	.000
Model	20.274	4	.000

Hypothesis

H0 – The internet accessibility, credit accessibility, the cost for machinery, farm income, receiving training, farming experience, and distance to the market center do not affect the technology adoption.

H1–The internet accessibility affects technology adoption, H2 – The credit accessibility affects technology adoption, H3 – The cost of machinery has an effect on technology adoption, H4 - The farm income has an effect on technology adoption, H5 - Receiving of training has an effect on technology adoption, H6 - The farm experience has an effect on technology adoption, H7- The distance to the market has an effect on technology adoption.

According to the binary logistic Regression results, the farm income, receiving training, and farming experience are not significant at α=0.05. The internet accessibility, credit accessibility, cost of production, and the distance to the marketplace are significant at α=0.05 level (Table 2). Therefore, we can reject the null hypothesis and accept the alternative hypothesis.

Table 2. Model test results of the logistic regression

	B	S. E	Wald	df	Sig	Exp(B)
(Intercept)	0.910	1.9940	0.208	1	.648	
Institutional factors						
Internet accessibility	4.275	1.822	5.508	1	.019	71.903
Credit accessibility	5.874	2.245	6.846	1	.009	355.701
Receive training	-0.355	1.469	.058	1	.809	.701
Economic factors						
Cost of production	0.000	.000	5.959	1	.015	1.000
Farm income	0.000	.000	.295	1	.587	1.000
Distance to marketplace	0.112	.056	.122	1	.726	1.023
Social factors						
Farm experience	0.023	.065	.122	1	.726	1.023
Constant	-8.907	2.928	9.257	1	.002	.000

According to (Table 2), internet accessibility was found to be a positively significant factor at 5% significance level. One unit increment of being a person with internet accessibility increases the technology adoption by 4.275. So, the odds of adopting technology for those who have an internet connection is e4.275=71.903 times the odds of adopting technology for those who don't have an internet connection. This is because farmers who have internet accessibility get the latest updates related to the new PhPTs, and their adoption rates are higher.

The model's coefficient for credit accessibility was positive and significant. One unit increment of being a person with credit accessibility increases the probability of technology adoption by 5.874. So, the odds of adopting technology for those who have credit accessibility is 355.701 times the odds of adopting technology for those who don't have credit accessibility. When farmers have more credit accessibility, they are more financially stable. Therefore, they would like to invest more in new technologies and adapt to those technologies. Findings of Bright (2017) revealed that credit accessibility has a positive impact on the adoption of, innovative agricultural practices to increase food safety. This result was supported by various researchers, such as Tadesse and Degu (2001) and Beshir *et al*. (2012). They found that the farmer's decision to use new technologies increases with the increase of credit accessibility.

The model's coefficient for the cost of production (COP) is positively significant. When increasing one unit of cost for machinery, the log odds of adopting the technology increase by 0.000 when other variables are at a constant level. This is because, when farm households adopt the technology, their cost of production increases as the machinery costs are higher. However, farmers are aware of this phenomenon. Another reason is, that the farmers believe that the machinery costs are fair, even though it increases the cost of production, they can get higher benefits by adapting to technologies. Moreover, as most of the technology adopters are educated in this sample, they can properly understand these financial concepts. This was also stated in the study done by Challa *et al*. (2014) in west wollega for technology adoption.

The distance to the market center was also positively significant for technology adoption. When increasing one unit of distance to the market center, the log odds of adopting the technology increase by 0.112 while other variables are at a constant mean. Technology adopted farmers sell their large quantities of processed pepper to the market, where they can get a higher price without thinking about the distance to the marketplace. Even though, it is a higher distance they carry their products to those markets. They mostly consider about the income they receive

other than thinking about the distance. Karugia (2003) found a positive correlation between distance to the market and the adoption of new technologies.

Impact of technology adoption on the farmers' wellbeing.

Hypothesis

H0–There is no difference in the income level or consumption expenditure between adopters and non-adopters, H1- There is a difference in the income level between adopters and non-adopters, H2- There is a difference in the consumption expenditure between adopters and non-adopters.

Table 3. Mann Whitney U test results.

Independent variable		Mean rank	Asymptotic sig	Tested hypothesis result
Farm income	Adopters	61.38	0.000	Reject the null
	Non adopters	40.85		
Consumption expenditure	Adopters	65.84	0.000	Reject the null
	Non adopters	36.90		

According to (Table 3), both the income level and consumption expenditures were significant and can reject the null hypothesis. Therefore, can conclude that there is a difference in income and consumption expenditures between both groups. The mean rank for income level (61.38) is higher in adopters than non-adopters. The consumption expenditure (65.84) was higher in adopters than non-adopters. This means that they can spend more money on essential needs like children's education, food, health, and insurance and thereby enhancing food security and alleviating poverty. Therefore, technology adopters' well-being was positively impacted with the use of new technology for their pepper production purposes. Bokusheva *et al*. (2012) also found that technology adoption has a positive impact on farmers' livelihood.

Conclusion

Institutional factors; Credit and internet accessibility and the economic factors; cost of production, and distance to the market were affected the technology adoption decision. None of the social factors affected for the adoption decision. All those factors positively affected the technology adoption. As the mean ranks for the income levels and consumption expenditures were higher in adopters, technology adoption had created a positive impact on their livelihood than the non-adopters. Finally, it can be concluded that the introduction of PhPT for the farmer households is very effective and created a positive impact on the farmers' wellbeing. Hence, the efforts taken by the DEA to enhance pepper farmers' well-being with the introduction of PhPT is a successful effort in the Kegalle district. Strategies should be taken in order to popularize those technologies among the farmers than present, by considering the above affected institutional and social factors. The findings of this study would be important for the decision-makers to make strategies to increase the rate of technology diffusion among the farmers. Future research can be conducted to investigate how pepper quality is impacted by the use of modern technologies at different post-harvest stages of pepper.

References

Beshir, H., Emana, B., Kassa, B. and Haji, J. (2012). Determinants of chemical fertilizer technology adoption in North eastern highlands of Ethiopia: the double hurdle approach. *Journal of Research in Economics and International Finance*, 1(2), pp.39-49.

Bokusheva, R., Finger, R., Fischler,M., Berlin,R., Marín,Y., Pérez,F. and Paiz,F. (2012).

'Factors determining the adoption and impact of a postharvest storage technology', *Food Security*, 4, pp. 279–293. DOI: 10.1007/s12571-012-0184-1.

Challa, M. and Tilahun, U. (2014). 'Determinants and Impacts of Modern Agricultural Technology Adoption in West Wollega : The Case of Gulliso District', *Journal of Biology, Agriculture and Healthcare*, 4(20), pp. 63–78.

Tadesse, M. and Degu, G. (2001). 'Review of on-farm research and adoption studies on maize in Southern Ethiopia', In Proceedings of the second national maize workshop of Ethiopia, pp. 137-143.

Wongnaa, C., Awuniyo vitor, D. and Bakang, J. (2018). Factors affecting adoption of maize production technologies : A Study in Ghana.', *The Journal of Agricultural Sciences*, 13(1), pp. 81–99.

LIVESTOCK, FISHERIES AND AQUACULTURE

EFFECT OF STOCKING DENSITY OF ALL-MALE NILE TILAPIA (*Oreochromis niloticus*) ON INTEGRATED RICE PRODUCTION: *Oryza sativa L.* (AT362)

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Abstract

The present study designed was to investigate the impact of the stocking density of fish on the production of both rice using *Oryza sativa* L. (AT 362) and *Oreochromis niloticus*. According to the stocking density of fish, there were four treatments. Stocking density of fish in T1, T2 and T3 were 30, 60 and 90 per 4 m^2 rice plot respectively while T4 was the control treatment only with rice plot. Each treatment with three replicates was randomly allocated into twelve experimental plots (4 × 4 m^2) using a completely randomized block design. 14 days old paddy plants were planted in the space of 25 cm x 25 cm. The initial weight and length of fish were 10.87g and 8.65 cm respectively. Fish were fed using a commercial diet at 2% body weight per day and the experiment was lasted for 105 days. Plant height was measured every 14 days, while manual weeding was done at same intervals. At the end of the experiment, all fish were harvested and their body weight and the length were recorded. Plant height, number of leaves per plant, number of panicles, root biomass, area of the roots and the chlorophyll content of leaves were measured. All growth parameters of the plants cultured with fish (T1-T3) were significantly higher than those of the control. The highest root length was similarly found in T1 and T2 followed by T3 and control respectively. There was a significant difference (p<0.05) in the root diameter of plants, where T3 (*O. niloticus*+90 fish) exhibited the highest value. The fish integration significantly improved the total biomass of rice while the 1000 grain weight (p<0.05) was significantly higher in integrated treatments than that of the control. The highest and the lowest number of tillers, panicles, and grain yield were observed (p<0.05) in the high density integration and the control respectively. A similar trend was observed for the root area diameter. The available space and feeding behaviour of tilapia could explain the increased root area diameter, which ultimately increased the nutrient uptake and, consequently, a higher yield. Compared to the control treatment, the average final length (16.63 cm) and weight (124.73 g) of fish were significantly improved with rice integration. The highest survival rate of fish among treatments was observed in 30 stocking density (83.33±0.96). In conclusion, it can be recommended to integrate *O. sativa* (AT362) with Nile tilapia (*O. niloticus*) at 2 fish/m^2 stocking density in terms of fish and paddy harvest.

Keywords: All-male tilapia, growth, rice-fish integration, stocking density, yield

Introduction

In the last few decades, agricultural research and modern technology developments have led to integrated farming being implemented to not only enhance the productivity per acre, but to maximize land use in such a way to ensure sustainability of food production to meet the growing demands created by an increase in global population. Due to the indiscriminate and

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erratic use of chemical pesticides and fertilizers in the past, our food and ecosystems have been poisoned. This challenge is further exacerbated by a combination of factors including soil system degradation, climate change, and dietary shifts (Tai *et al*., 2014). Rice fish integration is one of the best approaches to solve these problems (Ahmed *et al*., 2019). It increases the amount of animal proteins in the diet of the rural inhabitants, thereby improving their nutrition and increasing the returns per unit of land area, giving farmers a high disposable income (Thilsted *et al*., 2016). This approach is an eco-friendly system since less fertilizer usage where both rice and fish benefit from each other. For instance, fish excretion contains high nitrogen level, and metabolic ammonia provides the nitrogen requirement of paddy while fish consume some aquatic invertebrates such as worm larval stages of insects and act as biological pest control agents. Thus, this integration is an ecologically and economically sound method to control certain pests (Frei and Becker, 2005).

The traditional way of cultivating paddy in Sri Lanka is highly inefficient regarding water use, as it uses more than 80% of the freshwater consumed. Therefore, increasing the water use efficiency in paddy cultivation has become a must in Sri Lanka. The integration of rice fields with table fish increases the water use efficiency by producing both fish and rice simultaneously. Although rice-fish integration is a common farming practice in many Asian countries. Finding shows Effects of stocking density on the growth, production, and economics of all-male tilapia were investigated in a rain-fed rice-fish ecosystem for a period of 120 days. Fish were stocked at the rate of 4000, 5000, and 6000 ha−1 in treatments T1, T2, and T3, respectively in Bangladesh (Billah *et al*., 2020; Mridha *et al*., 2014).Thus, its potential applicability in the Sri Lankan context is largely unknown. To fill this information gap, the present study was designed to find the effects of stocking density of all-male tilapia fish on rice production in Sri Lanka.

Materials and Method

Oryza sativa (AT362) was selected as experimental plant, and tilapia (*Oreochromis niloticus*) was chosen as experimental fish species. The initial average weight and length of fish were measured when introduce them into plots which were 10.87 g and 8.65 cm respectively. Fish were fed twice per day. There were four treatments according to available fish species in different stocking densities (SD) as T1: Paddy + 30 tilapia, T2: Paddy + 60 tilapia, T3: Paddy + 90 tilapia and T4: (only paddy). Each treatment with three replications was randomly allocated into twelve (4×3) experimental plots (4×4 m^2) in a complete randomized block design (RCBD).

Each experimental plot consists of a middle area (3×3 m^2) for paddy while a water canal totally surrounded this paddy culturing area. This water canal provides habitat for fish. The entire experimental area was totally netted using a mesh (2×2 cm^2) to avoid bird predation. For each plot, 121 (11×11) rice plants were planted (one seedling per hill) keeping a 25 cm distance in between. Fish were acclimatized for two weeks before introduce to the experimental plots.

Measurements

Initial total weights of fish were measured for the fish species. After that, fish total weights were measured every two weeks using a randomly caught ten fish sample. At the end of the experiment, fish survival [Survival % = (Fish harvested nos. / Fish stocked nos.) × 100] and feed conversion ratio (F.C.R. = Feed given / fish weight gain) were calculated. In paddy plants, plant height, number of leaves, and number of tillers, while the number of panicles and total rice yield were measured at the end of the experiment. The amount of chlorophyll present in the extract was calculated on the basis of microgram of chlorophyll present in a milligram of leaf tissue sample using the following equations:

$C_a = 15.65A_{666} - 7.34A_{653}$ $C_b = 27.05A_{653} - 11.21\ A_{666}$

Where, A – Absorption, C_a - Chlorophyll a (µg mg- 1), C_b - Chlorophyll b (µg mg- 1)

Water quality parameters including nutrients (NO_3^-, and NH_4) were measured every two-week interval. Water nitrate level was measured using nitrate probe (Hi7609829-12, Hanna) and water ammonium level was measured using ammonium probe (Hi7609829-10, Hanna) in mg/L.

All statistical analyses were conducted using the Analysis of Variance (SAS 9.1).

Results and Discussion

Fish weight, survival rate and feed conversion ratio

At the end of the experiment, total weight of *O. niloticus* was significantly (p<0.05) higher in T1 (paddy + 30 tilapia). The lowest survival rate was found in *O. niloticus* reared in the highest stoking density (paddy + 90 tilapia) where the highest survival rate of fish (83.3%) was observed in rice integration with lowest fish stocking density (paddy + 30 tilapia) at p<0.05 significant level. There were significant (p<0.05) differences between treatments in the FCR of fish in the rice-fish co-culture during harvesting. The highest FCR was identified in the highest stocking density (2.57) and the lowest was observed in the lowest stocking density as 1.25.

Water quality

There were significant (p<0.05) differences between treatments in the dissolved Nitrate levels during the experimental period. The highest nitrate level was indicated in treatment one (0.63 mg/L) and which was followed by 0.61 mg/L in treatment two and 0.60 mg/L in treatment three consecutively.

Plant growth and rice production

At the end of the experiment, the number of leaves/m^2 and plant height (cm) were significantly increase (p>0.05) in paddy integrated with *O. niloticus* where the lowest were recorded in control for number of leaves and plant height. The chlorophyll *a* and *b* content of flag leaf was observed and it has significantly increase in paddy integrated with *O. niloticus* than rice monoculture (control).

Table 1: Effects of stocking densities of *Oreochromis niloticus* on paddy growth and yield parameters in the integrated rice-fish farming system.

	Plant height (cm)	Total biomass Mt/ha	1000 grain weight (g)	Root diameter	Paddy yield (Mt/ha)
T1	98.56 ± 0.01^a	16.29 ± 0.04^a	24.80 ± 0.13^a	31.40 ± 0.16^c	6.38 ± 0.03^c
T2	98.55 ± 0.03^a	16.60 ± 0.06^a	25.20 ± 0.14^a	33.67 ± 0.06^b	6.49 ± 0.10^b
T3	98.03 ± 0.02^a	17.20 ± 0.18^a	25.50 ± 0.10^a	35.67 ± 0.39^a	6.58 ± 0.12^a
T4	77.50 ± 0.01^b	13.29 ± 0.17^b	22.77 ± 0.20^c	25.60 ± 0.22^d	4.54 ± 0.16^d

The plant root diameter with *O. niloticus* integration was significantly improved than paddy with no fish. The highest root diameter was observed in plots integrated 90 fish. But no significant variation was observed in the total biomass of paddy plants in integrated treatments. Plants grown with *O. niloticus* showed the higher 1000 grain weight, and the lowest showed control treatment. It was found that there were significant (p<0.05) differences between treatments in the rice yield. The highest grain yield was identified in rice + 90 tilapia followed by rice + 60 tilapia and rice + 30 tilapia consecutively. The lowest was observed in control.

Discussion

According to this study, plant height, total biomass, number of tillers, 1000 grain weight and rice yield were significantly increased in paddy in the integration of fish with rice. This might be due to fertilizing effect from the fish excrement probably increased rice yield in this study. Moreover, fish movement of the soil-water interface may lead to a release of fixed nutrients from soil to water and make the soil porous for nutrients readily absorbed by the rice roots. Further, the estimated rice productions of the present study are acceptable as those estimations are within the production ranges published in the literature (Frei and Becker 2005).

The growth of tilapia (*O. niloticus*) depends on the stocking density, food quality, energy content, physiological status, reproductive state and environmental factors such as temperature, pH, etc. This study showed a significant difference in weight (P<0.05) with increasing stocking density in all treatments. The highest fish weight was recorded in rice integrated with 30 Tilapia (124.73g) which was followed by paddy integrated with 60 Tilapia (95.47g) and paddy integrated with 90 Tilapia (68.5gWhen stocking density increases definitely leads to hypoxia this also significantly impact the growth in each treatment. In this study, the food conversion ratio increased significantly (P<0.05). The highest FCR was indicated in rice integrated with 90 stocking density (2.57). Even though the FCR values of rice integrated with 60 stocking density and rice integrated with 30 stokcing density remained same. This may be influenced by the less competition for resources between *O. niloticus* and available space. It was precise the growth of tilapia in 60 tilapia and 90 tilapia drastically dropped. The food conversion ratio trend that was seen in this experiment is in agreement with that obtained by Billah *et al*., 2020; Mridha *et al*., 2014. There were no mass fish deaths except a few natural predations of herons and water snakes during the experimental period. Therefore, the observed mortality in all treatments was natural. However, the observed survival rates are comparable to the previous studies (Frei *et al*., 2007; Mirhaj *et al*., 2013). The experimental site is a plain open space with the comparatively higher wind.

Conclusion

It was concluded that the integration of *O. sativa* (AT362) in 30 stocking density of all-male Nile tilapia (*O. niloticus*) per 4 m^2 is suitable to increase the paddy yield in rice fish integration system.

References

Ahmed, N., Thompson, S. and Glaser, M. (2019). Global Aquaculture Productivity, Environmental Sustainability, and Climate Change Adaptability. *Environmental Management*, *63*(2), 159–172.

Billah, M. K., Uddin, M. K., Samad, M. Y. A., Hassan, M. Z. Bin, Anwar, M. P., Kamal, A. H. M., Shahjahan, M. and Al-Asif, A. (2020). Effects of different stocking density of nile tilapia (Oreochromis niloticus) and common carp (cyprinus carpio) on the growth performance and rice yield in rice-fish farming system. *AACL Bioflux*, *13*(2), 789–803.

Mridha, M. A. R., Hossain, M. A., Azad Shah, A. K. M., Uddin, M. S. and Nahiduzzaman, M. (2014). Effects of Stocking Density on Production and Economics of All-Male Tilapia (Oreochromis niloticus) Culture in a Rain Fed Rice-Fish Ecosystem. *Journal of Applied Aquaculture*, *26*(1), 60–70.

Berg, H., Berg, C. and Nguyen, T. T. (2012). Integrated Rice-Fish Farming: Safeguarding Biodiversity and Ecosystem Services for Sustainable Food Production in the Mekong Delta. *Journal of Sustainable Agriculture*, *36*(8), 859–872.

Frei, M., M. A. Razzak, M. M. Hossain, M. Oehme, S. Dewan and Becker, K. (2007). Performance of common carp, *Cyprinus carpio* L. and Nile tilapia, Oreochromis niloticus (L.) in integrated rice–fish culture in Bangladesh. *Aquaculture* 262(2):250-259.

Frei, M. and K. Becker, (2005). Integrated rice-fish culture: Coupled production saves resources. *Natural Resources Forum* 29(2):135-143.

Gibtan, A., Getahun, A. and Mengistou, S. (2008). Effect of stocking density on the growth performance and yield of Nile tilapia [Oreochromis niloticus (L., 1758)] in a cage culture system in Lake Kuriftu, Ethiopia. *Aquaculture Research*, *39*(13), 1450–1460.

Mirhaj, M., A. Boit, M. A. Razzak and M. A. Wahab, (2013). Yield performance comparison between cultures of rice cum prawn (Macrobrachium rosenbergii) and rice cum fish (Cyprinus carpio, Oreochromis niloticus) in North-Eastern Bangladesh. *Aquaculture* 392-395:26-33

Tai, A. P. K., Martin, M. V. and Heald, C. L. (2014). Threat to future global food security from climate change and ozone air pollution. *Nature Climate Change*, *4*(9), 817–821.

Thilsted, S. H., Thorne-Lyman, A., Webb, P., Bogard, J. R., Subasinghe, R., Phillips, M. J., and Allison, E. H. (2016). Sustaining healthy diets: The role of capture fisheries and aquaculture for improving nutrition in the post-2015 era. *Food Policy*, *61*, 126–131.

PRODUCTIVITY OF RED NAPIER (*Pennisetum purpureum cross*) GRASS WITH THE APPLICATION OF DIFFERENT KINDS OF ORGANIC MANURE IN EUSL LIVESTOCK FARM-BATTICALOA

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Abstract

The cultivation of higher-quality forage that appropriate for the various agro-climatic conditions of the country could significantly improve the feeding standard of ruminants. An experiment was carried out to assess the growth parameters, yield, and chemical composition of Red Napier (*Pennisetum purpureum cross*) treated with organic manure of different origin. The experiment was conducted from July to November 2022 at the Livestock farm, Faculty of Agriculture, Eastern University, Sri Lanka. Completely Randomized Design (CRD) was used with five treatments including cattle manure (T_1), goat manure (T_2), poultry manure (T_3), compost (T_4) and control (T_0). Each treatment was replicated three times. Fifteen 3m×3m plots (each plot contained 25 cuttings) were used for the establishment of Red Napier cuttings. The data for growth parameters [plant height (H) cm, leaf length (LL) cm, leaf width (LW) cm, number of leaves (NL), and number of tillers (NT), dry matter yield (DMY) kg/ha] and proximate analysis at 60 days and 90 days after planting were collected and were analyzed by using one-way ANOVA. The means were separated by the Tukey test at a 0.05 significance level. Application of poultry manure (T_3) showed the overall best performance for DMY, H, NL, NT, LL, LW and also for crude fiber (%) at 60 days and 90 days of harvesting as 3435;1551 kg/ha, 125.1; 54.93 cm, 125.17; 103.2, 10.33; 13.67, 103.56; 89.5 cm, 5.52;3.18 cm and 62.22; 59.33 %, respectively. Conclusively, Red Napier grass cultivated with poultry manure showed the best performance in EUSL livestock farm, Batticaloa.

Keywords: Growth parameters, Manure, Organic, Proximate analysis, Red Napier

Introduction

The main forage sources in the Batticaloa area are paddy straw, cassava leaves and stems, seasonal weeds, banana waste, and road side grazing. And also, a variety of Napier hybrids, among other high-yielding forages, have recently been introduced (Premaratne and Premalal, 2006). Even though the red Napier (*Pennisetum purpureum cross*) is still not much popular in Sri Lanka as a Napier hybrid, it is widely used as a livestock feed in many countries (Zailan *et al.,* 2016; Haryani *et al.,* 2018; Osman & Yunus, 2020). By applying bio fertilizers and farmyard manure, significant efforts have been made to reduce the use of fertilizer in field crops (Harris *et al.,* 2010). Concomitantly, this can reduce the production cost of high yielding forage cultivations. Manure produced by livestock activity is a capable of causing serious environmental pollution. Agronomic management practices on the use of manure may transform the target from a waste to a resource product. Therefore, the present study mainly focused on the evaluation of the performance of Red Napier with different kind of organic manure; to identify the most appropriate organic manure for a higher productivity of Red Napier and to analyze the growth and chemical component of Red Napier grasses cultivated with different organic manure.

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Materials and Methods

The present study was conducted in the livestock farm, Faculty of Agriculture, Eastern University, Sri Lanka from July to December 2022. The field experiment was carried out according to the completely randomized design (CRD) with five treatments such as cattle manure (T_1), goat manure (T_2), poultry manure (T_3), compost (T_4) and the control (T_0)). Each treatment was replicated three times. There were fifteen 3m×3m plots were prepared and added the farm yard manure (Goat manure, cow dung, poultry manure was about 5.4 kg/plot for all, respectively) and compost (13.5 kg/plot) according to the experimental layout. The fertilizer applications were done according to the calculations by using the standard fertilizer recommendations (Isamail *et al*., 2018). The uniform cuttings (length: 15 cm, diameter: 2 cm, nodes: 2) were obtained from Department of Animal Production & Health, Goat Breeding & Fodder Resource Center in Sathurukondan, Batticaloa. The cuttings were assigned just after land preparation according to the line method, keeping one node under the soil and maintaining 60 cm×60 cm distance between row-to-row and plant-to-plant spacing (each plots contained 25 cuttings). Irrigation was done similarly once it necessary for each plot and weeding was done in once every two weeks. After 60 days of planting, green fodder was manually harvested from each plot, 5–6 cm above the ground as the first harvesting and the second harvest was obtained after 90 days of planting. The samples were examined for dry matter Content (DM), moisture content (MC), crude fiber (CF), ether extract (EE), crude protein (CP), nitrogen free extract (NFE) and Ash according to the procedures described in (AOAC, 2005). The collected data were statistically analyzed using the one-way "Analysis of Variance" (ANOVA). The Tukey Test was used to determine the significance of mean differences between the treatments. All the analysis were done by using Minitab version 17.

Results and Discussion

The growth parameters and yield of the Red Napier grass at 60 days and 90 days of harvesting were elaborated in Table 1. Significantly a higher mean values were observed for DM, H, NL, NT, LL and LW, respectively from the plots treated with poultry manure (T_3) after 60 days and 90 days of planting ($p < 0.05$) while the lowest values were obtained from the control treatment where we didn't apply any organic manure.

Table 1: The growth parameters and the dry matter yield of Red Napier grass at 60 days and 90 days of harvesting

Attribute	T_0		T_1		T_2		T_3		T_4	
	After 60 days	After 90 days	After 60 days	After 90 days	After 60 days	After 90 days	After 60 days	After 90 days	After 60 days	After 90 days
DMY (kg/ha)	714± 136^{b}	391± 130^{b}	1012± 339^{b}	586± 269^{b}	1308± 426^{b}	625± 211^{b}	3435± 391^{a}	1551± 167^{a}	1005.8± 66.8^{b}	495± 182^{b}
H (cm)	68.85± 3.58^{b}	24.87± 2.78^{c}	83.39± 3.40^{b}	30.16± 4.29^{bc}	100.38± 7.29^{ab}	44.51± 1.23^{ab}	125.1± 11.5^{a}	54.93± 2.53^{a}	80.52± 4.83^{b}	33.85± 5.25^{bc}
NL	34.58± 5.67^{c}	34± 3.75^{a}	35.3± 10.9^{c}	52.9± 14.7^{a}	89± 16.4^{ab}	101.83± 5.07^{a}	125.17± 7.72^{a}	103.2± 37.5^{a}	46.83± 8.05^{bc}	53.42± 3.23^{a}
NT	2.833± 0.44^{b}	9± 0.433^{a}	3.333± 0.682^{b}	10± 3.83^{a}	2.75± 0.289^{b}	9± 2.43^{a}	10.33± 2.05^{a}	13.67± 4.59^{a}	3.917± 0.917^{b}	11.5± 2.47^{a}
LL (cm)	71.68± 4.76^{b}	46.94± 0.77^{c}	78.13± 3.66^{ab}	51.308± 0.853^{c}	95.55± 1.81^{ab}	61.85± 1.96^{b}	103.56± 9.76^{a}	89.5± 0.65^{a}	72.95± 4.06^{b}	51.6± 3.88^{c}
LW (cm)	3.57 ± 0.10^{b}	1.61± 0.15^{b}	4.058± 0.19^{b}	1.8± 0.05^{b}	4.275± 0.48^{ab}	2± 0.05^{b}	5.52± 0.27^{a}	3.18± 0.14^{a}	3.633± 0.14^{b}	1.692± 0.15^{b}

Means with different superscripts in the same row are significantly different ($p<0.05$). T_1=Cattle manure, T_2= Goat manure, T_3= Poultry manure, T_4=Compost, T_0=Control. DMY=Dry matter yield, H=Height, NL=Number of leaves, NT=Number of tillers, LL=Leaf length, LW=Leaf width.

This was confirmed by Tagoe *et al.,* (2008), who reported that the poultry manure is a good source of mineral such as Nitrogen, Phosphorus, Potassium, Calcium, Magnesium, Sulfur, Manganese, Copper, Zinc, Chlorine, Boron, Ferrous, and even Molybdenum. And also, the improvement in growth parameters like the plant height and the number of tillers with maturity enhanced the fodder yield and this finding is an agreement with the findings reported by Imran *et al.,* (2007).

The proximate analysis results of Red Napier grass with applications of organic manure of different origin were represented in Table 2. Dry matter was significantly higher in red Napier cultivated with poultry manure at the 1st and the 2nd harvests, whereas the lowest values were obtained for the control treatment among all treatments ($p < 0.05$). Even though Islam *et al.* (2003) observed that average DM of red Napier was around 20 %, the present results were quite lower than their reported value. But the red Napier cultivated under poultry manure showed 16.11 and 22.29 % DM content during the 1st and the 2nd harvest, respectively and it was more or less similar with the previous findings (Islam *et al.,* 2003). Furthermore, Manyawu *et al.* (2003) reported that the DM increased in a progressively linear manner, with the age of Napier grass. This was in a close agreement with the previous findings of Haryani *et al.* (2018) who found that the dry matter of Napier grass increases with the increment of the cutting interval.

Table 2: The proximate composition of Red Napier grass at 60 days and 90 days of harvesting

Attribute	T_0		T_1		T_2		T_3		T_4	
	After 60 days	After 90 days	After 60 days	After 90 days	After 60 days	After 90 days	After 60 days	After 90 days	After 60 days	After 90 days
DM (%)	11.75± 0.83^{b}	10.77± 0.09^{b}	12.35± 0.62^{ab}	11.44± 0.31^{b}	13.55± 1.14^{ab}	14.39± 1.07^{b}	16.11± 0.94^{a}	22.29± 2.11^{a}	12.00± 0.32^{b}	10.91± 0.48^{b}
CP (%)	8.11± 1.55^{a}	3.92± 0.75^{a}	8.14± 1.51^{a}	5.13± 0.69^{a}	8.60± 0.56^{a}	6.62± 0.93^{a}	8.31± 1.43^{a}	6.33± 2.03^{a}	8.4± 0.22^{a}	5.96± 0.96^{a}
CF (%)	38.33± 2.85^{b}	44± 1.73^{b}	35.56± 4.58^{b}	40.33± 0.667^{b}	49.11± 3.8^{ab}	40.33± 2.6^{b}	62.22± 4.93^{a}	59.33± 4.67^{a}	41.5± 1.26^{b}	47± 2.08^{ab}
EE (%)	2±0^{ab}	1.33± 0.33^{a}	1.33± 0.33^{b}	2.33± 0.88^{a}	1±0^{b}	2.33± 0.33^{a}	3.33± 0.67^{a}	1.333± 0.67^{a}	1.67± 0.33^{ab}	2± 0.58^{a}
NFE (%)	16.22± 3.01^{a}	25.75± 0.57^{a}	18.97± 3.73^{a}	26.20± 1.46^{a}	19.62± 3.78^{a}	27.05± 3.76^{a}	19.8± 6.65^{a}	27.67± 3.42^{a}	18.77± 1.87^{a}	26.7± 2.4^{a}
Ash (%)	35.33± 0.88^{a}	25± 0.58^{a}	36± 0.58^{a}	26± 1.15^{a}	21.67± 2.03^{b}	23.67± 1.76^{a}	6.33± 0.88^{c}	5.33± 0.67^{c}	29.67± 3.48^{ab}	18.33± 0.33^{b}

Means with different superscripts in the same row are significantly different ($p<0.05$). T_1=Cattle manure, T_2= Goat manure, T_3= Poultry manure, T_4=Compost, T_0=Control. DM=Dry matter, CP=Crude protein, CF=Crude fiber, EE=Ether extract, NFE= Nitrogen free extract.

The CF content was markedly higher in red Napier cultivated with poultry manure during the 1st and 2nd harvests, respectively, even though the CP, NFE contents were not much significantly different among the treatments ($p> 0.05$) but significantly different showed in Ash and EE ($p<0.05$). This was aligned with the findings of Tsegaye, (2021) who revealed that neutral detergent fiber (NDF), acid detergent fiber (ADF) and Acid detergent lignin (ADL) increased with advancing harvesting days (60<90<120days). An increase in the rate of N fertilization will increase the content of CP of Napier grass, although the same effect does not occur with P and K (Pieterse *et al.,* 2002). Moreover, the present study found that the ash content was decreased during the second harvest compared to first harvest in most treatments (without T_2). This was more or less similar with the findings of Lounglawan *et al.,* (2014) who reported that the ash content could decrease as the cutting interval increased. Similarly, Ansah

et al., (2010) reported that the application of animal manures to grasses can improve the mineral contents of soil thereby improves nutrient uptake of plant especially at early harvesting stage.

Conclusions

Conclusively, the use of organic manure significantly affects on the plant height, leaf length, leaf width, number of tillers and number of leaves as well as the dry matter yield of Red Napier grass. Elaborately, this study showed that the application of poultry manure represented the best performance for Red Napier either in growth and chemical composition compared with the other organic manures tested. Furthermore, the present study proved that the organic manure can be effectively used in forage cultivation despite of using inorganic fertilizers which is recently very expensive for small-scale and commercial dairy farmers.

References

Ansah, T., Osafo, E. and Hansen, H. (2010) 'Herbage yield and chemical composition of four varieties of Napier (*Pennisetum purpureum*) grass harvested at three different days after planting', *Agriculture and Biology Journal of North America*, 1(5), pp. 923–929. Available at: https://doi.org/10.5251/abjna.2010.1.5.923.929

AOAC. (2005). Official method of analysis.18th Edition, Association of Analytical Chemists, Gaters burg, M.D.; USA

Harris, K., Anderson, W. and Malik, R. (2010) 'Genetic relationships among Napier grass (*Pennisetum purpureum Schum.*) nursery accessions using AFLP markers', Plant Genetic Resources: Characterization and Utilization, 8(1), 63–70. Available at: https://doi.org/10.1017/S1479262109990165

Haryani H, Norlindawati A P, Norfadzrin F, And, A. A., & Azman A. (2018). Yield and Nutritive Values of Six Napier (*Pennisetum Purpureum*) Cultivars At Different Cutting Age. *Malaysian Journal of Veterinary Research*, *9*(2), 6–12.

Imran, M., Khan, S., Khalid, R., Gurmani, Z. A., Bakhsh, A. (2007) 'Performance of different millet cultivars for fodder production under rainfed condition of Islamabad', *Sarhad Journal of Agriculture*, 23(2), p. 4.

Islam, M. R., Saha, C. K., Sarker, N. R., Jalil, M. A., Hasanuzzaman, M. (2003) 'Effect of variety on proportion of botanical fractions and nutritive value of different napiergrass (*Pennisetum purpureum*) and relationship between botanical fractions and nutritive value', *Asian-Australasian Journal of Animal Sciences*, 16(6), 837–842. Available at: https://doi.org/10.5713/ajas.2003.837

Lounglawan, P., Lounglawan, W. and Suksombat, W. (2014a) 'Effect of Cutting Interval and Cutting Height on Yield and Chemical Composition of King Napier Grass (*Pennisetum Purpureum x Pennisetum Americanum*)', *APCBEE Procedia*, 8(Caas 2013), 27–31. Available at: https://doi.org/10.1016/j.apcbee.2014.01.075

Manyawu, G.J., Chakoma, C., Sibanda, S., Mutisi, C., Chakoma, I.C. (2003) 'The effect of harvesting interval on herbage yield and nutritive value of Napier grass and hybrid Pennisetums', *Asian-Australasian Journal of Animal Sciences*, 16(7), pp. 996–1002. Available at: https://doi.org/10.5713/ajas.2003.996

Osman, A., & Yunus, A. A. (2020). Biomass Yield and Chemical Composition of Red Napier Grass Harvested At 3 Different Dates After Planting in the Forest Zone of Ghana. *Ghanaian Journal of Animal* Science.10(1). 154-165

Pieterse, P.A. and Rethman, N.F.G. (2002) 'The influence of nitrogen fertilisation and soil pH on the dry matter yield and forage quality of *Pennisetum purpureum* and *P. purpureum x P. glaucum* hybrids', *Tropical Grasslands*, 36(2), 83–89.

Premaratne, S. and Premalal, G.G.C. (2006) 'Hybrid Napier (*Pennisetum perpureum X Pennisetum americarnum*) VAR. CO-3: a resourceful fodder grass for dairy development in Sri Lanka', *Journal of Agricultural Sciences*, 2(1), p. 22. Available at: https://doi.org/10.4038/jas.v2i1.8110

Tagoe, S.O., Horiuchi, T. and Matsui, T. (2008) 'Effects of carbonized and dried chicken manures on the growth, yield, and N content of soybean', *Plant and Soil*, 306(1–2), pp. 211–220. Available at: https://doi.org/10.1007/s11104-008-9573-9

Tsegaye, T. (2021) 'Effects of cutting interval on morphological parameters, biomass yield and chemical composition of para (*Brachairia muticastapf*), Napier (*Pennisetum purpureum*) and Desho (*Pennisetum pedicellatum*) grasses grown under irrigation condition in mecha woreda, W', p. 62.

Zailan, M. Z., Yaakub, H., & Jusoh, S. (2016). Yield and nutritive value of four Napier (*Pennisetum purpureum*) cultivars at different harvesting ages. *Agriculture and Biology Journal of North America*, *7*(5), 213–219. https://doi.org/10.5251/abjna.2016.7.5.213.219

MILK AND DAIRY PRODUCTS CONSUMPTION PATTERN AND PREFERENCES IN THE KILINOCHCHI DISTRICT OF SRI LANKA

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Abstract

Current study was carried out in four divisional secretariats of Kilinochchi district to study the consumption pattern and preferences for milk and dairy products. Out of 45,016 households 1000 households were selected using table of random numbers. Information on consumption pattern and preferences for milk and dairy products by the consumers were collected using structured questionnaires. Data were processed using Microsoft Excel 2007 and analyzed using Proc frequency and Chi-square test. Overall around 38% of the households relied on their own source of milk for consumption; in the Kandavali and Poonagary divisional secretariats around 50% of the households relied on their own source of milk. Source of milk from cattle, goat and both averaged to around 76%, 8% and 16%, respectively. Overall consumption pattern of major milk and dairy products viz. was milk powder (26%), yoghurt (19%), fresh milk (15%), curd (14%), flavored milk (11%) and ghee (6%). Consumption level of other dairy products such as cheese, butter and milk toffee averaged to around 3%. Overall reasons for not taking milk for family consumption was do not like to drink milk (73%), insufficient income (20%) and fear of contamination (7%). Chi square test revealed significant association between milk and dairy products and preference order. Most of the households gave first preference for fresh milk (73%) and milk powder (68%) on a nine scale preference order. Most of the households showed a preference order of 2nd (52%) and 3rd (37%) for curd. Significant percentage of households showed preferences for yoghurt, pasteurized milk, cheese, butter, ghee and milk toffee. Fresh milk consumption percentage of 15% is not an appreciable figure; hence, measures should be taken to encourage households to take milk for family consumption as well. Consumption pattern trend of various dairy products will pave way for value addition to milk and generate employment opportunities in the dairy value chain in the study area.

Keywords: Consumption pattern, dairy product, fresh milk, Kilinochchi preferences

Introduction

Milk is said to be the most complete food item because of its great biological value as it contains a variety of nutrients and these nutrients in milk help make it nature's most nearly perfect food. Improving human nutrition plays an important role to achieve food security. Dairy products have a unique contribution to nutritional status as well as health status of the smallholder household members (Melesse and Beyene, 2009). Understanding the consumption pattern and preferences for milk and dairy products will identify bottlenecks that hinder growth of the dairy cattle products value chain and target specific measures for developing market opportunities for producers and processors and for meeting the demand for consumers.

In the Kilinochchi district milk and dairy product consumption pattern is not well understood. Hence the current study was conducted to study the milk and dairy product consumption pattern and preference for milk and dairy products by the households in the Kilinochchi district.

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Materials and Method

The study area

Present study was carried out in four divisional secretariat (DS) divisions of the Kilinochchi district viz. Karachchi, Kandawalai, Poonakary and Pachchilaipalli and contained 45016 households.

Sampling procedure

From the total number of GN divisions 50% of the GN divisions were randomly selected from each DS division and from each GN division 20% of the households were randomly selected. Total numbers of 1000 households were selected for the study through stratified random sampling procedure using Table of Random Numbers.

Questionnaire preparation

A structured questionnaire was designed to conduct cross sectional survey and prepared in such a manner to gather the needed information to fulfill the objectives of the study. Questionnaire included particulars in respect to milk and dairy products consumption pattern and preferences by the households in the Kilinochchi district.

Data collection

Personal interview was conducted with each household head to collect information with the aid of structured questionnaire. Data collection was done for a period of three months; November 2018 to January 2019.

Coding of data

Divisional secretary divisions of Kandawalai, Poonakary, Pachchilapalli and Karachchi were coded 1, 2, 3 and 4 respectively.

Milk consumption pattern

Consumers had source of milk within the household was categorized into 'yes' and 'no'. The sources of own sources of milk were categorized into three groups viz. 'cattle', 'goat' and 'both'. The major reasons for not consuming fresh milk were categorized into 'do not like to consume', 'insufficient income', and 'fear of contamination'.

Milk and dairy products consumption pattern and preferences

The products were categorized into twelve different groups raw milk, pasteurized milk, UHT milk, yoghurt, cheese, butter, curd, powdered milk, flavored milk (packet), flavored milk (cartons), milk toffee and ghee. Preferences for milk and dairy products were ranked on a scale of 1 to 9.

Data entering and statistical analysis

The information collected via questionnaire were fed on MS Excel 2007 spread sheet. Data were analyzed using Pro frequency and Chi-square test. The analysis was performed using SAS 9.1.3 (©2002-2003).

Results and Discussion

Consumption Pattern

Major dairy products consumed in the study area were milk powder, milk, yoghurt, curd, flavoured milk, cheese, butter, ghee and milk toffee (Table 1). Households consuming fresh milk in the study area were around 15%. Alwis *et al*. (2009) stated that fresh milk consumption has suffered ruthless competition from soft drinks and powdered milk. They further stated that huge campaigns to promote consumption of different brand names of powdered milk are another reason low level of fresh milk consumption. The major reason given for not consuming milk in the study area 'do not like to consume milk' (73%) is in agreement with the findings

of Lakmali and Abeynayake (2016) who stated consumer attitude is the major influential factor on decision making to purchase fresh milk.

Table 1: Consumption pattern, source of milk and preferences for milk and dairy products by divisional secretariat in the Kilinochchi district

	Kandawalai	Poonagary	Pachchilaipalli	Karachchi	Overall	X^2P value
Consumption pattern						
Products						
Fresh milk	14.93	18.83	16.32	13.21	15.01	<0.0001
Pasteurized milk	00.00	00.00	00.15	00.06	00.06	
UHT milk	00.56	02.25	00.00	00.00	00.46	
Yoghurt	19.40	20.03	17.79	18.40	18.71	
Cheese	02.05	00.35	03.24	04.78	03.32	
Butter	01.68	00.69	01.91	03.54	02.46	
Curd	14.55	13.64	16.76	13.09	14.12	
Powdered milk	26.68	27.98	21.47	26.71	25.90	
Flavoured milk	11.38	11.40	09.26	11.14	10.86	
Pasteurized flavoured milk	00.00	00.00	00.00	00.12	00.06	
Milk toffee	04.10	00.86	03.82	02.36	02.66	
Ghee	04.66	03.97	09.26	06.60	06.39	
Total	100	100	100	100	100	
Own Source of milk						
Yes	48.75	50.56	39.44	29.38	38.10	<0.0001
No	51.25	49.44	60.56	70.63	61.90	
Total	100	100	100	100	100	
Source of milk						
Cattle	75.64	70.33	84.51	74.47	75.59	0.0526
Goat	05.13	06.59	04.23	12.77	08.14	
Both	19.23	23.08	11.27	12.77	16.27	
Total	100	100	100	100	100	
Reason for not taking milk for family consumption						
Do not like to consume	83.33	71.43	00.00	70.00	73.33	0.5264
Insufficient income	16.67	14.29	100.00	20.00	20.00	
Fear of contamination	00.00	14.29	00.00	10.00	6.67	
Total	100	100	100	100	100	

Order of preferences and the consumption pattern indicates that households in the Kilinochchi district consume a variety of milk products in addition to raw milk (Table 2). Consumption and preferences for variety of dairy products indicate, there is a potential for value addition of milk in small, medium and large scale production which will not only enhance the nutritional status but also will pave way for generation of employment opportunities for the people in the Kilinochchi district and others in the value chain. Contradicting percentages between order of preference for fresh milk (71% -first rank) and its consumption percentage (15%) reveals that educating the farmers regarding the importance of fresh milk will increase the fresh milk consumption in the study area. Schmid (2006) emphasized fresh milk is the best milk from the nutritional stand point due to the availability of heat liable elements; in milk powder some of the elements are destroyed by heat.

Table 2: Households' preference for milk and dairy products by DS division in the Kilinochchi district (%)

Rank	1	2	3	4	5	6	7	8	9	X^2P value
Raw milk	71.37	19.27	04.58	01.53	01.72	01.15	00.19	00.19	00.00	<0.0001
Pasteurized milk	00.00	00.00	00.00	50.00	50.00	00.00	00.00	00.00	00.00	
UHT milk	00.00	18.75	56.25	12.50	12.50	00.00	00.00	00.00	00.00	
Yoghurt	00.77	31.70	34.15	23.43	07.96	01.53	00.46	00.00	00.00	
Cheese	00.00	07.76	10.34	34.48	28.45	12.07	06.03	00.86	00.00	
Butter	00.00	05.95	19.05	17.86	22.62	25.00	07.14	02.38	00.00	
Curd	00.20	52.14	37.27	06.11	02.85	01.22	00.20	00.00	00.00	
Powdered milk	68.29	26.19	03.31	01.99	00.11	00.11	00.00	00.00	00.00	
Flavoured milk	00.52	13.87	31.68	26.96	16.23	06.28	02.62	01.31	00.52	
Pasteurized flavoured milk	00.00	00.00	50.00	00.00	50.00	00.00	00.00	00.00	00.00	
Milk toffee	00.00	05.38	12.90	24.73	16.13	16.13	10.75	09.68	04.30	
Ghee	00.00	07.17	31.39	29.15	19.28	09.42	03.14	00.45	00.00	
Overall	28.65	25.55	20.08	13.12	07.22	03.38	01.29	00.54	00.17	

Conclusion

In the study area, percentage of households consuming powered milk exceeded fresh milk consumption. Households consume other dairy products too. There is a possibility to value addition to milk which will generate employment opportunities.

References

De Alwis, A.E.N, Edirisinghe, J.C. and Athauda, A.M.T.P. (2009). Analysis of factors affecting fresh milk consumption among the mid-country consumers, Tropical Agricultural Research and Extension 12(2). https://tare.sljol.info/articles/abstract/10.4038/tare.v12i2.2799/

Melesse, K. and Beyene, F. (2009). Consumption pattern of milk and milk products in Ada'a woreda, East Shoa Zone, central Ethiopia. *Livestock Research for Rural Development.* Volume 21, *Article #56.* Retrieved January 29, 2023, from http://www.lrrd.org/lrrd21/4/mele21056.htm

Lakmali, W.M.T.C. and Abeynayake, N.R. (2016**)**. *Dynamics of Consumer Behaviour and Consumer Perception on Fresh Milk Consumption: Case in Kandy District Sri Lanka*. Proceedings of 15th Agricultural Research Symposium, Wyamba University, Sri Lanka 6-10.

Schmid, N.D. (2006). The health benefits of raw milk from grass fed animals. http://www.realmilk.com/healthbenefits.html.

DETERMINATION OF TIME REQUIREMENT FOR GOOD QUALITY SILAGE PROCESSING UNDER DIFFERENT CONCENTRATION OF COMMERCIALLY AVAILABLE LACTIC ACID BACTERIA

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Abstract

Lactic acid bacteria (LAB) is responsible for silage fermentation while reducing the pH. The duration requires to silage making vary from 45 to 60 days, depending on the types of the material used. Reduction of this time duration by adding commercially available LAB is still under investigations. Therefore, the present study mainly aimed to determine the time requirement for good quality silage processing under different concentrations of commercially available LAB using different fodder, grass and combination of fodders and to identify the forage species that should produce good quality silage within a short period. The study was carried out at the Department of Animal Science, Faculty of Agriculture, Eastern University, Sri Lanka from July to December 2022. Two factor factorial design was used [Different LAB concentrations (0%, 25%, 50%, 75% and 100%) and forage type (Maize, CO3, and Super Napier, *Brachiaria brizantha*, Super Napier+ Maize) as factors]. Five treatments were replicated four times each. The minimum time duration required to prepare olive green colored silage was measured and just after obtaining the color of the samples in addition to the physical appraisal such as odor, texture and the presence or absence of molds. Samples were analyzed for chemical composition and pH contents. Graphical representations were used to elaborate the time durations obtained for each treatment. All the data were analyzed by Minitab version 17. Combined silage required the lowest time to process good quality silage while the best significant physical and chemical performances were also found in the combined silage ($p<0.05$). There were no significant differences in required time, physical and chemical compositions under different LAB concentrations in the same forage ($p>0.05$). Conclusively, combined silage resulted good quality silage within 7 days when treated with LAB while identifying that Super Napier+ Maize was the best forage species that could produce good quality silage within the short time duration when treated with LAB.

Keywords: Forage, lactic acid bacteria, pasture, proximate analysis, silage

Introduction

The arability of pasture and forage available during the wet season often exceed animal requirements, however, the accumulated pasture and forage become coarse and lose most of their nutritive value with maturity. The excess grasses harvested at optimum nutritive value could be conserved as silage for dry season feeding when pasture is very scarce so as to sustain milk production. Silage is a type of feed made from grass or other green plants that have been cut, fermented in anaerobic circumstances in a silo, and then stored (Kim *et al*., 2021). Lactic acid bacteria (LAB) is responsible for the silage fermentation while reducing the pH of silage. Wang *et al*., (2021) revealed that this reduction of pH because of due to LAB are capable of fermenting carbohydrates to make lactic acid. Grass silage consists with 4.3 - 4.7 pH where cone silage consists with 3.7-4.0 pH (Kung *et al.*, 2018). During quick anaerobic primary silage fermentation, LAB act as a biological silage supplement which offers steady feed value and secondary metabolic products (Kim *et al*., 2021). The duration required to silage making vary

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from 45 to 60 days, depending on the types of material used (FAO, 2020). Reduction of this long-time duration by adding commercially available LAB was still under investigations. Hence, it's a timely need to develop a procedure by using commercially available LAB to reduce the required time duration for silage processing. The present study mainly aimed (i) to determine the time requirement for good quality silage process under different concentrations of commercially available LAB by using different fodder, grass and combination of fodder grasses and (ii) to identify the forage species that should produce good quality silage within a short time duration.

Material and Methods

The research study was carried out at the Department of Animal Science, Faculty of Agriculture, Eastern University, Sri Lanka from July to December 2022. All the forages (fodder grass and pasture grass) required for the study were obtained from the Livestock Farm, Faculty of Agriculture, Eastern University, Sri Lanka. Maize, CO3, and Super Napier were selected as fodder grasses while *Brachiaria brizantha (Signal grass)* was selected as the pasture grass. Super Napier + Maize was selected as the combination of forage. All the forage was cut at the flowering stage and chopped into an approximately 2 cm pieces by using electrical chopper. Commercially available LAB culture which contained 5×10^6 CFU/ 10 g of sample were used. Five grams from the original samples was dissolved in 5 L of distilled water. This 5L was used as the total LAB solution and added particular volumes of each and every treatment according to the determination. Two factor factorial design was used for the experiment by selecting different concentrations of LAB (0%; No added LAB, 25%: 25 ml of LAB solution with 75 ml distilled water, 50%; 50 ml of LAB solution with 50 ml distilled water, 75%; 75 ml of LAB solution with 25 ml distilled water and 100%; 100 ml of LAB solution) as one factor and type of forage as the second factor (Table 1). Five treatments were used and each treatment was four times replicated.

Table 1: Factorial arrangement of the experiment

	Factor 1	Factor 2 (Concentrations of LAB)				
		0% (a)	25% (b)	50% (c)	75% (d)	100% (e)
T1	CO3	T1[a]	T1[b]	T1c	T1d	T1e
T2	Maize	T2[a]	T2[b]	T2c	T2d	T2e
T3	Super Napier	T3[a]	T3[b]	T3c	T3d	T3e
T4	*B. brizantha*	T4[a]	T4[b]	T4c	T4d	T4e
T5	Super Napier+Maize	T5[a]	T5[b]	T5c	T5d	T5e

Slightly wilted chopped grasses were mixed well with different concentration level of LAB solutions and filled to plastic bottles (1 kg for each bottle) and compressed well to remove the internal air and sealed properly by covering the lid. Then bottles were placed in a dark room to avoid the exposure to direct sunlight. The minimum time duration required to prepare olive green colored silage was measured by comparing with a standard color code of the olive color once every three days until obtained the optimum expected color. After achieving the optimum color, the bottles were opened and samples were used for the further analysis of odor, texture, and mold as physical observations by sensory appraisals. Samples (Duplicates) were analyzed for their dry matter (DM), crude protein (CP), crude fiber (CF), ether extract (EE), nitrogenfree extract (NFE), ash, and pH contents as described by AOAC (2002). Graphical representations

were used to elaborate the time durations obtained for each treatment. Time durations, proximate analysis results obtained for process silage under each treatment were analyzed by general linear model of ANOVA by using Minitab version 17, and Turkey test with 5 % significant level was used to compare means.

Results and Discussion

The required time durations for obtaining good quality silage under different LAB concentrations from different forages were showed in Figure 1. This revealed that the time requirement for processing good quality silage can be reduced by adding LAB even though it was not significantly differed among the different concentrations of LAB ($p>0.05$). It can be suggested that we can induce the conversion of starch and sugars present in forages effectively by adding whatever the amount of LAB. Combined silage required the lowest time to process good quality silage among the four different LAB concentrations used in the present study. This time requirement is very low when compared with the previous findings and it could be suggested as a significant of the present study (Kim *et al.*, 2021).

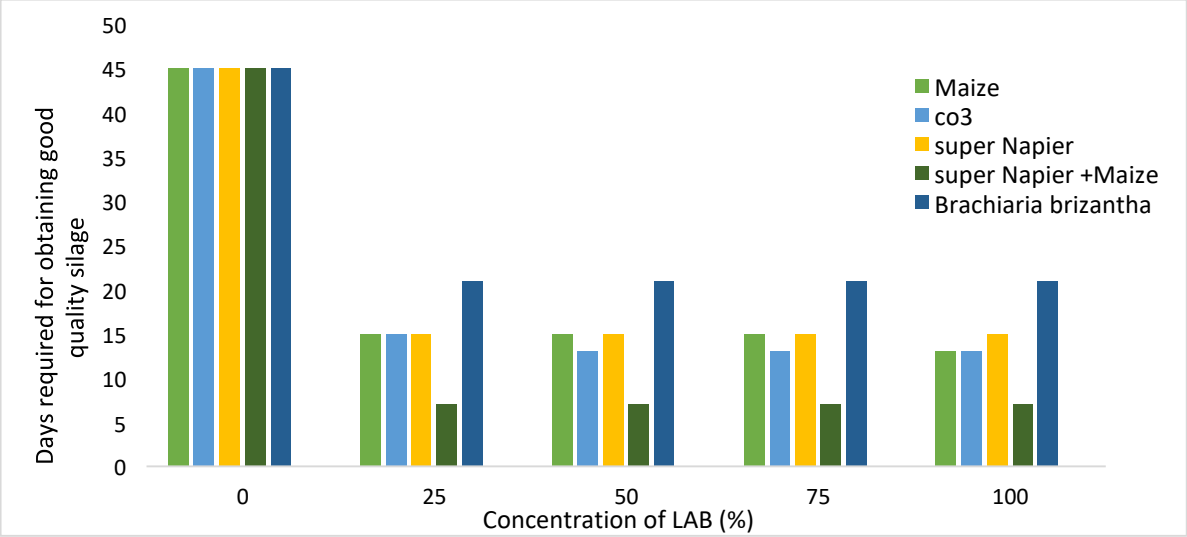

Figure 1: Time requirement for processing good quality silage under different LAB concentrations from different forages

The overall physical observations of prepared silage from different forages were presented in Table 2. These observations were also closely similar with the previous findings (Asaolu, 2018; Delena and Fulpagare, 2015) The combined silage was observed with a deep olive green color within shorter period of time. It was reported that the content of sugars and starch was increased with the maturity of grass while decreasing the cellulose and residues in maize (De Boever *et al.*, 1993). It could be suggested as a reason for that the present observations of time reduction for processing good quality silage with combination of fodders especially with maize.

Table 2: Physical attributes of silage resulted from different forages

Attribute	Maize	CO3	Super Napier	*B. brizantha*	Super Napier+ Maize
Color	Olive green	Olive green	Deep olive green	Olive green	Deep olive green
Odor	Pleasant	Pleasant	Fruity	Fairly pleasant	Pleasant
Texture	Firm	Firm	Firm	Soft	Firm
Mold	Free	Free	Free	Free	Free

The chemical composition and pH of prepared silage was elaborated in Table 3. There was a marked difference in DM of silage prepared by Super Napier and combined silage ($p< 0.05$). Delena and Fulpagare (2015) reported that the dry matter content was decreased after the ensiling process. The present findings were closely similar with the previous findings of Super Napier while more or less similar with the maize whereas the DM of maize and CO3 silage in present study was quite lower. Moreover, the pH, Ash content obtained for the present study were closely aligned with the previous findings (Delena and Fulpagare, 2015; Nusrathali *et al.*, 2021).

Table 3: Chemical Composition and the pH of silages resulted from different forages

Attribute	Maize	CO3	Super Napier	*B. brizantha*	Super Napier + Maize
DM (%)	14.45 ± 1.53^{bc}	14.52 ± 0.87^{bc}	13.22 ± 0.78^{c}	18.26 ± 0.41^{ab}	19.13 ± 0.46^{a}
EE (%)	1.66 ± 0.42^{a}	2.73 ± 0.16^{a}	1.39 ± 0.34^{a}	1.20 ± 0.25^{a}	2.30 ± 0.30^{a}
CF (%)	36.8 ± 0.63^{b}	37.4 ± 1.12^{b}	41.7 ± 2.24^{ab}	46.3 ± 0.71^{a}	40.3 ± 0.93^{ab}
CP (%)	4.04 ± 0.36^{c}	7.99 ± 0.27^{a}	3.69 ± 0.50^{c}	5.46 ± 0.46^{bc}	7.33 ± 0.42^{ab}
NFE (%)	44.86 ± 1.54^{a}	36.71 ± 2.11^{a}	38.65 ± 3.51^{a}	35.84 ± 1.04^{a}	40.39 ± 1.43^{a}
Ash (%)	13.22 ± 0.76^{ab}	14.56 ± 0.82^{a}	13.97 ± 0.82^{a}	11.51 ± 1.07^{ab}	9.95 ± 0.85^{b}
pH value	4.67 ± 0.12^{c}	5.23 ± 0.03^{ab}	5.29 ± 0.07^{a}	5.18 ± 0.14^{ab}	4.92 ± 0.04^{bc}

Means with different superscripts in the same row are significantly different ($p<0.05$).

The observations for the chemical compositions of EE, CF, CP, NFE were not significantly different among forage types ($p>0.05$). Furthermore, those observations including DM were not markedly differed among different LAB concentrations under different forages as well ($p> 0.05$).

Conclusions

Super Napier+Maize combination resulted a good quality of silage within 7 days treated with LAB. The control treatments for Maize, CO_3, Super Napier, *Brachiaria brizantha* and Super Napier + Maize took 45 days to achieve good quality silage. Therefore, Super Napier + Maize was identified as the forage species that produced good quality silage within the short period of time when treated with LAB.

References

AOAC. (2005). Official method of analysis.18th Edition, Association of Analytical Chemists, Gaters burg, M.D.; USA

Asaolu, V. O. (2018). Nutritive Evaluation of Ensiled Signal Grass (Brachiaria *decumbens*) and Cassava Leaves (Manihot Esculenta) With Millet Additive as Feed for Small Ruminants. *Academic Research Journal of Biotechnology Full*, 6(October), 18–28. https://doi.org/10.14662/ARJB2018.023

De Boever, J. L., De Brabander, D. L., De Smet, A. M., Vanacker, J. M. and Boucque, C. V.
(1993). Evaluation of Physical Structure. 2. Maize Silage. *Journal of Dairy Science*, *76*(6), 1624–1634. https://doi.org/10.3168/jds.S0022-0302(93)77496-2

Delena, M. F. and Fulpagare, Y. G. (2015). Characteristics of Silage Prepared from Hybrid
Napier, Maize and Lucerne. *IOSR Journal of Agriculture and Veterinary Science Ver. I*, *8*(5), 2319–2372. https://doi.org/10.9790/2380-08511316

FAO (2020). Silage making for small scale farmers. Training material. United States Agency for International Development (USAID). (Accessed on 28.12.2022 at 9.58 a.m.)

Kim, D., Lee, K. D. and Choi, C. (2021). Role of LAB in silage fermentation: Effect on nutritional quality and organic acid production—An overview. *AIMS Agriculture and Food*, 6(1), 216–234. https://doi.org/10.3934/AGRFOOD.2021014

Kung, L., Shaver, R. D., Grant, R. J. and Schmidt, R. J. (2018). Silage review: Interpretation of chemical, microbial, and organoleptic components of silages. *Journal of Dairy Science*, 101(5), 4020–4033. https://doi.org/10.3168/jds.2017-13909

Nusrathali, N., Mufeeth, M., Ahamed, A. S. and Majeed, U. A. (2021). Original Article Comparison of Chemical Composition and Quality of Maize, Sorghum and Hybrid Napier Grass CO-3 Silages Using Bag or Bucket Silos. *Journal of Bangladesh Agril Univ*, *19*(3), 348–353.

PRECISION AGRICULTURE AND GEOSPATIAL TECHNOLOGY

ELEVATIONAL BASED LAND USE LAND COVER DISTRIBUTION IN GALLE DISTRICT, SRI LANKA

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Abstract

A study was carried out to determine the impact of the elevation on the distributional pattern of the land use land cover in the Galle District. The objective of the study was achieved via mapping and assessing the spatiotemporal changes in land use land cover in the Galle District based on elevation from 2001-2021. The study used Landsat satellite images to assess the change detection of land use land cover of the Galle District and Shuttle radar topography mission (SRTM) digital elevation model data to assess the elevational features. The unsupervised classification was used to identify the land use land cover classes. Reclassify toolwas used to classify the terrain into <50 m, 50-250 m and > 250 m contour classes. Overlay analysis applied to asses and quantify the percentage share of the extent and the rate of change(km^2/year) of land use land cover based on elevation classes for the last 20 years. Galle Districtis highly dominated with an elevation of <50 m (61.74%), whereas 50-250 m shares 32.76%, and >250 m shares 5.50%, respectively. Land use land cover classification resulted that built- ups are the dominant land use while, paddy resulted as the second for the last 20 years. The multi-temporal assessment revealed that the agricultural lands and forests showed a negative rate of changes (1.9 km^2/year and 2.7 km^2/year) in <50 m and 50-250 m, respectively. The rate of change of the built-ups has always been positive for the last 20 years, which showed the highest (1.1 km^2/year) in <50 m elevation. The study revealed that the major changes in the forest, agricultural lands and built-ups exhibited in the areas below 50 m and 50-250 m. Thus, itis crucial to develop a monitoring system of land use land cover planning in <50 m and 50-250 m elevation to maintain the impacts of land use land cover systems on the ecosystems in the district.

Keywords: Change detection, overlay analysis, spatial-temporal changes, topography

Introduction

Topography is a detailed study or description of a particular place or region by describing the elevation of each point and its neighborhood. A land use land cover (LULC) study is essential in describing how the land is used and provides a starting point for present and future planning (Ayele *et al.,* 2018). Satellite imageries have the potential to provide spatial and temporal consistent data for studies on monitoring changes in atmospheric, oceanic, forest fragmentation, landscapes changes and other types of land use transitions. Digital Elevation Models (DEM) is one of the remote sensing data constructed by using SAR interferometry required as input for GIS to create a different type of thematic maps for land use and land cover, in addition to other terrain information (Fichera *et al.,* 2000). Therefore, the integration between GIS and remote sensing has become a useful tool in capturing, accumulating, modeling, analyzing and presenting spatial and descriptive data directly or indirectly from satellite images and available maps.

The study was conducted with the objectives to assess spatial and temporal relationships between elevational-based land use and land cover pattern in the Galle District spatial and temporal relationships between elevational-based land use and land cover pattern in the Galle District from 2001 to 2021 using change detection analysis and overlay intersect techniques in GIS and remote sensing.

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Materials and Method

The Study Area

Galle District is located between 6° 3' 12.6" latitude and 80° 13' 15.5" longitude in the Southern Province of Sri Lanka. It is extended within an area of 1652 sq. km. The topography of the Galle District indicates that its terrain is mostly low and flat in the coastal area to a rolling plainwith mountains in the central interior.

Image acquisition and data processing

The Orthorectified Landsat satellite data were downloaded from the United States Geological Survey (USGS) website (http://earthexplorer.usgs.gov/) in Universal Transverse Mercator (UTM) projection with the WGS84 datum. The images from Landsat 07 ETM+ (C2 Level-1) (for 2001) and Landsat 08 OLI/TIRS (C2 Level-1) (for 2015 and 2021) were used for image classification and change detection mapping of the LULC distribution. The images from SRTM (1 Arc-Second Global) were used for elevation classification to create a DEM map of the Galle District. Shapefiles of District and DSDs of Sri Lanka from the Survey Department of Sri Lanka were used as the base map to extract the study area.

Land use/land cover and DEM classification

The unsupervised classification was applied to extract the essential information from the imageries using the 'Iso-cluster unsupervised classification' tool from ArcGIS 10.7.1. Images were reclassified according to the classification scheme developed by the Survey Department, Sri Lanka, including Water bodies, Built-up areas, Forests, Paddy land, Tea, Coconut and other plantations. The SRTM DEM data were transformed from WGS1984 to UTM 44 projection using the project raster tool from ArcGIS 10.7.1. All DEM raster cells of the Galle district were classified into three elevation ranges (below 50 m, 50-250 m and above 250 m) to assess the magnitude of LULC transitions to elevation differences. Accuracy assessment of the classified satellite images (2001-2021) was conducted to conform to the classification accuracy. It was calculated through an error matrix, by using random points to select the truth/ referenced control points.

Change detection mapping and analysis

Overlay analysis using intersect tool was carried out to analyze the LULC distribution with the elevation of the study area between 2001 and 2021. Tabulate intersection was used to extract and tabulate the details of the area coverage of the LULC distribution with different levels of elevation in the study area. Temporal Change detection of the tea lands in the study area was determined from 2001 to 2021 using Landsat images. The classified images went through to estimate the rate of change km^2/year and percentage share of each class in the selected time periods.

Results and Discussion

Elevation and LULC distribution in Galle District

The area's elevation ranged from a minimum value of 0 m to a maximum value of 830 m (MSL). This was then reclassified into 3 categories below 50 m, 50-250 m and above 250 m. Around 61.74% of the total land area of the district lies between 0-50 m. The land area spread between 50-250 m is 32.76%, and only 5.5% is occupied in >250 m of elevation, which includes mountains and other high forest areas (Figure 1).

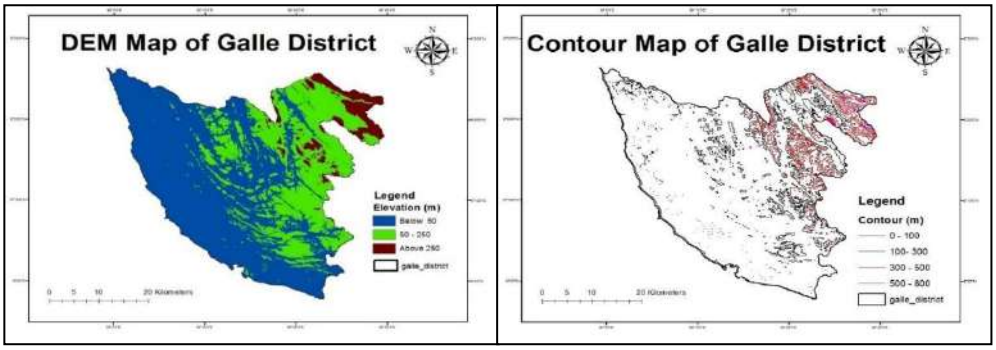

Figure 1: DEM and Contour map of the study area

The study recognized seven major LULC types: forests, water bodies, built-ups, paddy, tea, coconut, and other minor plantations. Figure 2 shows the LULC maps were prepared from 2001 to 2021 from multi-temporal Landsat satellite images which illustrate that in overall, the lowest elevation includes coastal belts, water bodies, agricultural land and built-ups, whereas forests in higher elevation. The overall accuracy of the classified images is 80.5, 79.7 and 85.2% for 2001, 2015 and 2021, respectively.

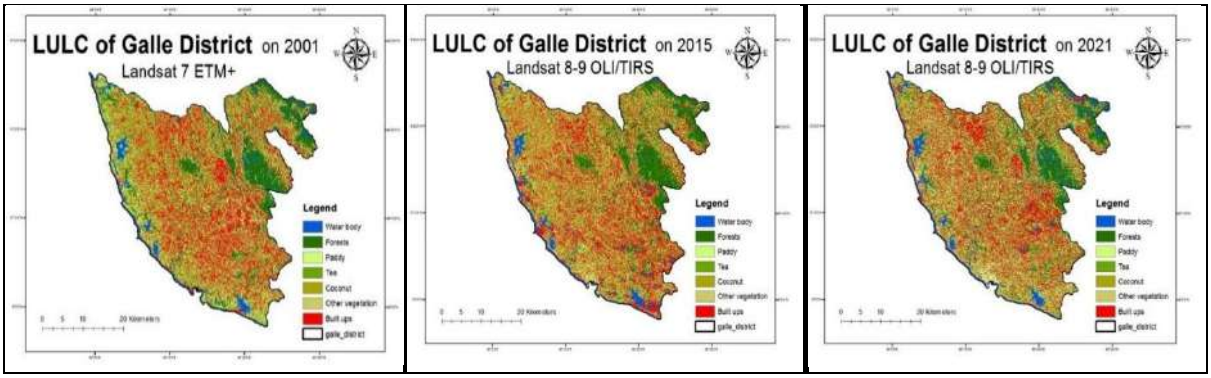

Figure 2: LULC map of Galle District (2001-2021)

Distribution of LULC based on elevation trend has been reported in previous studies (Hyandye, 2015) where, agricultural lands and urban areas are distributed mainly in low altitudes. This pattern of distribution can be attributed to the elevation barrier. As elevation increases, accessibility to the area and agricultural activities become difficult. Figure 3 illustrates the LULC maps with the elevational classes using overlay intersect analysis reveal the influence of the terrain of the district on LULC distribution from 2001 to 2021. The major part of water bodies (2.86, 3.37 and 3.21%) occupy the < 50 m elevation of the landarea in the Galle District including the coastal belt and Gin Ganga as the main river as well as few minor water bodies and reservoirs. The total water bodies only occupied 0.5-2.0% at 50- 250 m and above 250m between 2001 and 2021 (Figure 3). The agricultural lands are mainly distributed in Bope, Poddala, Baddegama, Elpitiya, Yakkalamulla, and Neluwa DSDs. In Sri Lanka, paddy is grown under various physical environments such as different elevations (0-2,575 m MSL), soils and hydrological regimes (Adhikarinayake, 2005).

The distribution of paddy from the whole Galle district rangedbetween 12-13% below 50 m, 5-6% between 50-250 m and 0.5-0.6%, above 250 m from 2001- 2021, respectively. Thus, it shows that the suitable elevation for paddy cultivation in the entireGalle district is at the lower elevations. Likewise, coconut palms (6-8%), and tea (Low countrytea) (9-10%) are widely distributed in the Galle district below 50 m and 50-250 m elevation. Galle experiences a high urbanization rate. According to figure 4, built-ups (such as residential,commercial, industrial,

mixed urban lands and other man-made structures), steadily increased from 27 – 30% over the last 20 years. Buildups were mostly distributed below 50 m (17.51, 18.64, and 18.82%) and 50-250 m (9.20, 9.60 and 9.92%) elevational area in the district in 2001, 2015 and 2021, respectively.

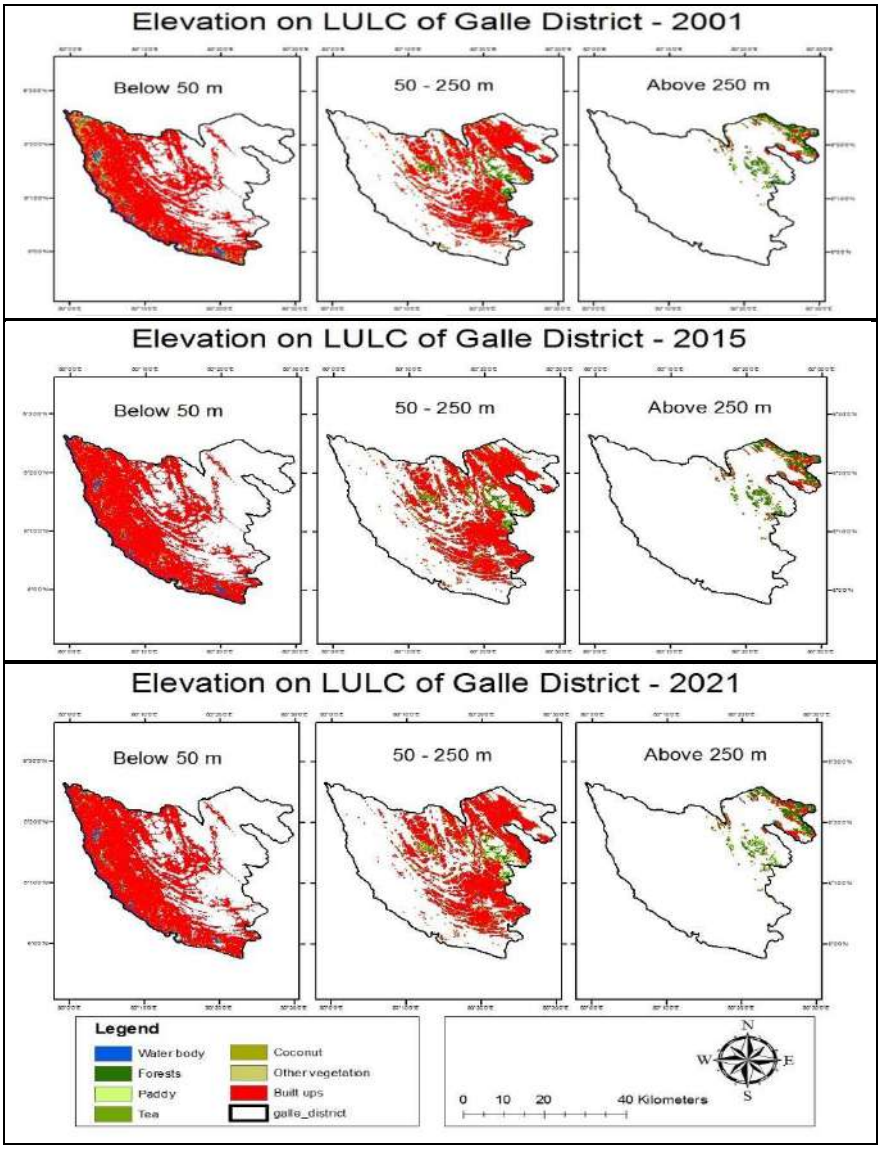

Figure 3: LULC map of Galle district with each elevation class 2001

Galle District is surrounded by forests, including Kanneliya, Kottawa and the part of Sinharaja forest. The forest coverage is greater in high elevation than in low elevation. Most of the forest area is situated within a 50-250 m elevational range (8.50, 9.36 and 8.14%) for 2001-2021. Around 3-4% of the forest cover can be observed above the 250 m elevation of the district. Elevation below 50 m class belongs to only a few mangrove forests that can be seen near the river and seashore.

Elevation and LULC distribution in Galle District

Table 1 indicates the rate of changes in the study area's forest, agricultural lands and buildups classes. The highest rate of increase is shown in built-ups below 50 m elevations. It shows the rapid increase of urbanization. The second highest change is in the forest between 50-250 m elevation, negatively impacting the environment. It implies the highest deforestation rate in the district. The rapid change is because the low and medium elevations are more suitable for

farming and settlements. Areas with the lower elevation of forests have been used mainly for urbanization. As a result, agriculture is gradually decreasing whereas, service and industrial sectors have become the main sources of income (Development Plan, 2019). Overall agricultural land has also decreased over the last 20 years. The decrease in forests and increase in built-up have caused a change in the entire district in the agricultural sector from paddy, tea and coconut crops in the study year.

Table 1: Rate of change in the LULC class type with elevation classes

	2021-2001 (km^2/year)		
LULC class type	Below 50 m	50-250 m	Above 250 m
Forest	-1.3	-2.7	-0.3
Built ups	1.1	0.5	0.1
Agricultural Land	-1.9	-0.6	-0.1

Conclusion

The study has identified that elevational differences have contributed to the LULC changes in Galle District from 2001 to 2021, particularly for vegetation classes, including forest and agricultural lands with paddy, tea, and coconut. The highest rate of increase is shown in built-ups (1.1 km^2/year) below 50 m elevations resulted a rapid increase of urbanization. The highest rate of decreases is in the forest (2.7 km^2/year) between 50-250 m elevations, negatively impact the environment. Overall agricultural land also shows the highest rate of negative changes (1.9 km^2/year) below 50 m elevation. The study revealed that areas <50 m and 50-250 m are highly prone to LULC changes. This change may result in an irreversible loss of biodiversity and the depletion of ecological services provided by the natural environment. Thus, agricultural development and urbanization should be managed properly without destroying the natural pattern of the LULC distribution under appropriate elevations in the district.

References

Adhikarinayake, T. B. (2005). Methodical design process to improve income of paddy farmers in Sri Lanka. Wageningen University and Research.

Ayele, G. T., Tebeje, A. K., Demissie, S. S., Belete, M. A., Jemberrie, M. A., Teshome, W. M. and Teshale, E. Z. (2018). Time series land cover mapping and change detection analysis using geographic information system and remote sensing, Northern Ethiopia. *Air, Soil and Water Research*. https://doi.org/10.1177/1178622117751603

Development plan for greater Galle Area 2019 – 2030. Urban Development Authority District office – Galle. uda.gov.lk https://www.uda.gov.lk

Fichera, C. R., Modica, G. and Pollino, M. (2012). Land Cover classification and change-detection analysis using multi-temporal remote sensed imagery and landscape metrics. *European journal of remote sensing* 45(1): 1-18. https://doi.org/10.5721/EuJRS20124501

Hyandye, C., Mandara, C. G. and Safari, J. (2015). GIS and logit regression model applications in land use/land cover change and distribution in Usangu catchment. Am. *J. Remote Sens* 3(6). https://doi.org/10.11648/j.ajrs.20150301.12.

DEVELOPMENT OF A DIGITAL DEVICE FOR THE AUTOMATION OF CLASS A EVAPORATION PAN MEASUREMENT BASED ON MODIFIED MAYER'S FORMULA FOR LOCAL CLIMATIC CONDITIONS

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Abstract

Evaporation estimates are needed for a wide array of problems in hydrology, water balance computation, irrigation management, river flow forecasting, etc. Class A evaporation pan is the most widely used instrument for the measurement of evaporation. However, its performance is affected by instrumental limits and practical issues which can reduce the accuracy of evaporation measurements. Automation of evaporation pan measurement using a digital device could eliminate these issues. Further, there are many empirical formulas proposed to estimate evaporation. Each formula has its own data requirements and is site-specific, and hence needs to be modified for the local conditions. In the above context, the present study aimed to develop a digital device for the automation of evaporation pan measurement. DHT 11 sensor was calibrated using automatic weather station data. Meyer's formula was modified to obtain empirical relations for estimating evaporation under local climatic conditions as functions of temperature, relative humidity and wind velocity. The performance of the device which runs based on modified Meyer's formula was evaluated using two accuracy parameters such as correlation coefficient (R) and Root Means Square Error (RMSE). A high correlation coefficient (R>0.968) and RMSE of 0.065 mm/hr were obtained between digital device values and observed Pan A evaporation values. A high correlation coefficient value (closer to 1) and low RMSE (closer to zero) between sensor data and observed data is an indication of the accuracy and sensitivity of the digital device for Class A pan evaporation measurement. Hence, the developed device could be used for a nearly real-time evaporation measurement under local climatic conditions.

Keywords: Class A pan, digital device, evaporation, Meyer's formula, meteorological data

Introduction

Evaporation has wide implications amongst hydrological processes and plays a key role in water resources management (Abtew and Melesse, 2012). Many weather stations include measurements of the evaporation from a U.S. Class A pan (Brutsaert, 1982) as the basis for calculating the water loss from lakes or from cropland. However, its performance is affected by instrumental limits and practical issues such as debris in the water, animal activity in and around the pan, pan size, materials employed to construct the pan, exposure of the pan, strong winds, and measurement of water depth in the pan, which can reduce the accuracy of evaporation measurement (Piri *et al.*, 2009). Further, evaporation direct measurement techniques are not recommended for routine hydrologic engineering applications as they imply a time-consuming procedure requiring expensive equipment in order to obtain precise and carefully designed experiments (Valiantzas, 2006). Hence, automation of pan evaporation measurement could be the best option for measuring real-time evaporation.

Evaporation estimation methods based on climatic data are very common in the case of hydrologic and irrigation applications. Empirical formulas have been derived to estimate evaporation based on field measurements of the evaporation pan and reservoir/lake water balance. All these formulas are linked with various weather factors impacting evaporation. As

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the complexity of the empirical methods increases, data requirements to drive the equations often make the empirical methods hard to apply for field applications. Further, these empirical formulas are site-specific and not applicable in all places due to their limitations in data availability (Valiantzas, 2006). An empirical formula that requires fewer weather inputs could be modified for the local climatic conditions. In the above context, the present study aimed to develop a digital device for the automation of pan evaporation measurement under local climatic conditions.

Materials and Method

The present study was carried out in the agro-ecological zone DL2b in the dry zone of Sri Lanka. A digital device was developed for measuring the evaporation rate using modified Meyer's formula. This device was developed with DHT 11 sensor, ESP8266 micro controller and LCD module and the output is showing evaporation rate from the modified Meyer's formula as well. Figure 1 shows the process of the development of a digital device for measuring evaporation.

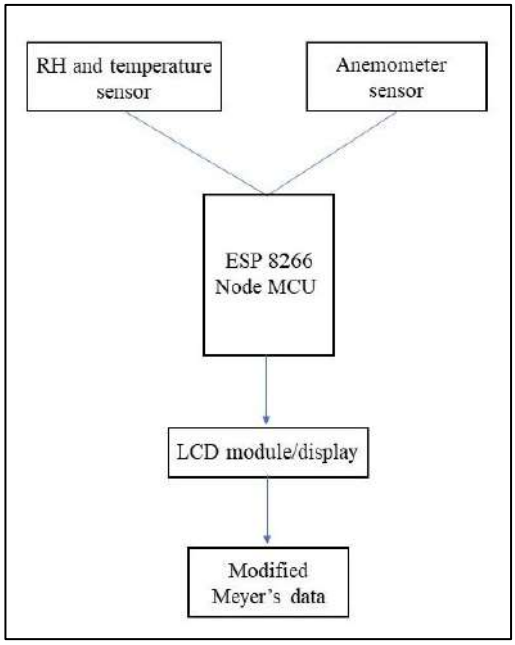

Figure 1: Process of the development of the digital device for measuring the evaporation rate

Measurement of evaporation using Class A pan

The Class A pan is a standard cylindrical with a diameter of 120.7 cm and a depth of 25.5 cm. The pan was installed as per the recommendation and evaporation was measured for the period from September to November 2022.

Estimation of evaporation using Meyer's formula

Eq.1 shows Meyer's formula for estimating evaporation.

$$\boldsymbol{E = \left(1 + \frac{U}{16}\right) \times C \times (e_s - e_a)} \qquad \text{Eq.1}$$

Where; E is the evaporation rate, Es is the saturation vapor pressure, Ea is the actual vapor pressure and U is the average wind velocity. C value ranges from 0.35-0.5 (Piri and Ansari, 2013). The estimated evaporation rate from Meyer's formula was compared with the evaporation pan data and the C value was modified to local climatic conditions.

Calibration and Validation of the DTH 11 Sensors and Device data

In this study, DHT 11 sensor was used to measure the required meteorological inputs. The sensor was calibrated using automatic weather station data. After calibration, it was used in the device to feed the required weather inputs. The device was developed based on modified Meyer's formula. The performance of the DTH 11 sensor and the device was checked using two accuracy parameters such as correlation coefficient (R) as given in Eq.2 and, Root Mean Square Error (RMSE) as given in Eq.3 were used.

$$R = \frac{\sum_{i=1}^{n}[(y_i{}^{obs} - y_{mean}{}^{obs})(y_i{}^{sensor} - y_{mean}{}^{sensor})]}{\sqrt{\sum_{i=1}^{n}(y_i{}^{obs} - y_{mean}{}^{obs})^2 \sum_{i=1}^{n}(y_i{}^{sensor} - y_{mean}{}^{sensor})^2}} \quad \text{Eq.2}$$

(Majhi *et al., 2019*)

Where; $\mathbf{y_i^{obs}}$, $\mathbf{y_i^{sensor}}$ are the observed and obtained values, respectively. n is the total number of input patterns.

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(O_i - P_i)^2} \quad \text{Eq.3}$$

(Chu and Shirmohammadi, 2004)

Where; n is the number of data points, O_i is the observed value (weather station value), and P_i is the predicted value (sensor data).

Results and Discussion

Performance evaluation of the DHT 11 sensor

The performance of the DHT 11 sensor was tested using two performance indices. Observed data and sensor data showed a good fit with a correlation coefficient (R) of 0.967 and 0.968 for temperature and RH, respectively (Table 1). However, the RMSE value was slightly higher for both temperature (6.14^{o}C) and RH (20.16%). Sensor values for temperature were slightly higher than observed values. On the other hand, sensor RH values were lower than the observed values. To get the best fit between the observed data and sensor data, the average mean error was estimated and added to Arduino IDE coding. After the adjustments, the sensor data showed a good fit with observed data with RMSE of 1.74^{o}C and R of 0.967 for temperature and 1.71% and 0.970 for RH, respectively.

Table 1: RMSE and R values between sensor data and observed data

Parameters	Temperature		RH (%)	
	Before adjustments	After adjustments	Before adjustments	After adjustments
RMSE	6.14^{o}C	1.74 ^{o}C	20.16%	1.71%
R	0.967	0.967	0.968	0.970

Modification of Meyer's Formula

In this study, the estimated evaporation rate from Meyer's formula was compared with the evaporation pan data and the Meyer's formula was modified to local climatic conditions of the dry zone and the modified formula is as follows.

$$E = \left(1 + \frac{U \times 1.37}{16}\right) \times K_m \times (e_s - e_a) \times 1.086$$

Where, E is evaporation rate (mm/ day), U is wind velocity (km/hr), e_s is saturation vapour pressure (mmHg), e_a is actual vapour pressure (mmHg) and K_m is a constant.

Performance of the digital device

In this study, a digital device was developed based on the modified Meyer's formula for the automation of the pan evaporation measurement. The performance of this device was tested using observed pan readings. The sensor data showed a good fit with observed pan readings. RMSE of 0.086 mm/hr and correlation coefficient (R) of 0.997 were obtained during calibration and 0.065 mm/hr and 0.968 during validation, respectively (Table 2). The RMSE value was closer to zero and R-value was closer to 1 indicating a good fit between sensor data and observed pan readings.

Table 2: RMSE and R values between derived data and observed data

Data set	RMSE (mm/hr)	R
Calibration	0.086	0.997
Validation	0.065	0.968

Conclusion

Meyer's formula was well modified for the local climatic conditions. The digital device which runs based on modified Meyer's formula reads the evaporation well. Hence, the developed device could be used for a nearly real-time evaporation measurement under local climatic conditions.

References

Abtew, W. and Melesse, A. (2012). Evaporation and evapotranspiration: measurements and estimations. *Climate Change and Evapotranspiration*,1-203.

Brutsaert, W. (1982). Evaporation into the Atmosphere, Reidel, *Amsterdam*, pp.299.

Chu, T.W. and Shirmohammadi, A. (2004). Evaluation of the SWAT model's hydrology component in the piedmont physiographic region of Maryland. *Transactions of the ASAE*, 47(4):1057.

Majhi, B., Naidu, D., Mishra, A.P. and Satapathy, S.C. (2020). Improved prediction of daily pan evaporation using Deep-LSTM model. *Neural Computing and Applications*, 32(12): 7823-7838.

Piri, J. and Ansari, H. (2013). Daily pan evaporation modelling with ANFIS and NNARX. *Iran Agricultural Research,* 31(2): 51-64.

Piri, J., S. Amin, A. Moghaddamnia, D. Han and Remesun, D. (2009). Daily pan evaporation modelling is hot and dry climate. *Journal of Hydrologic Engineering*, 803-811.

Valiantzas, J. D. (2006). Simplified versions for the Penman evaporation equation using routine weather data. *Journal of Hydrology*, 331(3-4):690-702.

HARNESSING THE BIOINOCULANT POTENTIAL OF *Bacillus* sp FOR SUSTAINABLE MANAGEMENT OF FUSARIUM WILT OF BRINJAL

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ABSTRACT

Brinjal (*Solanum melongena* L.) is formerly known as aubergine, garden egg, is the one of the world's most commercially important 'vegetable crop' grown in India and around the world. The subject of this study is associated with the search for eco-friendly methods of crop plant protection by natural biocontrol agents for the effective management of Fusarium wilt of brinjal in field condition. The dominant pathogen, which causes Fusarium wilt of brinjal, was isolated and identified as *Fusarium solani* f.sp. *melongenae.* The objective of this research was to study the Biochemical characterization of *Bacillus* sp. To identify the secondary metabolites produced by native strains of *Bacillus* spp. 15 native *Bacillus* spp antagonists were isolated from healthy brinjal rhizosphere soil in different geographical regions. Under *in vitro* conditions, *Bacillus* sp isolate [B(TM)-5] was found to effectively inhibit the mycelial growth of the pathogen by dual assay (82.00%) when compared to all other isolates. *Bacillus* sp strain B(TM)-5 was confirmed by 16s rRNA. Furthermore, the volatile constituents were isolated from *Bacillus* sp and subjected to gas chromatography mass spectrometry GC/MS analysis. Highly available compound was identified as 2-Piperidinone, 1-Dodecanol, 4-Methyloctanoic acid, 2,4-Decadienal, Hydrocinnamic acid. This potential indigenous *Bacillus* sp. is widely exploited as biocontrol agents because of its efficiency in impeding various plant pathogens with a multifaceted approach.

Keywords: *Bacillus* sp, Brinjal, dual assay, GCMS, Fusarium wilt

Introduction

The common diseases in brinjal are caused by a number of different organisms namely fungi, bacteria, oomycetes, viruses and nematodes (Sihachakr *et al*., 1994; Chakraborty, 2005). Among the fungal diseases, wilt caused by *Fusarium solani* f.sp *melongenae* is an economically important and destructive disease of brinjal crop worldwide. Later, symptoms of *Fusarium* wilt in brinjal crop were identified and initially described in Turkey (Altinok, 2005). Management of *Fusarium solani f.sp. melongenae* using chemical is environmental hazardous (Dukare *et al.*, 2019). As a result, in recent years, antagonistic effective bacteria have been considered ideal biological control agents owing to their rapid growth, easy handling and aggressive colonization in the rhizosphere (Theradimani *et al*., 2018). Antimicrobial and growth-promoting features of microbial Volatile Organic Compounds (mVOCs), hydrolytic enzymes secreted by antagonists have recently received a lot of attention because they have antimicrobial and growth-promoting properties in many plants.

With this background information, the present investigations on wilt of brinjal were undertaken with the following objectives.

1. Isolation and screening of effective bacterial antagonist under *in vitro* against *F. solani* f.sp. *melongenae.*
2. Characterization of *Baciullus* sp by biochemical and molecular methods.
3. Identification of secondary metabolites in effective bacterial antagonists using gas chromatography mass spectrometry (GC-MS).

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Materials and Method

Isolation of Bacillus spp. from the rhizosphere soil

The rhizosphere soil of brinjal was collected from various localities of Tamil Nadu for the isolation of bacterial biocontrol agent, *Bacillus* sp. *Bacillus* spp. were isolated by serial dilution method.

Biochemical characterization of Bacillus spp.

The identification and confirmation of *Bacillus* spp. were examined using the diagnostic tests described by (Schaad *et al.*, 2001). Biochemical tests for *Bacillus* sp included Gram staining, Catalase test, Starch hydrolysis test, Gelatin liquefaction test, Growth at 4ºC and 45ºC and KOH test.

In vitro of *Bacillus* spp. on the growth of *F. solani* f.sp. *melongenae*

Fifteen isolates of *Bacillus* spp. were taken for testing their antagonistic activity against *F. solani* f.sp. *melongenae* by dual plate technique (Dennis and Webster, 1971). A nine mm mycelial disc of *F. solani* f.sp. *melongenae* was placed on one side and isolates of *Bacillus* spp. were streaked on the plate at 10 mm away from the periphery which was exactly opposite to the mycelial disc of the Petri plate containing PDA medium. Fifty Culture plates were incubated at room temperature (28±2°C) for 10 days.

$$\mathbf{PI = Dc - Dt / Dc \times 100}$$

where, PI – Per cent inhibition, Dc- Average diameter of mycelial growth (cm) in control, Dt- Average diameter of mycelial growth (cm) in treatment

Molecular characterization of Bacterial antagonists

Confirmation of genomic DNA of Bacillus spp.

To confirm strain as *Bacillus* spp. 16S rRNA intervening sequence specific primers BCF1 and BCF2 were used .

16 S rRNA ITS sequence analysis of bacterial isolates

The rRNA homology searches was performed using the BLAST program of National Center for Biotechnology Information (NCBI), USA. Sequences and accession numbers to be compared with our sequences were retrieved from GenBank database

GC-MS analysis of crude antibiotics produced by bacterial antagonists

Detection of active bio-molecules present in the crude antibiotics of *Bacillus* sp. (BC2 and BC7) responsible for supression of *F. solani* was carried out through GC-MS (GC Clarus 500 Perkin Elmer).

Statistical analysis

The data were statistically analyzed using the IRRISTAT version 92 developed by the International Rice Research Institute Biometrics unit, the Philippines (Gomez and Gomez, 1984). Prior to statistical analysis of variance (ANOVA) the percentage values of the disease index were arcsine transformed. Data were subjected to analysis of variance (ANOVA) at significant level ($P<0.05$) and means were compared by Duncan's Multiple Range Test (DMRT).

Results and Discussion

Isolation of *Bacillus spp.* from the rhizosphere soil

Fifteen isolates of efficient bacterial strains were isolated from brinjal rhizosphere soil. They were subjected to morphological and biochemical tests for identification. Similarly, *B. subtilis* was isolated predominantly from suppressive soils for the management of soil borne diseases (Sundaramoorthy *et al.*, 2012).

Screening of the bacterial antagonists against *F. solani* f.sp. *melongenae in vitro*

Bacterial strains isolated from different parts of Tamil Nadu were maintained and screened against *F. solani f sp melongenae* for mycelial inhibition by dual culture technique *in vitro* as explained in 'Material and Methods'. Among the fifteen bacterial strains, B(TM)-5 inhibit mycelial growth of 82.00% followed by B(PK)-7. Six *Bacillus* spp. *viz.*, B(PG)-10, B (MN)-13, B (GY)-15, B (VG)-3, B(SC)-11 and B(KC)-8 exhibited maximum level of inhibition against the pathogen. Several strains of *Bacillus* spp. have been reported to produce a wide array of antibiotics *viz*., iturin A, bacillomycin, fengymycin, surfactin was responsible for their antifungal action (Romero *et al*., 2007) (Figure 1).

Table 1: Effect of various isolates of *Bacillus* spp. on *F. solani* f.sp. *melongenae* [IS (PAL) - 1] in dual culture technique

S.No.	Name of Isolates	Radial growth of mycelium(cm)*	PROC *
1.	B(AR)-1	6.92^{n}	$23.11(28.73)^{n}$
2.	B (TM)-2	4.87^{i}	$45.89(42.64)^{i}$
3.	B (VG)-3	4.12^{f}	$54.22(47.42)^{f}$
4.	B (AP)-4	5.24^{j}	$41.78(40.27)^{j}$
5.	B(TM)-5	1.62^{a}	$82.00(58.42)^{a}$
6.	B (SP)-6	6.39^{m}	$29.00(32.58)^{m}$
7.	B (PK)-7	2.75^{b}	$69.44(56.44)^{b}$
8.	B (KC)-8	4.63^{h}	$48.56(44.17)^{h}$
9.	B (MK)-9	7.86^{o}	$12.67(20.85)^{o}$
10.	B(PG)-10	3.24^{c}	$64.00(53.13)^{c}$
11.	B (SC)-11	4.46^{g}	$50.44(45.25)^{g}$
12.	B (VK)-12	6.18^{l}	$31.33(34.04)^{i}$
13.	B (MN)-13	3.57^{d}	$60.33(50.96)^{d}$
14.	B (VP)-14	5.52^{k}	$38.67(38.45)^{k}$
15.	B (ML)-15	3.81^{e}	$57.67(49.41)^{e}$
16.	Control	9.00	00.00
	CD (P=0.05)	0.60	4.72

PROC – Per cent Reduction Over Control

Values are the means of three replicates; means in a column followed by the same letters are not significantly different according to Duncan's Multiple Range Test at P= 0.05; Values in parentheses are arcsine transformed values

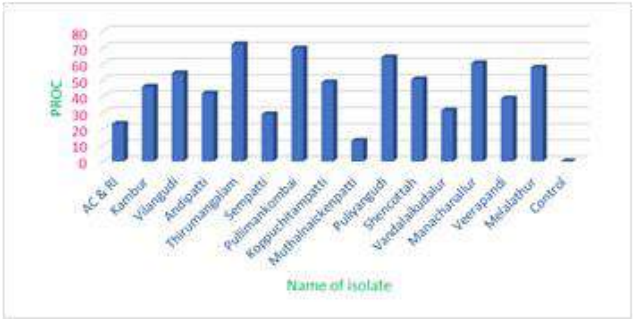
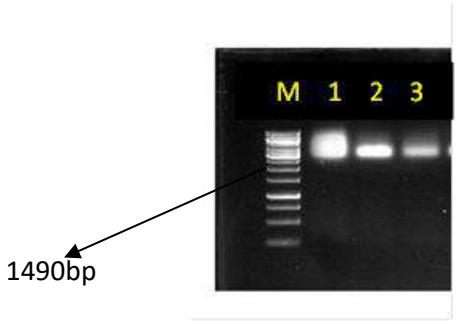


Figure 1: Effect of various isolates of *Bacillus* spp. on *F. solani* f.sp. *melongenae* [IS (PAL) - 1] in dual culture technique

Molecular characterization of *Bacillus* spp.

In the present study the ITS region of effective *Bacillus* sp was amplified with the 16S rRNA specific primers BCF1 and BCR2, which resulted in an amplicon size of 1490 bp. The results of this experiment were in accordance with the findings of Durand *et al.*, (2021) who detected the strain IUBTC2 as *Bacillus subtilis* using the same pairs of primer.



Bacillus subtilis strain BS5 16S ribosomal RNA gene, partial sequence

GenBank: OL872293.1

FASTA Graphics

Go to:

LOCUS OL872293 1257 bp DNA linear BCT 21-DEC-2021
DEFINITION Bacillus subtilis strain BS5 16S ribosomal RNA gene, partial sequence.
ACCESSION OL872293
VERSION OL872293.1
KEYWORDS .
SOURCE Bacillus subtilis
ORGANISM Bacillus subtilis
Bacteria; Firmicutes; Bacilli; Bacillales; Bacillaceae; Bacillus.
REFERENCE 1 (bases 1 to 1257)
AUTHORS Chandrika,K., Theradimani,M., Thiruvudainambi,S., Shanthi,M. and Renuka,R.
TITLE Bacillus subtilis BS5
JOURNAL Unpublished
REFERENCE 2 (bases 1 to 1257)
AUTHORS Chandrika,R., Theradimani,M., Thiruvudainambi,S., Shanthi,M. and Renuka,R.
TITLE Direct Submission
JOURNAL Submitted (16-DEC-2021) Plant Pathology, Tamil Nadu Agricultural University, VAIGAI ILLAM, AC & RI, MADURAI, Tamil Nadu 625104, India

Biochemical characterization of *Bacillus* spp. isolates

All the fifteen isolates of *Bacillus* spp. gave positive reaction to gram staining, starch hydrolysis, growth in 3 per cent NaCl, growth at 45 ºC and utilization of citrate and catalase test. These isolates gave negative reaction to growth at 4ºC (Figure 3).

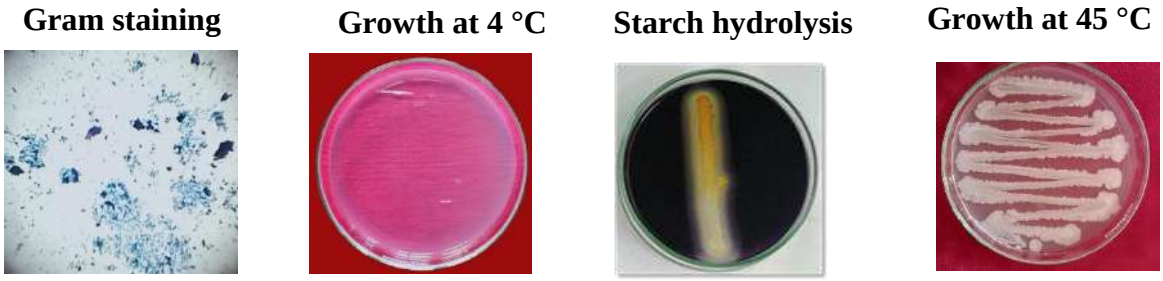


Figure 3: Biochemical characterization of *Bacillus* spp. isolate

GC-MS analysis of purified crude antibiotic and extracellular antifungal compounds of the effective *Bacillus* spp.

From *Bacillus subtilis* [B(TM)-5] antifungal compounds such as 2-Piperidinone, 1-Dodecanol, 4-Methyloctanoic acid, 2,4-Decadienal, (E,E), Hydrocinnamic acid, n-Tridecan-1-ol, Quinoline, 1,2-dihydro-2,2,4-trimethyl-Dodecanol, Dodecanoic acid, Diethyl Phthalate, 1-Hexadecanol, Carbonic acid, tetradecyl vinyl ester, 3-Methyl-1,4-diazabicyclo [4.3.0]nonan-2,5-dione were detected. Palanimanickam *et al.*, 2017 detected compounds such as Ethyl benzene, 1,3- dimethyl benzene, 1,2,4 tri methyl benzene, 4 ethyl 1,2-dimethyl benzene, 4-phenyl but-3-ene-lyne and 4-bromo-2 chloro phen could produce metabolites having antagonism against pathogens.

Table 1: GC-MS analysis of purified crude antibiotic of *Bacillus* sp.

S. No	Name of the compound	Retention Time	Peak area (%)	MW (g/mole)	Molecular Formula	Specific role
1	2-Piperidinone	10.269	14.67	99	C_5H_9NO	Antimicrobial activity
2	1-Dodecanol	10.579	5.85	186	$C_{12}H_{26}O$	Antifungal activity
3	4-Methyloctanoic acid	11.908	2.04	158	$C_9H_{18}O_2$	Antibacterial activity
4	2,4-Decadienal, (E,E)-	13.967	2.63	152	$C_{10}H_{16}O$	
5	Hydrocinnamic acid	14.425	1.68	150	$C_9H_{10}O_2$	Antibacterial activity
6	n-Tridecan-1-ol	15.971	1.55	200	$C_{13}H_{28}O$	Antimicrobial
7	Quinoline, 1,2-dihydro-2,2,4-trimethyl-	17.428	5.12	173	$C_{12}H_{15}N$	Antifungal Antibacterial
8	1-Dodecanol	18.108	1.34	186	$C_{12}H_{26}O$	Antifungal activity
9	Dodecanoic acid	20.263	1.73	200	$C_{12}H_{24}O_2$	Antibacterial activity
10	l-(+)-Ascorbic acid 2,6-dihexadecanoate	30.581	3.22	652	$C_{38}H_{68}O_8$	Antimicrobial activity
11	cis-10-Heptadecenoic acid	32.726	6.25	268	$C_{17}H_{32}O_2$	Antimicrobial activity

Conclusion

Wilt caused by *Fusarium solani* f.sp. *melongenae* is an economically important and destructive disease of brinjal crop worldwide. In this study, an attempt was made for the collection of different *F. solani* isolates and identify the effective bacterial antagonists for successful and eco-friendly management of *F. solani* f.sp *melongenae*. *Bacillus* sp. improve plant response to pathogen attack by triggering induced systemic resistance (ISR). Besides being the most promising biocontrol agents, Bacillus spp. promote plant growth via nitrogen fixation, phosphate solubilization, and phytohormone production.

Acknowledgement

We thank the infrastructure and materials provided by the Department of Plant Pathology, Faculty of Agriculture, Agricultural College and Research Institute, Madurai, in order to carry out this research.

References

Anitha Palanimanickam and Umamaheswari Sepperuma. 2017. Profenofos Degradation Potential of Bacillus cereus and Aneurinibacillus migulanus Isolated from Paddy Crop Field Soil. *Journal of pure and applied microbiology* 11: 221-227

Altınok, H,H. 2005. First report of Fusarium wilt of eggplant caused by *Fusarium oxysporum* f. sp. *melongenae* in Turkey. *Plant Pathology* 54 (4):577-577.

Chakraborty and Sukumar. 2005. Potential impact of climate change on plant-pathogen interactions. *Australasian Plant Pathology* 34 (4):443-448.

Dennis C.E. and Webster J . 1971. Antagonistic properties of species groups of *Trichoderma* III. Hyphal interactions. *Trans Brit Mycol Soc* 57:359–363

Dukare, Ajinath Shridhar and Sangeeta Paul. 2019. Exploitation of microbial antagonists for the control of postharvest diseases of fruits: a review. *Critical reviews in food science and nutrition* 59 (9):1498-1513

Romero D, Vicente AD , Olmos JL and vila JC. 2007. Effect of lipopeptides of antagonistic strains of Bacillus subtilis on the morphology and ultrastructure of the cucurbit fungal pathogen Podosphaera fusca. *Journal of Applied Microbiology* 103 : 969–976

Schaad N W, Jones J B and Chun W 2001. Laboratory Guide for identification of plant pathogenic bacteria 3rd Ed. *American Phytopathological Society* Press, USA

Sihachakr, D., Daunay, M.C, Serraf, I. and Chaput, M,H. 1994. "Somatic hybridization of eggplant (Solanum melongena L.) with its close and wild relatives. In *Somatic Hybridization in Crop Improvement* , 255-278. Springer.

Sundaramoorthy, S. and Balabaskar, P. 2012. Consortial effect of endophytic and plant growth promoting rhizobacteria for the management of early blight of tomato incited by *Alternaria solani*. *Journal of Plant Pathology and Microbiology*, *3*, 145.

Theradimani, M, Susitha, S. and Amudha. C. 2018. Biocontrol of Fusarium Wilt in Tomato caused by *Fusarium oxysporum* f. sp. *lycopersici*. *Int.J.Curr.Microbiol.App.Sci* 7(9): 420-429.

IMPACT OF LAND SURFACE TEMPERATURE ON MANGROVES AND MARSHES IN NEGOMBO LAGOON

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Abstract

Mangroves and marshes are unique, valuable and diverse group of ecosystems providing valuable services to nature and community, yet widely threatened by various natural and anthropogenic causes. The study was aimed to assess and map the impact of Land surface temperature (LST) on spatial and temporal changes of Mangroves and marshes in and around Negombo Lagoon from 2010 to 2022 using GIS and remote sensing techniques. The study used Landsat 4-5 TM and Landsat 8 OLI/TIRS images to assess the change detection of mangroves & marshes along with other Land Use Land Cover (LULC). Unsupervised classification and change detection analysis were used to assess and map the spatial and temporal changes of the mangroves and marshes in the Negombo Lagoon buffer zone, including 04 DSDs, Negombo, Katana, Ja Ela and Wattala. In addition, LST maps with stack profiles were prepared to compare the study area's temperature impact on mangroves and marshes distribution. The classification resulted that mangroves and marshes shared 12.18%, 10.37%, and 10.19% from 2010 to 2022, respectively in the study area. The multi-temporal assessment of LULC changes revealed that the mangroves and marshes have reduced by 16.36%, in the lagoon area including Negombo, Katana, Ja Ela and Wattala DSDs for the last 12 years. The change detection analysis revealed that mangroves and marshes are highly converted to natural vegetation (739.5 ha), followed by homesteads (499.7 ha) and built-ups (61.7 ha) in the study area. The LST profile illustrated how the surface temperature changed with LULC distribution while, the mangroves and marshes stack profile graphically represented the mangroves and marshes distribution in the study area. The profile shows the inverse relationship between LST and mangroves and marshes distribution in the Negombo lagoon buffer zone. The study will be useful in identifying the highly threatened spots of mangroves and marshes and to take necessary measures to conserve the ecosystem.

Keywords: Change detection, classification, land use land cover, spatial-temporal changes

Introduction

Negombo lagoon mangrove forest cover is one of the most productive ecosystems that provide many resources to the environment and people. The Negombo lagoon and Muthurajawela wetland complex is a diverse mangroves and marshes ecosystems located in a rapidly developing urban area close to Sri Lanka's capital which makes it an extremely vulnerable ecosystem that is being rapidly degraded by harmful activities related to increasing human population pressure and poorly planned development activities (IUCN and CEA, 2006). Natural landscapes undergo irreversible alteration due to changes in land use and cover (LULC) brought on by urbanization. Mangrove forests are among the most threatened coastal habitats, mainly in developing countries in tropical regions (Qin and Karniel, 1999). The major mangrove distribution around the Negombo Lagoon and the Muthurajawela marsh are threatened today by various human interventions, including major constructions around Negombo lagoon such as restaurants, hotels and site-visiting places and the construction of Katunayake Colombo expressway which cleared a large extent of mangroves. The surface temperature is an important factor in the growth of mangroves. Land surface temperature (LST)

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is an important indicator for quantifying the relationships between rapid changes of urbanization and environmental changes can be expressed in terms of temperature variations using remote sensing technology (Qin and Karniel, 1999).

The main objective of the study is to assess and map the impact of LST on spatial and temporal changes of mangroves & marshes in and around Negombo Lagoon for the period 2010 to 2022 using GIS and remote sensing. The above objective was achieved via mapping the distribution of mangroves and marshes along with other LULC classes in the study area and quantify and analyze the impact of LULC changes on mangroves and marshes distribution in the study area and to examine the influence of LST changes on mangroves and marshes extent for the period of 2010 to 2022.

Materials and Method

Study area

Muthurajawela and Negombo lagoon wetland complex is a saline coastal peat bog located on the Western province (70°3'N, 79°55'E) of Sri Lanka which covers a total extent of 6,232 ha. The study area considered four DS divisions, including Negombo, Katana, Ja-Ela and Wattala, around the Negombo lagoon. These DS divisions cover the major part of mangroves and marshes belonging to the Negombo lagoon ecosystem while bordering the lagoon (Figure 1).

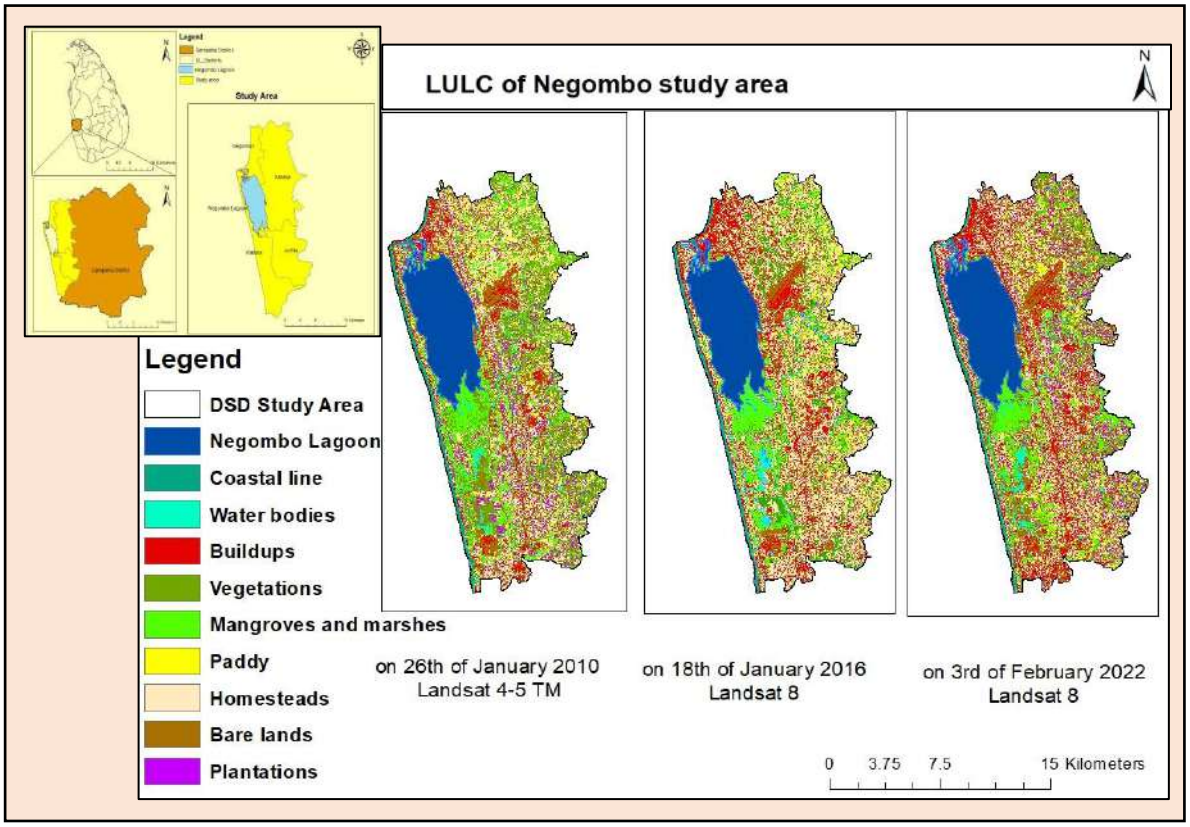


Figure 1: Study area map and LULC distribution of study area

The study area is comprised with different types of LULC classes, including lagoon, coastal aquifer, water bodies, buildups, vegetation, Mangroves and marshes, paddy, homesteads, bare lands and plantations. Negombo, Ja-Ela, Katana, and Wattala are highly commercialized areas with highly developed built-ups where the economy is high. Mangroves and marshes are found

mainly around the Negombo Lagoon and in the Muthurajawela wetland, but also in canals and riverways to small extents (https://www.survey.gov.lk).

Image acquisition and Satellite data processing

The Orthorectified Landsat satellite data were downloaded from the United States Geological Survey (USGS) website (http://earthexplorer.usgs.gov) in Universal Transverse Mercator (UTM) projection with the WGS84 datum. The images from Landsat 4-5 TM (C2 Level-1) (2010) Landsat 8 OLI/TIRS (C2 Level-1) (2016 and 2022) were used for image analysis, change detection, LST detection and developing stack profile for LST and mangroves and marshes in the study area. Shapefiles of District and DSDs of Sri Lanka from the Survey Department of Sri Lanka were used as the base map to extract the study area.

Land use/land cover classification and Change detection mapping and analysis

The unsupervised classification was used to extract the essential LULC information from the imageries from ArcGIS 10.7. Nine major LULC types were identified including Coastal line, Negombo Lagoon, Buildups, Natural vegetation, Mangroves and marshes, Paddy lands, Homesteads, Bare lands and Plantations. Temporal Change detection of the mangroves and marshes in the study area was determined from 2010 to 2022 using Landsat imageries. The change detection maps were used to estimate the change of mangroves and marshes (ha) in the selected time periods.

Developing LST map and stack profile

Thermal bands of Landsat 8 OLI/TIRS, and Landsat 4-5 TM were used to develop LST maps following the standard methods in Landsat 8 Data Users Handbook (2006). A polyline was drawn to create LST and mangroves and marshes stack profile across the classified image to get a graph of how the extent of mangroves and marshes varies with LST. Finally, the variations in mangrove extent and surface temperature were analyzed by combining the LST stack profile and mangrove stack profiles.

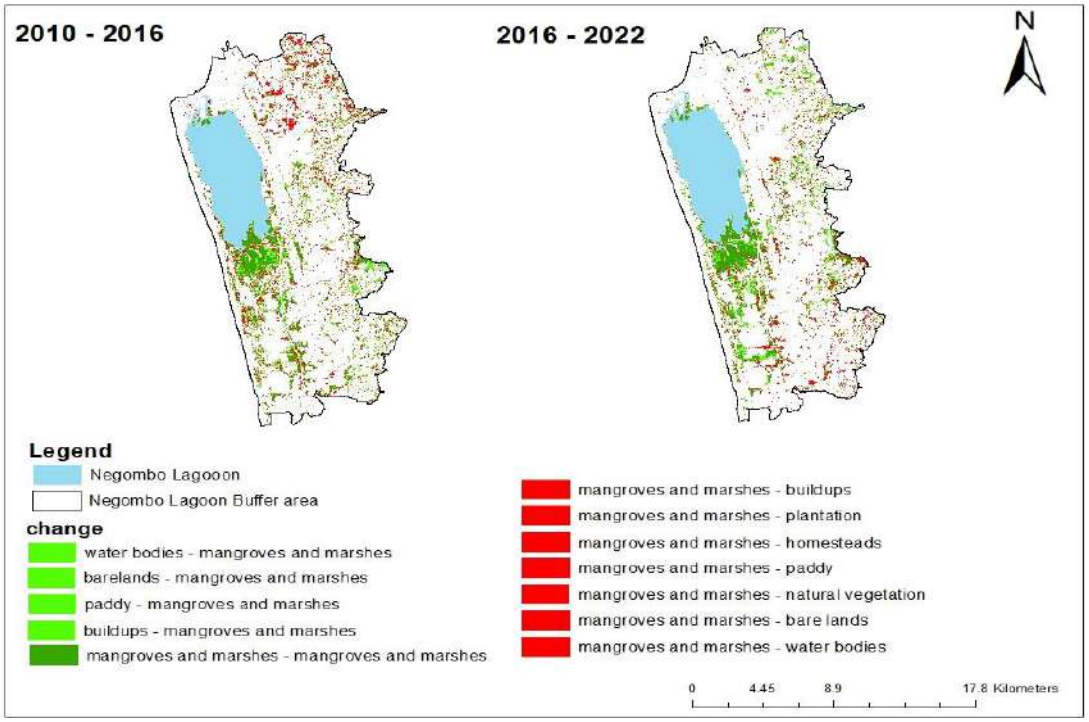
Results and Discussion

Assessment of temporal changes of Mangroves and Marshes

Mapping changes in LULC around Negombo Lagoon is vital for identifying dynamics in the land features of the study area to understand the effect of urbanization around the study area. The multi-temporal assessment of LULC changes revealed that the Homesteads, Bare lands and Buildups have increased by 57.5, 19.6 and 89.5%, respectively, in the lagoon buffer zone for the last 12 years, which results in the rapid urbanization and development in the area. On the other hand, the mangroves and marshes, natural vegetation, paddy, and plantations have reduced by 16.4, 54.7, 16, and 71.3%, respectively, in the lagoon buffer zone for the last 12 years. Previous studies regarding the Negombo Lagoon and the mangrove the extent shows that the extent of mangroves is degrading with a considerable change in the LULC classes of the Lagoon area due to high biodiversity and biological and aesthetic value as well as increase of human settlements. Figure 2 shows the overall changes of mangroves and marshes in the Negombo Lagoon area for the last 12 years and the area (ha) changes in mangroves and marshes over different LULC classes in the study area from 2010-2012. The greatest change can be seen in converting mangroves to natural vegetation, which is 739.5ha, which includes forests and grasses with high biodiversity. The change can occur for either man-caused or natural reasons. However, the true mangrove varieties can be reduced due to this process, especially around the Negombo Lagoon and Muthurajawela marsh, to large extents (Prakash *et al.,* 2017).

The second largest and the most obvious change is the conversion of mangroves to homesteads. The change is approximately 499.71 ha. The percentage change of the homestead between 2010

and 2022 is 57.51% which shows a massive increase in the human settlements as homesteads near these mangrove lands.



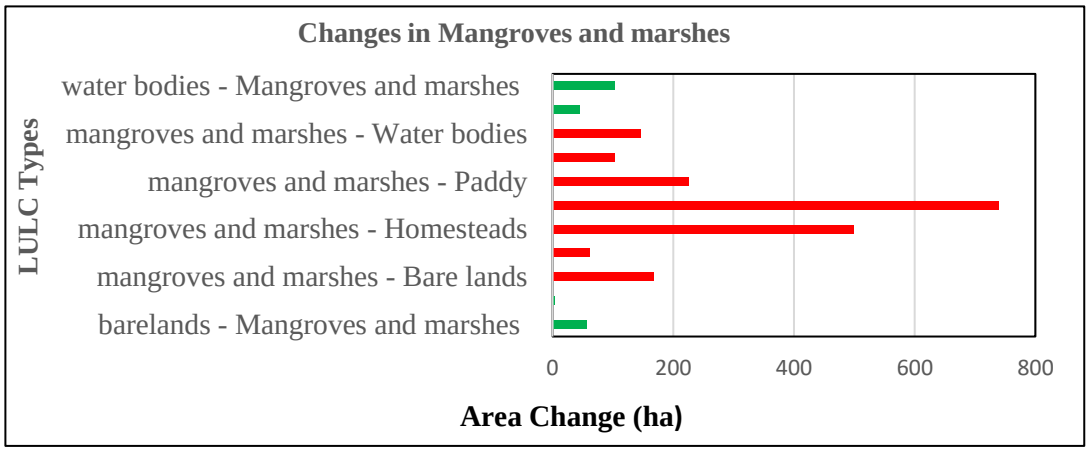


Figure 2: Change detection maps and Area (ha) changes on Mangroves and marshes in Negombo Lagoon study area from 2010 to 2022

Marshes are the lands with high water stagnation and moist soil all year round in this zone. Therefore, those lands can be easily converted into paddy lands. Urbanization and salinity changes in the study area leads to the conversion of mangroves and marshes lands to paddy lands. According to this study, the change in mangroves to bare lands is greater than the change from bare lands to mangroves. The change is approximately 167.58 ha, for mangroves and marshes to bare lands. This is mainly due to deforestation for different purposes like agriculture, settlements etc. Bare land spots were observed in Muthurajawela marsh in 2010, growing into a larger bare land spot by 2022.

Impact of land surface temperature on mangroves and marshes distribution

LST analysis in the study area revealed that high surface temperature prevails in built-up areas and low in healthy vegetative areas (Madumali and Delina, 2022). Figure 3 illustrates the LST maps and the stack profile of LST and Mangroves and marshes from 2010 to 2022. The study shows how urbanization and LST affect mangrove distribution. It is observable that the mangrove extent in the northern part of the study area has reduced from 2010-2022, and the areas of high temperature have increased. The highest LST from 2010-2022 varies between 32.8°C and 37.82°C respectively.

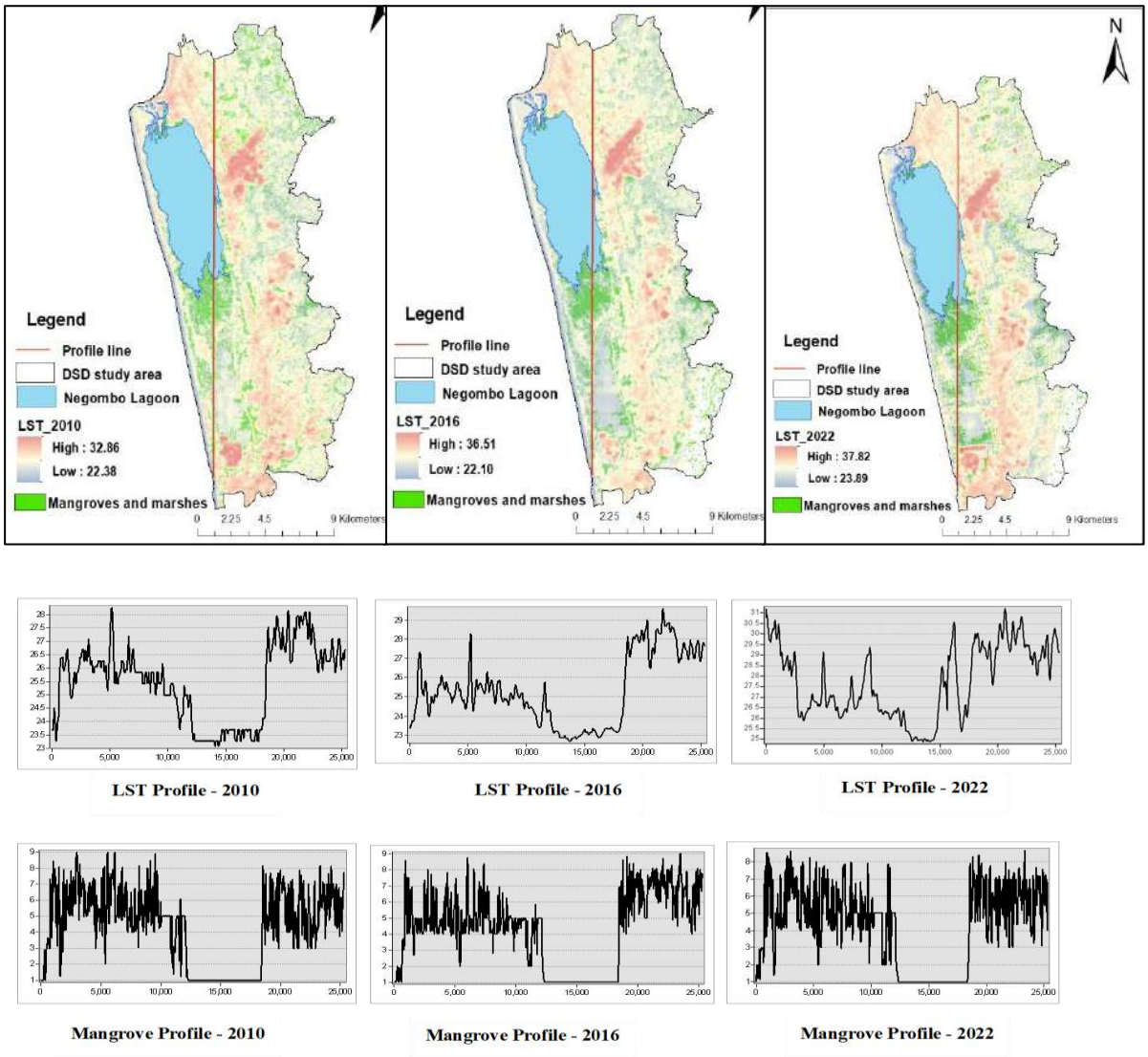


Figure 3: LSTs maps and stack profile for LST and Mangroves and marshes (2010-2022)

LST profile value was reduced from the Muthurajawela area and increased to the northern part of the study area. In 2022, there was an increase in surface temperature in the lower part of the study area, then reduced at water resources like Hamilton canal and the Negombo lagoon and again reached a very high value in the upper part of the study area. Negombo, a busier city and the Bandaranayke international airport caused the heating of the study area to considerable amounts. The mangroves and marshes profile are low at the below end and increases as passing the Muthurajawela marsh, again reduced across the Negombo lagoon and increasing as moving distance to the top corner in each year 2010, 2016, and 2022 respectively. According to the

study of Prakash *et al.* (2017) many factors affect this distribution variation, like temperature, soil condition, and water availability. The LST and Mangroves and marshes profile indicates that surface temperature impacts mangroves availability in the region. The direct impact of LST due to rapid urbanization influences the distribution and the growth of the mangroves around the Negombo lagoon.

Conclusion

The study aimed to map mangroves and marshes spatial and temporal changes and assess the impact of LST on changes in mangroves and marshes in and around the Negombo Lagoon, including 04 DSDs, Negombo, Katana, Ja Ela and Wattala for the period 2010 to 2022. The change detection analysis revealed that mangroves and marshes in the study area had been converted to other LULC classes. Among them, mangroves and marshes to natural vegetation showed the highest conversion (739.5ha) among other LULC classes, while 167.58 ha of mangroves and marshes to bare lands, 499.71ha mangroves and marshes to homesteads, and 61.71ha mangroves and marshes to build-ups. The LST map of the study area revealed that Wattala and Negombo DS divisions have the highest surface temperature value. The LST profile shows how the surface temperature changes with LULC, and the mangroves and marshes stack profile graphically represent the distribution across the study area. The profile shows the inverse relationship between LST and mangroves and marshes distribution in and around the Negombo lagoon.

References

IUCN and CEA. (2006). National wetland directory of Sri Lanka. IUCN Sri Lanka; Battaramulla, LK: Central Environmental Authority, International Water Management Institute. https://www.cea.lk/web/images/pdf/7-1.Book-National-Wetland-Directory-Low%20res(1).pdf

Landsat 8 Data Users Handbook (2006). Version 2.0. U.S. Geological Survey. https://landsat.usgs.gov/documents/Landsat8DataUsersHandbook.pdf

Madumali, B. B.P. and Delina, P. J. E. (2022). Remote sensing approach on land surface temperature and Urban Heat Islands in Gampaha district, Sri Lanka. Proceedings of the Annual Research Session– Faculty of Technology. p.05. http://www.esn.ac.lk/fte/porcee2022.

Prakash,T., Weerasingha, A., Withanage, P. and Kusuminda, T. (2017). Mangrove diversity in Muthurajawela and Negombo lagoon wetland complex, Sri Lanka:Insights for conservation and management. *Department of wildlife conservation, Sri Lanka*, *5*(3): 106. https://www.researchgate.net/publication/320623420_mangrove_diversity_in_muthurajawela_and_negombo_lagoon_wetland_complex_sri_lanka_insights_for_conservation

Qin, Z. and Karniel, A. (1999). Progress in the remote sensing of land surface temperatureand ground. *International Journal of Remote Sensing*, 20(12): 2367- 2393.

SOIL, ENVIRONMENT AND WASTE MANAGEMENT

EVALUATION OF THE EFFECTS OF INTEGRATING LOCALLY AVAILABLE ORGANIC SOURCES AND CHEMICAL FERTILIZERS ON THE ROOT PERFORMANCES AND SOIL RESIDUAL AND UPTAKE OF NUTRIENTS BY OKRA GROWN IN SANDY REGOSOL

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Abstract

The root system plays an important role in the growth and development of plants, and root growth is affected by nutrients, especially nitrogen (N) and phosphorus (P) availability in the soil. However, it is unknown how N and P affect roots under various organic manures in the sandy regosols of Batticaloa. Thus, this study aimed to assess the impacts of applying different organic sources on root growth, uptake and residual N, P of okra and sandy regosol soil. A field experiment was carried out at Eastern University, Sri Lanka. There have been four organic sources; Partly burned paddy husk (PBH), Poultry manure (PM), farmyard manure (FYM), and cow dung (CD). Inorganic sources as recommended quantity were evaluated as a combination of 10t/ha organic source with 100% NPK and sole 100% NPK in comparison with control without any fertilizer. Six treatments were replicated four times in a completely randomized design. The results showed a positive influence of poultry manure and chemical fertilizer combination on N, P uptake. These results further indicated that the integration of farmyard manure improved the projected root area of the okra plant. Additionally, poultry manure improved the root length of okra. The results indicate that combining poultry manure with chemical fertilizers and farmyard manure with chemical fertilizer can control the over usage of chemical fertilizers by increasing the uptake of N, and P as well as the residual nitrogen content of the soil while an increase in residual P content could be attributed to the application of partially burnt paddy husk. Thereby environmental pollution is often reduced.

Introduction

The root system is the main organ for plants and it will play a major role in nutrient absorption in plants. Roots are therefore of great importance for crop growth, and their growth affects shoot growth and crop yield by acting as the "receptors" in a crop plant's perception of environmental changes. Plant growth and development would be regulated by root. Nutrients reach the root system for plant uptake in three ways. Each different course is beneficial for certain nutrients depending on how those nutrients move throughout the soil profile. Root Interception, Mass Flow, and Diffusion are the major 3 ways. During diffusion, roots grow throughout the soil profile, and nutrients around the root system were used directly. Diffusion occurs as the concentration of nutrients around the root system drops, nutrients from higher concentrated areas move or diffuse toward low-concentration areas and toward the roots.

Organic manures with essential plant nutrients could enhance the uptake of nutrients by manipulating the root area. The availability of nutrients can change the morphology of roots to facilitate nutrient uptake. Nitrogen (N) plays an important role in the communications of root shoots and is difficult for maximizing plant productivity and agronomic applications. Roots sense internal and external N changes and coordinate developmental processes accordingly. This would aim to enhance crop yield whereas reducing input costs, like fertilizers, and at the same time keeping nitrogen out of the environment. Reducing fertilizer inputs would result in fewer greenhouse emissions and fewer nitrate leaching into the groundwater and surface water.

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Phosphorus plays a crucial role in plants' ability to absorb, store, and transform solar energy into biomolecules like adenosine triphosphate (ATP), which power biological reactions like photosynthesis from seed to mature grain. Deoxyribonucleic acid (DNA) and ribonucleic acid (RNA), provide instructions on how plants should carry out normal tasks including synthesising proteins, lipids, and nucleic acids, as well as metabolizing sugars, including phosphorus. Phosphorus enhances tillering, encourages early root growth, winter hardiness, and seed formation, and improves water usage efficiency. An increase in the uptake of the nutrient will facilitate scaling back farmers' input prices and increase profits. A high uptake of applied nutrients implies that more of the applied nutrient is haunted by the crop and features a positive impact on both the environment and farmers' profit. Thus, this study was conducted to judge the impact of locally available organic manures on the root area, root length and uptake of N, and P nutrients of okra and sandy regosol soil.

Materials and Method

Description of the experimental site

This study was conducted at the crop farm, Eastern University, Sri Lanka which belongs to the agro-climatic region of low country dry zone in Sri Lanka. It was conducted during the period of May 2022 to November 2022. The soil type of this region is Sandy regosol. Laboratory analysis was carried out at the faculty of Agriculture Eastern University.

Treatments

Table 1: Arrangements of treatments

Treatments	Details
T1	PBH + RRF
T2	PM + RRF
T3	FYM + RRF
T4	CD + RRF
T5	RRF
T6	Control

Table 2: Nutritional status of organic sources

Organic sources	N %	P %	K %
PBH	0.056	11.94	1.77
PM	3.1	4.3	0.8
FYM	1.93	2.1	0.76
CD	0.5	0.565	0.5

Experimental design

The land was prepared with 4 blocks by keeping a 50cm spacing. Six plots were laid out with a diameter of 4.86 m^2 in each block with a spacing of 50cm. sixteen holes were dug for each plot with a spacing of 90 x 60 cm. Two okra seeds were planted per hole and after 2weeks of germination, they were trimmed into one plant per hole. Among the 16 plants/plot, 4 of the middle plants were considered as sampling crops and all others were used as border crops to eliminate the border effects. Treatments were replicated four times in a randomized complete block design (RCBD).

Collection of samples

All the agronomic practices were adopted to raise the crop and at harvest whole plants were uprooted, cut into small pieces, placed on labeled cement bags, and kept 1 week for air drying. After 1week plant samples were kept in an oven at 70^oC for 12 hrs to dry and the dry weight of the sample was measured using electrical balance. Dried samples were ground to get the

powdered form of the sample and it was preserved in labeled polybags for further estimations. At harvest, soil samples were collected, processed, and kept for analysis.

Analysis of root parameters

Root parameters were analyzed by EPSON Flatbed Scanner (EPSON Perfection V800/V850)

Statistical analysis

All the data were analyzed using the Analysis of Variance (ANOVA) procedure to know the variance if any at each treatment level. Turkey's test was used to compare the significant difference between treatment means at $p < 0.05$ using Minitab.17 statistical software.

Results and Discussion

Table 3 pertains to the effect of the integration of locally available organic sources and chemical fertilizers on root performances. The integration significantly increased the root area of treatments T2, T3, and T4. They were significantly higher than the control. Among the treatments, T3 was superior and was followed by T2. Treatment T2 was superior in root length to control and on par with treatment T3.

Table 3: Effect of integration of locally available organic sources and chemical fertilizer on the root performances

Treatments	Root area (cm^2)	Root length (cm)
T1	259.800 ± 17.800^{ab}	17.500 ± 1.190^{b}
T2	311.400 ± 21.500^{a}	26.250 ± 3.070^{a}
T3	339.400 ± 15.300^{a}	25.500 ± 1.260^{a}
T4	282.400 ± 33.400^{a}	14.500 ± 2.180^{b}
T5	262.600 ± 19.100^{ab}	16.730 ± 1.010^{b}
T6	169.700 ± 15.200^{b}	13.900 ± 1.840^{c}

$P<0.05$. The values are means of replicates ± standard error. Means not labeled with the same letter in the same column are significantly different from the control level mean according to the Turkey test at a 5% significant level.

N and P significantly promoted root area elongation compared with the control treatment. The application of a moderate amount of N and P fertilizer treatment (farmyard manure) resulted in the largest roots. This may be due to the availability of N and P. Under high rates of N application, the transport of photosynthetic products to reproductive organs will decrease (Zhou *et al*., 2011). Under these conditions, the growth of the source system in the leaf then becomes the priority, and root growth is decreased. As per Grant *et al*. (2001) When the availability of P is at a moderate level, growth elongation is generally greater in roots, allowing the plant to maintain root growth and encounter and extract P from the belowground environment.

The significant positive influence of poultry manure and farmyard manure on root length and fresh weight of root than the other organic combinations may be due to the impact of poultry manure on soil property and nutrient availability. Bulk density is important to water infiltration, root distribution, and root function which in turn affects water uptake and growth (Adeleye *et al*., 2010). Reduction in soil bulk density could make differences in root growth. Improvement in soil total porosity because of poultry manure might be a result of the improved soil particle aggregation brought about by the improved soil organic matter content. The PM influenced physical parameters, as the highest level of the PM produced the lowest bulk density and total porosity (Agbede *et al*., 2017).

The following findings correlate with the above-mentioned results. Fresh root yields significantly differed with the rate of chicken manure, NPK fertilizer, and their combination. Root yield was lower in the control plot (Biratu *et al*., 2018). Agbede *et al.* (2017) also

mentioned that the integration of PM with chemical fertilizers increased the root length of carrots.

Table 4: Effect of integrating locally available organic sources and chemical fertilizer on soil residual and uptake of N, P by okra grown in sandy regosol

Treatments	Uptake (mg)		Residual nutrient	
	N	P	N (mg)	P (mg/100g)
T1	1324.000 ± 114.000^{b}	8.708 ± 0.706^{c}	1.500 ± 0.100^{bc}	69.28 ± 2.075^{a}
T2	2282.700 ± 0.420^{a}	208.500 ± 52.900^{a}	6.300 ± 4.900^{a}	64.6 ± 6.920^{a}
T3	1749.300 ± 19.000^{ab}	122.700 ± 25.500^{a}	4.900 ± 0.700^{ab}	55.70 ± 8.625^{ab}
T4	1339.000 ± 658.000^{b}	60.000 ± 33.100^{b}	4.900 ± 0.070^{ab}	54.52 ± 8.135^{ab}
T5	1090.000 ± 401.000^{c}	78.500 ± 30.600^{b}	3.500 ± 0.700^{b}	21.36 ± 3.380^{bc}
T6	9.730 ± 0.530^{d}	7.089 ± 0.976^{c}	1.200 ± 0.500^{bc}	16.31 ± 1.665^{c}

Further, the Results (Table 4) pertaining to the effect of nutrient integration on the uptake and residual of N, and P indicated that the treatment integrating poultry manure with chemical fertilizer significantly increased the N and P uptake. This may be due to the immediate availability of nutrients from the chemical fertilizer portion and the quick decomposition of poultry manure in soils treated with 10t/ha poultry manure + 100% chemical fertilizer. This was supported by Rahman *et al*. (2009). Integrated use of poultry manure with inorganic fertilizers is beneficial for improving soil health, and nutrient uptake (Sharma *et al*., 2020).

This was further supported by Amanullah *et al.* (2010) that poultry manure contains nutrient elements that can support crop production and enhance the physical and chemical properties of the soil he also stated that the C: N ratio is lower in fresh poultry manure, which probably contributes to higher mineralization rates. The application of poultry manure gave the highest nitrogen uptake while the control gave the lowest (Shanika and Premanandharajah, 2016). Residual soil nitrogen content was also significantly higher in poultry manure chemical fertilizer combinations than in other combinations. The Uptake of P is also significantly high in PM and FYM. Akande *et al*. (2005) stated that the efficacy of poultry manure in facilitating the release of P from applied chemical fertilizer would be the reason for this. The high nutrient content of poultry manure than other organic sources is the reason for an increase in the residual nitrogen content. Saha *et al*. (2004) supported the highest nutrient concentration in poultry manure. Zaman *et al*. (2002) reported that the organic matter and residual N remaining in the soil were greater with poultry manure than with chemical fertilizer.

Conclusion

Root length and distribution (area) were significantly affected by the amount of N and P applied. The moderate nitrogen treatment (farmyard manure integration) increased the projected root area. poultry manure with integration and FYM as integration improved root growth, uptake of N, P and positively influenced residual N content. These findings indicate that moderate N fertilization (farmyard manure) can promote root growth, especially for shallower roots (0-15 cm) for the maximum uptake of N, P and poultry manure exposed to the increase in uptake and residual nitrogen by causing an increase in root length.

References

Agbede, T. M., Adekiya, A. O. and Eifediy, E. K. (2017). Impact of poultry manure and NPK fertilizer on soil physical properties and growth and yield of carrot. Journal of Horticultural Research, 25(1), pp 81-88.

Biratu, G. K., Elias, E. and Ntawuruhunga, P. (2018). Cassava response to the integrated use of manure and NPK fertilizer in Zambia. *Heliyon, 4*.

Chowdhury, T., Chowdhury, M. H., Qingyue, W., Enyoh, C. E., Wang, W. and IslamKhan, M**.** (2021). Nutrient uptake and pharmaceutical compounds of Aloe vera as influenced by integration of inorganic fertilizer and poultry manure in soil. *Science direct*, *7*(7).

Selim, M. M. (2020). Introduction to the integrated nutrient management strategies and their contribution to yield and soil properties. *International Journal of Agronomy*.

Sharma, A. and Chetani, R. (2017). A Review on the Effect of Organic and Chemical Fertilizers on Plants. *International Journal for Research in Applied Science & Engineering Technology (IJRASET), 5*(II).

Shanika, W. and Premanandarajah, P. (2015). Nitrogen use efficiency of Okra Abelmoschus esculentus (L.) Moench) in sandy regosol amended with locally available organic manures and urea integrations. *Journal of Environment Protection and Sustainable Development, 1*(3), 121-125.

ASSESSMENT ON THE QUALITY OF COMPOST PRODUCED BY COMMERCIAL PRODUCERS AND THE POTENTIAL FOR COMPOST PRODUCTION IN KILINOCHCHI DISTRICT

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Abstract

Inorganic fertilizer supply has been limited in Sri Lanka since 2019, due to Covid 19 pandemic and the economic crisis. Therefore, farmers have to depend on organic fertilizers of which a viable alternative is compost. A quality compost could satisfy the nutrient requirements, and improve soil's physical, chemical and biological properties. To ensure good crop response, it is important that the compost produced is of good quality, meeting the Sri Lankan standards (SLS). In this background, this study was focused to identify the knowledge and issues of commercial compost producers, assessing the quality of compost produced by commercial compost producers in the Kilinochchi district and to assess the potential compost production in Kilinochchi district. The knowledge and issues of commercial compost producers were evaluated through a questionnaire survey of 11 producers who were actively involved in production during the study period. The quality of the commercially produced compost samples was assessed through standard laboratory analysis. Potential compost production in Kilinochchi district was assessed through secondary data analysis. The results showed that 64% of producers practiced open space (unprotected) type of compost system. 64% of the producers participated in training programs regarding compost production. According to the survey, the main problems faced by producers are lack of initial investment for commercialization, less availability of inputs, and lack of knowledge on commercialization. Through compost quality analysis none of the samples complied all the physical and chemical parameters of SLS (1635:2019) requirement. The major issues identified in most of the samples of commercial producers were high sand content and low potassium content. Further, the results of secondary data analysis showed that the potential production of compost from locally available resources is more than enough to satisfy the crop requirement in the Kilinochchi district.

Keywords: Commercial compost producers, Kilinochchi district, quality compost, potential compost production, SLS (1635: 2019)

Introduction

Plant nutrients are important inputs in agriculture in terms of yield and market value. Excessive use of chemical fertilizers has resulted in several environmental issues, including soil degradation, greenhouse gas emissions, air pollution, and water contamination (Jiang *et al*., 2022). The decision by the Government of Sri Lanka to stop the import of chemical fertilizers and the Covid-19 lockdowns impacted negatively on the crop production of Sri Lanka. Therefore, there is a need to increase the local production of organic fertilizer in Sri Lanka. Compost is a viable alternative that comes under organic fertilizers. Compost increases the yield, however, applying poor quality compost to soil can harm the ecosystem and affect the quality of food (García-Gil *et al*., 2000). Also, compost application was not practiced by farmers due to scarcity of resources, lack of farm-based compost production, and problems with the timing of compost production with materials and resource availability for production and

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demand for application (Hettiarachchi *et al*., 2020). In the current socioeconomic scenario of Sri Lanka, to ensure food production, a cheaper alternative way is to produce compost from locally available resources. It is important that the compost produced should be of good quality by meeting the Sri Lankan standards, to ensure good crop response. Therefore, this study was undertaken to identify awareness and knowledge of commercial compost producers on quality compost production and estimate the potential to produce compost by using locally available wastes in Kilinochchi district. The specific objectives were to identify knowledge and issues of commercial compost producers by using a questionnaire survey, to assess the quality of compost produced by commercial producers in Kilinochchi district and to provide suggestions to improve the quality, and to assess the potential to produce compost in Kilinochchi district.

Materials and Method

A survey was carried out to identify the knowledge and issues of commercial compost producers. To assess the quality of compost among commercial producers in the Kilinochchi district compost samples were collected and analyzed. Secondary data were obtained from the official publications and websites of the Department of Census and Statistics and Department of Agriculture. The variables included in the questionnaire survey were age, gender, level of education, involvement of family members in compost preparation, land holding, types and quantity of materials used, compost contamination with soil, basis and type of turning, way of cutting the waste, monitoring of temperature, regulation of aeration, quality checking of compost, participation in training programs, symptoms observed in labors, awareness of producers and problems faced by producers.

Compost sampling and compost analysis were done according to the SLS 1635:2019. Physical analysis of compost includes color, odor, texture, moisture content, sand content and decomposition rate in terms of particle size. Chemical properties of compost such as pH, Electrical conductivity (EC), total organic carbon (%), total organic matter (%), Carbon: Nitrogen ratio (C:N ratio), total nitrogen (N), total phosphorus (P), and total potassium (K) were analyzed. Determination of weed seed contamination in each sample was done according to SLS 1635:2019. Both primary and secondary data analysis was done by using MS excel 2016. Primary data were analyzed mainly based on the responses received through the questionnaire, and multivariate analysis such as tables, charts, mean and standard deviation were used to explain the data.

Results and Discussion

Responses of the questionnaire survey

The majority (63.6%) of the producers have been undergone training programs regarding compost making. Main issues reported by commercial producers regarding compost production in Kilinochchi district were, lack of initial investment for commercialization (72.7%), less availability of inputs (63.6%) and lack of knowledge on commercialization (54.5%).

Results of analysis of commercial compost samples

Changes in color, odor and texture of compost samples were analyzed according to SLS (1635: 2019). Changes in moisture content, sand percentage and particle size distribution were shown in figure 1. According to SLS (1635: 2019) moisture of the compost should be less than 25% in dry basis. The moisture content values in all composts were in the ranged from 8.7% to 41.2%. According to SLS (1635: 2019) sand percentage of the compost should be less than 20% in dry basis. Only 18.2% of samples complied SLS requirement. The decomposition rate values in terms of particle size ranged from 91.8% to 100.0%. The decomposition rate in final compost of all samples were higher than standard (80%).

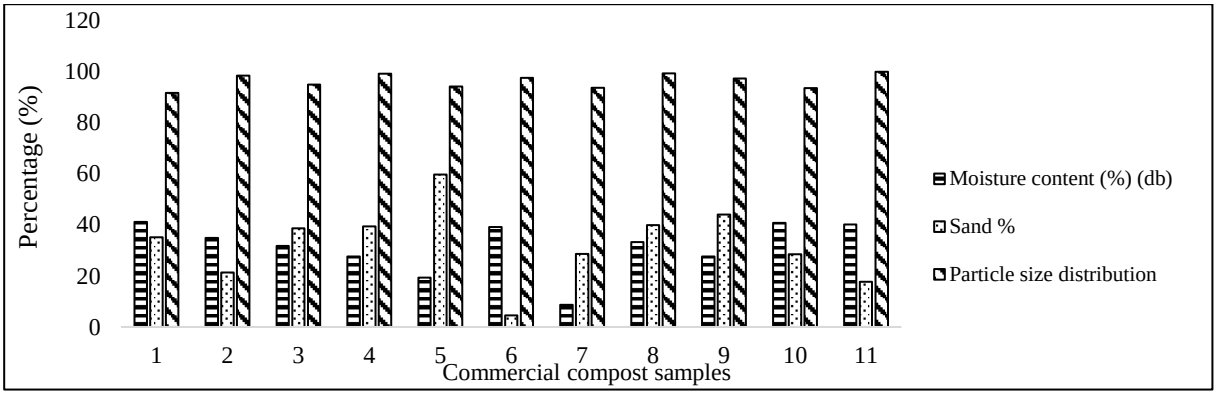

Figure 1: Moisture content, sand percentage and particle size distribution of commercial compost samples

Changes in organic carbon %, nitrogen % and C:N ratio are shown in Figure 2. Only 64% of samples complied with the SLS requirement. According to SLS (1635: 2019) C:N ratio of the compost should be in the range of 10-25. According to SLS (1635: 2019) nitrogen % of the compost should be more than 1% in dry basis. Only 64% of samples complied the SLS requirement. According to SLS (1635: 2019) organic carbon percentage of the compost should be more than 20% in dry basis. 81.8% of samples complied with the SLS requirement.

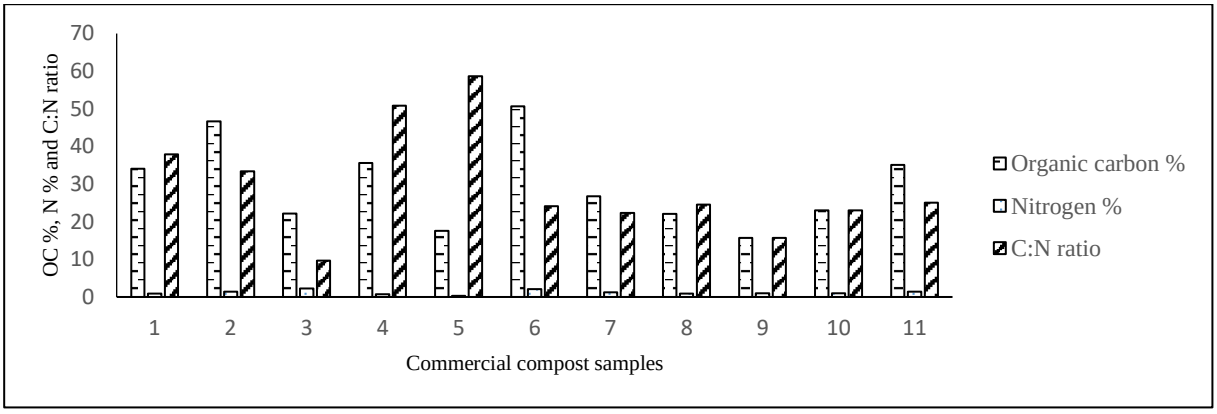

Figure 2: Organic carbon %, Nitrogen % and C:N ratio of commercial compost samples

Changes in phosphorus and potassium content were shown in figure 3. According to SLS (1635: 2019) potassium percentage should be >1%. Only 27% of the samples complied with the SLS requirement. All samples complied with the SLS requirement in phosphorus percentage. According to SLS (1635: 2019) phosphorus percentage should be >0.5%.

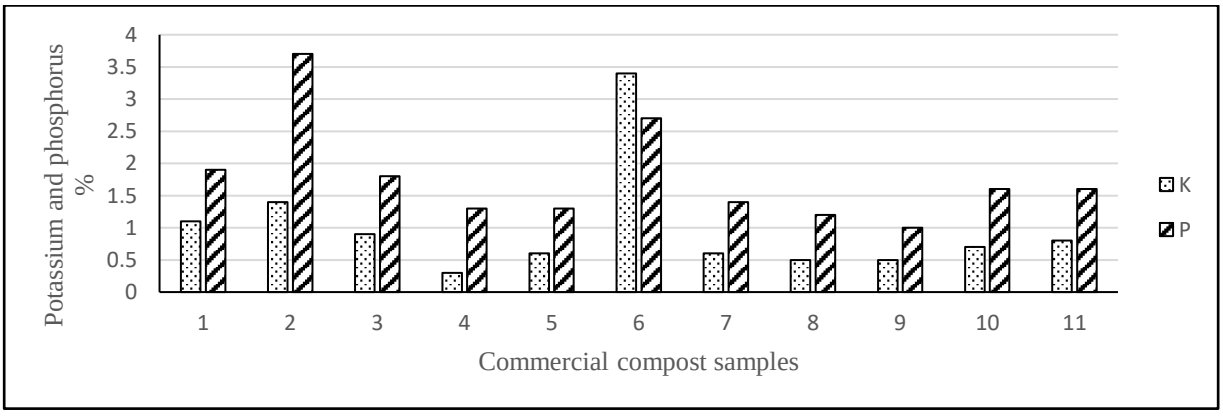

Figure 3: Phosphorus and potassium percentage of commercial compost samples

Changes in pH and electrical conductivity ratio were listed in figure 4. According to SLS (1635: 2019) pH of the compost should be in the range of 6.5 to 8.5. According to SLS (1635: 2019) EC of the compost should be 0.5-4 dS/m^3. Lowest electrical conductivity was observed in sample number 4 and highest was observed in sample number 6.

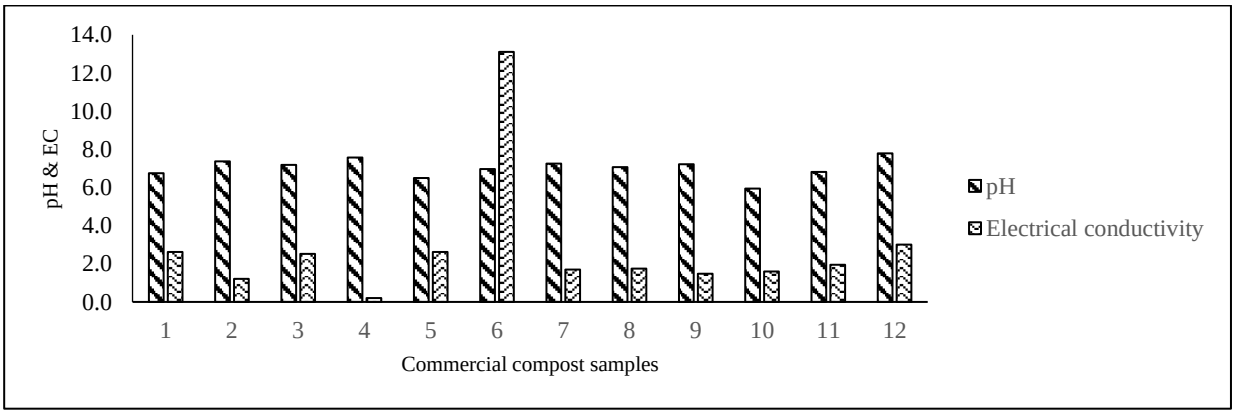

Figure 4: pH and Electrical conductivity of commercial compost samples

Results of the secondary data analysis

The total organic manure requirement for organic farming in Kilinochchi district was 172,134 tons. The total organic manure requirement for combining of organic and inorganic fertilizers in Kilinochchi district was 21,215 tons. The amount of compost that can be produced from domestic waste was 21,487 tons. Quantity of compost that can be produced from crop residues was 66,917 tons. The highest amount (427,272.8 tons) of compost can be produced from animal wastes. The potential total amount of compost that can be produced from locally available wastes was 515,677 tons. However, there is lack of systematic collection and efficient usage of such waste is practiced.

Conclusion

Most of the commercial producers (63.6%) practiced open space (unprotected) type of compost system, which may affect the quality of compost. None of the commercial compost samples complied with all SLS requirements in quality assessment (SLS 1635: 2019). Therefore, all the producers need further training to enhance the quality of compost in the commercial level. According to the estimation based on secondary data, to satisfy the needs of all crops in Kilinochchi district, 172,134 tons of organic manure was required. While potential production of compost considering only household waste, crop residues, and animal wastes is 515,676.512 tons. Therefore, production of compost from locally available resources was more than enough to satisfy the crops requirement in Kilinochchi district. A systematic plan to collect the available waste and use it for compost production by relevant authority is suggested.

References

Jiang, Y. *et al.* (2022) 'A sustainable agricultural supply chain considering substituting organic manure for chemical fertilizer', *Sustainable Production and Consumption*, 29, pp. 432–446. Available at: https://doi.org/10.1016/j.spc.2021.10.025.

García-Gil, J.C. *et al.* (2000) 'Long-term effects of municipal solid waste compost application on soil enzyme activities and microbial biomass', *Soil Biology and Biochemistry*, 32(13), pp. 1907–1913. Available at: https://doi.org/10.1016/S0038-0717(00)00165-6.

Hettiarachchi, H., Caucci, S. and Schwärzel, K. (eds) (2020) Organic Waste Composting through Nexus Thinking: Practices, Policies, and Trends. Cham: Springer International Publishing. Available at: https://doi.org/10.1007/978-3-030-36283-6.

https://www.agrimin.gov.lk/web/images/pdf/Forms/2021.10.11/Annexure%2007.pdf.

IMPACT OF BIOCHAR WITH DIFFERENT NUTRIENT SOURCES ON SOIL ORGANIC MATTER AND NITROGEN CONTENT OF OKRA (*Abelmoschus esculentus*) IN SANDY REGOSOL

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Abstract

Biochar is considered as a universal conditioner to improve soil quality. Combination of biochar with additives protects the environment by decreasing nutrient leaching due to its slow release of nutrients to the soil. A field experiment was carried out at Eastern university, Sri Lanka during the period of June 2022 to September 2022, to study the impact of biochar with different nutrient sources on soil organic matter content and nitrogen content of soil and okra (*Abelmoschus esculentus*) grown in sandy regosol using variety Haritha. There were five treatments including sole biochar (T1), biochar with FYM (T2), biochar with compost (T3), biochar with poultry manure (T4) and biochar combine with chemical fertilizer (T5) which were replicated four times in Randomized complete block design (RCBD). Soil analysis for available soil nitrogen and organic carbon were carried out at the time of harvest. Plant sample were analyzed for nitrogen content. Combination of biochar with nutrient sources favorably influenced nitrogen availability in soil. Among the nutrient sources, poultry manure had the greatest influence on soil available nitrogen plant nitrogen content and soil organic carbon content and pod yield.

Keywords: Biochar, FYM, poultry manure, plant nitrogen, soil nitrogen, soil organic carbon

Introduction

Nowadays the reducing availability of organic matter and the imbalance of nutrients in soil are the major problems for the depletion of soil fertility and decline in the productivity of agricultural crop (Agegnehu *et al.,* 2017). The soil degradation impact on food insecurity directly and indirectly, therefore, organic amendments can be added to soil for reclamation processes. Soil biological, chemical and physical properties have been improved as a result of the usage of amendments (Larney and Angers, 2012). Biochar is a carbon-rich by-product of biological residues deriving from the pyrolysis process carried out in high temperature and oxygen-free environment for the purpose of soil amendment and carbon sequestration (Jeffery *et al*., 2011). Through the application of biochar favorable results were also reported on the soil active organic carbon components, which includes the increment of fresh organic carbon input of the crops and crop biomass, enhancement of the soil structure, promotion in the formation of soil aggregate and supplying an optimal habitat for soil microorganisms. Biochar should be applied in combination with a source of plant nutrients, to further increase its effect on plant growth and soil properties, such as organic or inorganic fertilizers, or a combination of both of these. In recent times, some studies observed a significant improvement in soil fertility and crop yield when biochar and inorganic fertilizer were co-applied (Rivelli and Libutti, 2022). Some studies have reported on the additive effects of biochar and other organic amendments to improve soil quality and plant performance in degraded or contaminated soil (Glab *et al*., 2018). Biochar and farm manure retain nutrition and may stabilize inorganic contaminants through adsorption, binding, and co-precipitation (Wang *et al*., 2020). The objectives of this study were to study the impact of biochar as sole and in combination with other organic and inorganic sources on nitrogen availability in sandy regosols, to examine the use of biochar and other

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organic sources on soil chemical properties and to evaluate the feasibility of biochar and other organic nutritional source on okra cultivation in sandy regosol.

Materials and Method

Description of the experimental site

This study was conducted at the crop farm, Eastern University Vantharumoolai, Sri Lanka which belongs to the agro climatic region of low country dry zone in Sri Lanka. It was conducted during the period of June 2022 to September 2022. Soil type of this site is sandy regosol. Laboratory analyses were carried out at the Faculty of Agriculture Eastern University.

Treatments

Table 1: Details of treatments

Treatments	Details
T1	Sole biochar
T2	Biochar + Farmyard manure
T3	Biochar + Compost
T4	Biochar + Poultry manure
T5	Biochar + Chemical fertilizer

Experimental design

The experiment was conducted with 5 treatments which replicated 4 times in Randomized complete block design (RCBD). An area of 16.5 m ×9.7 m was used in this study which is divided into 20 subplots with a size of 2.7 m× 1.8 m each plot contains 16 plants.

Biochar and manures application

For one experimental plot, biochar was applied at rate of 2.5 kg; farmyard manure, compost and poultry manure were applied at rate of 3 kg, 1 kg and 1 kg respectively according to the treatment arrangement.

Inorganic fertilizers were applied according to the recommendation rate of Department of Agriculture as basal and top dressing.

Table 2: Recommended rates of biochar and organic manures

Fertilizer	Recommended rate	Sources
Biochar	5 ton/ha	Sandhya and Prakash, 2018
FYM	4-6 ton/ha	Teagasc
Compost	2 ton/ha	Melissa Hansen *et al*., 2015
Poultry manure	2 ton/ha	Lindi Botha, 2020

Soil sample

At the end of experiment, plants were uprooted and soil samples were collected at the depth of 0-20cm from each replicate of treatments separately. Then samples were allowed to be air dried then grounded and passed through a 2 mm sieve size, labeled and analyzed by using standard methods.

Plant sample

Plant samples were chopped and allowed for air drying; then samples were kept in the oven at 70°C for 12 hr. Then dry samples were labeled and preserved for further analyzed by using standard methods.

Statistical analysis

All the data were analyzed using Analysis of Variance (ANOVA) procedure to know the variance if any at each treatment level. Turkey's test was used to compare the significant different between treatment means at $p<0.05$ using Minitab.17 statistical software package.

Results and Discussion

The nitrogen content of T4 treatment at post-harvest soil was significantly ($p<0.05$) higher than other treatments. This may be due to the slow release of nitrogen from poultry manure biochar combination as this acts as a soil amendment to retain nitrogen in the soil. In addition, compare to other manures poultry manure has high nutrient content (Zublena,1993).

Table 3: Impact of treatments on soil organic carbon, plant and soil residual nitrogen content and pod yield

Treatment/ Chemical properties	Soil available nitrogen (%)	Plant nitrogen (%)	Organic carbon (%)	Pod yield (ton/ha)
T1	0.007 ± 0.000^{c}	6.30 ± 0.70^{c}	3.64 ± 0.14^{c}	5.49 ± 0.18^{c}
T2	0.011 ± 0.000^{bc}	19.15 ± 0.25^{ab}	4.34 ± 0.06^{b}	12.57 ± 0.45^{b}
T3	0.012 ± 0.000^{bc}	21.00 ± 2.80^{ab}	4.47 ± 0.02^{b}	8.69 ± 0.28^{c}
T4	0.017 ± 0.001^{a}	28.00 ± 1.40^{a}	4.98 ± 0.04^{a}	15.94 ± 0.46^{a}
T5	0.009 ± 0.001^{bc}	11.20 ± 2.80^{bc}	3.49 ± 0.09^{c}	12.61 ± 1.47^{b}

Values presented are means ± standard errors of four replicates. Means followed by the same letter are not significantly different according to the Turkey significance test at 5% level.

This was further supported by Amanullah *et al*. (2010) that poultry manure contains nutrient elements that can support crop production and enhance the physical and chemical properties of the soil and he also stated that the C:N ratio is lower in fresh poultry manure, which probably contributes to higher mineralization rates. Significantly higher plant nitrogen value was observed in T4. This may be due to the fresh poultry manure or broiler litter containing some organic N in the form of uric acid (similar to urea). In soil, uric acid can be converted to plant-available nitrogen within 1 to 2 weeks (Hochmuth *et al*., 1993). In post-harvest soil organic carbon content was significantly higher in T4 treatment due to the accumulation of organic carbon results in linked to changes in microbial community structure and functional diversity. Jangid *et al.* (2008) found that bacterial diversity, in terms of both species richness and evenness, was higher in soils amended with poultry litter than in those treated with inorganic fertilizers. Therefore, the results suggest that the observed response was largely due to the ability of poultry manure to act as nutrient sink for soils and also in the improvement and stabilization of soil structure and physical properties.

Excess supply of nutrients especially phosphorous and potassium from poultry manure may be the reason for obtaining the highest yield in T4 treatment. Poultry manure is not only a good source of NPK but it can serve as a supplier of micro as well as other macro nutrients which required for crop and enrichment of soil which is supported by Panda *et al.* (2008). De Silva *et al*. (2005) stated that high amount of calcium in poultry manure could increase soil pH level and facilitated organic matter decomposition and nutrient release thus enhance the growth of plant and help to increase the yield.

Conclusions

Results of the study revealed that the combination of biochar (5 t/ha) with poultry manure (2 t/ha): treatment performed well in terms of yield, plant nitrogen content of okra and the level of residual soil nitrogen at the end of harvesting in sandy regosol.

References

Agegnehu, G., Srivastava, A. K. and Bird, M.I. (2017). The role of biochar and biochar-compost in improving soil quality and crop performance: A review. *Applied Soil Ecology*, 119: 156–170.

Amanullah, M.M., Sekar, S. and Muthukrishnan, P. (2010). Prospects and Potential of Poultry Manure. *Asian Journal of Plant Sciences*, 9:172-182.

Borchard, N., Wolf, A., Laabs, V., Aeckersberg, R., Scherer, H., Moeller, A. and Amelung, W. (2012). Physical activation of biochar and its meaning for soil fertility and nutrient leaching–a greenhouse experiment. *Soil Use Manage*, 28: 177–184.

De Silva, S. H. S. A., Chandrapala, A. G. and Jayalaty, H. A. P. (2005). Evaluation of different organic manures on soil properties growth and yield of rice and maize under Rice/Maize crop rotation. Annals of the Sri Lanka, Department of Agriculture, Peradenia. 7: 87-94.

Glab, T., Zabinski, A., Sadowska, U., Gondek, K., Kopec, M., Mierzwa-Hersztek, M. and Tabor, S. (2018). Effects of co-composted maize, sewage sludge, and biochar mixtures on hydrological and physical qualities of sandy soil. *Geoderma*, 315: 27–35.

Hochmuth, R. C., Hochmuth, G. J., and Donley, M. E. (1993). Responses of cabbage yields, head quality, and leaf nutrient status, and of second-crop squash, to poultry manure fertilization. Soil and Crop Science Society of Florida Proceeding. 52:126-130.

Jangid, K., Williams, M.A., Franzluebbers, A. J., Sanderlin, J.S., Reeves, J.H., Jenkins, M.B., Endale, D. M., Coleman, D. C. and Whitman, W. B. (2008). Relative impacts of land-use management intensity and fertilization upon soil microbial community structure in agricultural systems. *Soil Biology and Biochemistry*, 40: 2843-2853.

Jeffery, S., Verheijen, F.G.A., van der Velde, M. and Bastos, A.C. (2011). A quantitative review of the effects of biochar application to soils on crop productivity using meta-analysis. *Agriculture, Ecosystem and Environment*, 144: 175–187.

Larney, F. J. and Angers, D. A. (2012). The role of organic amendments in soil reclamation: A review. *Canadian Journal of Soil Science*, 92:19–38.

Panda, A. K., Rama Rao, S.V. and Raju, M. V. L.N. (2008). Poultry manure a potential bio-fertilizer for crops. *Indian farming*, 58:13-14.

Rivelli, A.R. and Libutti, A. (2022). Effect of Biochar and Inorganic or Organic Fertilizer CO-Application on Soil Properties, Plant Growth and Nutrient Content in Swiss Chard. *Agronomy*, 12: 2089.

Sandhya, k. and Prakash, N. B (2018). Diatomite and rice husk biochar as silicon source and its effect on yield of wetland rice. *Journal of the Indian Society of Soil Science*, 66, 200-207.

Wang, Q.Q., Huang, Q., Guo, G.M., Qin, J.M., Luo, J.Y., Zhu, Z.Q., Hong, Y., Xu, Y.X., Hu, S., Hu, W., Yang, C. and Wang, J.F. (2020). Reducing bioavailability of heavy metals in contaminated soil and uptake by maize using organic-inorganic mixed fertilizer. *Chemosphere*, 261: 128122.

Zublena, J. P., Barker, J. C. and Corter, T.A. (1993). Poultry manure as a fertilizer source. Soil facts. North Carolina. Coop. Ext. Series Raleigh. North Carolina, 32.

PRODUCTION OF QUALITY COMPOST USING UNDERUTILIZED RESIDUES AND WASTES WITH *Spirulina* AND PANCHAGAVYA

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Abstract

The research study was aimed to produce good quality compost by using yard waste (YW), fruit waste (FW), cow dung (CD), Palmyrah leaf (PL), Coconut leaf (CL), Banana pseudostem (BP), Azolla (AZ) and *Spirulina* (SP). In addition, locally made solution (panchagavya - PC) was also assessed for its potential to improve composting process. An experiment was conducted in completely randomized design with six different treatments with degrees of freedom 11. Treatments were prepared according to the C, N content of raw materials which were adjusted to initial C/N ratio of about 40:1. Treatments were, T_1 - 25% BP + 25% PL + 25% CL + 24% AZ + 1 % SP + 5% PC, T_2 - 25% BP + 25% PL + 25% CL + 24% AZ + 1% SP, T_3 - 12.5% BP + 12.5% CL + 12% AZ + 0.5% SP + 50% CD + 5% PC + 12.5% PL, T_4 - 12.5% BP + 12.5% PL + 12.5% CL + 12% AZ + 0.5% SP + 50% CD , T_5 - 30% FW + 30% YW + 40% CD + 5% PC, T_6 - 30% FW + 30% YW + 40% CD. The physical and chemical properties of compost were analysed. Physical properties such as sand content, decomposition rate in terms of particle size, moisture content, were between 4.18% (T_1) to 15.64% (T_5), 66.13% (T_2) to 91.41% (T_5), 30.08% (T_3) to 35.50% (T_4) respectively. Blackish brown colour or Dark brown colour and odourless quality were observed in all compost treatments. Chemical properties such as pH, C, N, C: N ratio, P, K were between 7.13%(T_3) to 8.07%(T_6), 31.60% (T_6) to 49.48% (T_1), 1.49% (T_6) to 1.98% (T_3), 18.76% (T_5) to 25.84 %(T_4), 1.01% (T_4) to 1.88% (T_2), 1.10% (T_6) to 4.25% 38(T_1) respectively. The results showed that panchagavya treatments significantly increased decomposition rate than those of without panchagavya treatments. All compost treatments complied with SLS (1246:2003) in all aspects, except sand content and decomposition rate. All SLS requirements were complied in T_3 compost and T_4 compost. Thus, it can be concluded that the 5% of panchagavya solution can be used to improve the decomposition rate. It also revealed that, quality compost can be produced by mixing *Spirulina* and Azolla with locally available resources.

Keywords: Organic nutrient source, panchagavya, plant residues, quality compost, waste management

Introduction

One of the environmental issues faced by farmers and agro-based industries is the disposal of organic waste from cutting, harvest residues, postharvest residues, fecal materials of farm animals and fruit peels. On the other hand, due to the ban and high cost of inorganic fertilizers, farmers face difficulties in meeting the nutrition demand of crops. Organic fertilizer is beneficial one compared to inorganic, since it is environmentally friendly as well as economically sustainable by preserving and refining soil quality, minimizing water use, preserving biodiversity, halting the use of harmful chemicals, increasing carbon sink, thereby producing healthy food to consumers (Gomiero *et al*., 2011). Though farmers are willing to use organic fertilizers, the availability of such quality fertilizers in the required amount and reasonable cost is questionable. If organic fertilizers could be manufactured at low cost using available waste material, it will be beneficial to farmers. They can get fertilizers at low cost and waste material also could be disposed in an eco-friendly way.

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Composting is a biotic process in which microorganisms transform organic materials into humus (Rynk, 1992). It provides the chance to carefully convert organic waste into inputs for agricultural production and it is not only a foundation of plant nutrients but also a good soil conditioner. Therefore, the use of compost is profitable and environment friendly activity in sustainable agriculture. However, poor quality of compost in terms of low nitrogen and higher sand percentage (Kannan, 2010), which does not comply the Sri Lankan Standard (SLS) (1246: 2003) has been reported in Sri Lanka. Apart from that the available compost are with slow rate of composting and high C/N ratio. Therefore, this study aimed to identify a suitable composition of raw materials to produce quality compost according to SLS at a pilot scale by using different combinations of underutilized residues such as cow dung, Palmyrah leaf, Coconut leaf, Azolla, Fruit waste, Farmyard waste, *Spirulina* sp. and *panchagavya*. *Panchagavya* is an organic product which is a blend of five products obtained from cow, namely dung, urine, milk, curd and ghee in a unique way, is also rich in different kinds of microbes which can enhance decomposition rate of composting materials (Sailaja *et al*., 2014).

Materials and Method

Collection of Raw Materials for Composting

The basic raw materials used for composting were Palmyrah leaves, Coconut leaves, Cow dung, Banana pseudostem, Farm yard waste, Fruit waste, *Spirulina*, Azolla, and 5% of panchagavya (PC) solution. All the raw materials except PC were collected as fresh and then air-dried.

Composting Experiment

Composting was carried out in plastic bins of 20 L capacity. Each composting bin consists of different combinations of 4 kg composting materials made up of yard waste (YW), fruit waste (FW), cow dung (CD), Palmyraf leaf (PL), Coconut leaf (CL), Banana pseudostem (BP), Azolla (AZ) and *Spirulina* (SP). According to the C and N percentage of each raw material each bin was mixed with different compositions and ratios of raw materials to prepare six different compost treatments with approximate C: N ratio of 35:1, with two replicates. The treatments were T1 - 25%BP + 25%PL + 25%CL + 24%AZ + 1%SP + 5%PC, T2 - 25%BP + 25%PL + 25%CL + 24%AZ + 1%SP, T3 - 12.5%BP + 12.5%CL + 12%AZ + 0.5%SP + 50%CD + 5%PC + 12.5%PL, T4 - 12.5%BP + 12.5%PL + 12.5%CL + 12%AZ + 0.5%SP + 50%CD , T5 - 30%FW + 30%YW + 40%CD + 5%PC, T6 - 30%FW + 30%YW + 40%CD. Each bin was watered two times in a week to maintain optimum moisture content about 60%. It was monitored by hand-squeeze quick test. During the composting, every day, temperature of each treatment was monitored with compost thermometer. The content of composting bins was turned every two weeks. The experimental study was laid out in a Completely Randomized Design (CRD) with df 11.

Compost Analysis

Physical and chemical properties of compost were analyzed according to SLS 1246: 2003 methods. Triplicates from each composting bin were analyzed. Physical properties, were analyzed as follows; Colour by Munsell Soil Colour Chart, Odour by smelling, Moisture Content -oven dry method and Particle Size by sieving. Chemical properties were analyzed by the following methods: pH by using digital pH meter, Nutrient content analysis was done according to standard method (Kalra, 1971). Total Organic Carbon by loss on ignition method, Total Nitrogen by Kjeldhal method, Total Phosphorus content was determined by Vanadomolybdate method - Dry ash method and Total Potassium content was measured using flame photometer- Dry ash method.

Statistical Analysis

The data were statistically analysed using Statistical Analysis Software version 9.1.3 (SAS, 2009), Duncan's multiple range test was used to compare means.

Results and Discussion

Table I shows the physical and chemical properties of final compost from /different treatments. Compost of T_1 and T_2 was turned dark brown and all other compost were turned blackish brown colour. According to SLS (1246: 2003), colour for final compost should be brown / grey to dark black. There was no any unpleasant smell observed in any of the compost bins. Initially, all the compost treatments were kept at 60% of moisture level. Moreover, at 8th week, the moisture content values in all composts were ranged from 30.08% to 35.50%. The highest moisture content was recorded in compost T_4 whereas no significant difference was observed among others except T_1. According to SLS (1246: 2003) moisture of the compost should be less than 33.33% in wet basis. Except T_4 compost, others complied with SLS. The sand content of 15.64% in T_5 compost was significantly higher than the rest of the compost treatments. The lowest sand content 4.18% was observed in T_1 compost whereas T_3 compost was not significantly different from that of T_4. According to SLS (1246:2003) sand content of the final compost should be less than 10%. However, except T_5 and T_6 other compost treatments were complied with SLS in sand content. The possible reason for having high sand content in T5 and T_6 may be due to the farmyard waste as one of the components, which contained sand.

The highest decomposition rate was observed in compost T_5 (91.41%), while the lowest decomposition rate (66.13%) was observed in compost T_2. Moreover, when comparing the compost of panchagavya treatments and without panchagavya treatments, significant difference (p=0.05) was observed among their pairs because panchagavya is rich in various kinds of microbes which possibly increased decomposition rate of composting (Sailaja *et al*., 2014). According to SLS (1246: 2003) the decomposition rate in final compost should be higher than 80%.

Table 1: Results of chemical and physical properties of produced different compost

Treatment	Moisture Content %	Sand Content %	pH	Decomposition Rate %	Organic C %	Total N %	C/N ratio	P (P_2O_5) %	K (K_2O) %
T_1	32.51^{a}	4.18^{e}	7.23^{b}	75.37^{d}	49.48^{a}	1.95^{a}	23.21^{a}	1.55^{a}	4.26^{a}
T_2	31.22^{b}	6.13^{d}	7.33^{b}	66.13^{e}	42.46^{b}	1.72^{ab}	22.54^{a}	1.88^{a}	3.06^{ab}
T_3	30.08^{b}	7.73^{c}	7.13^{b}	86.70^{b}	39.99^{b}	1.99^{a}	20.23^{ab}	1.44^{a}	3.73^{a}
T_4	35.50^{a}	7.15^{c}	7.23^{b}	83.95^{c}	43.66^{b}	1.69^{ab}	23.52^{a}	1.01^{b}	1.46^{cd}
T_5	31.34^{b}	15.64^{a}	7.93^{a}	91.41^{a}	31.83^{c}	1.74^{ab}	18.76^{c}	1.38^{a}	2.45^{bc}
T_6	30.42^{b}	13.08^{b}	8.07^{a}	87.83^{b}	31.60^{c}	1.50^{b}	21.16^{ab}	1.61^{a}	1.01^{d}

T1 – 25% Banana pseudostem + 25% Palmyrah leaf + 25% Coconut leaf + 24% Azolla + 1% Spirulina + 5% Panchakavya , T2 - 25% Banana pseudostem + 25% Palmyrah leaf + 25% Coconut leaf + 24% Azolla + 1% Spirulina , T3 – 12.5% Banana pseudostem +12.5% Palmyrah leaf + 12.5% Coconut leaf + 12% Azolla + 0.5% Spirulina + 50% Cow dung + 5%Panchakavya ,T4 - 12.5% Banana pseudostem +12.5% Palmyrah leaf + 12.5% Coconut leaf + 12% Azolla + 0.5% Spirulina + 50% Cow dun,g T5 – 30% Fruit waste + 30% Yard waste + 40% Cow dung + 5%Panchagavya , T6 - 30% Fruit waste + 30% Yard waste + 40% Cow dung

Same letters within columns are not statistically different by the DUNCAN at p=0.05

Except T_1 and T_2, others complied with SLS. The possible reason for that T1 and T2 were prepared using Palmyrah leaves and Coconut leaves which have high lignin content. The highest pH was found in compost T_6 (8.07). According to SLS (1246:2003), pH for compost should be in the range of 6.5 to 8.5. All compost treatments complied with SLS in pH.

The lowest carbon content was observed in compost T_6 (31.60%). The highest carbon content was observed in T_1 (49.48%). According to SLS (1246:2003) for total organic carbon content of compost should be greater than 25 %. All compost treatments complied with SLS. The highest nitrogen content was observed in compost T_3 (1.98%). The lowest nitrogen content was

observed in compost T_6 (1.49%). Moreover, there was significant difference (p= 0.05) between panchagavya treatments and non - panchagavya treatments. The highest C:N ratio was recorded in compost T_4 and lowest C:N ratio was recorded in compost T_5 (18.76%). According to SLS (1246:2003), for C:N ratio should be in between 10-25. All compost treatments complied with SLS. The highest phosphorous content was observed in compost T_2 (1.88%). The lowest phosphorus content was observed in compost T_4 (1.01%). According to SLS (1246:2003), total phosphorus content should be greater than 0.5% in the final compost. In comparison with SLS, total phosphorus content was higher in the all composts. Total phosphorus content regularly rises during the composting process. The highest potassium content was observed in compost T_1 (4.25%), The lowest potassium content was observed in compost T_6 (1.10%). According to the SLS (1246:2003), total potassium content in final compost should be greater than 1 %. In comparison with SLS, total potassium content was higher in the compost produced from all treatments.

Conclusion

The result of the study revealed that, panchagavya has the potential to increase the decomposition rate. All compost treatments complied SLS (1246:2003) in all aspects, except sand content in T_5 and T_6 and decomposition rate in T1 and T2. Out of six treatments the highest nutrient content was recorded in T1 compost (25% Banana pseudostem + 25% Palmyrah leaf + 25% Coconut leaf + 24% Azolla + 1% Spirulina + 5% Panchakavya). All SLS requirements were complied in T3 compost (12.5% Banana pseudostem +12.5% Palmyrah leaf + 12.5% Coconut leaf + 12% Azolla + 0.5% Spirulina + 50% Cow dung + 5%Panchakavya) and T4 compost (12.5% Banana pseudostem +12.5% Palmyrah leaf + 12.5% Coconut leaf + 12% Azolla + 0.5% Spirulina + 50% Cow dung). Results therefore indicated that the T3 and T4 combination of raw materials has the potential to produce quality compost in all tested aspects. If the farmyard waste is propery handled to avoid sand content, quality of compost of the treatments T5 and T6 also could meet all SLS standards tested. Nutrient content of T1 and T2 was higher compared to other treatments, therefore further studies are recommended to improve the decomposition rate of these two treatments.

References

Gomiero, T., Pimentel, D. and Paoletti, M.G., (2011). Environmental impact of different agricultural management practices: conventional vs. organic agriculture. *Critical reviews in Plant Sciences*, 30(1-2):95-124.

Kalra, Y.P. (1971). Methods used for soil, plant, and water analysis at the soils laboratory of the Manitoba- Saskatchewan region, 1967-1970. Environ. Can., Can. For. Res. Cent., Edmonton, Alberta, Canada. Inf. Rep. 6935-2.

Kannan, N., Prabhaharan, M., and Jeyapiratha, V. (2010). Field trail of enriched compost in red-yellow latosol of Jaffna Peninsula, Sri Lanka. *Am-Euras. J. Agric. & Environ. Sci*., 7 (4): 370- 373.

Sailaja, V., Nagaragini, N., Dileep kumar, K., Rajasekhr reddy, B., and Satyanarayana, S.V. (2014). Effect of folir application of panchagavya on growth and development of leafy vegetables. *International Journal of Agricultural and Food Science*, 4 (4):119-122.

Rynk, R. (1992). On farm-composting hand book. Northeast Regional Agricultural Engineering Service, Coop. Ext., NRAES-54 Ithaca, NY, USA. 4 Ithaca, NY, USA.

NITROGEN ENRICHMENT OF ORGANIC COMPOST THROUGH DIFFERENT FORMULATED STEPS

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Abstract

Agriculture sector is the main factor deciding the country's position in terms of economy and development. The main aim of the study was to enrich the compost with different steps such as changing the ratio of raw materials, using different fermented organic moisturizing solutions and incorporating different nitrogen rich organic liquids. The study was conducted in RARDC during period of February to May 2022 different types and ratio of raw materials. Plant and animal materials were used with different moisturized solution, enrichment process and ratio of the raw materials. T1 (2:1, plant materials: animal manure, moisturized with decomposing solution), T2 (1:2, plant materials: animal manure, moisturized with decomposing solution), T3 (1:1, plant materials: animal manure, moisturized with decomposing solution), T4 (2:1, plant materials: animal manure, moisturized with water), T5 (1:2, plant materials: animal manure, moisturized with water),T6 (1:1, plant materials: animal manure, moisturized with water). Raw materials were analyzed for, moisture content, total N, P and K. The treatments were kept in model structure and for maturation upto 8th week. In 2 weeks, interval temperature and moisture content were recorded. After the maturation all six treatments were sub- dived into 18 portions for another finding. After the maturation compost sample was collected and enriched with organic fertilizer. And the samples were analyzed for their physical and chemical properties. Physical properties such as sand content, odor, color and moisture content and chemical properties such as pH, EC, C, and C:N ratio, N P, and K were measured. And those results were compared with SLSI standard. The results indicated that the enrichment process significantly gives a positive effect on compost total nitrogen content.

Keywords: Compost, nutrient enrichment, organic fertilizer, plant-animal manure, soil nutrient, soil physical properties

Introduction

In world, organic wastages are beneficial matters for producing valuable organic fertilizers. A good management system can help to convert organic waste to a beneficial product and also to improve the health of humans and to conserve the rural and urban societies (Hoornweg and Bhada-Tata, 2012). However, half of the waste is turned into beneficial compounds such as compost like fertilizer for planting, half of the waste is dumped in low land. Fertilizer plays a major role in agriculture in terms of yield, and, market value. Now a days, agriculture mostly depends on chemical fertilizers thereby inorganic agriculture plays a major role in world food agriculture. For the organic cultivation compost is used as fertilizer by most of the farmers. Compost is known as partially decomposing organic matters consist decayed organic matter and it is used to fertilize the land (Riwandi *et al*., 2018). Compost is made from crop residues and/or animal manures which are incubated for several days up to three months. the major problem in using compost is deficiency of nutrients mainly nitrogen. The detrimental issue can be overcome by enriching the compost which will be favourable to the farmer. The enrichment can eliminate the large amount of fertilizer need. Compost can be enriched by using leguminous plant as the raw material (Losia and Taguiling, 2013). Also, compost can be enriched via various

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methods such as adding the beneficial microorganisms (Pugliese *et al.*, 2016), adding an organic solution in the final maturation of the composting. Enriching is of cost-effective method, when using locally available materials for enriching, it will be helpful to the farmer to reduce the cost of cultivation.

Material and Method

The experiment was designed to find out the effective solution for compost enrichment with three replicates and six treatments. T1 (2:1 (plant materials: animal manure, moisturized with decomposing solution)), T2 (1:2(plant materials: animal manure, moisturized with decomposing solution)), T3 (1:1(plant materials: animal manure, moisturized with decomposing solution)),T4 (2:1(plant materials: animal manure, moisturized with water), T5 (1:2(plant materials: animal manure, moisturized with water)),T6 (1:1(plant materials: animal manure, moisturized with water)). The model structure for preparing compost was designed and fixed in the field. To prepare the compost, the materials were selected and chopped with multi chopper and were put into the model structure, were allowed for maturation for 8weeks. In one week, interval, the compost temperature was checked and moisturized with water and decomposing solution. To prepare decomposing solution cow dung and cow urine were mixed and allow for 14 days. After the maturation compost was sieved and fish tonic, panchagauvya were added according to treatment design. Total nitrogen content, total phosphorus content and, total potassium content compostes prepared were analysed. C:N ratio, moisture content, temperature, sand percentage, pH, EC and total organic carbon content were tested according to the SLSI standard. The data were analysed using SAS and mean separation. Mean separation was done via Duncan multiple range test at p=0.05 level.

Results and Discussion

Analysis of nutrient content

Total nitrogen content

The nitrogen analysis was done using Kjeldhal method. After the maturation samples were collected and tested. Here enriching with fish tonic and panchagauvya showing the better results. Therefore, enhance of total nitrogen concentration is commonly observed in the matured compost (Riwandi *et al*., 2018). However, enriching with fish tonic was the better method in increasing the total N content.

Total potassium content

Analysis was done Flame photo meter method. Here enriching with fish tonic and panchagauvya was showing the better results. In here adding the fish tonic was the best method for get a good compost.

Total phosphorus content

Analysis was done Spectrophotometer method. Here enriching with fish tonic and panchagauvya was showing the better results. In here enriching with fish tonic was the best method for get a good compost.

Analysis of other parameters

Other parameters were tested to ensure the SLS standard. Organic carbon was tested via Walkley-black method, total moisture content was tested via dry ash method, total p^H and EC were tested via p^H meter and EC meter, color, odor and sand content also tested via physical analysis.

Treatments		pH	EC	Moisture content(%)	Sand content(%)	Total N(%)	P(%)	K(%)	OC(%)	C:N ratio(%)
Standard		**6.5-8.5**	**0.5-3**	**<25**	**<20**	**>1**	**>0.5**	**>1**	**>20**	**10-25**
T1	T1No enrichment	6.79a	1.58a	26.75a	14.36a	1.02a	3.91a	0.34c	44.67a	16.43a
	T2Enriched with fish tonic	6.29c	1.83b	27.15b	14.36a	1.41b	4.54b	0.86b	46.26a	21.33b
	T3Enriched with panchagauvya	6.33ab	1.98a	26.89a	14.36a	1.21a	5.41a	0.66a	43.55c	21.44b
T2	T4No enrichment	6.62c	2.51c	32.75c	19.76a	1.01c	4.16c	0.44a	42.45a	21.56a
	T5Enriched with fish tonic	6.4Ib	2.81a	32.35b	19.76a	1.19b	4.42a	0.61b	41.33c	19.98a
	T6Enriched with panchagauvya	6.54c	2.41c	31.96c	19.76a	1.04a	4.55a	0.52a	45.64a	17.87b
T3	T7No enrichment	6.23b	2.17a	20.49b	14.36a	0.89a	3.62c	0.66a	43.87c	21.56a
	T8Enriched with fish tonic	6.22c	2.57b	21.01a	14.36a	0.96c	5.04b	0.72b	41.64b	19.45b
	T9Enriched with panchagauvya	6.13a	2.89a	20.34ab	14.36a	1.01b	5.03a	0.61a	43.76a	12.15c
T4	T10No enrichment	6.63a	2.83c	22.76a	22.12a	0.98b	4.02b	0.45c	38.76a	13.56a
	T11Enriched with fish tonic	6.43c	2.33b	21.96b	22.12a	0.96c	4.42b	0.76b	39.87b	19.45b
	T12Enriched with panchagauvya	6.93a	2.23a	22.43c	22.12a	0.89a	4.67a	0.32a	42.76a	14.75a
T5	T13No enrichment	6.56a	1.37a	32.75c	24.65a	0.92a	4.68b	0.48a	38.76a	21.47a
	T14Enriched with fish tonic	6.86b	1.77c	31.87b	24.65a	1.03c	4.85c	0.83b	36.45c	19.45b
	T15Enriched with panchagauvya	6.36b	1.67a	32.99b	24.65a	1.04b	4.77a	0.67b	40.83b	21.56a
T6	T16No enrichment	6.84c	2.26a	23.12a	23.87a	0.74b	4.08c	0.66c	37.87a	19.45a
	T17Enriched with fish tonic	6.65a	2.22c	22.83b	23.87a	0.96a	4.67a	0.87a	40.52b	13.66a
	T18Enriched with panchagauvya	6.43b	2.66b	23.52a	23.87a	0.89a	4.87a	0.71b	39.88b	18.98b
	CV	**8.3**	**4.2**	**7.3**	**16.9**	**21.14**	**6.7**	**3.8**	**13.3**	**10.7**

Conclusions

The study was proved that 2:1 ratio of raw materials (Plant: Animal), moisturized with decomposition solution and enrich with fish tonic treatment gave the significant nitrogen content in organic compost. The enrichment process was recommended for increase the compost usage among farmers.

References

Agamuthu, P., Tan, Y.S., and Fauziah, S.H. (2013). Bioremadiation of hydrocarbon contaminated soil using selected organic wastes. *Proceeding of environmental science and technology, International Symposium on Environmental Science and Technology*, 18: 694-702.

Hoornweg, D and Bhada-Tata, P., 2012.What a waste: a global review of solid waste management

Inckel, M., de Smet, P., Tersmette, T. and Veldkamp, T., 2005. The preparation and use of compost (Vol. 27). Agromis

Riwandi M, Handajaningsih and Hasanudin. 2012 Teknologi Tepat Guna*: Pupuk Kompos dan Teknologi Pembuatannya* (Unib Press) 61p.

PRODUCTION OF QUALITY COMPOST USING LOCALLY AVAILABLE RESOURCES

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Abstract

Compost is a high-demand organic fertilizer in agriculture. Though farmers are willing to use compost, the availability of quality compost is a question. It is one of the reasons for higher inorganic fertilizer usage by farmers. Therefore, it is essential to focus on large-scale production of low-cost eco-friendly quality organic fertilizers. In this background, a study was aimed to produce good quality compost by using locally available resources such as cowdung (CD), goat manure (GM), poultry manure(PM), paddy straw(PS), yard waste(YW), banana residues (BR), palmyrah leaf (PL), *Gliricidia sepium* (GS) and a locally made solution (panchagavya (PA). Treatments were prepared according to the C, N content of raw materials which were adjusted to an initial C/N ratio of about 40:1. The compost treatments were carried out in a Complete Randomized Design (CRD) with six treatments namely T1 - CD+ GS+ PL+ BR+ PS, T2 - CD+ GS+ PL+ BR+ PS + 20% PA, T3 - CD+ PM+ PL+ BR+ PS, T4 - CD+ PM+ PL+ BR+ PS + 20% PA, T5 - CD+ GM+ PL+ BR+ PS+YW, T6 - CD+ GM+ PL+ BR+ PS+ YW + 20% PA. The treatments were composted in bed for two months period. After two months, the physical and chemical properties of compost were analysed. The data were statistically analysed using Analysis of Variance and treatment means were compared using Duncan's multiple range test. Results showed that physical properties such as sand content, decomposition rate in terms of particle size, moisture content, were in-between 5.61% (T3) to 2.86% (T4), 91.87% (T5) to 94.64% (T2), and 14.88% (T2) to 19.37% (T1) respectively. Blackish brown colour and odourless quality were observed in all compost treatments. Chemical properties such as pH, C, N, C: N ratio, P_2O_5 and K_2O were in-between 7.54 (T2) to 8.07 (T3), 27.97% (T2) to 31.44% (T6), 1.84% (T6) to 2.5% (T1), 11.6% (T1) to 17.13% (T6), 0.55% (T1) to 1.29% (T4) and 4.19% (T2) to 8.59% (T4) respectively. Results revealed that compost produced in all treatments complied with SLS standards (1246:2003) in all chemical and physical quality aspects. This finding indicates that all compost treatments have potential nature of quality compost and farmers can use any of the compost treatments out of six to produce quality compost depending on the availability of raw materials in the farm.

Keywords: Organic nutrient source, panchagavya, plant residues, quality compost, waste management

Introduction

One of the environmental issues faced by farmers and agrobased industries is the disposal of organic waste from cutting, harvest residues, postharvest residues, fecal materials of farm animals and fruit peels. On the other hand, due to the ban and high cost of inorganic fertilizers, farmers face difficulties in meeting the plant nutrition demand of crops. Organic fertilizer is beneficial one compared to inorganic, it is environmentally friendly as well as economically sustainable by preserving and refining soil quality, minimizing water use, preserving biodiversity, halting the use of harmful chemicals, increasing carbon sink, thereby producing healthy food to consumers (Gomiero *et al*., 2011). Though farmers are willing to use organic fertilizers, availability of such quality fertilizers in required amount and reasonable cost is questionable. If quality organic fertilizers could be manufactured at low cost by using available waste material, it will be beneficial to farmers. They can get fertilizers at low cost and waste material also could be used in an eco-friendly way. Composting is a biotic process in which

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microorganisms transform organic materials into humus (Rynk, 1992). It provides the chance to carefully convert organic waste into inputs for agricultural production and it is not only a foundation of plant nutrients but also acts as a soil conditioner. Therefore, the use of compost is an essential activity in sustainable agriculture. However, poor quality of compost in terms of low nitrogen and higher sand percentage (Kannan *et al*., 2010) which does not comply with Sri Lankan Standard (SLS) (1246: 2003) has been reported in Sri Lanka. Apart from that available compost with low decomposition rate and high C/N ratio. In addition to that of countries which largely depend on imported inorganic fertilizers (Sri Lanka), it is essential to focus on large-scale production of low-cost eco-friendly organic fertilizers in order amidst the situations like Covid-19 pandemic and economic crisis. Therefore, this study was undertaken to convert animal waste and underutilized plant residues into a valuable organic fertilizer. The experimental study was conducted with the overall objective to produce a quality compost using locally available resources.

Materials and Method

Study location

The experimental study was conducted at the Integrated Farm and Training Centre, anakarayankulam and the laboratory analysis was carried out at Soil testing JICA Laboratory, Department of Agricultural Chemistry, Faculty of Agriculture, University of Jaffna.

Collection of raw materials for composting

The basic raw materials used for the composting were cowdung, goat manure, poultry manure, paddy straw, yard waste, banana residues, palmyrah leaf, and *Gliricidia sepium*, locally made solution panchagavya (PA). All the raw materials except PA were collected as fresh and then air dried.

Composting experiment

PA solution was prepared by following standard procedure (Natarajan, 2002). Composting has carried out in pile (bed) method. Raw materials were collected and chopped in to small particles by chopping machine. 5 feet * 5 feet * 5 feet size beds were prepared for each treatment. All the treatments were labelled accordingly. All parameters were monitored for each compost pile. For each treatment same amount of water was added and turned frequently. The overall C: N ratio of all compost piles were adjusted to 40:1, by altering the amounts of each raw material, based on their C/N ratio. The compost treatments were carried out in Complete randomized design (CRD) with six treatments namely T1 - CD+ GS+ PL+ BR+ PS, T2 - CD+ GS+ PL+ BR+ PS + 20% PA, T3 - CD+ PM+ PL+ BR+ PS, T4 - CD+ PM+ PL+ BR+ PS + 20% PA, T5 - CD+ GM+ PL+ BR+ PS+YW, T6 - CD+ GM+ PL+ BR+ PS+ YW + 20% PA. The treatments were composted in bed for two months period. Thereafter the decomposed materials in the piles were spread on the floor. After drying, compost was sieved by using 4mm sieve.

Compost analysis

Physical and chemical properties of compost were analyzed according to SLS 1246: 2003 methods. Triplicates from each pile were analyzed. Physical properties were analyzed as follows; Colour by Munsell Soil Colour Chart, Odour - by smelling, Moisture Content-oven dry method and Particle Size by sieving. Chemical properties were analyzed by following methods: pH by using digital pH meter, Nutrient content analysis was done according to standard method (Kalra, 1971). Total Organic Carbon by loss on ignition method, Total Nitrogen by Kjeldhal method, Total Phosphorus content was determined by Vanadomolybdate method - Dry ash method and Total Potassium content was measured by using flame photometer - Dry ash method.

Statistical Analysis

The data were statistically analysed using Statistical Analysis Software version 9.1.3(SAS, 2009), Duncan's multiple range test was used to compare means.

Results and Discussion

Table I shows the physical and chemical properties of final compost from /different treatments. All compost treatments were turned to blackish brown colour at 8th week. According to SLS (1246: 2003), colour for final compost should be brown / grey to dark black. There was no any unpleasant smell observed in any of the compost pile. Initially, all the compost treatments were kept at 60% of moisture level. Moreover, at 8th week, the moisture content values in all composts were ranged from 14.88% to 19.37%. The highest moisture content was recorded in compost T1 and the lowest moisture content was recorded in compost T2. According to SLS (1246: 2003) moisture of the compost should be less than 33.33% in wet basis. All treatments complied with SLS. Among all treatments the highest sand content was recorded in T3 (5.61%) and the lowest sand content was observed in T4 (2.86%) compost. According to SLS (1246: 2003) sand content for final compost should be less than 10%. Raw materials used to make compost especially cow dung was collected from cemented surface. Therefore, the final compost contained lower sand percentage than SLS (1246: 2003).

The decomposition rate values in terms of particle size ranged from 91.87% to 94.64%. The highest decomposition rate was observed in compost T2 (94.64%), while the lowest decomposition rate (91.87%) was observed in compost T5. According to SLS (1246: 2003) the decomposition rate in final compost should be higher than 80 %, All treatments comply with SLS. At 8th week of composting pH values ranged from 7.54 to 8.07. The highest pH was found in compost T3 (8.07) and the lowest pH (7.54) was found in compost T2 how ever there were no significant difference among treatments. According to SLS (1246: 2003), pH for compost should be in the range of 6.5 to 8.5. Here all treatments complied with SLS.

At the 8th week, total organic carbon values varied from 27.97% to 31.44%. The lowest carbon content was observed in compost T2 (27.97%), which was significantly lower than all other treatments. The highest organic carbon content was observed in compost T6 (31.44%) however there were no significant difference among T1 (29%), T3 (29.54%), T4 (31.03%), T5 (30.61%) and T6 (31.44%). According to SLS (1246: 2003) total organic carbon content of compost should be less than 20%. All compost treatments complied with SLS. Total nitrogen content varied from 1.84% to 2.5%. The highest nitrogen content was observed in compost T1 (2.5%) and it was significantly higher than other treatments. The lowest nitrogen content was observed in compost T6 (1.84%). According to SLS (1246: 2003), nitrogen content in final compost should be greater than 1%. Therefore, all compost treatments were complied with SLS. At 8th week, the values of C: N ratio for all the compost treatments had less than 25 which is indicating the approaching the mature stage. According to SLS (1246: 2003), the C: N ratio should be in-between 10 - 25. Therefore, all compost treatments were complied with SLS. Significantly lowest C: N ratio was recorded in compost T1 (11.6%) and significantly highest C: N ratio was recorded in compost T6 (17.13%). A significant difference found between the panchagavya treatments and non panchagavya treatments pair except T3 and T4 pair. The phosphorus content varied from 0.55% to 1.29%. Significantly highest phosphorus content was observed in compost T4 (1.29%) and significantly lowest phosphorus content was observed in compost T1 (0.55%). According to SLS (1246: 2003), total phosphorus content of compost should be greater than 0.5%. In comparison with SLS, total phosphorus content was higher in the all composts. Total potassium content varied from 4.19% to 8.59%. The highest potassium content was observed in compost T4 (8.59%) and lowest potassium content was observed in compost T2 (4.19%). According to the SLS (1246: 2003), total potassium content of compost should be

greater than 1%. In comparison with SLS, total potassium content was higher in the all composts.

Table 1. Results of chemical and physical properties of produced different compost

Treatment	Moisture Content %	Sand Content %	pH	Decomposition Rate %	Organic C %	Total N %	C/N ratio	P (P_2O_5) %	K (K_2O) %
T_1	19.37	3.79	7.76^{a}	92.28	29.00^{ab}	2.52^{a}	11.71^{c}	0.55^{e}	4.41^{b}
T_2	14.88	4.44	7.54^{a}	94.64	27.97^{b}	2.08^{bc}	13.48^{b}	1.10^{b}	4.19^{b}
T_3	16.74	5.61	8.07^{a}	94.51	29.54^{ab}	2.22^{b}	13.49^{b}	0.84^{d}	6.61^{ab}
T_4	16.94	2.86	7.95^{a}	93.11	31.04^{ab}	2.36^{b}	13.16^{b}	1.3^{a}	8.59^{a}
T_5	18.74	3.83	7.95^{a}	91.87	30.62^{ab}	2.31^{b}	13.34^{b}	1.01^{c}	6.39^{ab}
T_6	18.23	3.63	7.57^{a}	93.34	31.44^{a}	1.84^{c}	17.13^{a}	0.8^{d}	6.83^{ab}

T1 - CD+ GS+ PL+ BR+ PS, T2 - CD+ GS+ PL+ BR+ PS + 20% PA, T3 - CD+ PM+ PL+ BR+ PS, T4 - CD+ PM+ PL+ BR+ PS + 20% PA, T5 - CD+ GM+ PL+ BR+ PS+YW, T6 - CD+ GM+ PL+ BR+ PS+ YW + 20% PA. The same letters within columns are not statistically different by the DUNCAN at p=0.05

Conclusion

The result of the study revealed that, compost produced in all treatments complied SLS standards in all chemical and physical quality aspects. In terms of chemical properties T4 (Cow dung+ Poultry manure+ Palmyra+ Banana+ straw+ 20% Panchagavya.) gave significantly highest phosphorous content among all treatments , T1 (Cow dung+ Gliricidia+ Palmyra+ Banana+ straw) gave significantly highest nitrogen content among all treatments, T 4(Cow dung+ Poultry manure+ Palmyra+ Banana+ straw+ 20% Panchagavya) gave higher potassium content among all treatments and T6 (Cow dung+ Goat manure+ Palmyra+ Banana+ straw+ grass/yard waste+ 20% Panchagavya) gave higher organic carbon content among all treatments. Out of six different compost treatments the highest nutrient content were recorded in T4 Cow dung + Poultry manure + Palmyra + Banana + straw + 20% Panchagavya. All compost treatments complied SLS (1246:2003). Therefore, depend on availability of raw materials in farm; farmers can use any of the compost treatment out of six to produce quality compost.

References

Gomiero, T., Pimentel, D. and Paoletti, M.G., (2011). Environmental impact of different agricultural management practices: conventional vs. organic agriculture. *Critical reviews in Plant Sciences*, 30(1-2):95-124.

Kalra, Y.P. (1971). Methods used for soil, plant, and water analysis at the soil laboratory of the Manitoba- Saskatchewan region, 1967-1970. Environ. Can., Can. For. Res. Cent., Edmonton, Alberta, Canada. Inf. Rep. 6935-2.

Kannan, N., Prabhaharan, M., and Jeyapiratha, V. (2010). Field trail of enriched compost in red-yellow latosol of Jaffna Peninsula, Sri Lanka. *Am-Euras. J. Agric. & Environ. Sci*., 7 (4): 370- 373.

Natarajan, K. (2002). Panchagavya – manual. Other India Press, Mapusa, Goa, India. 33.

Rynk, R. (1992). On farm-composting hand book. Northeast Regional Agricultural Engineering Service, Coop. Ext., NRAES-54 Ithaca, NY, USA. 4 Ithaca, NY, USA.

FORMULATION OF A LOW-COST MEDIUM FOR THE CULTIVATION OF *Spirulina*

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Abstract

Spirulina is a spiral shaped, multicellular and filamentous blue-green microalgae. Although it has high nutritional potential, mass production of *Spirulina* is expensive due to the high cost of culture medium. Therefore, the present study was conducted to formulate a low-cost medium for the cultivation of *Spirulina.* Eight different growing media were formulated with ash of cow dung, rice husk and paddy straw in combination with Zarrouk's medium (Control- 100% Zarrouk's medium, T1- 50% Zarrouk's medium, T2- 100% cow dung, T3- 100% husk, T4-50% husk + 50% cow dung, T5- 50% cow dung + 50% Zarrouk's medium, T6- 50% husk + 50% Zarrouk's medium, T7- 100% cow dung + 50% $NaHCO_3$ and T8-100% husk + 50% $NaHCO_3$). Fresh culture of Spirulina was inoculated in to each medium and kept in a polyhouse. Optical density (OD), pH, weight of dry biomass, total nitrogen, potassium, phosphorus and chlorophyll content of *Spirulina* biomass were measured using standard methods. Data were statistically analyzed using SAS University edition. The pH of culture media was increased in all treatments throughout the growing period. The higher dry biomass was obtained from control (0.367 g/l), T1 (0.366 g/l) and T6 (0.363 g/l) after 28 days of inoculation. The highest total nitrogen, phosphorus and potassium of *Spirulina* biomass were recorded in T6 (50% husk+50% Zarrouk's, medium) as 6.10%, 0.24% and 4.54 % respectively. The highest total chlorophyll content was obtained from control (15.74%) followed by T6 (13.48%). Among all treatments, T6 (50% husk+50% Zarrouk's medium) had better responses to growth parameters, dry biomass, nutrient availability and chlorophyll content. Therefore, this study has verified the husk ash medium to partially substitute Zarrouk's medium to culture *Spirulina* could help to decrease the cost of medium.

Keywords: Biomass, cultivation, formulation, low-cost, *Spirulina*

Introduction

Spirulina is a spiral shaped, multicellular, filamentous and unbranched blue-green microalgae. It can play an important role in sustainable agriculture by improving crop growth and production, as well as environmental quality (Shedeed, 2022). The mass production of *Spirulina* is highly expensive due to high cost of standard medium (Zarrouk's medium). In order to decrease the cost of chemicals, waste materials can be utilized to supplement nutrients. This approach could lower the cost of production while efficiently using the waste from the environment (Markou and Georgakakis, 2011). Cow dung has high amount of nutrients, such as nitrogen, phosphorus and potassium. Paddy husk and paddy straw have considerable amount of minerals and other macro and micro nutrients (Koyama *et al*., 2016). On this background the present study was carried out with the overall objective to formulate a low cost medium using cow dung ash, paddy straw ash and paddy husk ash for semi mass production of *Spirulina* and assess the biomass production in the medium.

Materials and Method

Collection and Analysis of Raw materials

Raw materials (Cow dung, Paddy straw, rice husk) were collected and allowed to air dry for 6 days, and impurities were removed. They were burnt in field, at local conditions. The ash was

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sieved using 2 mm sieve and stored for further analysis and for formulation of medium. Nutrient Analysis of different ash of raw materials were analysed.

Formulation of low-cost medium and culturing of Spirulina

Eight culture media formulations were used in this study (Table 1). Semi mass culturing was carried out in a net house with eight treatments from laboratory culturing (Table 1). Mother culture of Spirulina was obtained from previous studies (Pirushanthi *et al.*, 2021). Complete randomized design was used with three replicates of treatments.

Table 1: Formulated medium for culturing of *Spirulina*

Treatment	Combination
Control	100% Zarrouk's medium
T1	50% Zarrouk's medium
T2	100% Cow dung
T3	100% Husk
T4	50% Husk + 50% Cow dung
T5	50% cowdung + 50% Zarrouk's
T6	50% husk + 50% Zarrouk's
T7	100% Cow dung + 50% $NaHCO_3$
T8	100% Husk + 50% $NaHCO_3$.

Harvesting and Drying of Biomass of Spirulina

Spirulina biomass was harvested on 28th day from inoculation by filtering with 63 µm sieve. Harvested biomass was oven dried at 75 ^{0}C for 48 hours to reach the constant weight then the dry weight of biomass was measured (Buddhika *et al.*, 2013).

Assessment of biomass and nutrient analysis

Changes of optical density was measured by using spectrophotometer at 560nm, changes of pH were measured by using pH meter, dry biomass was measured by using oven dry method, total nitrogen of *Spirulina* was estimated by Kjeldhal method, total potassium content was measured by using flame photometer, total phosphorus content was determined by Vanadomolybdate method and chlorophyll a and chlorophyll b were measured by using spectrophotometer at 663 nm and 647 nm respectively.

Results and Discussion

pH and Optical density

Changes in pH values of the *Spirulina* cultures were ranged from 7.78 to 10.0 within 28 days. Among all treatments control (100% Zarrouk's medium) recorded the highest optical density at 28th day, followed by T1 – 50% Zarrouk's medium, T6 - 50% husk + 50% Zarrouk's medium.

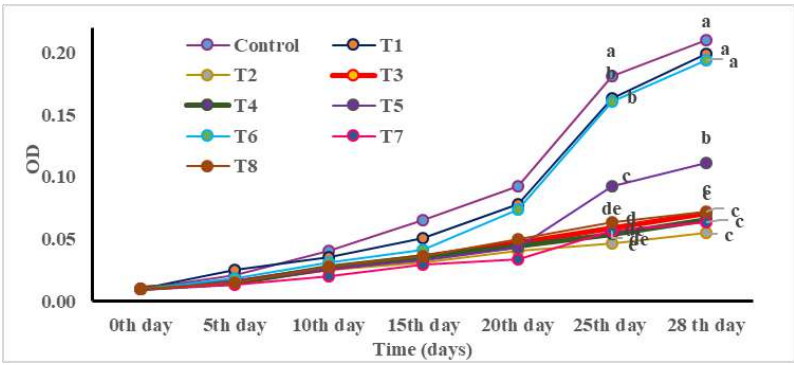

Figure 1: Optical density of growing medium in semi mass culture

However, there was no significant difference ($p>0.05$) between control, T1 and T6. Treatment with 100% cow dung (T2) without Zarrouk's medium had the least optical density at 28th day. This may be due to the less adaptation of *Spirulina* in 100% cowdung ash medium.

Dry Biomass of Spirulina in Different Culture Medium

Dry biomass yield of *Spirulina* under the different culture media are shown in Figure 2. The highest yield was obtained from 100% Zarrouk's medium (0.367 g/l), T1 (50% Zarrouk's medium) (0.366 g/l) and T6 (50% Husk + 50% Zarrouk's medium) (0.363 g/l). However, no significant differences ($p>0.05$) observed between those three treatments.

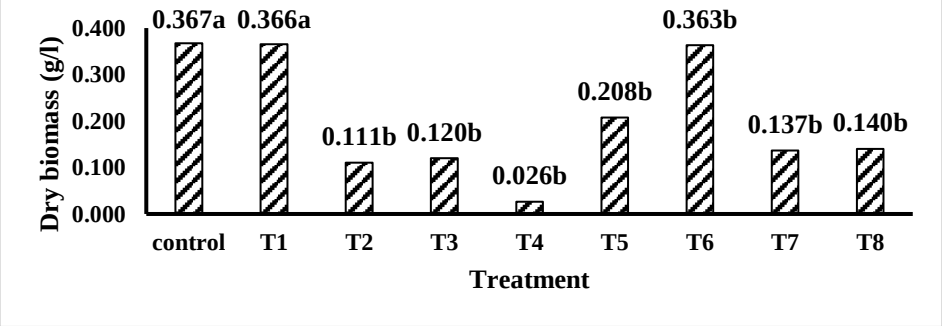

Figure 2: Dry biomass of *Spirulina* in different culture medium after 28 days of inoculation

Control – 100% Zarrouk's medium, T1 – 50% Zarrouk's medium, T2 – 100% Cow dung, T3 - 100% Husk, T4 - 50% Husk + 50% Cow dung, T5 - 50%Cowdung + 50% Zarrouk's, T6 - 50% husk + 50% Zarrouk's, T7 - 100% Cow dung + 50% $NaHCO_3$, T8- 100% Husk + 50% $NaHCO_3$

Nutrient Content of Spirulina in Different Culture Medium

Figure 3 shows the total nitrogen percentage of *Spirulina* biomass in different treatments. The highest total nitrogen and Phosphorus percentage was recorded in T6 (50% husk + 50% Zarrouk's medium) which was about 6.10% and 0.24 % respectively.

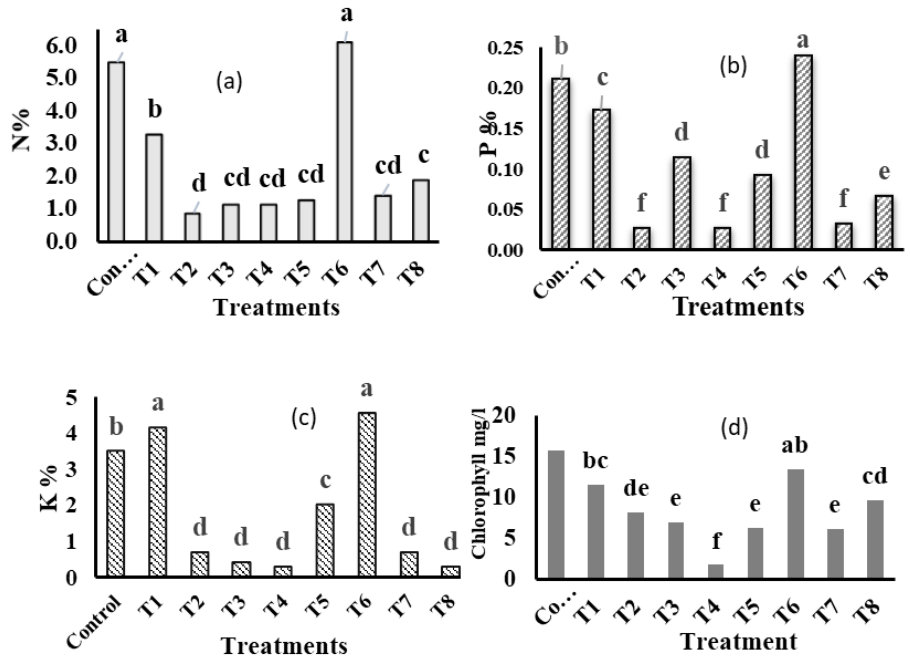

Figure 3: Nutrient content of Spirulina biomass (Percentage of total nitrogen (a), Phosphorous (b), Patassium (c) and Cholorophyll (d))

The difference in phosphorus percentage might be nutrient availability and adaptation of microalgae to medium (Solovchenko *et al*., 2016). Higher percentage of total potassium was observed in T6 (50% husk + 50% Zarrouk's medium) and T1 (50% Zarrouk's medium) as 4.54% and 4.14% respectively. There was no significant difference observed in between T6 (50% husk + 50% Zarrouk's medium) and T1 (50% Zarrouk's medium). Control (100% Zarrouk's medium) had the highest Total chlorophyll percentage which was 15.74 mg/l. However, there was no significant difference between control and T6 (13.48%). A study on *Spirulina* sp reported total chlorophyll of *Spirulina* as 37.64 mg/l in Zarrouk's medium (Mata *et al*., 2020). The reason for less total chlorophyll content might be due to the variance of temperature of culture medium (Usharani *et al*., 2012).

Conclusion

Control (100% Zarrouk's medium), T1 (50% Zarrouk's medium) and T6 (50% husk + 50% Zarrouk's medium) had high biomass of 0.367 g/l, 0.366 g/l and 0.363 g/l respectively. Nitrogen percentage of dry biomass was 5.47%, 3.30% and 6.10% respectively in control, T1 and T6. Available phosphorus of dry biomass was 0.21%, 0.17%, 0.24% was respectively in Control, T1 and T6. Available potassium of dry biomass was recorded as 3.48% 4.14%, 4.54% respectively in control, T1 and T6. Therefore, formulated medium T6 (50% husk + 50% Zarrouk's medium) has the potential to produce high biomass of *Spirulina* with higher nutrient content and also it is cost effective for higher biomass production. This study has verified that utilizing agricultural waste as ash medium to partially substitute Zarrouk's medium to culture *Spirulina* could help to decrease the cost of medium without affecting nutrient content of *Spirulina*.

References

Buddhika, U.V.A., Athauda, A.R.W.P.K., Seneviratne, G., Kulasooriya, S.A. and Abayasekara, C.L., 2013. Emergence of diverse microbes on application of biofilmed biofertilizers to a maize growing soil. *Ceylon Journal of Science (Bio. Sci.)*, 42(2):87-94.

Koyama, S., Katagiri, T., Minamikawa, K., Kato, M. and Hayashi, H., 2016. Effects of rice husk charcoal application on rice yield, methane emission, and soil carbon sequestration in andosol paddy soil. *Japan Agricultural Research Quarterly:* 50(4):319-327.

Mata, S.N., de Souza Santos, T., Cardoso, L.G., Andrade, B.B., Duarte, J.H., Costa, J.A.V., de Souza, C.O. and Druzian, J.I., 2020. Spirulina sp. LEB 18 cultivation in a raceway-type bioreactor using wastewater from desalination process: Production of carbohydrate-rich biomass. *Bioresource Technology*, 311:123495

Markou, G. and Georgakakis, D., 2011. Cultivation of filamentous cyanobacteria (blue-green algae) in agro-industrial wastes and wastewaters: a review. *Applied Energy*, 88(10):3389-3401.

Munirathna, K.S.P., Coswatte, A.C.W.W.M.C.L.K. and Jayamanne, S.C., 2019. Development of Low-Cost Mass Culture Media for Spirulina platensis. International Research Conference of Uva Wellasa University (IRCUWU 2019). University of Uva Wellasa, Sri Lanka.

Pirushanthi. G, Kirisan. A. Priyatharshini, B, Gnanavelrajah, N. and Ratnayake (2021). Production of Quality Compost Using Locally available waste incombination with Spirulina subsalsa. Proceedings of the Young Scientist Conference on Multidisciplinary Research - 2021, pp.25.

Shedeed, Z. A., Gheda, S., Elsanadily, S., Alharbi, K. and Osman, M. E. (2022). Spirulina platensis Biofertilization for Enhancing Growth, Photosynthetic Capacity and Yield of Lupinus luteus. *Agriculture*, 12(6): 781.

Usharani, G., Saranraj, P. and Kanchana, D., 2012. Spirulina cultivation: a review. *International Journal of Pharmaceutical & Biological Archives*, 3(6):1327-1341.

THE IMPACT OF LIQUID FERTILIZER FROM COW DUNG AND ITS COMBINATION WITH OTHER ORGANIC SOURCES ON NITROGEN AVAILABILITY, FLOWERING AND YIELD OF OKRA (*Abelmoschus esculentus*) IN SANDY REGOSOL

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Abstract

Adding chemical fertilizers to the soil for a long period of time may cause soil degradation and groundwater pollution. Sandy regosol soil is very low in plant nutrients, especially nitrogen, and poor in other nutrients due to its poor retention capacity. In order to overcome this, researches are going on to check the usage of organic sources as nutrient substitute in agriculture. Organic liquid nutrient solution is one of the alternative sources which consists of beneficial microorganisms to reduce harmful effects to humans and the environment by reducing the usage of chemical fertilizer. Hence, a field experiment was carried out at the crop farm, Eastern University of Sri Lanka to study the impact of liquid fertilizer from cow dung and its combination with other organic sources on nitrogen availability, flowering and total yield okra (*Abelmoschus esculentus)* grown in sandy regosol. The experiment was carried out in a RCBD design with five treatments having four replicates. Treatments were fresh cow dung, jaggery, water with respective organic material such as gliricidia leaves, insect-infested black gram flour and rotten banana fruit with peel, and DOA- recommended chemical fertilizers. The experiment evaluated soil and plant parameters: such as available nitrogen, days for 50% flowering and total yield. Data were statistically analyzed using Minitab, and the differences between treatments means were compared using the Tukey test at 5% significant level. The application of fresh cow dung and rotten banana fruit with peel showed the highest soil and plant performance. Hence, it could be used as an alternative source to improve soil and plant growth in okra cultivation in sandy regosol with reduced hazardous effects on the environment.

Keywords: Cow dung, insect-infested black gram flour, liquid organic fertilizer, rotten banana fruit with peel, plant growth promoting bacteria

Introduction

In our country, farmers are highly dependent on inorganic fertilizers as a source of plant nutrients, and the improper use of chemical fertilizers is linked to both environmental contamination and the destruction of soil (Phiri and Mbewe, 2010). Excessive use of artificial fertilizers in sandy regosol increases the risk of nitrogen loss and groundwater contamination (EPA, 2005). Nowadays the negative impact of excessive inorganic fertilizers on the environment and human health is increasing. Therefore, it is time to look for safe and environmentally friendly alternative sources of nutrients to improve plant and soil health. Traditional organic formulations may contain numerous plant growth-promoting bacteria (PGPB), which may enhance plant growth through nitrogen fixation, growth hormone production, and phytopathogens control (Amalraj, 2013). Banana fruits are frequently available in large quantities in Sri Lanka. Such materials can be used as a natural nutrient source for plants. Banana peels are a good source of P, and K as macronutrients and Ca, Mg, and Na as other nutrients. Peels are most effective when composted to blend with nitrogen-rich materials (Swain and Ray, 2019). Cow dung contains three major plant nutrients N, P, and K, and many essential nutrients such as Ca, Mg, S, Zn, B, Cu, Mn, etc. (Raj, 2014). Cow dung serves as a source of beneficial microorganisms. Gram flour contains good levels of amino acids that

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improve the beneficial microflora which helps a healthier root system that can fight diseases and maintain effectiveness in adverse conditions (Kulkarni and Gargelwar, 2019). The foliage of *Gliricidia sepium* is used for green manuring and to produce other kinds of organic manure due to its higher nutritional composition. This is a good trend for the sustainable development of agriculture while maintaining future biodiversity (Bengtsson *et al*, 2005). Organic fertilizers are available and relatively cheaper than chemical fertilizers (Wang *et al*., 2018). Organic liquid fertilizer production from biodegradable waste can be one of the most economical and effective ways of solving the garbage disposal problem in the world (Le *et al.*, 2018).

Materials and Method

A field experiment was conducted at the crop farm, Eastern University, Sri Lanka. The experimental site, located in the Eastern province of Sri Lanka, falls under the low country dry zone. The annual temperature varies from 26^0C to 32^0C. Annual rainfall varies from 1400 mm to 1680 mm. The soil of the experimental site is a sandy regosol. For this experiment, *Haritha* seeds were used. The experiment was carried out in a Randomized Complete Block Design (RCBD) with five treatments and four replicates.

Table 1: Details of treatments

Treatments	Amount	Fermentation Duration
T1	Fresh cow dung (8 kg), jaggery (300 g), water (3 l)	20-30 days
T2	Fresh cow dung (8 kg), gliricidia leaves (8 kg), jaggery (300 g), water (3 l)	14-21 days
T3	Fresh cow dung (8 kg), rotten banana fruit with peel (8 kg), jaggery (300 g), water (3 l)	40-50 days
T4	Fresh cow dung (8 kg), insect-infested black gram flour (300 g), jaggery (300 g), water (3 l)	48 hours
T5	Recommended chemical fertilizer	-

Organic liquid fertilizer preparation

Four plastic buckets with 50 l capacity, were filled with fresh cow dung, jaggery, water, and respective organic material such as gliricidia leaves, chopped rotten banana fruit with peel, and insect-infested black gram flour were added solely in first three buckets and the fourth was kept as it is as one treatment. The contents were mixed thoroughly, and the buckets were covered with a muslin cloth in order to prevent the propagation of harmful worms and maggots. Buckets were kept in shady condition. The fermentation process was carried out under aerobic conditions for the desired duration in between clamps were mixed well in the morning and evening for one week. The fermentation process was allowed at ambient temperature for aerobic microbial fermentation until the cycle of fertilizer production was completed without the presence of any odor. The degree of readiness of the organic liquid fertilizer was determined according to its physio-mechanical and organoleptic properties (homogeneity, looseness, and lack of smell) as recommended by Haji *et al*. (2020). When the above conditions are achieved, it was assumed that the fermentation cycle is completed. Thereafter, liquid organic fertilizer was filtered by using muslin cloth and transferred into a clean container with a tied lid. Each prepared organic liquid fertilizer was labeled clearly and kept under shaded condition.

Twenty experimental plots were prepared with a size of 1.8 m × 2.7 m. The seeds were soaked overnight and were sown at the spacing of 90cm×60cm. All agronomic practices were carried out in accordance with the Department of Agriculture recommendation. Organic liquid fertilizer treatments were applied soil application as well as foliar application. Soil sampling was done at initial and harvest stage. At harvest, four plants were uprooted from each plot for analysis. Data were statistically analyzed using Minitab, and the differences between treatments means were compared using the Tukey test at 5% significant level.

Table 2: Physio-chemical properties of prepared organic liquid fertilizers

Treatments	pH	EC (µS/cm)	N (%)	P (%)	K (%)	Organic carbon (%)
T1	5.87	8.82	0.71	0.95	1.53	2.859
T2	6.52	10.41	2.02	1.80	1.96	0.967
T3	6.96	10.08	2.58	3.12	3.19	2.695
T4	6.88	7.61	1.32	0.34	1.26	2.742

Results and Discussion

The statistically analyzed data of mean nitrogen content of soil and plant at 5% significant level is illustrated in Table III, which shows that there was significant difference (P<0.05) among treatments on soil and plant nitrogen content at harvesting stage. Significantly maximum soil nitrogen content was recorded in T2, while significantly minimum nitrogen content in soil was recorded in T1. Significantly maximum nitrogen content in plant dry matter was recorded in T3, while significantly minimum nitrogen content of plant was recorded in T1.

Table 3: Soil and plant nitrogen content (%) with respect to treatments at harvesting stage

Treatments	Soil nitrogen	Plant nitrogen
T1	0.00105 ± 0.00020^{c}	14.70 ± 0.70^{c}
T2	0.01365 ± 0.00020^{a}	24.50 ± 2.10^{ab}
T3	0.01015 ± 0.00141^{b}	26.60 ± 0.00^{a}
T4	0.01173 ± 0.00017^{ab}	23.10 ± 2.10^{ab}
T5	0.01137 ± 0.00053^{ab}	18.20 ± 0.00^{bc}
F test	**	*

*Value represent mean ± standard error of four replicates. F test :- *: P<0.05; **: P<0.01; Means followed by the same letter(s) in each column are not significantly different according to the Tukey Test at 5% level.*

In this present study results pertaining to the plant N content indicated higher plant N content in T3 than other treatments. Therefore, this clearly indicated that the nitrogen was readily available from T3 treatment and which favors the plant absorption (Mustapha *et al*., 2021). This may be the reason for lower nitrogen in soil at harvest in T3 that was supported by the initial value of this study (Table 2).

Table 4: Days for 50% flowering and total yield with respect to treatments

Treatments	Days for 50% flowering	Yield (kg/ha)		
		1st picking	2nd picking	3rd picking
T1	40	1.455 ± 0.250^{c}	1.438 ± 0.268^{c}	1.507 ± 0.253^{c}
T2	39	2.267 ± 0.262^{bc}	2.337 ± 0.300^{bc}	2.505 ± 0.373^{bc}
T3	35	3.846 ± 0.179^{a}	4.247 ± 0.237^{a}	4.439 ± 0.193^{a}
T4	36	2.713 ± 0.367^{ab}	3.259 ± 0.236^{ab}	3.436 ± 0.508^{ab}
T5	36	2.040 ± 0.301^{bc}	2.950 ± 0.120^{b}	3.636 ± 0.132^{ab}
F test	**	**	**	**

*Value represent mean ± standard error of four replicates. F test: *: P<0.05; **: P<0.01; Means followed by the same letter(s) in each column are not significantly different according to the Tukey Test at 5% level.*

The results indicated a significant difference (P<0.05) among treatments on days for 50%, flowering and total yield (Table 4). Significantly minimum duration was taken by T3 plants to attain the 50% flowering. Significantly longer time period was taken by T1 for 50% flowering. Theoretically, it was indicated for an additional need of nutrients for flowering and as banana is rich in nutrients this may influence the flowering and may be the reason for the shortest time period for flowering. Significantly the highest total yield was obtained in T3, while significantly the lowest total yield was obtained in T1 at each picking. The results are in agreement with Bakry *et al*. (2016) that effect of foliar application of banana peel extract significantly increased

the performances of plants. The initial highest nutrient content of banana peel liquid supported the finding (Table 2).

Conclusion

The results reveal that, soil and plant application of fresh cow dung and rotten banana fruit with peel had positive influence on soil and plant nitrogen content, days to 50% flowering and total yield. It could be suggested that among the all treatments fresh cow dung and rotten banana fruit with peel treatment would be the most suitable to get optimum growth and yield of okra in sandy regosol.

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References

Amalraj, E.L.D., Praveen Kumar, G., Mir Hassan Ahmed, S.K., Abdul, R. and Kishore N. (2013). Microbial analysis of panchagavya, vermicompost, and FYM and their effect on plant growth promotion of pigeon pea (*Cajanus cajan* L.) in India. *Organic Agriculture*, 3:23- 29.

Bakry, B.A., Ibrahim, F.M., Abdallah, M.M.S. and EI-Bassiouny, H.M.S. (2016). Effect of banana peel extract or tryptophan on growth, yield and some biochemical aspects of quinoa plants under water deficit. *International Journal of Pharm Tech Research*, 9(8):276-287.

Bengtsson, J., Ahnstrom, J. and Weibull, A.C. (2005). The effects of organic agriculture on biodiversity and abundance: A meta-analysis. *Journal of Applied Ecology*, 42(2):261-269. https://doi.org/10.1111/j.1365-2664.2005.01005.x

EPA. (2005). Protecting water quality from agricultural runoff, *United States Environmental Protection Agency, Washington,* DC. EPA 841-F-05-001. http://smithfieldri.com/pdf/engineer/Ag_Runoff_Fact_Sheet

Haji, K., Zekeria, Y. and Misrak, K. (2020). Production of bioorganic liquid fertilizer from cow manure and banana peels. *Advanced Research Journal of Biotechnology*, 4(5), 098-102

Kulkarni, S.S. and Gargelwar, A.P. (2019). Production and microbial analysis of jeevamirtham for nitrogen fixers and phosphate solubilizers in the rural area from Maharashtra. *ISOR Journal of Agriculture and Veterinary Science* (ISOR-JAVS), 12(8), pp 85-92. Doi: 10.9790/2380-1208018592

Le, N.P., Nguyen, T.T.P. and Zhu, D. (2018). Understanding the stakeholder's involvement in utilizing municipal solid waste in agriculture through composting: A case study of Hanoi, *Vietnam. Sustainability*, 10, 2314. https://doi.org/10.3390/su10072314

Mustapha, M., Alasa, J.J., Bashir, A.U. and Mohammed, B. (2021). Study on the use of banana and pineapple peel waste as biofertilizers: Enhancing soil fertility, promoting sustainable agriculture and environmental sanitation. *Arid zone journal of engineering, technology & environment,* 17(4): 569-574.

Phiri, C. and Mbewe, D. N. (2010). Influence of *Moringa oleifera* leaf extracts on germination and seedling survival of three common legumes. *International Journal of Agriculture and Biology*, 12:315-317.

Raj, A. (2014). Cow dung for ecofriendly and sustainable productive farming. *International Journal of Scientific Research,* 3(10): 201-202.

Swain, M.R. and Ray, R.C. (2009). Biocontrol and other beneficial activities of Bacillus subtilis isolated from cow dung microflora. *Microbial Res*, 164(2):121-130. Doi:10.1016/j.micres.2006.10.009

Wang, Y., Zhu, Y., Zhang, S. and Wang, Y. (2018). What could promote farmers to replace chemical fertilizers with organic fertilizers? *Journal of Cleaner Production*, 199, 882-890. https://doi.org/10.1016/j.jclepro.2018.07.222.

BIOCONVERSION OF SOLID WASTE INTO AN ORGANIC LIQUID FERTILIZER FOR IMPROVING CROP GROWTH AND YIELD

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Abstract

Management of solid waste has become one of the biggest issues in the world. Solid waste is one of the good sources for vermicomposting. Vermiwash is a liquid organic bio-fertilizer. A pot experiment was carried out to assess the efficacy of vermiwash, which was prepared through vermicomposting of solid waste, on the vegetative and yield components of pulse crops. The treatments were a recommended rate of commercial (T1) and 50% doses of commercial biofertilizer with four different concentrations of vermiwash: 20% (T2), 40% (T3), 60% (T4), and 75% (T5), along with the control. Two cowpeas (*Vigna radiata*) varieties, *MICP1* and *Dawala*, were used and the experiment laid out a complete randomized design with ten replicates. Recommended rate of commercial biofertilizer and 8 ml vermiwash were applied four times at 7, 14, 28, and 42 days after planting (DAP) as foliar sprayers. Plant height, number of leaves per plant at 20 and 60 DAP, days to first picking, number of branches per plant at harvesting stage, and number of pods per plant were measured. Data were subjected to an analysis of variance (ANOVA), and means pertaining to different parameters were separated using the least significant difference (LSD) test at P=0.05, The plant height of two selected varieties was influenced by varying concentrations of vermiwash ($P<0.05$). At 30 days after planting (DAP), the application of T4 resulted in the maximum plant height of var. *Dawala*, which was recorded as 29.31 ± 2.45 cm. Additionally, in comparison to the control group, *MICP1* exhibited the highest number of leaves, which was measured as 9±2.12 and was statistically significant.Var. *MICP1* reported significantly the lowest number of days to first picking (53±2.65) followed by T4. In the T4 treatment, var. *Dawala* reported the highest number of branches per plant, with a mean value of 15±2.31. Meanwhile, var. MICPI had the highest average number of pods per plant, which was recorded as 19±1.31 and was significantly different from all other treatments ($P<0.05$). The combination of 60% vermiwash and a half dose of commercial biofertilizer results in the greatest increases in plant height, number of branches at the harvesting stage, and number of pods per plant. The usage of vermiwash could be a suitable biological technique for the bioconversion of food, medical, and paper waste into organic nutrients-rich that can reduce the need for chemically synthesized fertilizers.

Keywords: Bioconversion, organic agriculture, solid waste, vermiwash

Introduction

Solid waste management is an enormous global challenge that interlinks with the Sustainable Development Goals (SDGs) of the United Nation. This threat has become more intense due to the increasing population and per capita income. By 2025, it is projected that the amount of municipal solid waste will increase to 1.42 kg/capita/day globally and 1 kg/capita/day in Sri Lanka (Saja *et al.*, 2021*)*. In the real scenario, waste management techniques and practices vary from location to location. It extends beyond the 4R concepts, 10R concepts, open dumping, landfill, thermochemical conversion, and bioconversion techniques. Open dumping is the most adaptable practice in Sri Lanka as well as in other developing Asian nations (Gunaruwan and Gunasekara, 2016). Because of the highly unhygienic and unscientific nature of this practice, an environmentally sound solid waste management method is required.

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A bioconversion process is an affordable approach that involves the microorganisms to produce the biobased compounds through fermentation, digestion, or solubilization. The exponential increase in food demand and nutritional security rises the necessity for biofertilizer research. The biomass from various feedstocks such as municipal waste, agriculture waste, and food waste can be incorporated into the bioconversion process to prepare organic-based fertilizer in the form of composting, vermi-wash, anaerobic and aerobic digestion using different techniques (Kiruba and Saeid, 2022).

Vermicompost/ vermiwash is an organic liquid that is rich in macro and micronutrients, vitamins, and growth hormones obtained from a rich population of earthworms (Gudeta *et al.*, 2021). The application of vermiwash enhances crop productivity along with disease suppression and pest control. The more the fertilizer liquified, the more nutrient became bioavailable. Even though the application of chemically synthesized fertilizers improves the soil property thus enhancing plant growth in different vegetative stages, sustainability is the main issue that chemical fertilizers could not address in the long run (Bhattacharyya *et al.*, 2020). The objective of this study is to evaluate the effectiveness of vermiwash prepared by vermicomposting using solid waste on vegetative and yield components of pulse crops.

Materials and Method

Construction of Vermiwash Unit: The shaded brick tank with the dimension of 1 m:1 m:0.75 m (length: width: depth) and a hole at the bottom. Organic waste collected from agricultural and food residues was used with cow dung with native earthworms (Perionyx ceylanensis) as an inoculant. Periodical sprinkling was performed to maintain adequate moisture. The brick tanks were covered properly to shade the content.

Planting Materials: Two cowpea (*Vigna radiata*) varieties, *MICP1* and *Dawala*, all of which are members of the Leguminosae family, were used in the current study. The experiment was laid out in a pot experiment in CRD with ten replicates. The treatments were biofertilizer fertilizer (T1) and 50% doses of biofertilizer with four different concentrations of vermiwash; 20% (T2), 40% (T3), 60% (T4),75% (T5) along with the Control. Recommended rate of commercial biofertilizer and 8 ml vermiwash were applied four times at 7, 14, 28, and 42 days after planting (DAP) as foliar sprayers. Commercial biofertilizer was applied based on the recommended amount of powder (3 g/L.). Plant height, number of leaves per plant at 20 and 60 DAP, days to first picking, number of branches per plant at harvesting stage, number of pods per plant, and average pod length were measured. Data were subjected to an analysis of variance, and means pertaining to different parameters were separated using the least significant difference (LSD) test at P=0.05.

Results and Discussion

Plant height**:** It was determined that plant height was statistically affected by different concentrations of warmish with commercial biofertilizer. Means of plant height (cm) of selected two varieties affected by different concentrations of vermiwash ($P<0.05$) (Figure 1). The maximum plant height at 30 DAP, 29.31 cm was recorded by the *Dawala* variety under the application of T4 while the minimum plant height was 14.15 cm followed by control treatment in variety MICPI. Tested two varieties have shown the highest plant height at 30 DAP and 60 DAP followed by T4 (60% vermiwash + ½ dose of commercial biofertilizer). Four concentrations were tested and found to be significantly different from the control treatment.

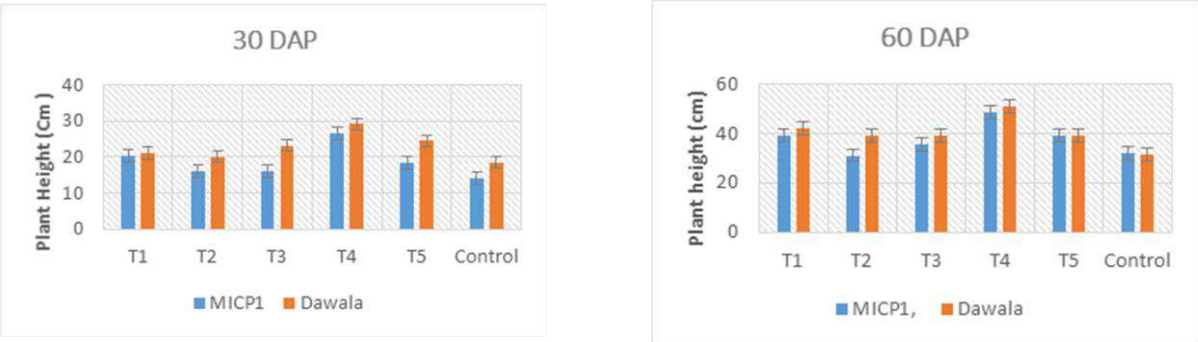

Figure 1: Effect of different vermiwash concentrations on plant height

Number of Leaves: The differences between the applications were found to be statistically significant for the number of leaves after 30 days and 60 days of plantings (Figure 2). Vermiwash concentration of 40% + half of the commercial biofertilizer has increased the number of leaves (9±2.12) of MICP1 significantly with compare to the control group. The variety *Dawala* reported the highest number of leaves (9±2.12) followed by T5 (vermiwash 75% + Half of Biofertilizer).

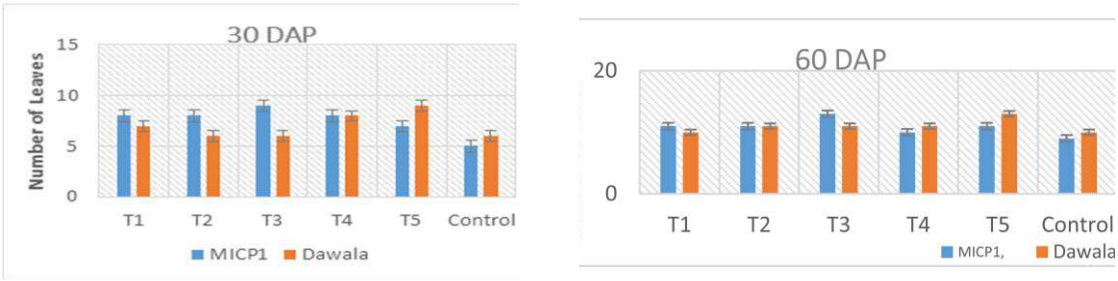

Figure 2. Effect of different vermiwash concentrations on the number of leaves

Days to first Picking: The days to first picking varied significantly between the tested treatments (P<0.05). Var. *MICP1* reported the lowest number of days to first picking (53 ±2.65) followed by T4 while the control group reported the highest number of days to first picking.

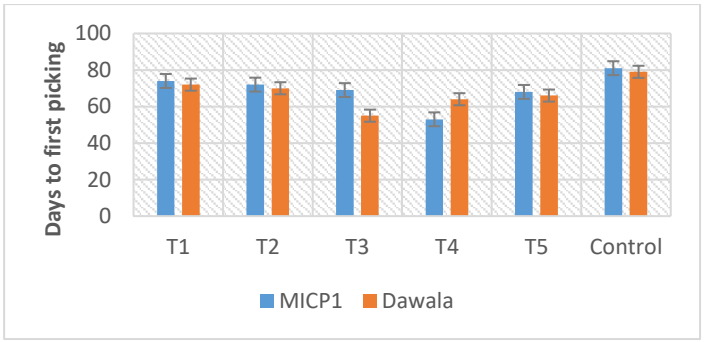

Figure 3. Effect of different vermiwash concentrations on days to first picking

Yield components: There were significant differences (P<0.05) between treatments in the number of branches per plant and the number of pods per plant (Fig 4). The highest number of branches per plant (15±2.31) was observed in var. Dawala followed by T4 (vermiwash 60 % + ½ Commercial biofertilizer). It was significantly different from the control group and T1 (Recommended rate of commercial Bio Fertilizer). The lowest number of branches per plant

(6±3.42, 6±2.12) was reported by the control group by both tested two varieties. The average number of pods per plant of each cowpea variety was calculated. The highest average number of pods per plant (19±1.31) was recorded in var. *MICPI* followed by T4 (vermiwash 60% + ½ dose of commercial biofertilizer). It was significantly different from other all treatments (P<0.05). Var. *Dawala* reported the second-highest number of pods per plant (18 ± 36) under again T4, and it was substantially different from all other treatments (P< 0.05).

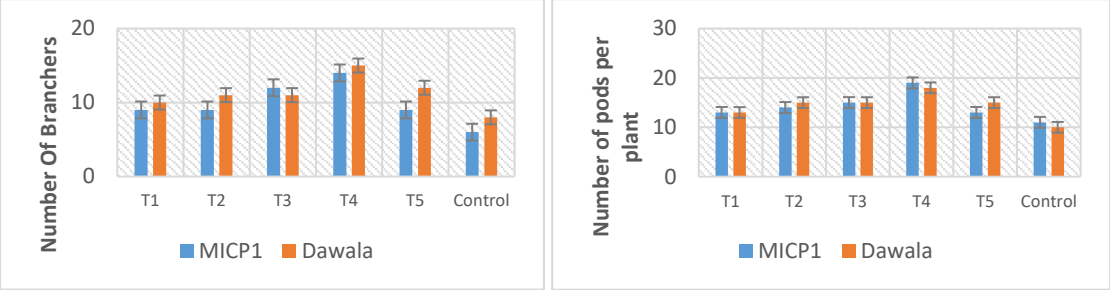

Figure 4: Effect of different vermiwash concentrations on yield components

Zaman *et al.* (2015) investigated the effects of vermicompost and vermiwash on cowpea growth and found that vermiwash significantly improved plant height, number of branches, leaf area, and dry weight of the cowpea plants. According to the study conducted by Kumar *et al.* in 2013, the use of vermiwash resulted in improvements in various growth parameters of the plants. Specifically, at 45 days after bud emergence, the application of vermiwash led to an increase in plant height and number of leaves to 56.29 cm and 6.14 days, respectively. The length of the spike and rachis also increased to 90.68 cm and 47.07 cm, respectively, while the number of florets increased to 15.08. The vase-life of the plants increased to 10.02 days, and the number of corms per square meter increased to 28.66. Additionally, the weight of the corms increased to 50.68 g, and the number of cormels per plant.

Conclusion

The findings show that the plant's vegetative development and yield components can be impacted by the application of different vermiwash concentrations. The combination of 60% vermiwash and a half dose of commercial biofertilizer results in the greatest increases in plant height, number of branches at the harvesting stage, and number of pods per plant. In addition, the combination of 60% vermiwash and a half dose of commercial biofertilizer reported the lowest days to first picking (53±2.65) of var. *MICP1*.The usage of vermiwash could be a suitable biological technique for the bioconversion of food, medical, and paper waste into organic nutrients-rich that can reduce the need for artificial fertilizers and improve natural soil fertility by delivering diverse plant nutrients in agricultural fields.

References

Bhattacharyya, C. *et al.* (2020) *Biofertilizers as substitute to commercial agrochemicals, Agrochemicals Detection, Treatment and Remediation*. LTD. doi: 10.1016/b978-0-08-103017-2.00011-8.

Gudeta, K. *et al.* (2021) 'Vermiwash: An agent of disease and pest control in soil, a review', *Heliyon*, 7(3), p. e06434. doi: 10.1016/j.heliyon.2021.e06434.

Gunaruwan, T. L. and Gunasekara, W. N. (2016) 'Management of Municipal Solid Waste in Sri Lanka: A Comparative Appraisal of the Economics of Composting', *NSBM Journal of Management*, 2(1), p. 27. doi: 10.4038/nsbmjm.v2i1.19.

Kiruba N, J. M. and Saeid, A. (2022) 'An Insight into Microbial Inoculants for Bioconversion of Waste Biomass into Sustainable "Bio-Organic" Fertilizers: A Bibliometric Analysis and Systematic Literature Review', *International Journal of Molecular Sciences*, 23(21), p.

13049. doi: 10.3390/ijms232113049.

Saja, A. M. A., Zimar, A. M. Z. and Junaideen, S. M. (2021) 'Municipal solid waste management practices and challenges in the southeastern coastal cities of Sri Lanka', *Sustainability (Switzerland)*, 13(8). doi: 10.3390/su13084556.

Kumar P, Shekhar C, Basoli M, Kumar V. (2013) Sequential spray of vermiwash at critical stages influences growth and quality in gladiolus cv. white prosperity. *Annals of Horticulture.* 6(1):71-75.

Zaman, M.M., Chowdhury, M.A.H., Islam, M.R. and Uddin, M.R. (2015). Effects of vermicompost on growth and leaf biomass yield of stevia and post-harvest fertility status of soil. *J. Bangladesh Agril. Univ*., 13(2): 169–174.

THE EFFECT OF PLANT GROWTH PROMOTING RHIZOBACTERIA [PGPR] WITH BIOCHAR AND CHEMICAL FERTILIZERS ON SOIL PHYSICOCHEMICAL PROPERTIES AND ROOT GROWTH OF MAIZE GROWN IN SANDY REGOSOL

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Abstract

Chemical fertilizers used in agriculture show a harmful impact on the ecosystem although we do rely on them to enhance agricultural production. The major drawbacks of sandy regosol are poor water and nutrition retention. In low-fertility soils, applying biochar as a soil amendment is feasible thus improving soil quality. However, biochar is not a substitute to fulfill the total fertilizer requirement. Plant Growth Promoting Rhizobacteria (PGPR) has been identified as an alternative fertilizer for increasing soil fertility. PGPR has been attracted for its ability to enhance productivity and sustainability when food security and rural livelihood are key priorities. However, limited literature is available on the effect of the combined use of PGPR with biochar in field conditions. Therefore, this study was contemplated to determine the impact of lower rates of inorganic fertilizers combined with PGPR and biochar on, soil physicochemical properties and root growth of maize grown in sandy regosol. The field experiment was carried out at Eastern University, Sri Lanka. There were eight treatments replicated three times in a Randomized Complete Block Design (RCBD). Among the 8 treatments: four treatments combining sole PGPR (*Azospirillum, Azotobacter*, Phosphorous Solubilizing Bacteria (PSB) and Potassium Solubilizing Bacteria (KSB)) respectively with biochar and 50% Recommended Chemical Fertilizers (RCF), two treatments by combining KSB, PSB, biochar, 50% RCF with *Azospirillum* and *Azotobacter* respectively, a treatment combining biochar with 50% RCF, and control as RCF. Biochar was made by using coconut husk in a modified traditional kiln preparation technique and used at the rate of 8 t/ha. PGPR inoculants were used in seed treatment and field application. Triple Super Phosphate (TSP), Muriate of Potash (MOP) and urea were used as RCF. At harvest CEC, bulk density and organic carbon were measured. The root area was scanned through an Epson flatbed scanner. Statistical analysis and mean separation were done. The results indicated that the Co-inoculated *Azotobacter* combined treatment positively influenced on soil physicochemical properties and root growth of maize.

Keywords: Biochar, Biofertilizer, PGPR, PSB, KSB

Introduction

The provision of nutrients by the soil is essential for crop growth and development. To achieve our food demands, we rely a lot on chemical fertilizers. The recommendations for chemical fertilizers for annual crops in Sri Lanka are highly based on soil N, P and K content (Amarasekara *et al.*, 2007). The chemical-based fertilizers, cause a serious threat to human health and the environment. Chemical fertilizers ignore the biological potential of roots by increasing nutrient mobilization and acquisition and decreasing the interactions between plants and rhizospheric microorganisms. The dominant soil group in the Batticaloa district is sandy regosol. The main drawbacks of sandy soil are its low cation exchange capacity, low organic matter content, poor nutrient supply, and water retention (Dandeniya and Dharmakeerthi, 2020).

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To maintain healthy soil, good management procedures are crucial. Previous studies demonstrated that in low-fertility soils, applying biochar as a soil amendment is feasible. The biochar amendment to the soil proved to be beneficial to improve soil quality and retain nutrients, thereby enhancing plant growth (Bonanomi *et al.,* 2017). Biochar application also favors the soil microorganisms thus it improves the survival of the inoculated bacteria, protecting them from biotic and abiotic stresses and serving as a refuge to be a continuous source. Biochar is not a substitute to fulfil the fertilizer requirement.

PGPR biofertilizer has been identified as an alternative fertilizer for increasing soil fertility. PGPR is a group of bacteria that colonize plant roots, and they promote plant growth. PGPR biofertilizers have been proven a successful technology for the mobilization of immobile nutrients in the soil. And they keep the soil environment rich in all kinds of nutrients via N fixation, P and K solubilization or mineralization, the release of plant growth regulating substances, and the biodegradation of organic matter in the soil. When PGPR biofertilizers are applied as seed or soil inoculants, they multiply and participate beneficially in nutrient cycling and crop productivity (Sinha *et al.,* 2014). Therefore, this study was contemplated to examine the PGPR biofertilizers with biochar and chemical fertilizers on soil physicochemical properties and root growth of maize grown in sandy regosol.

Materials and Method

There were eight treatments replicated three times in a Randomized Complete Block Design (RCBD). Biochar was made by using coconut husk in a modified traditional kiln preparation technique. Biofertilizers were gotten from Biofood (Pvt) Ltd. Among the 8 treatments: 4 treatments by combining sole PGPR with biochar and 50% Recommended Chemical Fertilizers (RCF), two treatments combined KSB, PSB, biochar, and 50% RCF with *Azotobacter* and *Azospirillum* respectively and a treatment combining biochar with 50% RCF, and control as RCF. For all seven treatments biochar was used at the rate of 8 tons/hectare (Cruz-Mendez *et al.,* 2021). In the treatments with PGPR: PGPR inoculant was used for seed treatment and field application (300 ml/acre, diluted with 1 liter water). TSP, MOP, and urea were used as RCF. Maize seeds (Badra variety) were treated with liquid biofertilizers before the sowing (Malusa *et al.,* 2012). Seeds were sown at the spacing of 60 cm × 30 cm. Agronomic practices were carried out. Soil samples were collected at harvest. Collected soil samples were air-dried, passed through a 2-mm sieve, and soil physicochemical properties were measured. The following standard methods were used for analyzing the soil samples. Soil bulk density-core sampler method, organic carbon chromic acid wet digestion method, CEC as determined by ammonium acetate method and root area (cm^2) was scanned using an Epson flatbed scanner V800.

Statistical Analysis

Variance analyses of the experimental data were accomplished in a completely randomized block design using Turkey test at 5% significant level for precise and easy interpretation of results of this experiment.

Results and Discussion

The results pertaining to the impact of treatments on soil physicochemical properties (soil CEC, soil bulk density and soil organic carbon) and root area at harvest. Throughout the whole reading there was a significant difference ($P<0.05$) recorded among the treatments.

Table 1 Impact of Treatments on Root and Soil Parameters

	Root Parameter	Soil Parameters		
Treatments	Root Area (cm^2)	Soil Bulk Density (g/cm^3)	Soil Organic Carbon (%)	Soil CEC (meq/100 g)
T1	255.49 ± 1.50^{d}	1.39 ± 0.00^{b}	0.94 ± 0.00^{d}	3.90 ± 0.05^{cd}
T2	290.34 ± 1.40^{c}	1.34 ± 0.04^{d}	0.86 ± 0.00^{f}	3.90 ± 0.01^{cd}
T3	304.73 ± 1.45^{b}	1.35 ± 0.00^{c}	1.17 ± 0.00^{c}	4.95 ± 0.85^{bc}
T4	308.32 ± 1.65^{b}	1.33 ± 0.00^{f}	1.50 ± 0.00^{a}	10.40 ± 0.00^{a}
T5	306.09 ± 1.50^{b}	1.32 ± 0.05^{e}	0.90 ± 0.00^{e}	6.10 ± 0.00^{b}
T6	337.52 ± 2.00^{a}	1.34 ± 0.05^{d}	1.41 ± 0.00^{b}	8.80 ± 1.00^{a}
T7	243.08 ± 1.70^{e}	1.34 ± 0.00^{d}	0.75 ± 0.00^{g}	3.10 ± 0.35^{d}
T8	198.30 ± 1.55^{f}	1.41 ± 0.00^{a}	0.83 ± 0.00^{h}	0.50 ± 0.00^{e}
F test	*	*	*	*

*Values represent the mean value of three replicates ± standard deviation. Mean followed by the same letter in each column are not *significantly different, statistically, at $p<0.05$ based on the Turkeys test. T1: Azospirillum+biochar+50% RCF, T2:Azotobacter+biochar+50% RCF, T3:PSB+biochar+50% RCF, T4: KSB+biochar+50% RCF, T5:Azospirillum+PSB+KSB+biochar+50%RCF, T6:Azotobacter+PSB+KSB+ biochar+50% RCF, T7: Biochar+50 % RCF, T8: RCF (control).*

Root Area

Analysis on root area indicated that the treatment T6 (biochar incorporated co-inoculated PGPR which composed of *Azotobacter*) achieved significantly highest root area than the other treatments. There was no significant difference between T5, T4, T3. Among the treatments significantly lowest mean value was noted in T7, which was significantly higher than the control. The significantly highest mean value was noted in T6 (*Azotobacter* PSB+ KSB+ biochar+ 50% RCF). Research findings indicated that the enhancement of plant growth by N-fixer and P and K-solubilizers. PGPR improve the plant growth and root growth by enhance the accessibility of micro-nutrients to the roots of host plant (Jeyanthi and Kanimozhi, 2018). When bacteria are used as PGPR, can stimulate plant growth by a series of mechanisms, including the production of phytohormones, such as indole-3-acetic acid (IAA), gibberellins, cytokinins and salicylic acid (Fukami *et al.*, 2017). IAA phytohormone helps the production of longer roots and increases number of root hairs and lateral roots (Mohit, 2018).

Soil Bulk Density

The comparison of mean values indicated that the significantly highest soil bulk density was 1.41 g/cm^3 recorded by biochar-free non-PGPR treatment (T8). Which was followed by T1, T5, and T3. And significantly lowest bulk density was 1.32 g/cm^3 observed in biochar combined with co-inoculated PGPR composed of *Azospirillum* treatment (T5). The significantly highest soil bulk density was recorded by biochar-free non-PGPR treatment (T8). So, the result is good agreement with previous reports by Arabi *et al*. (2018) in which they reported the highest soil bulk density was achieved by biochar-free treatment. Within the treatments also there were considerable significant differences in bulk density so other than biochar the PGPR also contribute to decreasing soil bulk density. This may be due to the impact of PGPR on soil granulation and porosity.

Soil Organic Carbon

The comparison of mean values indicated a significantly highest organic carbon content in KSB combined biochar treatment (T4). Among the treatments, significantly lowest organic carbon content was obtained in T7 (non–PGPR combined chemical 50% RCF) which was significantly higher than the control (T8).

According to the statistical scrutiny of the data, significantly highest organic carbon content was recorded in KSB combined biochar treatment. The chemical nature of the organic amendment favorably influenced the rate of decomposition by the microbial community (Hahn *et al.,* 2013). The amount of organic matter can increase the accumulation of total organic carbon in the soil (Folletet *et al.,* 2001). Organic acids released from the K-solubilization by rhizospheric microorganism, facilitated the solubilization of potassium nutrients as well as other nutrients thereby enhancing the crop growth. Several organic acids like tartaric acid, succinic acid, α-ketogluconic acid, citricacid and oxalic acid are the most important acids involved in the solubilization of insoluble K are released by K-solubilizing bacteria (Meena *et al.,* 2014).

Soil CEC

The comparison of mean values indicated that the significantly highest soil CEC was 10.4 meq/100g soil was achieved by KSB combined biochar treatment (T4). Among the treatments significantly lowest CEC was 3.10 meq/100 g soil which was noted in biochar combined with chemical fertilizer which was significantly higher than the control (T8). Among the treatments, the soil CEC was higher in T6 and T4 this may be due to the impact of K Solubilizing PGPR on soil CEC. According to overall results from T4 and T6 (Table 1) the lower bulk density and higher organic carbon were obtained from these treatments. Thus, the lower bulk density increased the stability of soil aggregates which cause the availability of nutrient cations in the soil it causing increases in CEC. Schmidt *et al*. (2011) stated that the availability of nutrient cations in the soil is related to the stability of soil aggregates, and related to soil organic matter stability. And also, aggregates should be weak enough to favour plant roots, yet strong enough not to lose their structural porosity. Since the root area is also significantly higher in T4 and T6 so, aggregation is weak enough to be explored by plants roots.

Conclusion

The results indicated that co-inoculated Azotobacter combined with PSB, KSB, 50% recommended chemical fertilizer with biochar positively influenced soil physicochemical properties (soil CEC, organic carbon, soil bulk density) and root growth performances of maize plants.

References

Amarasekara, M.G.T.S., Indraratne, S.P., Kumaragamage, D. and Sultanbava, F. (2007). Formulation and testing of site-specific fertilizer recommendation for bitter gourd (*Momordica charantia* L.)

Arabi, Z., Eghtedaey, H., Gharehchmaghloo, B. and Faraji, A., (2018). Effects of biochar and bio-fertilizer on yield and qualitative properties of soybean and some chemical properties of soil. *Arabian Journal of Geosciences*, 11(21): 1-9.

Bonanomi, G., Ippolito, F., Cesarano, G., Nanni, B., Lombardi, N., Rita, A., Saracino, A. and Scala, F., (2017). Biochar as plant growth promoter: better off alone or mixed with organic amendments? *Frontiers in Plant Science*, 8: 1570.

Cruz-Mendez, A.S., Ortega-Ramirez, E., Lucho-Constantino, C.A., Arce-Cervantes, O., Vazquez-Rodríguez, G.A., Coronel-Olivares, C. and Beltran-Hernández, R.I., (2021). Bamboo biochar and a nopal-based biofertilizer as improvers of alkaline soils with low buffer capacity. *Applied Sciences*, 11(14): 6502.

Dandeniya, W.S. and Dharmakeerthi, R.S., (2020). Integrated Plant Nutrient Management in Major Agricultural Soils of Sri Lanka: A Review of the Current Status and the Way Forward. Agricultural Research for Sustainable Food Systems in Sri Lanka, 213-238.

Follett, R.F., Kimble, J.M. and Lal, R., (2001). The potential of US grazing lands to sequester soil carbon. The potential of US grazing lands to sequester carbon and mitigate the greenhouse effect, 401-430.

Fukami, J., Ollero, F.J., Megias, M. and Hungria, M., (2017). Phytohormones and induction of plant-stress tolerance and defense genes by seed and foliar inoculation with Azospirillum brasilense cells and metabolites promote maize growth. *AMB Express*, 7(1): 1-13.

Hahn, A.S. and Quideau, S.A., (2013). Long-term effects of organic amendments on the recovery of plant and soil microbial communities following disturbance in the Canadian boreal forest. *Plant and soil*, 363(1): 331-344.

Jeyanthi, V. and Kanimozhi, S., (2018). Plant growth promoting rhizobacteria (PGPR)-prospective and mechanisms: a review. *J Pure Appl Microbiol*, 12(2): 733-749.

Malusa, E., Sas-Paszt, L. and Ciesielska, J., (2012). Technologies for beneficial microorganism's inoculant used as biofertilizers. *The scientific world journal*, *2012*.

Meena, V.S., Maurya, B.R. and Verma, J.P., 2014. Does a rhizospheric microorganism enhance K+ availability in agricultural soils? *Microbiological research*, 169(5-6): 337-347.

Mohite, B., (2013). Isolation and characterization of indole acetic acid (IAA) producing bacteria from rhizospheric soil and its effect on plant growth. *Journal of Soil Science and Plant Nutrition*, 13(3), 638-649.

Sinha, R, K., Valani D., Chauhan K., Agarwal S. (2014). Embarking on a second green revolution for sustainable agriculture by vermiculture biotechnology using earthworms: reviving the dreams of Sir Charles Darwin. *International Journal of Agricultural Science and Health Safety*, 1: 50-64.

Schmidt, M.W., Torn, M.S., Abiven, S., Dittmar, T., Guggenberger, G., Janssens, I.A., Kleber, M., Kogel-Knabner, I., Lehmann, J., Manning, D.A. and Nannipieri, P., (2011). Persistence of soil organic matter as an ecosystem property. *Nature*, 478(7367):49-56.

VALUE CHAIN AND KNOWLEDGE DISSEMINATION

THE FACTORS ASSOCIATED WITH CASHEW PRODUCTION IN THE BATTICALOA DISTRICT

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Abstract

Cashew is an evergreen, drought-resistant tree. Batticaloa District is one of the most popular districts for cashew production in Sri Lanka. The study was conducted to determine the factors influencing the production of cashew in Batticaloa District after the COVID-19 pandemic. This study was carried out in two Divisional Secretariat (DS) divisions in the district. The study area was chosen based on the existing higher number of cashew farmers. The simple random sampling method was used to select 100 cashew farmers for the primary data collection. In addition, secondary data were used from various sources. Data were analyzed using SPSS software with descriptive statistics, frequencies, and chi-squared test. The findings revealed that the average age of the respondent was 54 years and all the farmers used their own land for cultivation. The average extent of land was 2.2 acres. Among that, 87% of the growers were engaged in small-scale farming. The total annual production in the study area was 12700 kg. The mean net profit per annum was Rs 70 014. Further, there was a significant association observed between the production of cashew nuts and pest & disease attacks ($P<0.01$), animal attacks ($P<0.01$), thieves attacks ($P<0.01$), inadequate capital ($P<0.01$), lack of extension services ($P<0.01$), lack of processing knowledge ($P<0.01$), insufficient price information ($P<0.05$), educational level ($P<0.01$), gender ($P<0.01$) and the extent of land ($P<0.01$). Therefore, the farmers should educate with proper knowledge on production, disease management, and price flows. Furthermore, the relevant authorities should consider the above factors when designing extension programs to enhance cashew production further.

Keywords: Cashew nut, harvesting, marketing, net profit, production

Introduction

Cashew (*Anacardium occidentale* L.), a native of Brazil, is one of the essential nuts grown in the world and ranked first among various nuts, such as hazelnuts and almonds. For many nations, the tropical nut tree crop, known as cashew provides food, income, raw materials for industry, and foreign exchange (Adeigbe *et al*., 2015). Tree nuts include a large amount of mono and polyunsaturated fatty acids (FA), a wide range of vitamins, minerals, amino acids, phytosterols, and fiber. The risk of cardiovascular disease and mortality was lower in people who consumed nuts as part of a balanced diet (Rico *et al*., 2015). In Sri Lanka, more than half of the cashew extent was shown to be restricted to the country's arid (dry) zone. To increase yields, the crop needs better management and greater attention (Thirumarpan, 2014). As an export crop, cashew brings in a lot of money from abroad to the country, and the processing of cashews became a cottage business (Wettasinghe and Pannilage, 2002). The annual production of cashews is estimated to be around 10000 MT – 12000 MT (SLCC, 2016). Sri Lanka's cashew production is insufficient for export and local consumption. Although there is a high demand for Sri Lankan cashews in the international markets, Sri Lanka only has about 10-15 traders (SLCC, 2010). In Sri Lanka, eliminating the barriers to productivity growth, improving the knowledge and expertise of farmers, and the amount of cashews produced may expand significantly if the industry's barriers to technology adoption were removed (Umashankar and Parththini, 2022).

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Batticaloa district is located in Eastern Sri Lanka. The District consists of 14 DS divisions. Most people are engaged in Agriculture for their livelihood and are under the poverty line. Among them, a certain number of people are involved in the production and marketing of cashew nut and fruit-based products in the Batticaloa district. In this district, the land availability and the climate conditions are preferred for cashew cultivation. Dry regions are the greatest places to grow cashews since the climate and soil conditions are ideal for producing a good crop (Thusyanthini and Sanotharan, 2018). From the production, processing, storage and marketing of cashew nuts, farmers are experiencing different types of problems during and after cultivation in the Batticaloa district. The production of cashew nuts is lesser than the anticipated amount in the district (Priyashantha *et al*., 2020). After thirty years of civil conflict, the government has adopted several measures to increase cashew output in the Batticaloa district (SLCC, 2015). Increasing cashew production in Batticaloa will surely be one of the crucial components in the local community of this district's ability to generate revenue (Priyashantha *et al*., 2020). Therefore, it becomes compulsory to identify the current status of cashew production in the Batticaloa district to design future production enhancement activities. However, no recent studies have been conducted on cashew production in the district, especially after the Covid 19 pandemic. By taking the importance and need of this crop, the research was carried out to determine the factors influencing cashew production in the district.

Methodology

The study was carried out in two DS divisions in the Batticaloa district; Eravur Pattu and Koralaipattu-South DS divisions. Both are major cashew production regions in the Batticaloa district. A total of 100 cashew farmers were randomly selected from these DS divisions for the study. The number of chosen farmers from each DS division was proportionate to the total number of cashew farmers. Data were collected from the respondents using a structured pre-tested questionnaire. The collected data were arranged to Microsoft excel 2016 worksheet properly. Then arranged data were entered through the SPSS version 29 statistical software package, and the database was created for further study. Descriptive statistics were used to analyze the socio-economic characteristics of the cashew growers in the study area. Chi-square analysis was used to find the association between different variables influencing cashew production.

Results and Discussion

Socio-economic characteristics of the Cashew farmers

The results of the study indicated that 65% of the respondents were male farmers, and the rest were female farmers, 94% of the respondents were married, 2% were single, and 4% were widowed. Only 3% were engaged in cashew production as a full-time occupation, and the other 97% were involved as part-time. Most of them are doing paddy farming (29%), followed by wage labour (21%) and vegetable farming (19%).

Table 1 shows the socio-economic characteristics of the cashew farmers. The table reveals that the average age of a cashew farmer was 54 years. The minimum and maximum ages of the respondents were 38 years and 71 years, respectively. The data further revealed that the average family size of a family was five members in the study area. The average farming experienced years of a farmer was nine years.

Table 1. Socio-economic characteristics of the Cashew farmers

Trait	Range	Minimum	Maximum	Mean
Age	33	38	71	53.70
Family size	5	2	7	4.95
Farming Experience	24	3	27	8.99

Cashew production in the study area

The total annual production in the study area was 12700 kg (220 acres of total cultivated land). Maximum and minimum productions were 550 kg/ac and 15 kg/ac respectively.

The constraints faced by the cashew growers

Table 2 shows the constraints faced by the cashew farmers in the study area. Pest, disease and animal attacks are common problems all farmers face. Most of the growers (92%) stated that they faced difficulties due to poor marketing channels for raw nuts and low availability. 76% of them indicated that they had insufficient price information. Thus, everyone sold the products at different prices. They stated that the buyers buy the products according to their desired price. Almost 40% did not have enough capital for cultivation. Moreover, 24% of the farmers commonly stated a problem of thieves during harvesting season. They stole the fruit and nuts from the field at night times. They said that it was challenging to protect the production from thievery.

Table 2: Constraint factors in cashew production

Constraints	Responses		Per cent of Cases
	N	Per cent	
Pest and disease attack	100	18.1	100.0
Animal attacks	100	18.1	100.0
Thieves	24	4.3	24.0
Inadequate capital	40	7.2	40.0
Lack of extension services	60	10.8	60.0
Lack of processing knowledge	18	3.3	18.0
Poor marketing channel for raw nuts	92	16.6	92.0
Insufficient price information	76	13.7	76.0
Lack of storage facility	43	7.8	43.0
Total	553	100.0	553.0

** Multiple responses*

The factors influencing the cashew production

The results in table 3 revealed that there was a significant association between pest & disease attacks (X^2=23.202, P<0.01), animal attacks (X^2=23.844, P<0.01), thieves (X^2=27.434, P<0.01), inadequate capital (X^2=20.774, P<0.01), lack of extension services (X^2=19.701, P<0.01), lack of processing knowledge (X^2=21.293, P<0.01), insufficient price information (X^2=9.944, P<0.05), educational level (X^2=42.023, P<0.01), gender (X^2=29.638, P<0.01), marital status (X^2=19.055, P<0.05), the extent of land (X^2=97.193, P<0.01), and production of cashew.

It implies that these factors are associated with cashew production in the study areas. Land area under cultivation (P<0.01) and educational level (P<0.01) were significantly influence the production of cashew. This aligned with the results of a study by Thirumarpan (2014) on factors affecting the production of cashew in Batticaloa district and Wongnaa (2013) on an analysis of factors affecting the production of cashew in Wenchi Municipality, Ghana. The lack of extension services (P<0.01) significantly influenced the production. This was consonance with

the findings in a study by Wongnaa (2013) on analyzing factors affecting cashew production in Wenchi Municipality, Ghana.

Table 3. Factors influencing the production of cashew

Variables	X^2	Df	P value
Pest & disease attack	23.202	4	<.001*
Animal attacks	23.844	4	<.001*
Thieves	27.434	4	<.001*
Inadequate capital	20.774	4	<.001*
Lack of extension services	19.701	4	<.001*
Lack of processing knowledge	21.293	4	<.001*
Poor marketing channel for raw nuts	5.641	4	0.228
Insufficient price information	9.944	4	0.041**
Lack of storage facility	8.075	4	0.089
Educational level	42.023	12	<.001*
Gender	29.638	12	0.003*
Marital status	19.055	8	0.015**
Farming experience	5.97	8	0.651
Extend of land	97.193	36	<.001*

*df - Degree of freedom, X^2 - Chi-square, P<0.05**, P < 0.01**
Dependent variable = Production

Conclusion

The study was conducted to understand the current status of cashew production in the Batticaloa district and determine the factors influencing cashew production. Most of the cashew farmers were male. A significant association was observed between the production of cashew nuts and factors like pest & disease attacks, animal attacks, thieves, inadequate capital, lack of extension services, lack of processing knowledge, insufficient price information, educational level, gender, marital status, and extent of land. As such, the farmers should be properly educated about processing, disease management and price flows. The relevant authorities should consider the above factors when designing extension programs to enhance cashew production further.

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References

Adeigbe, O. O., Olasupo, F. O., Adewale, B. D. and Muyiwa, A. A. (2015). A review on cashew research and production in Nigeria in the last four decades. *Scientific Research and Essays*, 10(5): 196-209.

Priyashantha, A.K.H., Krishanthiny, K. and Mahendranathan, C. (2020). Pre and post-harvest losses of cashew (Anacardium occidentale L.) in Batticaloa district, Sri Lanka. Biology and Life Sciences, 43(1): 8-8.

Rico, R., Bulló, M. and Salas-Salvadó, J. (2015). Nutritional composition of raw fresh cashew (Anacardium occidentale L.) kernels from different origin. Food Science & Nutrition, 4(2): 329-338.

SLCC (2016), Sri Lanka Cashew Corporation Annual Report and Account. [Online]Available: https://www.parliament.lk/uploads/documents/paperspresented/annual-report-srilanka-cashew-corporation-2016.pdf (October 18, 2022)

SLCC (2015), Sri Lanka Cashew Corporation, Annual Report and Account. [Online] Available: https://www.parliament.lk/uploads/documents/paperspresented/annual-report-srilanka-cashew-corporation-2015.pdf (October 18, 2022)

SLCC (2010), Sri Lanka Cashew Corporation, Annual report and Account. [Online] Available: https://www.parliament.lk/uploads/documents/paperspresented/annual_report_srilanka_cashew_corporation_2010.pdf (October 18, 2022)

Thirumarpan, K. (2014). Factors affecting the production of cashew in Batticaloa district. Social Sciences and Humanities, 1(1): 319–325.

Thushyanthini, R. and Sanotharan, N. (2018). Factors affecting the adoption of recommended agricultural practices by cashew growers in Mannar district of Sri Lanka. International Journal of Advanced Scientific Research, 3: 04-07.

Umashankar, K. and Parththini, K. (2022). Factors prompting in technology adoption of cashew farmers: Case of Eastern dry zone of Sri Lanka. Proceedings of AgInsight 2022, Department of Agricultural Economics, Faculty of Agriculture, UOJ, Sri Lanka 2022, p. 220-223.

Wongnaa, C.A. (2013). Analysis of factors affecting the production of cashew in Wenchi municipality, Ghana. The Journal of Agricultural Sciences, 8(1): 8-16.

Wettasinghe, K. and Pannilage, U. (2002). Cash crops and transport: cashew growing and processing. In P. Fernando and & G. Porter (Eds.), Balancing the load: women, gender and transport (pp. 258-272). United Kingdom: Academic press.

FARMERS' ACCEPTANCE TO GROWING SUPPLEMENTARY FOOD CROPS ORGANICALLY

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Abstract

A wide variety of supplementary food crops, including groundnuts, green gram, maize, black gram, and kurakkan, are cultivated in Sri Lanka. Farmers in the Bibile DS division of the Monaragala districts engage in organic farming in order to produce supplementary food crops. Despite this, the local agricultural community had less interest to adopt organic farming practices. The objective of this research is to identify the factors that influence the acceptance of organic farming techniques among farmers growing supplementary food products. The sampling method used was stratified random sampling, and the number of farmers who grew supplemental food crops was equal to 80. The primary information was gathered through the use of a structured questionnaire that had been pre-tested, and it was then analyzed. Secondary data was collected from published literature to complete the study. The results of the research revealed that many farmers are male and between the 36-55 age category with an education level up to the GCE ordinary level. In accordance with the primary purpose of the research, the Perceived Ease of Use (PEU) and Perceived Usefulness (PU) factors in the Technological Acceptance Model (TAM) were not found to be significant contributors to the acceptance of organic farming practices among the farmers who participated in the study. Because of our findings, policymakers should be prompted to consider the critical role that supply chain management practices, such as collaboration, play in increasing the sustainability of organic farming systems.

Keywords: Acceptance, farmers, organic farming, perceived ease of use, perceived usefulness

Introduction

Organic farming is described as "a production system that sustains the health of soils, ecosystems, and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than using inputs with adverse effects (IFOAM, 2005). The agricultural section of Sri Lanka depends on agro chemical such as inorganic fertilizer, pesticides, and growth regulators due to the enhancement of demand for food quantity from a limited area. But currently, there is a trend of developing organic farming units from the accumulated knowledge of organic farming and enhancing demand for the export of organic agricultural products. Supplemental food crop farming in Sri Lanka is also known as Chena farming. Supplemental food crops are increasingly widespread in the dry zone, and it is most popular among the farmers in many districts in Sri Lanka (Ministry of Agriculture of Sri Lanka, 2022). In Sri Lanka, there are very few studies on using organic fertilizers, particularly in the cultivation of supplementary food crops. As a result, understanding farmers' acceptance of organic cultivation methods in supplementary food crops is critical to improve and popularize healthy food security in Sri Lanka.

Materials and Method

The Bibile Divisional Secretariat in Monaragala district was selected as the study area where considerable farmers practicing organic farming techniques to supplementary food crop

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cultivation. All the farmers from all GN divisions practicing organic food crop cultivation were selected as the population for the study. Under the stratified random sampling technique, eighty (80) supplementary food crop farmers were chosen as the sample, representing all GN divisions (Two farmers from 40 GN divisions). Pretested survey questionnaire was developed and distributed among the selected sample to obtain primary data. The questionnaire consisted of the general socio-economic variables and variables (external) which important to determine acceptance of organic farming techniques in supplementary food crop farmers. The questionnaire's constructs were graded using a Likert scale ranging from strongly agreed (5) to strongly disagreed (5). Secondary data were gathered from previously published literature. Collected data were coded for analysis using the Statistical Package for Social Sciences (SPSS, 26). Associations and impacts were analyzed by using statistical methods.

Table 1. External variables in Technological Acceptance Model (TAM)

Variable	Criteria
Perceived ease of use	I feel comfortable to practice OF
	The knowledge I gain is important in OF
	Resources can be found easily
	Availability of information and technology
Perceived usefulness	Organic farming increases business
	OF increase income
	OF increases farmer health
	Having social respect for society and the next generation
Organic farming acceptance and adoption	Organic farming is better than inorganic
	Organic farming increases my satisfaction
	Organic farming saves time
	I will recommend the organic farming

Results and Discussion

Demographic and socio-economic status of the producers

According to Table 2, most farmers belonged to the 36-55 age group category (59.3%). This indicates that middle-aged participation in supplemental food crop farming is comparatively high. Further, the table represents that males are more engaging in supplemental food crop farming while fewer females are involved in supplemental food crop farming. When considering the number of households in the sector, the farm families have more than 5 family members, which is more than 72.8% of the total sample. A higher number of respondents are having education level of GCE ordinary level. The income from supplemental food crops for the total household income in the Bibile GN division and the majority had more than 76% share from supplemental food crops for the total household income (69.1%) in the study area.

Technological Acceptance Model (TAM) for the organic farming adoption by supplemental food crop farmers

a) Reliability test

The Cronbach alpha coefficient was used to measures the reliability (Tavakol and Dennick, 2011). Reliability evaluates (coefficient alphas) for the Perceived usefulness (PU), Perceived ease of use (PEU) and Organic farming adoption (OFA) were 0.655, 0.721 and 0.683 respectively. These all values are in the range of acceptable levels.

b) Effect of perceived usefulness (PU) of organic farming and perceived ease of use (PEU) on organic farming to the organic farming adoption (OFA) by the farmers.

Table 2: General socio-economic status of the respondents

Variable	Levels	Frequencies	Significant/Not significant
Age	< 35 Years	12.30%	Significant
	36 – 55 Years	59.30%	
	> 56 Years	27.20%	
Gender	Male	81.50%	Significant
	Female	17.30%	
Number of Household members	< 2	4.90%	Significant
	2 – 5	21.00%	
	> 5	72.80%	
Education level	GCE O/L or less	25.90%	Significant
	GCE O/L	39.50%	
	GCE A/L	25.90%	
	Diploma	4.90%	
	Graduate	2.50%	
Contribution from the supplementary food crop farming to the total income of households	< 25%	2.50%	Significant
	26% - 50%	7.40%	
	51% - 75%	19.80%	
	> 75%	69.10%	

Table 3: Descriptive statistics of the selected variables

Criteria	Median	Standard deviation	N
Perceived usefulness (PU)	-1.00	0.760	80
Perceived ease of use (PEU)	-1.25	0.560	80
Organic farming adoption (OFA)	-1.00	0.891	80

Table 4: Correlation results of the latent variables

		PU	PEU
OFA	Pearson Correlation	-0.006	0.026
	Sig. (2-tailed)	0.956	0.820
	N	80	80

OFA – Organic Farming Adoption – Perceived Usefulness, PEU – Perceived Ease of Use, PU – Perceived usefulness, PEU – Perceived ease of use

Correlation analysis was done to determine the effect of the perceived usefulness (PU) of organic farming and perceived ease of use (PEU) on organic farming to the Organic farming adoption (OFA) by the farmers. Correlation values and significance levels are mentioned in Table 4. The results indicated that the perceived usefulness (PU) of organic farming and perceived ease of use (PEU) on organic farming do not significantly correlate (p value> 0.05) to the organic farming adoption by farmers in the Bibile DS division. The farmers in the area are constantly attempting to compare their organic farming practices with inorganic farming practices, particularly in terms of harvest, without considering the numerous other impacts. Recently, there has been a high demand for foods in Sri Lanka, so they are attempting to

produce more and more crops in short periods. Without inorganic fertilizers, they try to produce more and more crops, but they eventually fail to meet the demand for those specific crops. As a result, organic farming is not widely accepted.

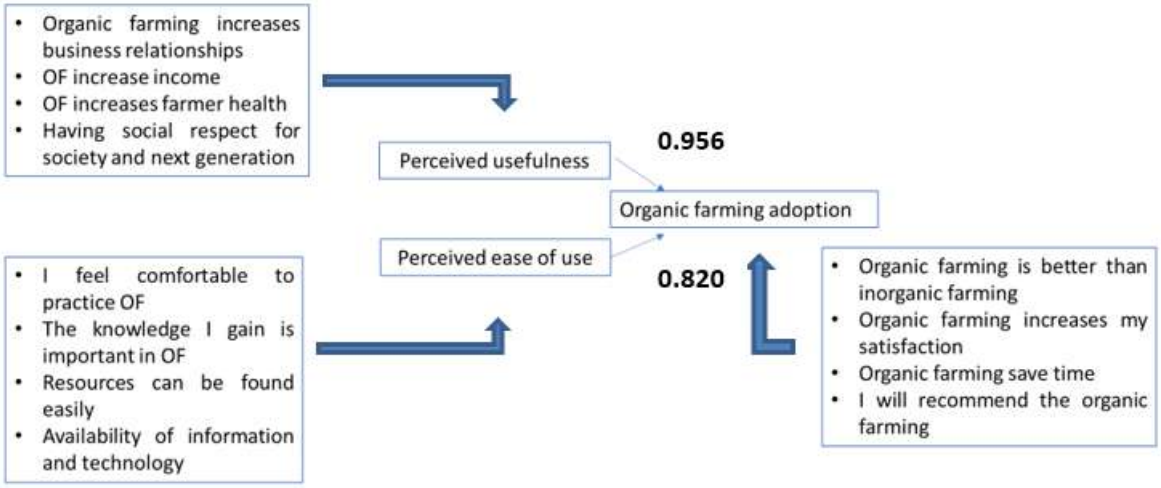

Figure 1: Technological Acceptance Model – Significance levels

Conclusion

This research aimed to evaluate the farmers' acceptance of organic cultivation methods in supplementary food crops in Bibile DS division in the Monaragala district. The study results revealed that many farmers are male and between the 36-55 age category with an education level up to the GCE ordinary level. Many farmer families have more than five numbers of households. In the technological acceptance model, all the constructs have acceptable range of reliability levels. Further, perceived usefulness and perceived ease of use of organic farming technology by the selected farmers were not significant on organic farming adoption in Bibile DS division in Monaragala district of Sri Lanka.

References

Available at http://www.ifoam.org/en/organic-landmarks/definition-organic-agriculture.pdf, (7th March 2022)

IFOAM, (2005). International Federation for Organic Agriculture Movement, Definition of organic farming. [Online]

Ministry of Agriculture – Sri Lanka. (2022) [Online] Available at https://www.agrimin.gov.lk/web/index.php/project/12-project (31st July 2022]

Tavakol, M. and Dennick, R., 2011. Making sense of Cronbach's alpha. *International Journal of Medical Education*, 2:53.

ENTREPRENEURIAL ABILITY OF FISHERMEN IN HIKKADUWA DIVISIONAL SECRETARIAT AREA OF GALLE DISTRICT

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Abstract

A study was carried out in the Hikkaduwa Divisional Secretariat (DS) division of the Galle district to find out the entrepreneurial behaviour of fishermen. By following a random sampling procedure, 100 fishermen were selected, and a structured interview schedule was used to collect the information through personal interviews. The relevant secondary data for the study were collected from various published sources. Descriptive statistics and Likert scaling were used to analyze the data. The personal and socio-economic characteristics of fishermen revealed that all of the fishermen were male, more than half of the fishermen belonged to the old age category, half of the fishermen were educated up to primary education level, and more than half of the respondents depended mainly on fishing activity. Further, most of the fishermen had medium family sizes, and the majority of fishermen had above 36 years of experience in fishing activity. The result further revealed that most fishermen have medium levels of decision-making and risk-taking abilities, low levels of leadership ability and cosmopoliteness and high levels of knowledge regarding the fishing enterprise. Overall, the study indicated that more than half (60%) of fishermen had a medium entrepreneurial ability in the Hikkaduwa DS division of Galle District. As such, fishermen should be given educational efforts and policy support by the field extension workers of the development departments, NGOs, private organizations and government officers to further enhance their entrepreneurial ability.

Keywords: Cosmopoliteness, decision-making ability, entrepreneurial behaviour, fishermen, risk-taking ability

Introduction

Around the world, millions of people have been involved in fishing and fish trading since ancient human times. Among the seaside livelihood opportunities, a fishery has been the oldest and most important activity in Sri Lanka since ancient times. The coastal areas of Sri Lanka are usually affluent in their natural resources that offer great opportunities for livelihood activities, mainly resource-based economic activities such as fishing, tourism, and recreation. The coastal fishery area in Sri Lanka largely depends on small-scale fishing. It also supplies a significant source of protein for people. Moreover, it is a prominent social and economic contributor to the country (Dayalatha, 2020). The fisheries sector in Sri Lanka comprises primarily small-scale operators except for a small number of large commercial operators with modern facilities. The most impoverished industry workers are the fishermen who use small traditional boats, fish workers, small-scale vendors, and low-paid workers of associated, often labour-intensive industries. Overall, the fishing subsector is one of the most vulnerable communities in Sri Lankan society. The country's total fish production in 2019 was 505,830 metric tons (MT); of them, marine fish production was 415,490 MT, while the rest (90,340 MT) were from inland and aquaculture. Of total fish production, 114,900 MT of fresh fish had been utilized locally for dry fish production. Although there are 15 fisheries districts in the country, Tangalle (15%) and Galle (12%) districts together contributed 27 per cent to the total marine fish production of the same year (MFAR, 2020).

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An entrepreneur is an economic man who strives to maximize profits through innovations. The entrepreneurial ability of an individual is operationally defined as the cumulative outcome of six components; innovativeness, economic motivation, decision-making ability, risk orientation, information-seeking behaviour, and leadership (Balasaravanan and Vijayadurai, 2012). Entrepreneurship as a composite variable implies that the person with entrepreneurship ability has specialized characteristics (Priyanka and Jahanara, 2018). A large part of an interest in entrepreneurship stems from economic development resulting from purposeful human activity. Hence, promoting entrepreneurship is the key to it. Entrepreneurship in fisheries is not solely guided by profit, and entrepreneurs in fisheries do not form a social class like capitalists. Recent interest in fishery development coupled with poverty and unemployment and the opening of markets has brought the concept of rural entrepreneurship to the fore.

The coastal fisheries sector is the main occupation of fishermen in the Hikkaduwa DS division of Sri Lanka. The fishermen mainly depend on marine fishing for their livelihood, even though they have other professions. An understanding of the level of entrepreneurial ability of these fishermen helps to design relevant programs to enhance their entrepreneurial ability further. However, a lack of studies has been conducted on the entrepreneurial ability of fishermen in the area. Based on this context, a study was designed to determine the entrepreneurial behaviour of fishermen in the Hikkaduwa Divisional Secretariat area of Galle District, Sri Lanka.

Methodology

The study was conducted in the Hikkaduwa Divisional Secretariat division of the Galle District. There are 19 DS divisions in the Galle district. Among those, six DS divisions *viz*., Bentota, Balapitiya, Ambalangoda, Hikkaduwa, Galle four Gravest and Habaraduwa are major fishing areas. The Hikkaduwa DS division was purposively selected for the study based on the higher number of fishermen and fishing area. Under the Hikkaduwa DS division, four villages, namely Dodanduwa, Rathgama, Gammeddegoda and Pitiwella, were selected for the study. The four villages were chosen based on the high number of fishermen. A total of 100 fishermen were randomly chosen from the four villages, proportionate to the number of fishermen in each village.

Table 1. Fishing Villages, Number of Fishermen and Sample Size

No	Village	Fishermen number	Sample size
01	Dodanduwa	1086	80
02	Rathgama	49	03
03	Gammeddegoda	95	07
04	Pitiwella	125	10
Total		1,335	100

A questionnaire was used to collect the data, and it consisted of background information of the respondent and the components of entrepreneurial ability. The questionnaire was pre-tested with fishermen in the Rathgama area to assess the suitability of the prepared questionnaire. In the light of pre-testing, necessary changes were incorporated into the questionnaire. The interviews were conducted with the sampled 100 fishermen at their homes and small fisheries harbours. Secondary data needed for the study were collected from various published sources. The collected data were analyzed using SPSS (Statistical Package for Social Science) version 28.0. Descriptive statistics were used to describe the basic features of study variables. Entrepreneurial behaviour was taken as a function of five components: decision-making ability, risk-taking ability, leadership ability, knowledge of fishing and cosmopoliteness. Each component was measured by asking for relevant statements. The Likert scaling method was

used for the measurement. The total score of each component of the Entrepreneurial behaviour was calculated based on the statement scores obtained by each respondent. Based on the total score obtained by respondents on each component, they were grouped into three categories, keeping the mean and standard deviation as check. The summation of scores of all five components constitutes the entrepreneurial behaviour score of the respondents.

Results and Discussion

Socio-economic characteristics of the fishermen

The data exposed that the average age of fishermen was 50 years old. The minimum age for fishermen was 26 years old, and the maximum age was 85 years old.

Table 2. Socio-economic Characteristics of Respondents

Traits	Mean	Std. Deviation
Age of fishermen (years)	50.08	12.325
Family size (Nos.)	4.20	1.137
Experience in fishing (years)	31.50	13.445
Amount of annual fish production (kg)	11652.50	3601.495

The average family size of a household was four members, and the fishermen in the study area had 32 years of average fishing experience. The minimum experience of fishermen was seven years, and the maximum experience was 64 years. The average annual fish production was 11652.50 kilograms.

Entrepreneurial ability components of Respondents

a) Decision-making ability

According to Table 3, the majority of the respondents (50.0%) had medium decision-making ability, followed by high (37.5%) and low (12.5%) decision-making ability, respectively. This might be due to poor education and the irregular record-keeping of the fishermen.

Table 3. Decision-making ability of fishermen

Category	Percentage
Low	12.5
Medium	50.0
Higher	37.5

b) Knowledge of fishing enterprise

The findings from Table 4 show that the majority (60%) of the respondents had a high level of knowledge regarding the fishing enterprise, followed by low (22.5%) and medium (17.5%) knowledge, respectively. It might be because fishermen in Hikkaduwa DS of Galle district have engaged in fishing for an extended period. Therefore, they had adequate knowledge of fishing enterprise and higher experience fishermen availability.

Table 4: Knowledge of respondents

Category	Percentage
Low	22.5
Medium	17.5
Higher	60.0

c) Leadership ability

Table 5 shows that the majority (52.5%) of the respondents had a low level of leadership ability, followed by medium (35%) and high (12.5%) levels of leadership ability, respectively. This might be because they had low education and lower social participation compared to other sectors.

Table 5: Leadership Ability of Respondents

Category	Percentage
Low	52.5
Medium	35.0
Higher	12.5

d) Cosmopoliteness

Cosmopoliteness is how a fisherman is oriented outside his community to seek information. The findings from Table 6 show that the majority (72.5%) of the respondents had a low level of cosmopoliteness followed by a medium (20%), and the rest of them (7.5%) had a high level of cosmopoliteness. This result might be due to fishermen's low interest in adopting new fishing activities and low social participation.

Table 6: Cosmopoliteness of respondents

Category	Percentage
Low	72.5
Medium	20.0
Higher	7.5

e) Risk-taking ability

Table 7 indicates that the majority (47.5%) of the respondents had a medium risk-taking ability, followed by high (40%) and low (12.5%) risk-taking ability, respectively. It could be attributed to their old age and non-willingness to take risks in fish production.

Table 7: The Risk-taking ability of respondents

Category	Percentage
Low	12.5
Medium	47.5
Higher	40.0

The entrepreneurial ability of respondents

The summation of scores of all the five selected components constitutes the entrepreneurial behaviour score of the respondents. Table 8 indicates that the majority (60%) of the respondents belonged to the medium entrepreneurial behaviour category, whereas 27.5 per cent were in the low entrepreneurial behaviour category and 12.5 per cent were in the high entrepreneurial behaviour category.

Table 8: Entrepreneurial ability

Category	Percentage
Low	27.5
Medium	60.0
Higher	12.5

The possible reason for the medium entrepreneurial behaviour of fishermen might be due to the high number of old-age fishermen, low financial condition of them to take risks, and their low interest in adopting new technologies.

Conclusion

Based on the results, the study concluded that most fishermen in the Hikkaduwa area had medium risk-taking and decision-making abilities, high levels of knowledge regarding fishing enterprise, and low levels of leadership ability and cosmopoliteness. Further, most of the fishermen in the study area had medium entrepreneurial ability. The fact that most of the fishermen had medium entrepreneurial ability is a clear indication of the progressiveness of the fishermen. Therefore, fishermen should be given educational efforts and policy support by the field extension workers of the development departments, NGOs, private organizations and government officers. As most fishermen are old, they can act as catalysts in motivating other fishermen through communication networks.

References

Balasaravanan, K. and Vijayadurai, J. (2012). Entrepreneurial Behavior among Farmers – An empirical study. *International Journal of Engineering and management research*, 2(1): 1-5.

Dayalatha, W. K. V. (2020). Low Socio-Economic Status Among Coastal Fishing Families in Southern Sri Lanka. In N. Samat, J. Sulong, M. Pourya Asl, P. Keikhosrokiani, Y. Azam, & S. T. K. Leng (Eds.), In: Innovation and Transformation in Humanities for a Sustainable Tomorrow, vol 89. European Proceedings of Social and Behavioural Sciences (pp. 139-151). European Publisher. https://doi.org/10.15405/epsbs.2020.10.02.13

MFAR, (2020). Fisheries Statistics 2020. *Ministry of Fisheries and Aquatic Resources Development*, pp. 1–70.

Priyanka, C. and Jahanara, D. (2018). Extent of Adoption of Entrepreneurial behaviour of chickpea growers in Komaram Bheem district (Telangana). International Journal of Research CultureSociety, 2(5): 173–174.

WATER MANAGEMENT

PERFORMANCE ASSESSMENT OF IRRIGATED AGRICULTURAL SYSTEMS USING COMPARATIVE INDICATORS: A CASE STUDY IN POLONNARUWA DISTRICT, SRI LANKA

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Abstract

Proper management of land, water, and agricultural inputs along with efficient operation and maintenance of irrigation systems are prerequisites for achieving optimum crop yield. Farmers in Polonnaruwa district face water shortages in both *Yala* and *Maha* seasons due to erratic nature of rainfall distribution and failure of monsoonal rainfalls. Some irrigation systems perform well even under stress conditions through better management of available water and land resources. Performance assessment of irrigation systems using suitable comparative performance indicators helps to identify the shortcomings and solutions for increasing the systems' productivity. In the above context, the present study aimed to assess the performance of four irrigation systems such as Parakrama Samudraya, Girithale, Minneriya and Kaudulla in Polonnaruwa district using comparative performance indicators. Total water demand of Parakrama Samudraya system was found to be 267.83 MCM in *Maha* season. Corresponding figures for Minneriya, Girithale and Kaudulla are 238.98 MCM, 80.81MCM and 143.55 MCM, respectively. Water demand in *Yala* season for above mentioned irrigation systems are 323.88 MCM, 289 MCM, 97.73 MCM and 173.59 MCM, respectively. Paddy yield varies from 6.8 t/ha to 10.2 t/ha in *Maha* and from 5.4 t/ha to 10.2 t/ha in *Yala* season under above mentioned irrigation systems. Average production per unit cropped area of Girithale and Minneriya were 3134 $/ha and 2968 $/ha, respectively. Kaudulla showed the lowest production of 2393 $/ha and 2349 $/ha in *Maha* and *Yala* seasons, respectively. According to the relative water supply and relative irrigation supply, there is water shortage in all systems in both seasons. Girithale system shows lowest water scarcity. In overall, irrigation systems in the study area facing water shortage in both cultivation seasons. Minneriya and Girithale systems show highest performance among other systems. However, Kaudulla system shows lower performance. Therefore, appropriate measures should be taken to improve the performance of irrigation systems, particularly Kaudulla and Parakrama Samudraya.

Keywords: Irrigated agriculture, performance assessment, water demand

Introduction

Polonnaruwa district is one of the major farming districts in the dry zone of Sri Lanka. There are four major irrigation systems in this district. The livelihood of farmers mainly depends on crop cultivation. Farmers cultivate paddy as the main crop in both *Yala* and *Maha* seasons and face water shortages very often and couldn't fulfill agricultural practices mainly in *Yala* season. Further, farmers lose cultivation due to prolonged extreme weather conditions encountered in both seasons. Since irrigation water is completely necessary for cultivation, every effort should be made to use water as efficiently as possible. Efficient use of limited water resources in crop production will both enhance producer's yield per unit of water and hinder such negative effects on environment as drainage, salinity and increase in the level of underground water, resulting from over use of water. Further, performance assessment of irrigation systems using suitable comparative performance indicators helps to identify the shortcomings and solutions for increasing the systems 'productivity (Rajendran *et al*., 2017). The performance of an irrigation system is represented by its measured levels of achievement in terms of one, or several,

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parameters which are chosen as indicators of the system's goals (Gorantiwar and Smout, 2005). In addition, the exploration and utilization of water resources for irrigation require that there are periodic evaluations of its utility and efficiency of use. Any enterprise requires feedback on the management of resources and the end result in terms of increased output through efficient management of existing resources. Further, there is an increasing concern about the performance of an irrigated agricultural system as pressure grows on water resources in all parts of the world and as concerns increase regarding the food security and sustainability of irrigated agricultural systems. In the above context, the present study aimed to assess the performance of major irrigation systems in Polonnaruwa district using comparative performance indicators.

Materials and Method

Study Area

The study was carried out in Polonnaruwa district, located in the North Central Province of Sri Lanka. Figure 1 shows the location of the study area and the selected major irrigation systems.

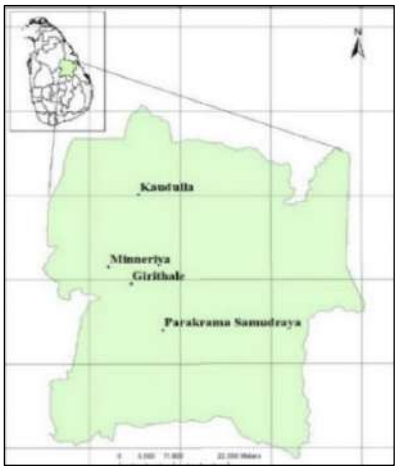

Figure 1: Location of study area

Data Collection

Data such as reservoir operational data, cultivation data, rainfall data, effective rainfall data, monthly average evapotranspiration data, percolation and seepage data, and water diversion data were collected from the irrigation department and available secondary resources.

Estimation of water demand

Seasonal water demand was assessed for the last 5 years. In this study, crop water demand (CWR) was estimated for 31/2 months rice variety as it is the common paddy variety grown in this region. Irrigation water requirement for paddy was calculated using Eq.1.

$$\mathbf{IWRpaddy = ETcrop + Wlp + Wps + W1 - Pe} \quad \text{Eq.1}$$

Where, IWR is irrigation water requirement of paddy, ETcrop is the evapotranspiration, Wlp is the water required for land preparation, Wps is the percolation and seepage losses, Wl is the water required to establish standing water layer for paddy, and Pe is the effective rainfall. Wlp, Wps, W1 and Pe data were collected from the irrigation department and ETcrop was calculated for different seasons.

Performance Assessment of Irrigation Systems

In this study, three performance indicators such as Agricultural performance, Water use performance and Physical performance were used. The details are given in Table 1.

Table 1: Selected indicators for assessing the performance of irrigation systems

Performance indicators	Estimation
Agricultural	
Crop yield per unit area	Total paddy yield/Total cultivated extent
Output per cropped area	Seasonal value of agricultural production/irrigated crop area
Output per unit irrigation	Seasonal value of agricultural production/Diverted irrigation supply
Water delivery performance	
Relative water supply	Total water supply (Rainfall + irrigation) /Crop water demand (Evapotranspiration + seepage and percolation losses)
Relative irrigation supply	Irrigation supply/Irrigation demand (Crop ET-effective rainfall)
Physical performance	
Cropping intensity	Annual cropped area/Cultivated area

Results and Discussion

Water demand of different irrigation systems in Polonnaruwa district

Table 2 shows total water demand of different irrigation systems in Polonnaruwa district in *Maha* season over the past five seasons. Total water demand mainly depends on extent of cultivation, evapotranspiration, type of crop and efficiency of system. Total water demand was zero for Girithale and Kaudulla stems in 2016/17 *Maha* as the cultivation was abandoned in that season. Higher water demand (267.83 MCM) was observed in Parakrama Samudraya system. Lowest water demand (80.81 MCM) was observed in Girithale system. Total water demand of Minneriya and Kaudulla systems are 238.98 MCM and 143.55 MCM, respectively.

Table 2: Total water demand of different irrigation systems in *Maha* season

Irrigation system	Total water demand (MCM)				
	2016/17	2017/18	2018/19	2019/20	2020/21
Parakrama Samudraya	267.83	267.83	267.83	267.83	267.83
Minneriya	238.98	238.98	238.98	238.98	238.98
Girithale	0	80.81	80.81	80.81	80.81
Kaudulla	0	143.55	143.55	143.55	143.55

Water demand in *Yala* season is given in Table 3. Highest total water demand (323.88 MCM) was observed in Parakrama Samudraya system. Lowest total water demand of 97.73 MCM observed in Girithale system. Minneriya system showed water demand ranged from 144.5-289.0 MCM. Variation in total water demand is mainly due to variations in extent of cultivation and crop type. As observed, total water demand was very low in Minneriya in 2017 *Yala* season as they reduced extent of cultivation due to water shortage.

Table 3: Total water demand of different irrigation systems in *Yala* season

Irrigation system	Total water demand (MCM)				
	2017	2018	2019	2020	2021
Parakrama Samudraya	323.9	323.9	323.9	323.9	323.9
Minneriya	144.5	289.0	289.0	289.0	289.0
Girithale	97.73	97.73	97.73	97.73	97.73
Kaudulla	173.6	173.6	173.6	173.6	173.6

Agricultural performance

Crop yield per unit cropped area

Highest production was observed in Minneriya and Girithale systems over the past five years, it is nearly 10.2 t/ha except 2016/17 *Maha* season. Lowest production of nearly 6.8 t/ha was observed in Kaudulla system in 2019/20 *Maha* (Figure 2). Production was lower than *Maha*

season in some years in *Yala* season. Highest yield was recorded in Minneriya and Girithale systems in every year. 10.2 t/ha is the highest value. Lowest production is 5.4 t/ha in Kaudulla system in 2017 year.

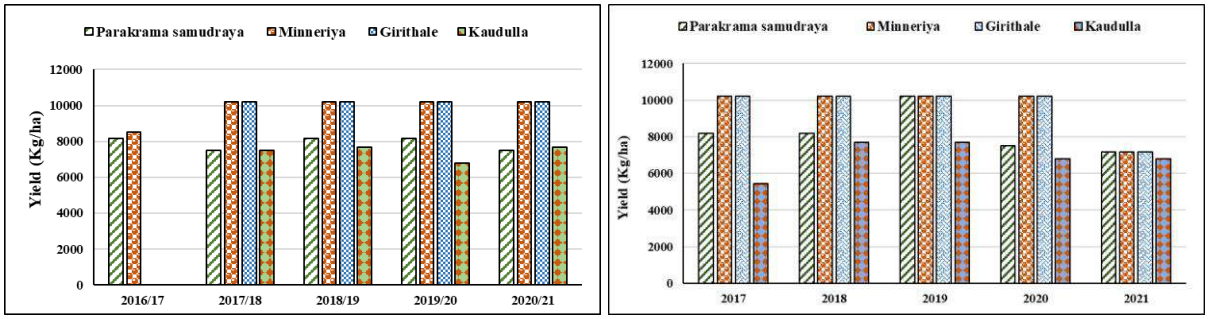

Figure 2: Production per unit cropped area in in *Maha and Yala* season

Production per unit cropped area

Girithale and Minneriya systems show highest production (3354.4 $/ha) in 2020/21 *Maha* season. Kaudulla system recorded lowest production in 2017/18, 2018/19 and 2019/ 20 with the lowest value of 2200.9 $/ha. Farmers in Girithale and Kaudulla system abandoned 2016/17 *Maha* season due to failure of monsoonal rainfall. Average production in Girithale was 3134 $/ha. The corresponding values for Parakrama Samudraya, Minneriya and Kaudulla were 2492 $/ha, 2968 $/ha and 2393 $/ha respectively.

Table 4: Agricultural production per unit cropped area in *Maha* season

Irrigation system	Production per cropped area ($/ha)				
	2016/17	2017/18	2018/19	2019/20	2020/21
Parakrama Samudraya	2212.7	2200.9	2353.9	3236.6	2459.8
Minneriya	2304.8	3001.2	2942.4	3236.6	3354.4
Girithale	-	3001.2	2942.4	3236.6	3354.4
Kaudulla	-	2200.9	2216.6	2438.2	2714.4

Table 5 shows production per unit cropped area during *Yala* season. Maximum production of 3748 $/ha was observed in Parakrama Samudraya, Minneriya and Girithale systems in 2021. Although yield per unit cropped area was high in 2019, production was high in 2021 due to increased unit price. Average production of Minneria and Girithale systems was 3162 $/ha, while it was Parakrama Samudraya and Kaudulla showed 2805 $/ha and 2349 $/ha, respectively.

Table 5: Agricultural production per unit cropped area in *Yala* season

Irrigation system	Production per unit cropped area ($/ha)				
	2017	2018	2019	2020	2021
Parakrama Samudraya	2306.8	2259.7	3118.9	2589.3	3748.6
Minneriya	2883.5	2824.7	3118.9	3236.7	3748.6
Girithale	2883.1	2824.3	3118.9	3237.0	3748.6
Kaudulla	1537.9	2127.9	2349.6	2157.7	3570.1

Output per unit irrigation supply

Output per unit irrigation supply varies season to season. Highest output per unit irrigation supply was observed in Minneriya and Kaudulla systems in *Maha* season (Table 6). On average, Parakrama Samudraya and Girithale showed the same output per unit irrigation water supply.

Table 6: Output per unit irrigation supply in different irrigation systems in *Maha* season

Irrigation system	Output per unit irrigation supplied ($/m^3)				
	2016/17	2017/18	2018/19	2019/20	2020/21
Parakrama Samudraya	0.27	0.13	0.19	0.25	0.16
Minneriya	0.37	0.46	0.35	0.37	0.32
Girithale	0	0.24	0.27	0.25	0.24
Kaudulla	0	0.33	0.40	0.37	0.35

Compared to *Maha* season, output per unit irrigation supply was low in *Yala* season in both Minneriya and Kaudulla systems (Table 7). The lowest output was observed in Parakrama Samudraya. Reduction in overall output per unit irrigation supply in *Yala* season might be due to water stress.

Table 7: Output per unit irrigation supply in different irrigation systems in *Yala* season

Irrigation system	Output per unit irrigation supply ($/m^3)				
	2017	2018	2019	2020	2021
Parakrama Samudraya	0.19	0.14	0.20	0.19	0.23
Minneriya	0.24	0.24	0.29	0.36	0.29
Girithale	0.21	0.16	0.18	0.22	0.25
Kaudulla	0.25	0.24	0.28	0.21	0.33

Water use performance

Relative water supply

Relative water supply relates water supply to demand and indicates the condition of water abundance or scarcity and how tightly supply and demand is matched. More than 1 of relative water supply indicates excess water supply while less than 1 indicates water shortage. All systems showed less than 1 for relative water supply, therefore all the systems recorded water shortage in *Maha* season (Table 8). Relative water supply was lower in Kaudulla system compared to other systems.

Table 8: Relative water supply in *Maha* season

Irrigation system	2016/17	2017/18	2018/19	2019/20	2020/21
Parakrama Samudraya	0.35	0.65	0.56	0.54	0.63
Minneriya	0.36	0.30	0.40	0.55	0.75
Girithale	NC	0.51	0.50	0.69	0.75
Kaudulla	NC	0.31	0.28	0.36	0.51

NC-Not cultivated

Compared to *Maha* season, severe water shortage, particularly in Kaudulla system was observed in *Yala* season (Table 9). Almost 50% of the water demand was met in both Parakrama Samudraya and Girithale systems.

Table 9: Relative water supply in *Yala* season.

Irrigation system	2017	2018	2019	2020	2021
Parakrama Samudraya	0.40	0.51	0.49	0.45	0.53
Minneriya	0.42	0.40	0.37	0.31	0.46
Girithale	0.46	0.58	0.59	0.51	0.52
Kaudulla	0.24	0.36	0.28	0.37	0.37

Relative irrigation supply

Table 10 shows relative irrigation supply in *Maha* season in different irrigation systems. Relative irrigation supply values were less than 1 in all systems in *Maha* season. Lowest value

(0.23) was recorded in Kaudulla system and highest value (0.68) was recorded in Girithale system.

Table 10: Relative irrigation supply in *Maha* season

Irrigation system	2016/17	2017/18	2018/19	2019/20	2020/21
Parakrama Samudraya	0.33	0.64	0.52	0.52	0.62
Minneriya	0.27	0.26	0.35	0.42	0.61
Girithale	NC	0.49	0.46	0.61	0.68
Kaudulla	*NC*	0.27	0.23	0.28	0.38

NC-Not cultivated

Relative irrigation supply in *Yala* season also less than 1 in all the systems (Table 11). Lowest relative irrigation supply was observed in Kaudulla system. In overall, both relative water supply and relative irrigation supply was less than 1 in all the systems in both *Maha* and *Yala* season in the selected irrigation systems.

Table 11: Relative irrigation supply in *Yala* season

Irrigation system	2017	2018	2019	2020	2021
Parakrama Samudraya	0.39	0.50	0.48	0.44	0.53
Minneriya	0.40	0.38	0.35	0.29	0.43
Girithale	0.45	0.57	0.57	0.48	0.50
Kaudulla	0.20	0.30	0.27	0.34	0.35

Physical performance

Cropping intensity

Cropping intensity (CI) is the primary and essential criteria to measure irrigation service performance. In 2019, 2020 and 2021 all systems cultivated all command area both seasons (Figure 3). However, CI was 1.5 in Minneriya system in 2017 whereas it was 1 in both Girithale and Kaudulla systems. It reveals that farmers in all systems except Parakrama Samudraya could not cultivate entire command area in 2017 due to water shortage.

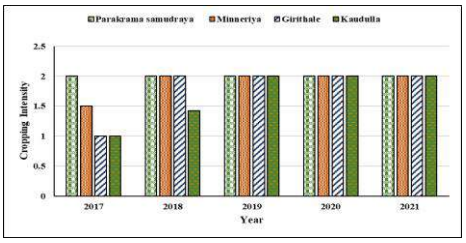

Figure 3: Cropping intensity of different irrigation systems

Conclusion

Irrigation systems in the study area face water shortage in both *Yala* and *Maha* season. Minneriya and Girithale systems show highest performance among other systems. Parakrama Samudraya system also shows good performance. However, performance of Kaudulla system is lower compared to other irrigation systems. Therefore,it can be recommended to take appropriate measures to improve the performance of Kadulla irrigation system

References

Gorantiwar, S. D. and Smout, I. K. (2005). Performance assessment of irrigation water management of heterogeneous irrigation schemes: 1. A frame work for evaluation. *Irrigationand drainage systems*, 19(1): 1-36.

Rajendran, M., Gunawardena,E.R.N. and Dayawansa, N.D.K. (2017). Assessment of performance and water Demand and Supply Deficit of Hakwatuna Oya irrigation System, SriLanka.Research Journal of Engineering,6(9):23-28.

SUITABLE IRRIGATION METHOD IN DRY ZONE UNDER THE CHILLI (*Capsicum annum* L) CULTIVATION AND THE EFFECT OF MULCHING

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Abstract

Chilli (*Capsicum annum* L) is one of the most important cash crops grown in Sri Lanka and belongs to the Solanaceae family. The crop production is affected by many biotic and abiotic stresses. Moisture stress is one of the main abiotic stress lower the chilli production in the country. Selection of a low cost, efficient irrigation system will lower the moisture stress to the crop hence increase the chilli crop production. Ridge and furrow irrigation is one of such low cost efficient irrigation method. The development of the salinity at the top of ridges is a drawback of the ridge and furrow irrigation. This study was done to investigate the salinity development, its effect on chilli crop production and possible method to control salinity development under ridge and furrow irrigation. The study was conducted in Regional Agriculture Research and Development Centre, Kilinochchi during the period from February to May 2022. The trial was laid out as a two factor factorial design in RCBD with three blocks. Four treatments (T1, T2, T3, and T4) were arranged to conduct this study. T1 denoted as basin with mulching, T2 denoted basin without mulching, T3 denoted ridge and furrow irrigation with mulch and T4 denoted ridge and furrow irrigation without mulching. The Plant height (PH), Canopy width (CW), Pod length (PL), Pod width (PW), Pod thickness (PT) and Yield (Y) were recorded. The data were analysed using SAS computer software package. An increase of the salinity level was observed from furrow to ridge top in T4. The other three treatments showed equal salinity distribution across the plot. The interaction effect of the irrigation method and the mulch were not significant for all the traits except pH. Both main effects also showed non significant difference for all the traits analysed. Therefore, farmers can use ridge and furrow irrigation method as it is more advantageous and other cultural practices.

Keywords: Chilli, growth, irrigation, mulching, RCBD

Introduction

In Sri Lanka, *Capsicum annum* is one of the most important cash crops grown by farmers. It has become an essential part of ingredient in Sri Lankan meals (Abeysiriwardena *et al.*, 1991). Chilli is a distinctive and popular spice product found in almost every country on the planet, and it's known for its fiery, pungent flavour (Dharmasena, 1995). Chilies have been used in agriculture since the dawn of time. It is one of the Western Hemisphere's oldest domesticated crops (Nijamudeen and Dharmasena, 2002).

Basin, ridge and furrow systems are the most common types of surface irrigation. ridge and furrow systems are a widely used for chilli cultivation and thus well-known system that may be operated without the use of any additional technical applications (Kulkarni, 1993). Mulching materials can help to retain soil moisture, improve soil fertility, and boost soil productivity and use the suitable irrigation method in dry zone under the chilli cultivation.

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Materials and Method

Study location

This research study was conducted at the Regional Agricultural Research and Development Centre, Kilinochchi where, average temperature and rainfall was recorded as 32.7 ^{0}C and 149.1 mm correspondingly during the study period.

Soil analysis

Soil samples from the field were collected to analyse the parameters such pH and salinity.

Field establishment of chilli plants

The experiment was carried out in a randomized complete block design (RCBD) with four different treatments with three replicates. Four different treatments were designed as basin irrigation with mulching (T1), basin irrigation without mulching (T2), ridge and furrow irrigation with mulching (T3) and ridge and furrow irrigation without mulching(T4).

Transplanting the chilli

Maha Iluppallama green chilli variety seeds were sown in nursery beds and healthy, disease-free and good quality seedlings were selected for transplant. The Seedlings were transplanted in experimental plots at 45 cm × 60 cm spacing.

Application of paddy straw

Paddy straw was used as mulching in six treatments plots.

Data collection

Readings on growth parameters such as plant height, plant width, as well as yield parameters such as number of 50% flowering, pod length, pod diameter, pod thickness, number of pods and the total yield were recorded in all harvesting period.

Results and Discussion

Nutrient analysis

The pH and salinity were analysed before and after planting. There is a significant difference was observed. The pH value was observed as (5.98 to 6.26) before planting and higher pH value was observed after planting (pH 7.06 to pH 7.27) and salinity level was significantly differed in all the treatments (p values weren't mentioned). Irrigation method and the mulch were not significantly differ (p values weren't mentioned).

Plant analysis

As far as the plant growth parameters are concerned. Ridge and furrow irrigation with mulching(T3) were significantly differed with basin irrigation with mulching, basin irrigation without mulching and ridge and furrow irrigation without mulching at $p< 0.05$. Among the variations, the highest significance was observed in second harvest time (Figure 1). Further, there was a significant difference in the plant height from treatment 4 in first and second harvest time. Mulching does not affect crop growth and yield of chilli under irrigated situation. However, it could be used to suppress the weeds.

Results on yield parameters showed that there was a significant difference between all of the treatments, similar to the findings for growth parameters. Ridge and furrow irrigation with mulching (T3) were observed with higher performance than other treatments. Among the parameters analysed, higher pod length was observed in ridge and furrow irrigation with mulching (T3) and lower pod length value was observed in basin irrigation with mulching (Figure 2).

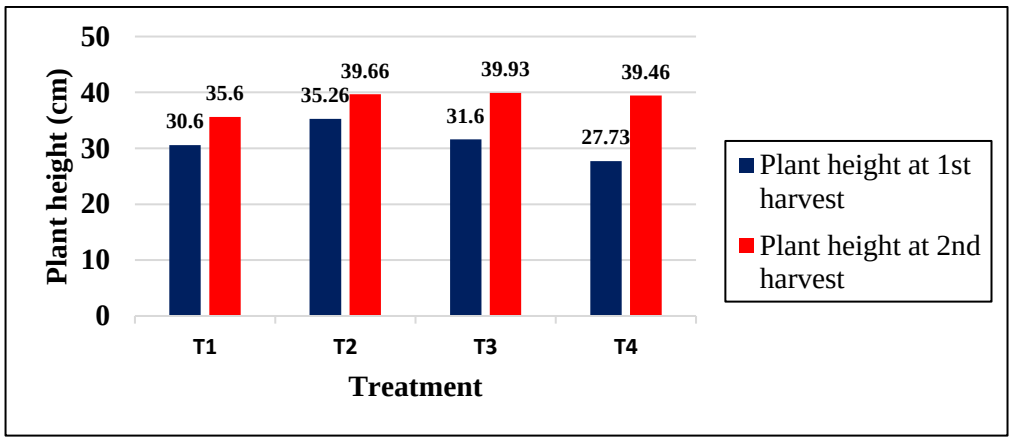

Figure 1: Plant height at first and second harvest

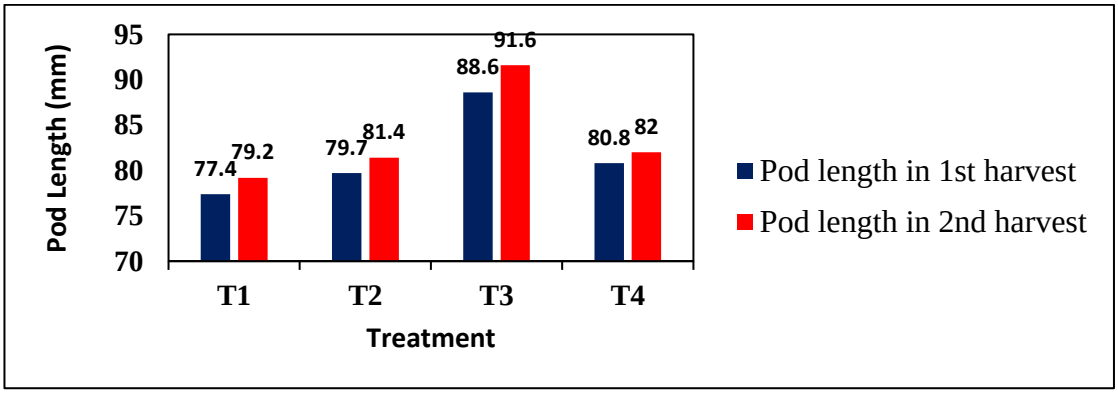

Figure 2: Pod length first and second harvest

There was a significant difference found in the yield and highest yield was found in treatment T4 than the other treatment and the lower yield was observed in T1 at first and second harvest time (Figure 3). Under rain fed farming situation mulching can increase the chilli yield (Citation was deleted). Yield increment depends on type of mulching material and time of application (Citation was deleted).

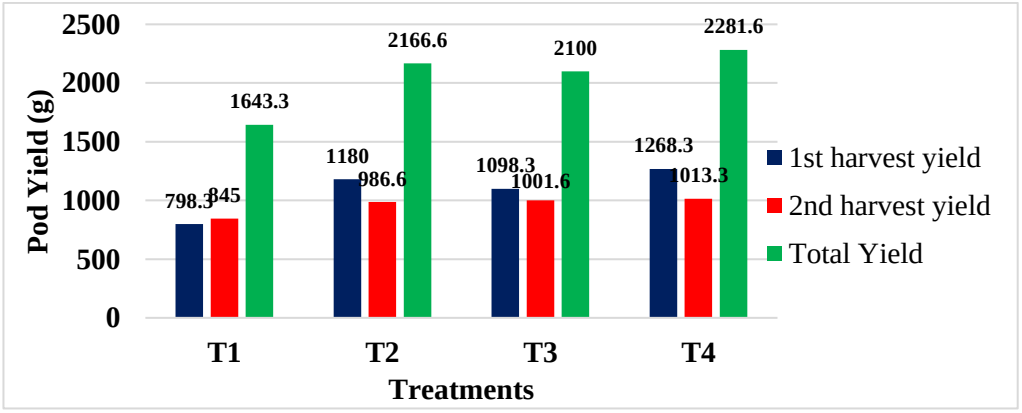

Figure 3: Pod yield at first and second harvest

Conclusion

The salinity distribution across the plot was equal in all the treatments except T4 where, an increase in salinity from the furrow to the ridge top was noticed. With the exception of pH,

there was no significant interaction between the irrigation technique and the mulch. Therefore, farmers can use ridge and furrow irrigation method as it is more advantageous in terms of water use efficiency and other cultural practices such as weed control compared to basin irrigation.

References

Abeysiriwardena. S., Glen, de Z. R.B., Paul, F. and Reese, J.R. (1991) Analysis of multi environmental yield trials for testing adaptability of crops. *Tropical Agriculturist*, 147: 85-97.

Dharmasena, P.B. (1995) Mulching for water conservation in agro-well farming. Farming. *In Proceeding of the 51st SLAAS annual session, Sri Lanka*, 191-192.

Nijamudeen M. S., Dharmasena P. B. (2002) Performance of chilli under the irrigation with mulch. Annual of the Sri Lanka Department of Agriculture,4: 89-94.

Kulkarni, U.P. (1993). Constraints in adoption of improved chilli cultivation practices in Motala Panchayat Samiti. M.Sc. (Ag.) thesis (Unpublished). PDKV, Akola.

ASSESSMENT OF GROUNDWATER QUALITY AND ITS SUITABILITY FOR DRINKING IN MANNAR ISLAND

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Abstract

Groundwater has been the primary source of water in Mannar Island. In most parts of the Island, groundwater is polluted mainly due to seawater intrusion and wastewater discharge. Salinity is detected by sour and bitter-sensing taste and thus most people now use pipe-borne water for drinking. Still, some people use groundwater for drinking and other domestic purposes. However, the level of other pollutants in groundwater is not well documented in this region. The present study aimed to assess the quality of groundwater and its suitability for drinking in Mannar Island. Groundwater samples were collected from 30 sampling points from August-November, 2022 and analyzed for major water quality parameters by adopting standard analytical methods. The period from August-September 2022 was considered as dry period and the period from October- November 2022 was considered as wet period as there was monsoonal rains during this period. The pH of groundwater ranged from 7.1–8.8 in dry period and 7.3–8.65 in wet period. EC of groundwater showed high variations, ranged from 500-7305 µs/cm in dry period and 480-7615 µs/cm in wet period. TDS and Salinity also showed high variations ranged from 346-8498 mg/l in dry period and 500-9500 mg/l in wet period. High level of EC, TDS and Salinity were observed at Savatkaddu, Periyakamam, and Eluthur 2 in both dry and wet periods. Except NO_3^- other parameters such as Ca^{2+}, Mg^{2+}, and PO_4^{3-} exceeded the maximum permissible limit at some locations. Elevated levels of heavy metals were also observed in this area. The highest level of Cd^{2+} and Cu^{2+} was observed at Savatkaddu. High level of Mn^{2+} was observed at Thalvupadu and Pattithoddam in wet period. Groundwater in the major part of the study area showed salinity level greater than 1200 mg/l. Estimated values of WQI ranged from 158.3-284.1 in dry period and 102.9-555.2 in wet period, revealing that the groundwater is not safe for drinking at all locations in the study area.

Keywords: Groundwater quality, sea water intrusion, water quality index

Introduction

Groundwater plays an important role in the development and management of water resources (Sophocleous, 2002). It serves as the only supply of freshwater in several locations in many parts of the world. Three main types of coastal sand aquifers have been recognized and characterized in Sri Lanka. Shallow aquifers on coastal spits and bars are one type of coastal sand aquifers found in the Mannar Island in the North West of Sri Lanka (Panabokke and Perera, 2005). Between Sri Lanka and India is the Rawana Bridge (Adams Bridge) island chain, which includes Mannar Island. Groundwater had been the main source of freshwater used for drinking and other domestic purposes in this region. However, a high level of salinity makes the groundwater objectionable or offensive to taste. As a result, people have been switching to the pipe-borne water supply, and the majority of the population nowadays uses pipe-borne water, particularly for drinking. However, groundwater is the only source of water for drinking in many locations in this region. There are a number of small and medium industrial outlets and garages scattered around the Island which directly discharge wastewater into the environment. However, the level of other major pollutants in the groundwater is not documented well. Assessment of groundwater quality in this Island would help to understand the levels of salinity and other major groundwater quality parameters and how the level of

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pollutants varies spatially and seasonally. Further, the estimation of WQI would give insight into the status of groundwater quality and its suitability for drinking (Lkr *et al*., 2020). In the above context, the present study aimed to assess the variations of groundwater quality and its suitability for drinking in Mannar Island.

Materials and Method

Description of the Study Area

Mannar Island, which lies off the north-western coast of Sri Lanka, is part of Mannar District of Sri Lanka. The Mannar Island falls into semiarid climate area and receives a mean annual rainfall of about 975 mm. The temperature in the area ranges from a minimum of 23°C to a maximum of 35°C.

Sample Collection

In the present study, 30 wells were selected randomly covering the entire Mannar Island and monthly water samples were collected from August 2022 – November 2022. Coordinates of the sampling locations were recorded using GPS device. Figure 1 shows sampling locations.

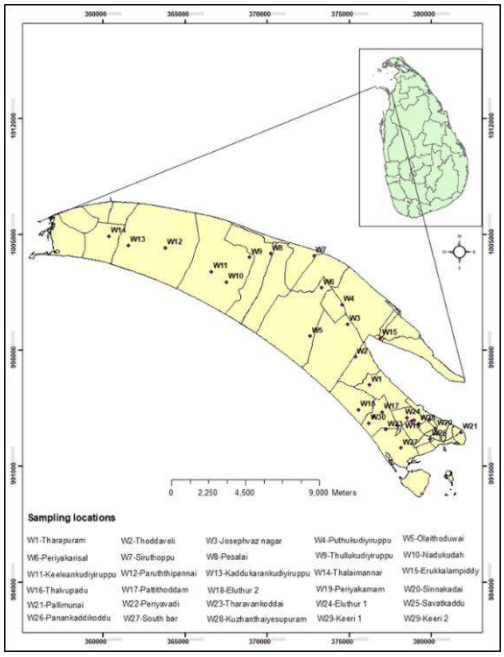


Figure 1: Location of the study area and sampling locations

Analysis of Water Quality Parameters

Water quality parameters such as pH, Electrical Conductivity (EC), and Total Dissolved Solids (TDS) were measured using portable pH, EC, and TDS meters at the sampling site. Other water quality parameters such as Total hardness (TH), Turbidity, Salinity, Ca^{2+}, and Mg^{2+} were measured using standard procedures. NO_3^- and PO_4^{3-} were measured using spectrophotometer. Heavy metals such as Cr, Cd, Cu, and Mn were measured using Atomic Absorption Spectrophotometer (AAS).

Estimation of Water Quality Index (WQI)

The weighted arithmetic WQI method was applied to assess water suitability for drinking purposes. The following formula were used to calculate WQI (Al-Mohammed and Mutasher, 2013).

Proportionality constant "K" value was estimated using formula Eq.1.

$$K = \frac{1}{1/\sum_i^n Si} \quad \text{Eq.1}$$

Quality rating for the n^{th} parameter (q_n) was estimated using Eq.2

$$qn = 100\{(Vn - Vio)/(Sn - Vio)\} \quad \text{Eq.2}$$

Where, as Vn is the estimated value of the nth parameter of the given sampling station. Vio is the ideal value of nth parameter in pure water. And Sn is the standard permissible value of the n^{th} parameter.

Weight of the n^{th} parameter Wn was estimated using Eq.3

$$Wn = \left(\frac{k}{Sn}\right) \quad \text{Eq.3}$$

Finally, overall WQI was calculated according to the following expression Eq.4

$$WQI = \sum qnWn / \sum Wn \quad \text{Eq.4}$$

Statistical Analysis

Descriptive analysis and one-way ANOVA available in Minitab software (v.17) were used for Statistical analysis. Graphical presentation of results was performed using Microsoft Excel Software and the spatial variation map was prepared using ArcGIS software (v.10.5) adopting Kriging interpolation method.

Results and Discussion

Physio-chemical Characteristics of Groundwater

pH

The pH of drinking water should be within the range of 6.5-8.5 (WHO, 2011). Figure 2 shows the variations of pH in the groundwater samples taken at different locations in the study area in both wet and dry period. All pH values (96.7%) were within the standard range except location 18 (Eluthur 2). The pH of groundwater samples was slightly higher in wet period than dry period at many locations in the study area. In general, chemicals, minerals, pollutants, soil or bedrock composition, and any other contaminants that interact with a water supply will create an imbalance in the water's natural pH of 7. Maximum pH was observed at Eluthur 2 in both dry (8.8) and wet period (8.65). However, minimum of 7.1 was recorded at Thoddaveli in the dry period and of 7.3 at Thalvupadu in wet period.

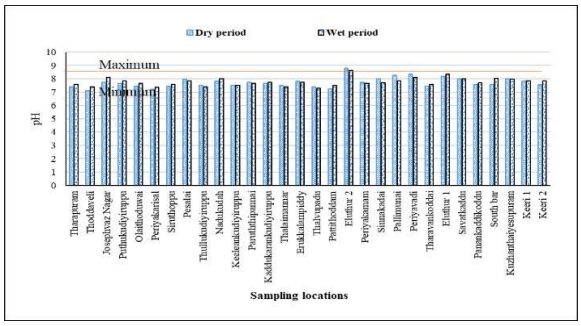


Figure 2: Variation of pH in the groundwater in wet and dry period

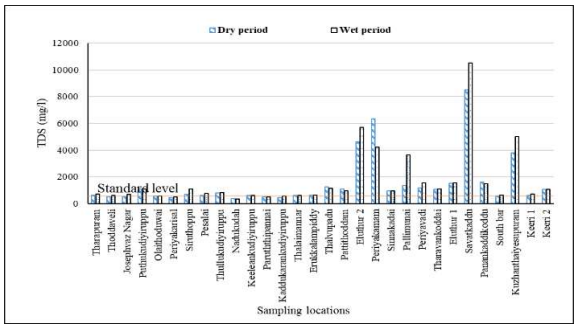
Total Dissolved Solid (TDS)

According to WHO standards, TDS level of less than 300mg/l is recommended for drinking water. The highest TDS value of 8498 mg/l was observed at Savatkaddu and the lowest TDS of 500 mg/l was observed at Nadukudah in dry period. The corresponding values for wet period are 10500 mg/l at Savatkaddu and 346 mg/l at Nadukudah (Figure 3). About 87% of the

sampling locations showed higher level of TDS in the dry season whereas it was 90% in wet season.

Turbidity

According to the SLS standard, maximum acceptable level of Turbidity of drinking water is 2 NTU. A maximum Turbidity value of 6.1 NTU was observed at Periyavadi and a lower Turbidity of 0.38 NTU was observed at South Bar in dry period. The corresponding values for wet period are 4.3 NTU at Kuzhanthaiyesupuram and 0.38 NTU at Erukkalampiddy (Figure 3). Nearly 20% of sampling locations showed turbidity level above the standard limit in dry period and the corresponding value for the wet period is 13%. Lower Turbidity values during the dry season are probably due to less groundwater recharge and the filtration (Makwe and Chup, 2013).



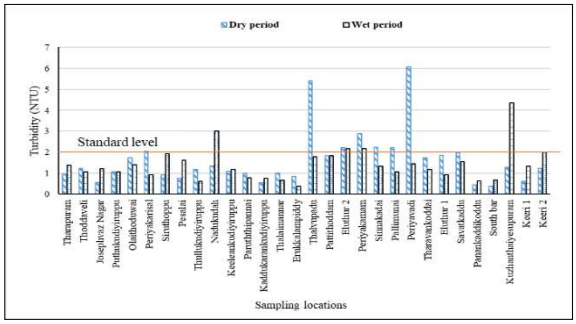
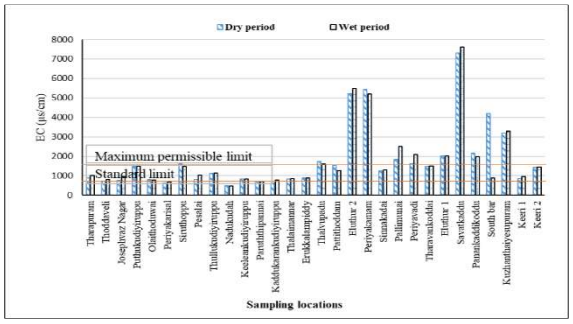


Figure 3: Variation of TDS and Turbidity in the groundwater in wet and dry period

Electrical Conductivity (EC)

Standard level of EC in drinking water is 750 µs/cm whereas the maximum acceptable limit is 1500 µs/cm (WHO, 2011). EC level of groundwater showed high spatial and temporal variation, ranged from 480-7615 µs/cm (Figure 4). The highest level of EC was recorded at Savatkaddu in both wet and dry period. EC level of groundwater exceeded the standard level of 750 µs/cm at 97% of the sampling locations. Further, 27% of the sampling locations showed the EC level above maximum permissible limit of 1500 µs/cm. Higher EC level in groundwater might be due to sea water intrusion at many locations in the study area.



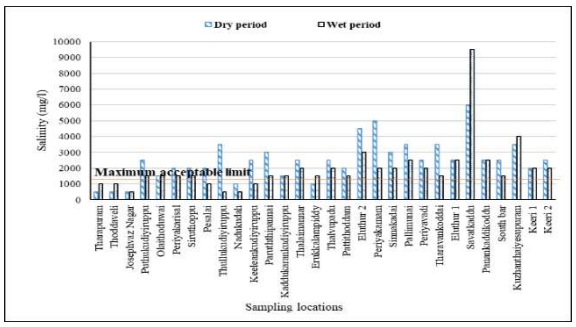


Figure 4: Variation of EC and Salinity and in the groundwater in wet and dry period

Salinity

The level of salinity less than 600 mg/l is regarded as good quality drinking water and 600 to 900 mg/l is regarded as fair quality. Salinity level ranges from 900 to 1200 mg/l is regarded as poor quality and more than 1200 mg/l is regarded as unacceptable (WHO, 2011). A maximum salinity level of 6000 mg/l was observed at Savatkaddu and the lower level of 500 mg/l was observed at Tharapuram, Thoddaveli, and Josephvaz Nagar in dry period. During wet period, the maximum salinity level of 9500 mg/l was observed at Savatkaddu and the lower salinity of 500 mg/l was observed at Josephvaz Nagar, Thullukudiyiruppu, and Nadukudah. Accordingly,

only 10% of sampling locations showed salinity level less than 600 mg/l (Figure 4). However, 83% of sampling locations showed more than 1200 mg/l in dry period.

Calcium (Ca^{2+})

A maximum Ca^{2+} concentration of 114.2 mg/l was observed at Savatkaddu and a lower level of 38.1 mg/l was observed at Eluthur 2 in dry period. In wet period, maximum (186.4 mg/l) and minimum (62.1 mg/l) concentration were observed at Savatkaddu and Eluthur 1, respectively (Figure 5). According to WHO, the standard limit of $Ca^{2+}$is 100 mg/l. Accordingly, about 87% of the sampling locations showed Ca^{2+} level less than100 mg/l in dry period whereas 70% of the sampling locations showed Ca^{2+} level more than 100 mg/l in wet period. Calcium is found in groundwater that has come in contact with certain rocks and minerals, especially limestone and gypsum. When these materials are dissolved, they release calcium.

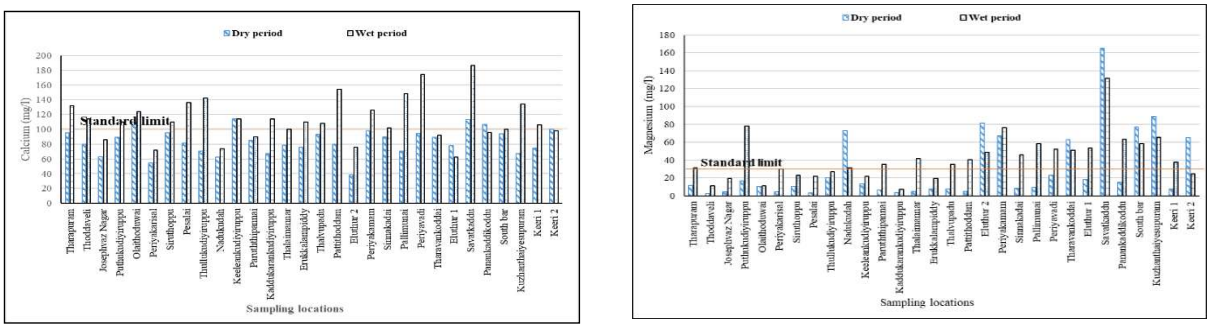


Figure 5: Variation of Calcium and Magnesium in the groundwater in wet and dry period

Magnesium (Mg^{2+})

The standard limit of Mg^{2+} in drinking water is 30 mg/l. Nearly, 77% of the sampling locations showed Mg^{2+} level less than 30 mg/l. However, Mg^{2+} level exceeded the standard level at 23% of sampling locations in dry period. The corresponding figure for wet period is 67%, reveals that concentration of Mg^{2+} increases in the wet period than dry period (Figure 5). Magnesium is found in groundwater that has come in contact with certain rocks and minerals, especially limestone and gypsum. When these materials are dissolved, they release magnesium. A maximum magnesium concentration of 165.3 mg/l was observed at Savatkaddu and a lowest concentration of 2.7 mg/l was observed at Thoddaveli in dry period. The 39 corresponding values for wet season are 131.3 mg/l at Savatkaddu and 7.3 mg/l Kaddukarankudiyiruppu in wet period.

Nitrate

The standard level for Nitrate in drinking water is 50 mg/l (WHO, 2011). Accordingly, none of the sampling location exceeded the desirable limit in both periods. A maximum Nitrate concentration of 35.7 mg/l was observed at Pallimunai and the lowest level of 0.78 mg/l was observed at Olaithoduwai in dry period (Figure 6). The corresponding figures for wet period were 38.67 mg/l at Pallimunai and of 0.99 mg/l at Puthukudiyiruppu. At many locations, Nitrate was slightly higher in wet period, might be due to leaching effect during rainy period. However, elevated level of Nitrate was found at some locations. This could be due to the reduction in groundwater recharge resulting from low precipitation, higher temperature and evaporation during the dry season (Makwe and Chup, 2013).

Phosphate

Maximum permissible level of phosphate in drinking water is 5 mg/l (WHO, 2011). However, as per the SLS standard, the desirable limit is 2 mg/l. A maximum Phosphate concentration of 12.64 mg/l was observed at South Bar and lowest concentration of 0.107 mg/l was observed at Olaithoduwai in dry period (Figure 6). The corresponding figures for wet season are 12.24 mg/l

at Periyavadi and of 0.283 mg/l Tharapuram. Nearly, 43% of the sampling locations showed Phosphate level above 2 mg/l in dry period. The corresponding figure for wet period is 33%. This could also be due to less groundwater recharge resulting from low precipitation, higher evaporation during the dry season (Makwe and Chup, 2013).

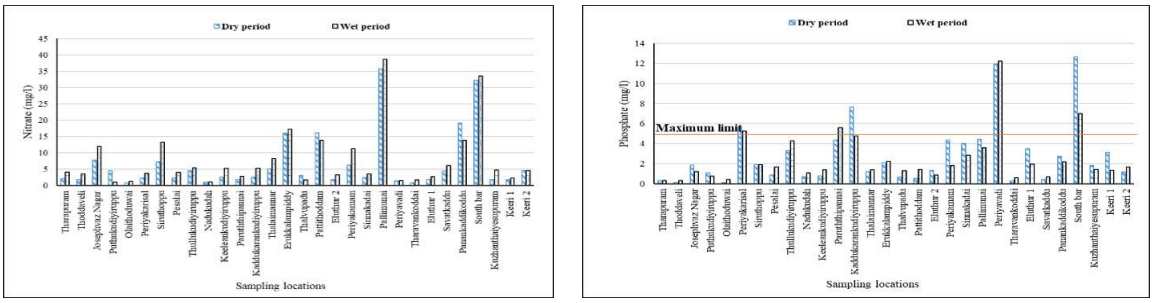


Figure 6: Variation of Nitrate and Phosphate in the groundwater in wet and dry period

Heavy metals

Figure 7 shows the variation of heavy metals in the groundwater samples collected at different locations in the study area in dry and wet period. Standard limit of Chromium, Cadmium, Copper, and Manganese are 0.05, 0.005, 0.05, and 0.05 mg/l, respectively. Chromium level of groundwater at all sampling location was below the permissible limit in both dry and wet period. Groundwater samples collected at Tharapuram showed highest level of Chromium in dry (0.0255 mg/l) and wet (0.005 mg/l) periods.

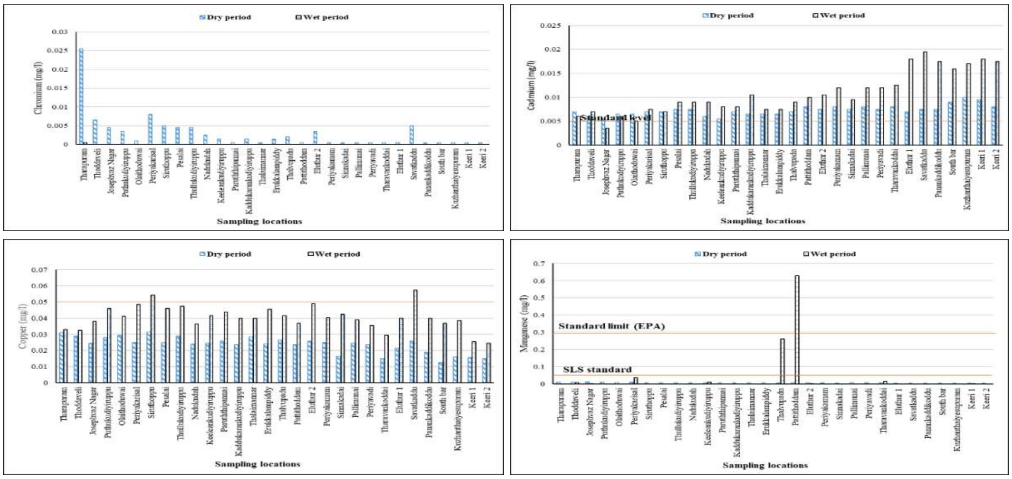


Figure 7: Variation of heavy metals in the groundwater in wet and dry period

Cadmium level exceeded the limit at many sampling locations in both dry and wet periods. A maximum concentration of 0.01 mg/l was observed at Kuzhanthaiyesupuram and a lower concentration of 0.005 mg/l was observed at Josephvaz Nagar and Keeleankudiyiruppu in dry period. The corresponding values for wet period are 0.0195 mg/l at Savatkaddu and 0.0035 mg/l at Josephvaz Nagar. Copper concentration exceeded the permissible level at Sinthoppu and Savatkaddu in wet period. Maximum concentration of 0.0315 mg/l was observed at Tharapuram and lower concentration of 0.0125 mg/l was observed at South Bar in dry period. The corresponding figures for wet period are 0.0575 mg/l at Savatkaddu and 0.0245 mg/l at Keeri 2. Manganese level exceeded the permissible level at Thalvupadu and Pattithoddam in wet period. Maximum Manganese concentration of 0.014 mg/l was observed at Josephvaz Nagar and lowest concentration of 0.005 mg/l was observed at Keeri 2 in dry period.

Spatial variation of salinity in both Dry and Wet season

Figure 8 illustrates spatial variation of Salinity in the study area in dry and wet periods. Accordingly, Salinity level was higher than 1200 mg/l in the major part the study area. Further, Salinity level in the groundwater samples shows high seasonal variations.

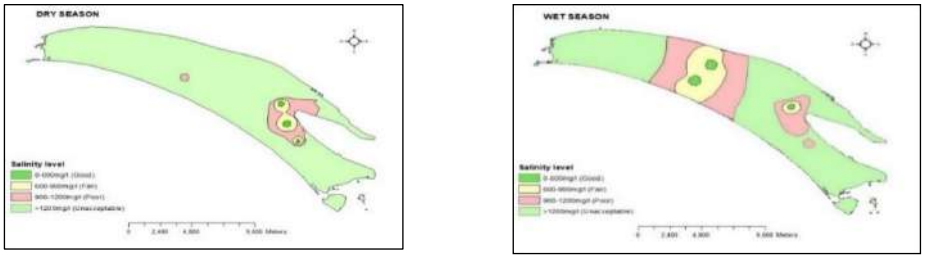


Figure 8: Spatial variation of Salinity in dry and wet period

Suitability of Groundwater for Drinking

WQI was greater than 100 at all locations in both dry and wet periods. WQI ranged from 158.3-284.1 in dry period. The highest value was observed at Kuzhanthaiyesupuram whereas the lowest value was observed at Keeleankudiyiruppu (Figure 9). WQI ranged from 102.9-555.2 in wet period. The highest value was observed at Savatkaddu whereas the lowest value was observed at Josephvaz Nagar. In comparison, WQI was higher in wet period than dry period. It may be due to elevated levels of pollutants in wet period. Overall, groundwater in the study area is not suitable for human consumption.

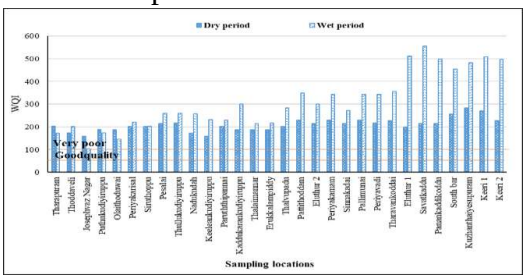


Figure 9: Variation of WQI in the groundwater in wet and dry period

Conclusion

High spatio-temporal variation of groundwater quality was reported in the study area. Elevated levels of tested quality parameters were observed at many locations. According to the WQI analysis, groundwater in this study area is not safe for human consumption.

References

Al-Mohammed, F.M and Mutasher, A.A. (2013). Application of water quality index for evaluation of groundwater quality for drinking purpose in Dibdiba Aquifer, Kerbala City, *Iraq J. Babylon Univ. Eng. Sci*. 21: 1647–60.

Lkr, A., Singh, M.R. and Puro, N., (2020). Assessment of water quality status of Doyang river, Nagaland, India, using water quality index. *Applied water science*, 10(1): 1-13.

Makwe, E. and Chup, C.D., (2013). Seasonal variation in physico-chemical properties of groundwater around Karu abattoir. *Ethiopian journal of environmental studies and management*, 6(5): 489-497.

Panabokke, C.R. and Perera, A.P.G.R.L., (2005). Groundwater resources of Sri Lanka. Water Resources Board, Colombo, Sri Lanka, 28.

Sophocleous, M., (2002). Interactions between groundwater and surface water: the state of the science. *Hydrogeology Journal*, 10(1): 52-67.

WHO. (2011). Guidelines for drinking-water quality. World health organization, 216: 303-304.

EFFECT OF DIFFERENT MULCHING ON BRINJAL (*Solanum melongena* L.) YIELD UNDER DRIP IRRIGATED ORGANIC SYSTEM

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Abstract

A field experiment was carried out at Regional Agriculture Research & Development Centre, Kilinochchi from the period February 1st 2022 to May 20th 2022 to evaluate the effect of different mulching on brinjal yield under drip irrigated organic system. Purified Plastic brinjal cultivar was selected for the study. The field experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Five different treatments of mulching were used such as treatment 1- Black Polythene, treatment 2- Paddy straw, treatment 3- Control, treatment 4- Lemon grass and treatment 5- Banana leaves. Soil moisture and soil temperature readings were taken at weekly interval. Based on the soil analysis, T1 (black polythene) had the highest temperature (35.36 ℃) and moisture (9.2%). Highest numbers of weeds were measured under T4 (36.80). Plant growth parameters were measured after 40 and 80 days of transplanting (DAT) and yield parameters were measured at the time of harvest. Data were analyzed by ANOVA using SAS (9.4) package. Results of the growth parameter measurements indicated that T5 (banana leaves) showed better performance with highest leaf length and number of leaves per plant. T2 (paddy straw) was showed better performance with highest plant height. Similarly, like growth attributes, T5 (banana leaves) also produced the highest fruit length (21.03 cm), fruit diameter (13.08 cm) and yield (20.32 t/ha). All the treatments resulted a good yield when compared to T3 (control). It could be concluded that T1 (black polythene), T2 (paddy straw) and T5 (banana leaves) had a great impact of *Solanum melongena* L. growth and yield when compared to other treatments.

Keywords: Brinjal, drip irrigation, growth, mulching, yield

Introduction

Brinjal belongs to the family of Solanaceae, which comprises of over 3,000 species that are well distributed across 90 genera (Singh *et al*., 2022). The most favorable temperature for its successful production on a daily basis is 13°C- 21°C. Temperatures below 17°C can captiously affect the growth of the crop. The average yield of brinjal varieties from 20-30 t/ha (https://doa.gov.lk). A local brinjal cultivar so called plastic also one of the popular cultivar is being planted by farmers in the northern region, especially in Vanni area of Sri Lanka. The average yield of this regional cultivar is varying from 15-20 t/ha. The Total extent of brinjal under cultivation in Sri Lanka is about 11,312 ha with total production of about 106,173 t and an average yield of about 10.3 t/ha (Wijesooriya *et al*., 2015).

Organic mulches are obtained from plant and animal materials such as straw, hay, peanut hulls, leaf mold, compost, sawdust, wood chips, shavings and animal manures. Now a day's application of black plastic mulch film is becoming popular and very good results have been realized particularly in arid and semi-arid regions (Bhardwaj *et al*., 2013). Black polyethylene mulches are utilized for weed control in a range of crops under the organic system of crop production. Das *et al*. (1990) and Purohit *et al*. (1990) observed that use of polyethylene mulch in the field, increased the soil temperature mainly in the early spring, lowered weed problems, grower moisture conservation, reduction in define insect pest population, higher crop yield and more efficient use of soil nutrients.

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Drip irrigation is a systematic method of application of water at the plant bottom at a rate nearly equal to the consumptive use rate of the plant. Drip irrigation, also called trickle irrigation or micro- irrigation, is a localized irrigation method that slowly and regularly supplies water directly to the plant root zone (Swamy *et al*., 2013).

Materials and Method

The experiment was conducted at Regional Agriculture Research and Development Centre, Kilinochchi from February 1st to May 20th 2022. Average temperature and rainfall were recorded as 32.7℃ and 149.1mm, respectively during the experiment period. The experiment was carried out in a Randomized complete block design. Experiment was designed with five treatments and three replicates (T1-black polythene, T2- paddy straw, T3- control, T4- lemon grass and T5- banana leave.)

The experimental field was ploughed with tractor drawn cultivator and rotator in order to achieve proper tilth. Fifteen beds were prepared with a bed size of 80×17m. The selected mulching was used to cover the beds as per treatments. Twenty five days old seedlings were planted with a spacing of 90×60cm. The drip irrigation was installed with main and sub main pipe and place lateral tubes. Soil temperature readings were taken using a soil thermo meter at 1.00 pm and moisture content of the soil was also recorded at 11.00 am from each bed at weekly interval throughout the experiment. Numbers of weeds were counted periodically. Readings on growth parameters such as plant height, leaf length and number of leaves as well as reproductive parameters such as fruit length, fruit diameter and the total yield were recorded periodically to study the effect of mulching on brinjal. Results were analyzed by using SAS (9.4) package and the mean separation was done by Duncan multiple range test at $p<0.05$.

Results and Discussion

Soil temperature

Mean soil temperature of brinjal was recorded for five different treatments at weekly intervals. There was a significant different in soil temperature at weekly intervals. Highest significant difference was observed under T1 (35.36℃ at $p<0.05$), when compared to other treatment at $p<0.05$. The lowest soil temperature was recorded in T5 (30.15℃ at $p<0.05$) at weekly intervals (Figure 1).

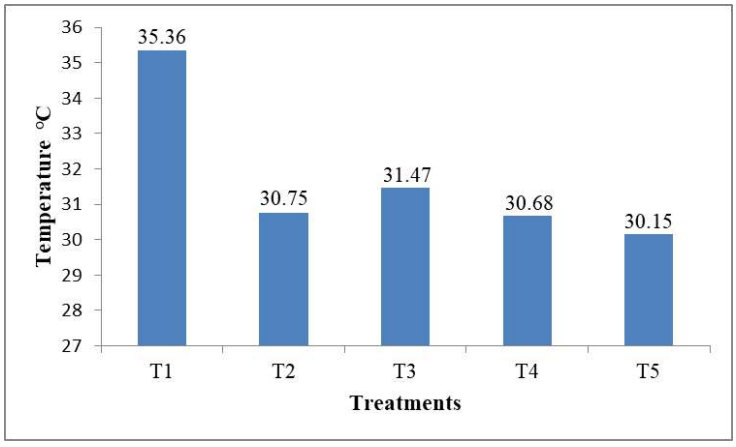

Figure 1: The average soil temperature at 1.00 pm under different mulching treatments

Soil moisture

There was a significant different ($p<0.05$) in soil moisture at weekly intervals. Highest significant difference was observed under T1 (9.2%), when compared to other treatments. The lowest soil moisture was recorded in T5 (6.18%) at weekly intervals (Figure 2).

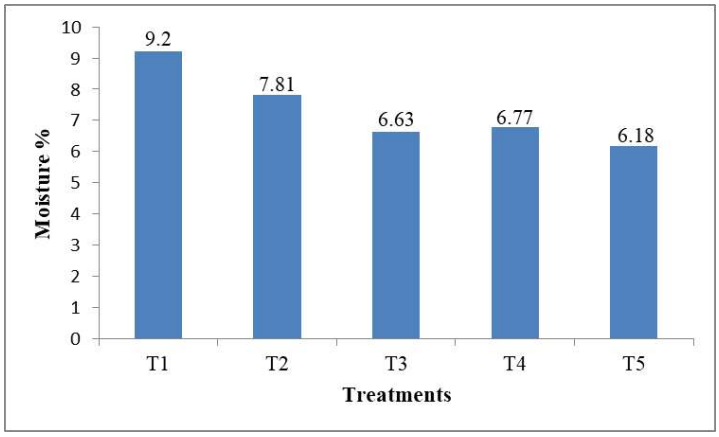

Figure 2: The soil moisture at 11.00 am under different mulching treatments

Number of weeds

There was a significant different ($p<0.05$) in number of weeds were measured at weekly intervals. Highest significant difference was observed under T3 (107.14 Nos.), when compared to other treatments. The lower number of weeds were counted in T1 (7.07 Nos.) at weekly intervals. All the mulching materials have recorded with least number of weeds when compared to T3 (control).

Plant analysis

Table 1: Effect of different mulching on brinjal yield and growth parameters

Trt	Plant height (cm)		Leaf length (cm)		No. of. leaves		Fruit length (cm)	Fruit diameter (cm)	Yield/ ha(ton/ ha)
	40 DAT	80 DAT	40 DAT	80 DAT	40 DAT	80 DAT			
1	20.03ab	48.7a	14.93a	23.76a	27ab	62bc	20.0ab	12.20b	18.13a
2	23.1a	50.6a	15.76a	23.13a	29ab	73ab	19.18b	11.36c	17.03a
3	14.6c	34.3b	10.53b	16.83b	17.33b	44d	13.95d	8.80e	6.57a
4	16.13bc	34.5b	11.9b	17.73b	23ab	48.6c	16.04c	10.30d	11.59b
5	21.3a	47.2a	15.9a	23.82a	29.33a	82a	21.03a	13.08a	20.32b
CV	12.32	12.03	10.19	8.17	19.47	13.39	9.52	7.73	19.49

Mean plant height of brinjal was recorded from five different treatments at 40 DAT and 80 DAT intervals. The Highest plant height was recorded in T2 than other treatments at 40 DAT and 80 DAT intervals (40 DAT 23.1 and 80 DAT 50.6) which is significant with other treatments. The Lowest height was recorded in T3 at 40DAT and 80 DAT intervals (80 DAT 34.3). The Highest leaf length was recorded in T5 than other treatments at 40 DAT and 80 DAT intervals (40 DAT 15.9 and 80 DAT 23.82). Highest number of leaves were recorded in T5 than T2 treatment at 40 DAT and 80 DAT intervals (T5-82 80DAT, T2-73 80DAT) which is significant at 5% level. The Lowest number of leaves were recorded in T3 at 40 DAT and 80 DAT intervals.

At harvest, the maximum yield per hectare of fruit was observed in T5 (20.32) followed by T1 (18.13) while the minimum fruit yield was observed in T3 (6.57). The response was similar at T4 and T3. There was significant variation ($p<0.05$) on yield per hectare by different mulching on brinjal. Mulching of banana leaves increased the average yield per hectare of fruit compared to control. Kirda *et al*. (2004) revealed that use of polyethylene mulch significantly increase values of plant height, number of leaves, canopy fresh and dry weights per plant.

Conclusion

The study revealed that T5 (banana leaves), T1 (black polythene) and T2 (paddy straw) treatments had a great impact of brinjal growth and yield when compared to other treatments.

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References

Bhardwaj, R.L., 2013. Effect of mulching on crop production under rainfed condition-a review. *Agricultural Reviews*, 34(3):188-197.

Singh, D.P., Kumar, J., Silas, V.J., Giri, H., Aashish, K.C. and Khadka, H., 2022. Efficacy of bio-fertilizers and the combinations of macronutrients on the growth, yield and quality of Brinjal (Pusa ankur) under the Agro-climatic conditions of Kanpur.

Swamy, D.K., Rajesh, G., Pooja, M.J.K. and Krishna, A.R. 2013. Microcontroller based drip irrigation system. *International Journal of Emerging Science and Engineering*, *1*(6):1-4.

Wijesooriya, H.D.S.N., Debarawatta, R.D.N., Yakandawala, K., Dabarera, R. and Sanjeevanie, W.A.P., 2015. Effect of Growth and Yield of Brinjal (*Solanum melongena* L.) Grown under Different Poly Mulches. *Journal of Food and Agriculture*, *8*(1 2).