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Editor's Note

On behalf of the Editorial Board of the Journal of Dry Zone Agriculture (JDZA), I am delighted to present its 7th Volume (Number 1 and Number 2). JDZA is a peer-reviewed scientific journal aiming to publish up-to-date, high-quality original research articles related to all facets of dry zone agriculture. Six volumes of the JDZA have been published so far with the substantial contribution of many individuals, especially the authors and reviewers to the early development and success of the journal. Since the publication of the maiden volume, the editorial board of the JDZA constantly aspires to improve the quality and visibility of this journal. In this journey, initial steps are being taken to include the JDZA in online journal databases. Further, I am pleased to announce that, starting from the current volume (Volume 7), the JDZA operates under the terms of a Creative Commons license: Attribution 4.0 International (CC BY 4.0) which allows reusers to distribute, remix, adapt, and build upon the material in any medium or format, so long as attribution is given to the creator.

Agriculture is the mainstay of the Sri Lankan economy. Currently, the country is facing additional challenges due to COVID 19 pandemic together with the unpredictable climate changes which threaten the nation's food production profoundly. The research aiming to find innovative solutions to address these challenges has a key role to ensure food production sustainably. Despite the pandemic that intruded the scholarly works, the researchers are striving to discover solutions for the issues related to agriculture. As a result, thirty manuscripts were submitted to the Volume 7 of this journal. After preliminary screening and rigorous double-blind review, thirteen full-length research articles are published in this Volume. Needless to say that the findings published in this volume will contribute to improving the dry zone agriculture and related industries. I am certain that, upcoming volumes of this journal will carry more research articles in a diversity of perspectives related to dry zone agriculture.

I take this opportunity to extend my heartfelt gratitude to all who contributed immensely amidst the pandemic to bring out yet another volume of JDZA as per the schedule. My special thanks are due to the authors who submitted their works to the JDZA. I am especially indebted to the reviewers for sacrificing their time voluntarily to ensure the standard of the journal. Further, I would like to thank the Associate Editor and members of the Editorial Board for their relentless support to the release of this Volume of the JDZA possible. On the last note, I would like to express my sincere gratitude to the University of Jaffna for providing

partial financial assistance (University Research Grant - 2021) for the successful publication of this journal.

Best wishes and thank you in advance for your contribution to the upcoming volumes of JDZA.

Mrs. Subajiny Sivakanthan

Editor-in-Chief 3rd December 2021

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Determining response to nitrogen of promising rice line (O*ryza sativa* L.) in the low country wet zone of Sri Lanka

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Abstract

A field experiment was conducted during the *Maha* season from August 2019 to May 2020 at Regional Rice Research and Development Center, Bombuwala, Sri Lanka to investigate nitrogen response of promising rice line of Bw 12-574 compared at growth and flowering stages of that recommended rice variety (Ld 368). Growth parameters and yield components of both treatments were compared under five different nitrogen levels i.e., 0, 50, 100, 150, and 200% recommended by the Department of Agriculture. The experimental design was a Randomized Complete Block Design with three replicates. Two varieties were tested under 5 nitrogen levels. Data were analyzed by analysis variance (ANOVA) and mean separation procedure by LSD using appropriate SAS procedures. Plant height, number of productive tillers, panicle length, leaf colour

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intensity, and chlorophyll content of leaves in both Bw 12-574 and Ld 368 showed an increasing trend against added nitrogen. The higher nitrogen dosages were influencing the increase of flowering days. The yield parameters including length of panicle and number of grains per panicle have shown significant differences (p=0.05) between the tested line and recommended variety. However, no significant difference was observed between the tested line and recommended variety with respect to filled grain percentage and grain yield. Hence, the response to nitrogen of Bw 12 – 574 was found to be similar to the recommended variety, Ld 368. The study concludes that the same nitrogen recommendation applied for Ld 368 would be recommended for promising rice line Bw 12-574. However, further investigations are needed to confirm the findings.

Keywords: fertilizer, nitrogen response, paddy yield, parameters, rice

INTRODUCTION

The rice production and the use of fertilizer N in rice-growing countries have been increasing over the past decade. In order to produce enough food for the large Asian population, the use of N fertilizer combined with fertilizer reactive rice varieties and the areas under irrigation have been expanded. Since N fertilizer is a costly input, it is imperative that it has to be used effectively**.** The importance of nitrogen fertilization on the grain yield of the rice plant is necessary to know what is best for each variety as well as its influence on components of yield and other agronomic parameters such as tillering, plant height, lodging, and days to maturity. A taller plant is more susceptible to lodging and responds less to nitrogen (Albornoz, 2016). Panicles with a low percentage of sterile flowers permit the application of higher doses of nitrogen and produce better yields. Some factors, like early sowing, meet the twin objectives of producing higher yields and improving the grain quality. Other factors, like increased rates of fertilizer nitrogen, may increase the yield but reduce the quality of the grain (Albornoz, 2016). An adequate supply of nitrogen to the crop plants during their vegetative growth period is very important for the initiation of leaves and florets primordial (fundamental parts).

The type of nitrogen fertilizer can also affect the grain yield and quality (Albornoz, 2016). Some of these fertilizers, such as urea, are considerably cheaper than others, and their use may be justified on economic backgrounds so long as they do not adversely affect grain yield or performance. Chaturvedi (2005) reported a higher yield of calcium

ammonium nitrate is a more efficient source of nitrogen than urea, with a higher content of grain nitrogen.

Plants use both NO_3^- and NH_4^+ in the form of nitrogen (N) (Choudhury and Kennedy, 2004). Treatment of 200% of Department of Agriculture (DOA) recommended nitrogen amount (N4) has shown a significant difference with all other treatments on the chlorophyll content of leaves. It is the most essential factor for proper plant growth and development which increases and enhances yield and performance dramatically by playing a vital role in plant biochemical and physiological functions (Sirisena *et al*., 2006). Nitrogen deficiency is one of the most important nutritional disorders in areas cultivating lowland rice around the world. Recommendations for nitrogen fertilizer for lowland rice varieties (*Oryza sativa* L.) grown on Inceptisols are restricted. In order to achieve higher rice yields, nitrogen fertilization is important and is widely practiced in rice cultivation. This experiment is conducted to detect the nitrogen response of rice in the low country wet zone of Sri Lanka.

The healthy growth of rice plants depends on both internal and external factors; the external factors are light, water, temperature, and nutrients. These factors affect the plant's growth hormones, making the plant grow more quickly or slowly (Choudhury and Kennedy, 2004). The internal factors of plants are the viability of seeds and the performance of the variety (Sirisena *et al*., 2006). Establishment of the crop at the correct time according to the season, selection of the suitable variety for both cultivation area and season, using high quality seeds, proper land preparation practices, optimum water management, proper pest and disease management, and proper weed management are other important factors affecting to yield (Sirisena *et al.,* 2006).

Nitrogen is one of the major nutrients which directly affect the yield of rice. However, N requirement depends on the rice variety and soil condition of the cultivation area. Sometimes the selected rice variety has a higher nitrogen requirement than the DOA recommended level; hence higher rate of N is needed for better yield. On the other hand, over application of N fertilizer may create many environmental issues. In addition, excess application of fertilizer increases the cost of production as fertilizer is a costly input.

The yield of some recommended varieties is low compared to the yield of improved newly released rice varieties (Sirisena *et al*., 2006). There are

different experimental stages during the process of releasing a new variety of paddy. Assessing response to nitrogen is one of the experimental stages above mentioned processes. Therefore, the promising lines need to be tested for their nitrogen response level before release as a recommended variety. Hence, this study aimed to investigate the nitrogen response of a promising rice line of Bw 12-574.

MATERIALS AND METHODS

Location

This study was carried out at the Regional Rice Research and Development Center (RRDC), Bombuwala. The duration of the research was about 9 months from August 2019 to May 2020.

Rice line/ variety

In this experiment, promising line Bw 12-574 was compared with recommended variety: Ld 368 (Table 1). Bw 12-574 is a three and half month promising line (red samba) developed at RRDC, Bombuwala. Parental lines were Bw 361 x Bw 372. Bw 12- 574 showed good taste and higher yield (3.7 t/ha). The plant height of the Bw 12-574 is 80 cm - 95 cm (based on season and soil condition), 1000 grain weight is 15 g. It is moderately tolerant to Brown Plant Hopper (BPH), and iron toxicity. Ld 368 is DOA recommended variety (samba type) which gives a good yield, 1000 grain weight is 15 g. It shows similar characteristics compared to the tested line.

Experimental design and treatments

The experimental design was a Randomized Complete Block Design with three replicates. Two varieties were tested under 5 nitrogen levels as given below.

Nitrogen level (percentage based on DOA recommendation)

N_0 = zero nitrogen
N_1 = 50% of DOA recommended nitrogen fertilizer dosage
N_2 = 100% of DOA recommended nitrogen fertilizer dosage
N_3 = 150% of DOA recommended nitrogen fertilizer dosage
N_4 = 200% of DOA recommended nitrogen fertilizer dosage

V1 = Bw 12-574
V2 = Ld 368

Table 1: Different treatment combinations used for the study

Bw 12-574 (promising variety)	Ld 368 (comparing variety)
T_1 - V_1N_0	T_6 - V_2N_0
T_2 - V_1N_1	T_7 - V_2N_1
T_3 - V_1N_2	T_8 - V_2N_2
T_4 - V_1N_3	T_9 - V_2N_3
T_5 - V_1N_4	T_{10} - V_2N_4

There were thirty (30) plots in the field layout and the plot size was 18 m^2. The total area of the field was 540 m^2. The diameter of inter-channel was 0.30 m and the bund diameter is 0.50 m. Each plot included an inlet and outlet channel for irrigation and drainage practices. In addition to that, each plot was fully separated by the bunds from other plots to avoid mixing of irrigated water with drainage (Figure 1).

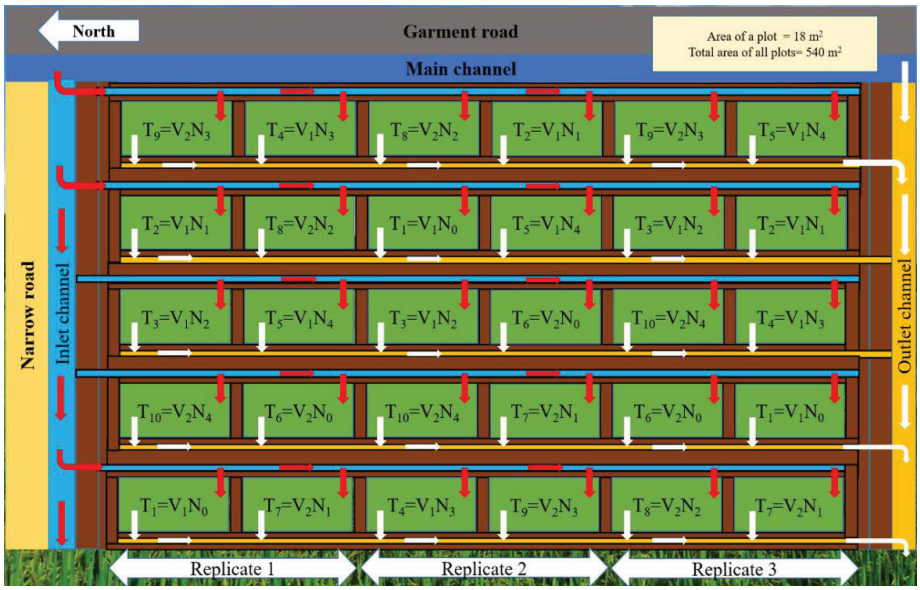

Figure 1: Experimental field layout

Land preparation

First, the field was kept with standing water layer, after the primary land preparation practices. After two weeks, the field was arranged according to the field layout. Also, the channel system and bunds were roughly prepared by mud according to the format. Then the secondary land preparation practice was done also each plot was inundated with water. After one week, the excess water was drained through the channels. Then, the field bunds were prepared sharply using a hoe. Also, each plot was done with puddling as the tertiary land preparation practice before the broadcasting of seeds.

Preparation of the planting materials

First, 160 g of seed paddy was put into the labeled polythene bags (15 bags of Bw 12-574 and 15 bags of Ld 368 separately (Figures 2 and 3)). Five hundred grams of Bw 12-574 seeds were weighed in another bag for border cultivation. Then, these seed bags were soaked in water during the 24 hours and kept for incubation with pressure for about 48 hours. The soaked seeds are wrapped tightly using by wet wool bag and some weight was put on it. That is important to germination of seeds before the broadcasting date.

Figure 2: Weighed Ld 368 egg seed bags

Figure 3: Weighed Bw 12-574 egg seed bags

Sampling

Soil samples (10 g) were collected into the labeled bags from each of the plots in the field to analyze chemical parameters. The sample was tested at the soil chemistry division of RRRDC at Bombuwala.

Figure 4: Sowing of seeds

The procedure of crop establishment

The manual seed broadcasting (sowing) method was used (Figure 4). Hundred grams of Tripple Super Phosphate (TSP) were applied into the field as an initial fertilizer before the sowing of seeds. The plots were labeled according to the field plan. All agronomic practices were conducted as recommended by DOA (Figure 5).

Figure 5: Weedicide application

Data collection

Soil pH and EC were measured using pH and EC meter after shaking the soil sample vigorously. Measurement of soil available N amount was conducted on digestion of samples using by Kjeldhal method. Measurement of available P amount was conducted using by spectrophotometer. Measurement of available K amount was conducted using by flame photometer. Measurement of organic matter percentage was conducted using by Walkey and Black method. Plant height from each replicate was recorded by measuring the height from ground level to the highest point of the plant and then three of the plant heights were taken from each treatment at marked points. The number of leaves of the plants, whose number of leaves was taken using the square feet frame and recorded on a two-week basis and the means determined. The number of tillers was

taken of the plants using the square feet frame and recorded. The number of the plants, whose plant count was taken using the square feet frame and recorded after and the means determined. The colour intensity of leaves was taken of the plants using by leaf colour chart and recorded (Figure 6). The chlorophyll content of leaves was taken from the plants and recorded using the SPAD meter (Figure 7).

Figure 6: Measuring colour intensity

Figure 7: Measuring chlorophyll content

Flowering index

The flowering index of the plants was taken and recorded, day count from sowing date to flowering date, its mean number of flowered plants per square feet as 5%, 50%, and 100% stages into each plot.

Initial soil parameters

According to the initial soil parameters (Table 2), N % is 0.58, Phosphorus content is 12.07 ppm and K is 142.7 ppm. Soil pH is approximately near to 4.87. EC of the initial soil sample is 0.092 µs/cm. The organic matter percentage of the initial soil sample is 10.5 %. Soil parameters of the initial soil sample consist of enough nutrients favorable for better plant growth.

Table 2: Properties of initial soil sample

Sample No.	Sample Name	Total N (%)	P content (ppm)	K content (ppm)	pH	EC (µs/cm)	Organic matter (%)
01	V_1N_0	0.60	12.24	138	4.88	0.07	10.202
02	V_1N_1	0.43	11.32	97	4.92	0.09	8.10
03	V_1N_2	0.57	12.59	103	4.80	0.08	10.53
04	V_1N_3	0.60	11.77	187	4.87	0.08	10.53
05	V_1N_4	0.66	11.57	136	4.91	0.10	11.34
06	V_2N_0	0.63	11.98	239	4.88	0.13	11.34
07	V_2N_1	0.53	11.11	121	4.94	0.08	11.34
08	V_2N_2	0.64	17.92	165	4.87	0.11	11.34
09	V_2N_3	0.53	11.43	102	4.83	0.08	9.72
10	V_2N_4	0.630	8.77	139	4.84	0.10	10.53
Mean		**0.58**	**12.07**	**142.7**	**4.87**	**0.09**	**10.49**

RESULTS AND DISCUSSION

Growth parameters

Height of the plant

Plant height showed an increasing trend from the first two weeks up to six weeks (Figure 8). Plant height has increased in a similar pattern every two weeks in both varieties. The treatment of 100% of DOA recommended nitrogen amount (V1N2), treatment of 150% of DOA recommended nitrogen amount (V1N3) and treatment of 200% of DOA recommended nitrogen amount (V1N4) were not significantly different from each other. Treatment of 150% of DOA recommended nitrogen amount (V1N3) was given the highest plant height (59.5 cm) in a promising line. The lowest plant heights were observed from the treatment of zero nitrogen (V2N0) after six weeks from the sowing date. There was a rapid increase of plant height after the six weeks and the reason may be due to the response of application of chemical fertilizer treatment, 3 weeks and 5 weeks after sowing date. Plant height has increased proportionally to the amount of

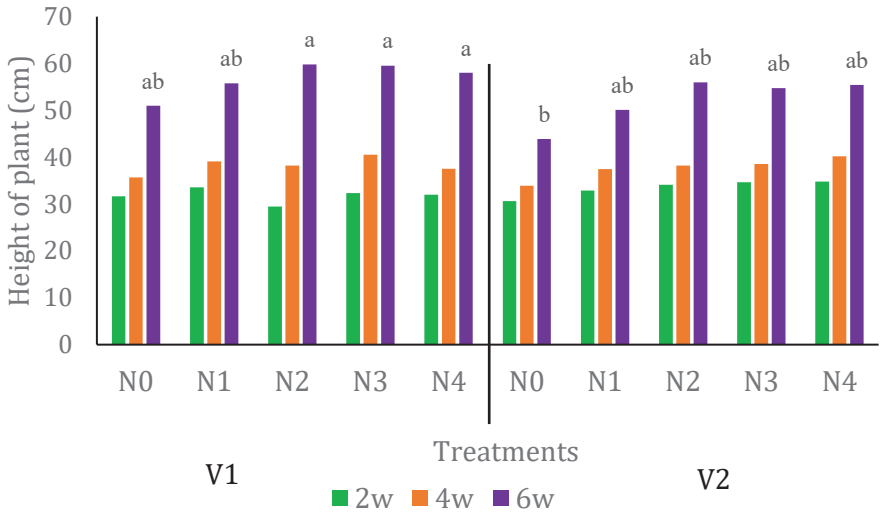

Figure 8: Plant height of the promising line and comparing variety under different nitrogen levels. V1- promising line, V2- comparing variety, N0- zero nitrogen, N1- 50% of DOA nitrogen recommendation, N2- 100% of DOA nitrogen recommendation, N3- 150% of DOA nitrogen recommendation, N4- 200% of DOA nitrogen recommendation. Means with the same letters are not significantly different among the treatments at 6th week.

urea contained in the treatments. Singh and Singh (2017) and Sirisena (2006) have reported plant height and all growth characters in rice crop significantly increased with nitrogen application. Major two factors, variety and nitrogen have significantly influenced the plant height variations and also interaction effects, such as variety and nitrogen interaction have shown a significant contribution on plant height.

Number of leaves

The number of leaves showed an increasing trend from the two weeks up to six weeks. Also, it has increased in a multiple pattern in the 2^{nd}, 4^{th}, and 6^{th} weeks. However, treatments are not significantly different from each other. Interaction effects, such as variety nitrogen have not shown a significant contribution to the number of leaves.

Number of tillers

The number of tillers showed an increasing trend after the six weeks (Figure 9). The number of tillers has increased in a similar pattern between the promising line (V1) and comparing variety (V2). The highest number of tillers was observed in the treatment of 200% of DOA recommended amount of nitrogen (N4) in both promising line (V1) and comparing variety (V2) after six weeks of sowing. However, these treatments were not significantly different from each other. The lowest numbers of tillers were observed in the treatment of zero nitrogen (N0) in both promising line (V1) and comparing variety (V2) after the six weeks of sowing date. Treatment of 200% of DOA recommended amount of nitrogen (N4) is significantly different from both varieties which were treated with 50% of DOA recommended nitrogen (N1) and the treatment which not treated with nitrogen (V1N0, V1N1, V2N0, V2N1). The reason for the above observation may be due to the quick response to the application of chemical fertilizer, in 3 weeks and 5 weeks. The number of tillers has increased proportionally to the amount of nitrogen (urea) contain in the treatments. Interaction effects (variety and nitrogen) have significantly influenced the variations. Variety has not shown a significant contribution to the number of tillers.

Colour intensity of leaves

According to the leaf color chart (LCC), low intensity (light green) to high intensity (dark green) is shown by colour series, these colours

are denoted by 1 to 6 values (Figure 10). The increase of the nitrogen value is proportional to increase in the intensity of leaf colour. Further, the increasing of LCC value means a high concentration of chlorophyll contained in the leaves. The Colour intensity of leaves showed an increasing trend after 4 weeks.

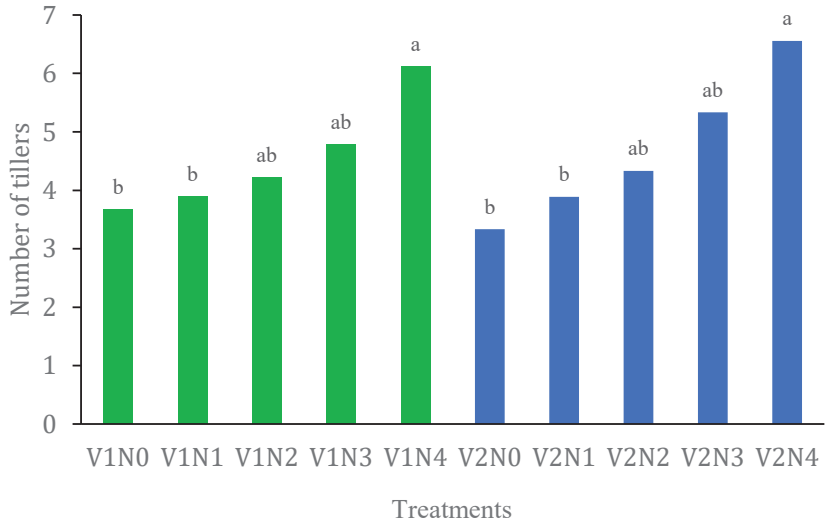

Figure 9: Number of tillers per plant of promising line and comparing variety under different nitrogen levels. V1- promising line, V2- comparing variety, N0- zero nitrogen, N1- 50% of DOA nitrogen recommendation, N2- 100% of DOA nitrogen recommendation, N3- 150% of DOA nitrogen recommendation, N4- 200% of DOA nitrogen recommendation. Means with the same letter are not significantly different.

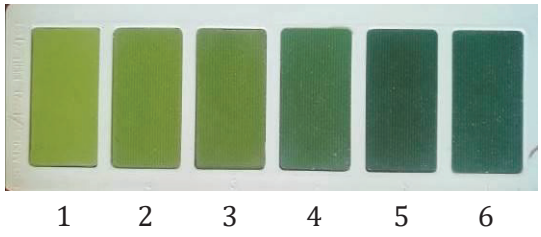

Figure 10: Leaf colour chart to measure colour intensity of leaves

The highest intensity of leaves was observed in the treatment of 200% of DOA recommended nitrogen amount (N4) and the lowest number of leaves was observed in the treatment of zero nitrogen (N0) in both

promising line (V1) and comparing variety (V2) regarding the intensity after the 4 weeks from sowing date (Figure 11). But, the variety and interaction effects of treatment combination have not shown a significant contribution to the colour intensity of leaves. There is a rapid increase of colour intensity after the 4 weeks and the reason may be due to the response of application of chemical fertilizer treatment, 3 weeks after sowing date. Colour intensity has increased proportionally to the amount of urea contained in the treatments. Sirisena *et al*. (2006) reported that leaf color chart (LCC) reading is a good indicator to determine the N requirement of rice varieties under Sri Lankan conditions.

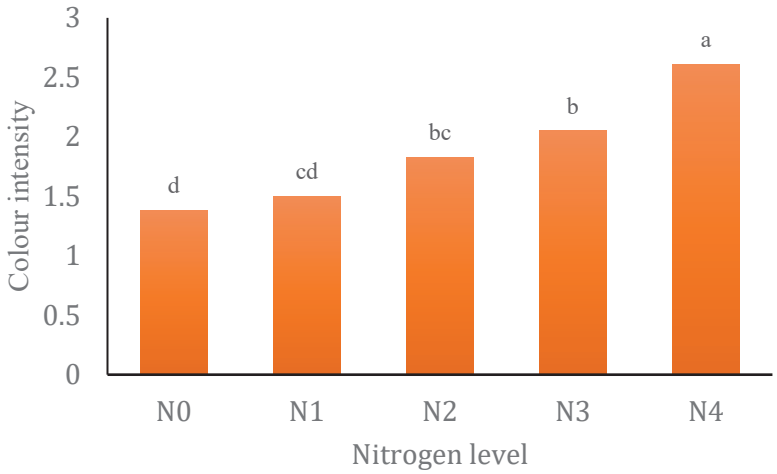

Figure 11: Colour intensity of leaves of promising line and comparing variety under different nitrogen levels. N0- zero nitrogen, N1- 50% of DOA nitrogen recommendation, N2- 100% of DOA nitrogen recommendation, N3- 150% of DOA nitrogen recommendation, N4- 200% of DOA nitrogen recommendation. Means with the same letter are not significantly different.

Chlorophyll content of leaves

Chlorophyll content of leaves had an increasing trend after 6 weeks (Figure 12). Significantly highest intensity (2.6) of leaves was observed in the treatment of 200% of DOA recommended nitrogen amount (N4) and the lowest number of leaves (1.38) was observed in the treatment of zero nitrogen (N0) in both promising line (V1) and comparing variety (V2) after the 6 weeks from sowing date. Also, the interaction effects of treatment

combination have not shown a significant difference in the chlorophyll content of leaves. There is a rapid increase of chlorophyll content after the 6 weeks and the reason may be due to the response of application of chemical fertilizer treatment, 3 weeks and 5 weeks after sowing date. Chlorophyll content has increased proportionally to the amount of urea contained in the treatments (Chaturvedi, 2005).

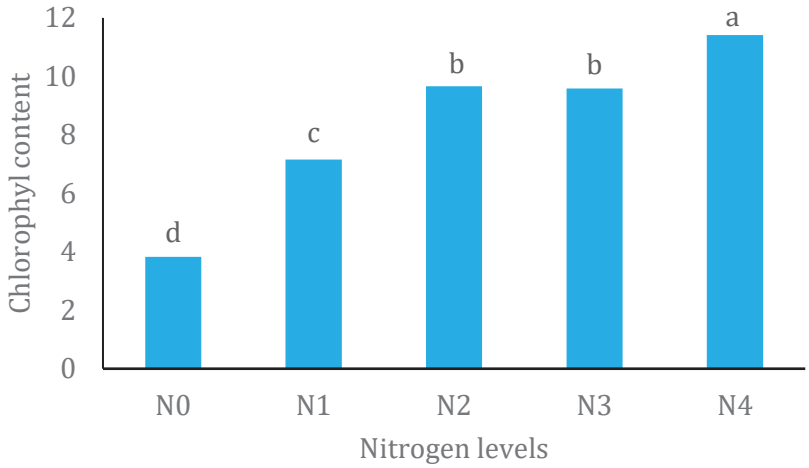

Figure 12: Nitrogen effects of chlorophyll content of leaves of promising line and comparing variety under different nitrogen levels. N0- zero nitrogen, N1- 50% of DOA nitrogen recommendation, N2- 100% of DOA nitrogen recommendation, N3- 150% of DOA nitrogen recommendation, N4- 200% of DOA nitrogen recommendation. Means with the same letter are not significantly different.

Yield parameters

Flowering percentage of plants

The flowering percentage of plants showed an increasing trend (Figure 13). The treatment of 150% of DOA recommended amount of nitrogen (V2N3) and treatment of 200% of DOA recommended amount of nitrogen (V2N4) have shown the highest number of days for flowering than promising line (V1). The promising line (V1) and comparing variety (V2) have shown a significant difference during the flowering. This implies that comparing variety (V2) has required more days for flowering than promising line (V1).

Also, treatments 100% of DOA recommended amount of nitrogen (N2), 150% of DOA recommended amount of nitrogen (N3), 200% of DOA recommended amount of nitrogen (N4) in promising line (V1), and zero nitrogen (N0) in comparing variety (N2) have shown same days for 100% flowering. Treatment of zero nitrogen (V1N0) has shown the lowest number of days for flowering and treatment of 200% of DOA recommended amount of nitrogen (V2N4) has shown the highest number of days (72) for flowering. This may be due to the higher nitrogen dosage and variety characteristics directly influencing on flowering days of paddy (Choudhury and Kennedy, 2004).

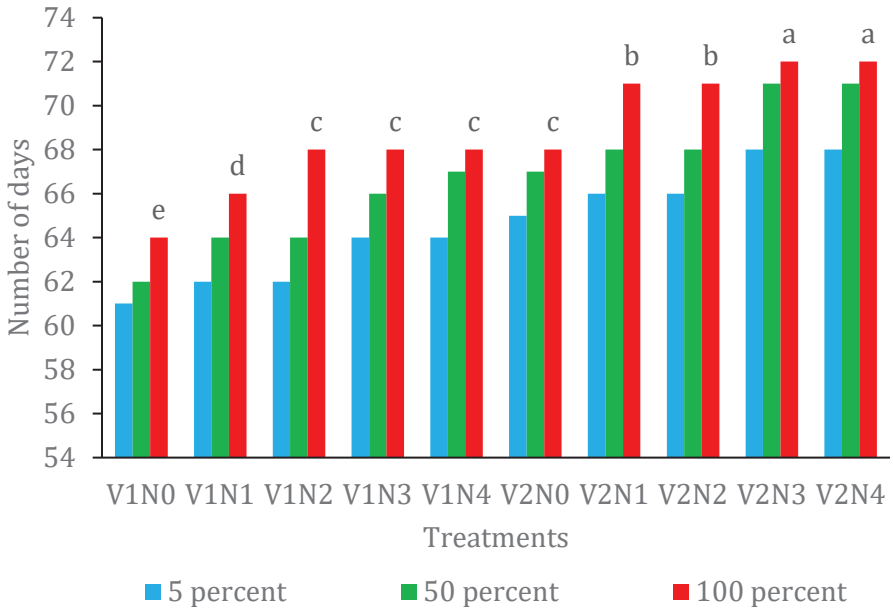

Figure 13: Flowering % stages of plants of promising line and comparing variety under different nitrogen levels. V1- promising line, V2- comparing variety, N0- zero nitrogen, N1- 50% of DOA nitrogen recommendation, N2- 100% of DOA nitrogen recommendation, N3- 150% of DOA nitrogen recommendation, N4- 200% of DOA nitrogen recommendation. Means with the same letters are not significantly different among the treatments at 100% flowering stage.

Length of panicles

The treatment of 150% of DOA recommended amount of nitrogen (V1N3) has shown the significantly highest length of panicle in promising line and different from others. Also, treatments 100% of DOA recommended amount of nitrogen (V1N2), 200% of DOA recommended amount of nitrogen (V1N4) in promising line, zero nitrogen (V2N0), and 100% of DOA recommended amount of nitrogen (V2N1) in comparing variety have shown the lower length of panicle, but not significantly different from others (Figure 14).

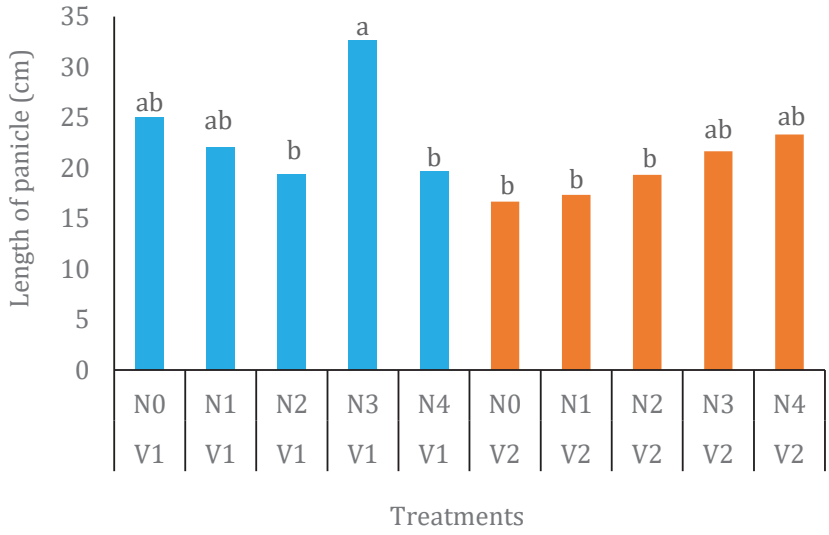

Figure 14: Length of panicle (cm) plants of promising line and comparing variety under different nitrogen levels. V1- promising line, V2- comparing variety, N0- zero nitrogen, N1- 50% of DOA nitrogen recommendation, N2- 100% of DOA nitrogen recommendation, N3- 150% of DOA nitrogen recommendation, N4- 200% of DOA nitrogen recommendation. Means with the same letter are not significantly different.

Number of grains per panicle

The treatment of 50% of DOA recommended amount of nitrogen in comparing variety (V2N1) has shown the highest number of grains per panicle (158) (Figure 15). Also, treatments zero nitrogen (V1N0),

100% of DOA recommended amount of nitrogen (V1N2), 200% of DOA recommended amount of nitrogen (V1N4) have shown a lower number of grains per panicle between the promising line (V1) and comparing variety (N2).

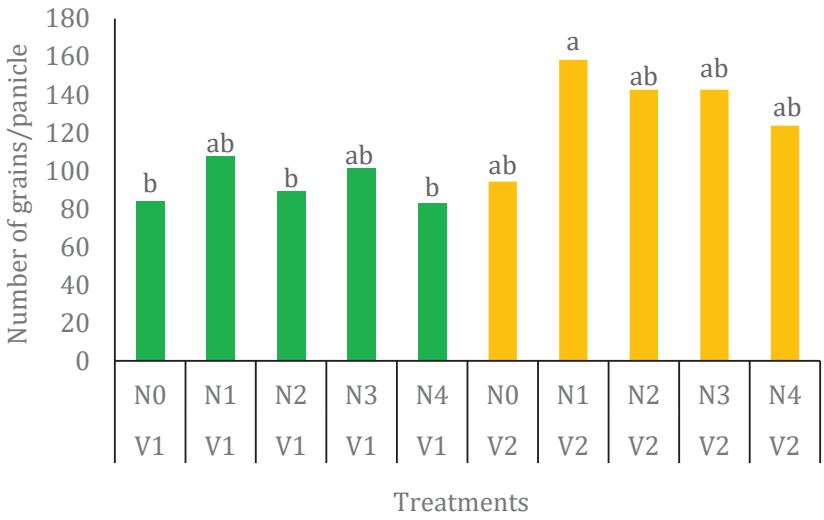

Figure 15: Number of grains per panicle of promising line and comparing variety under different nitrogen levels. V1- promising line, V2- comparing variety, N0- zero nitrogen, N1- 50% of DOA nitrogen recommendation, N2- 100% of DOA nitrogen recommendation, N3- 150% of DOA nitrogen recommendation, N4- 200% of DOA nitrogen recommendation. Means with the same letter are not significantly different.

Percentage of filled grains, thousand grains weight, and total grain weight per plot (kg)

The promising line (V1) and comparing variety (V2) have not shown a significant difference in the percentage of filled grains. Also, the highest dosage of nitrogen may adversely affect the increase of filled grains according to the bar chart data. Treatments have not shown any significant difference in thousand grains weight. Therefore, the percentage of DOA recommended nitrogen dosages are not affecting the thousand grains weight of both promising line (V1) and comparing variety (V2). Total grain

weight per plot (kg) is also not significantly different as the percentage of DOA recommended nitrogen dosages are not affecting the total grain weight per plot of both promising line (V1) and comparing variety (V2).

CONCLUSIONS

It could be concluded that promising line is not significantly different in most of the growth parameters except plant height. Treatment of 150% of DOA recommended amount of nitrogen (V1N3) has shown the highest height in promising rice line (V1) and treatment of zero nitrogen (V2N0) has shown lowest height in comparing variety (V2). Only nitrogen level has a significant difference in colour intensity of leaves and chlorophyll content of leaves. The number of tillers, nitrogen level, and their interaction effect has shown a significant difference with all treatment. Flowering percentage in plants, variety, and nitrogen level have shown a significant difference in both promising rice line (V1) and comparing variety (V2). During the flowering stage, the promising rice line (V1) has shown a lower number of days than comparing variety (V2). Further, the high nitrogen dosages influenced on increasing in flowering time.

Considering the yield parameters, lengths of panicle and number of grains per panicle have shown a significant difference. However, the percentage of filled grain, thousand grains weight, and total grain yield have not shown a significant difference. Therefore, it can be concluded the promising line of Bw 12 – 574 doesn't need special nitrogen requirements compared to the comparing variety Ld 368.

DECLARATION OF CONFLICT OF INTEREST

Authors have no conflict of interest to declare.

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Time poverty and food production of women farmers: Case of Imbulpe DS division in Sri Lanka

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Abstract

Gender equity has been emphasized as a considerable aspect regarding sustainable development in any nation of the world. Thus, this study was conducted to assess the level of time poverty of women farmers and its impact for food production in the Imbulpe Divisional Secretariat (DS) division in Rathnapura district in Sri Lanka. The objectives were to identify the time allocation of women farmers and to assess the time poverty and the effect of time poverty on food production in the study area. A sample of 300 women farmers was randomly selected through the simple random sampling method from five selected Grama Niladhari (GN) divisions of the Imbulpe DS division. A self-administered questionnaire survey was used with the help of a pre-tested questionnaire, in data collection from April to July 2019. The model of Harvey and Mukhopadhyay (2007) was used as the measurement of time poverty with necessary modifications based on the situation of the study area. Descriptive statistics and regression analysis were used in data analysis. The findings revealed that the respondents have obtained a considerably high headcount index of time poverty (0.79)

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in their efforts in food production. Therefore, it can be concluded that women farmers who live in the Imbulpe area consist of a low level of time for their farming and leisure activities. Therefore, conducting extension programs related to the application of modern farming technologies and enhance market information accessibility to reduce the time consume when marketing their agricultural products and enhance the participation in stress management programs are timely important activities to help these women farmers.

Keywords: farming activities, food production, gender equity, time poverty, women farmers

INTRODUCTION

Currently, time is gradually becoming a significant determinant of the overall capacities and wellbeing of human beings (Mogilner *et al.,* 2018). When consider the present status of developed as well as developing countries, time poverty acts as a conspicuous issue rather than the poverty associated with income and other physical assets (UNDP, 2014). Because most of the workers are paying much more attention to the paid and unpaid care work of family members and they have not adequate time for leisure activities (Glynn, 2019; Rusu, 2015; UN, 2019).

Generally, time poverty is defined as the situation that individuals do not have adequate time for rest and leisure after allocating their time for working, domestic activities, or for any other activity such as caring and sharing with family members (Irani and Vemireddy, 2020; Zilanawala, 2014). Most of the economists showed that, time is a limited resource and if any person allocates a considerable amount of time for a paid or an unpaid work-related activity that means less leisure is available for their lives. It causes a high level of tiredness and time poverty for that individual (Matulevich and Viollaz, 2019).

Recent research findings demonstrate the variations in time poverty in the gender basis. According to the findings, women are more time-poor than men because child caring, household activities, and some other income generating activities are performed by the women (Arora and Rada, 2016; Bardasi and Wodon, 2010; Jabeen *et al.,* 2020; Urakawa *et al.,* 2020). Further, the findings of previous studies proved that women have a higher level of work intensity index than men. This higher level of work intensity index leads to an enhanced level of time poverty of women by increasing

physical and mental stress and also the higher working hours due to higher level of the workload of women than men. Therefore, a higher level of time poverty causes to reduce their working efficiency and capabilities of women farmers than men (Arora, 2015; Arora and Rada, 2016).

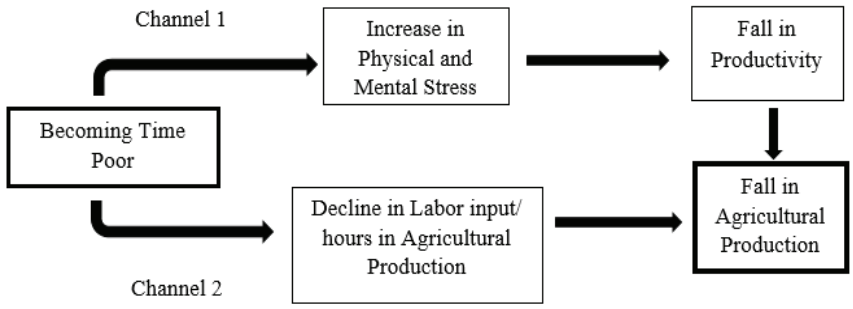

Figure 1: Impact of time poverty on agricultural production (Source: Arora and Rada, 2016).

Figure 1 shows the basic relationship between time poverty and agricultural production. This figure demonstrated the mental stress related to time poverty. An illness condition of a family member causes maximum demand for a woman's work time duration within the household. Further, the reduction of labor input or hours in agricultural production leads to minimizing the total amount of agricultural production (Arora and Rada, 2016). When consider the demand for gender division of labor in domestic activities and the agricultural sector, it reduces women's leisure time and minimizes the working capacity on the farm (Arora and Rada, 2019). As per the Channel 2 of figure 1, the reduction of women's leisure time by increasing the day length of working of women farmers has happened (Arora and Rada, 2016). According to channel 1, the high degree of women's time poverty generates negative consequences for their physical and mental stress. These factors can help to reduce agricultural production (Arora and Rada, 2016; FAO, 2013).

Some researchers and policymakers focus their attention on the use of time and time scarcity of workers. They use global measurement for the concept of time poverty, Vickery's (1977) has developed a two-dimensional demonstration of income poverty by adjusting the time based on the US

context. Douthitt (2000) developed a model, deviated from Vickery's model, by using the existing data from US Time Use Survey. Harvey and Mukhopadhyay (2007) made three adjustments to Vickery (1977) model, based on the comparison of allocatable time (TA) by making linkages between the paid work (TW) and the remaining time for the leisure (TL). If the actual allocatable time is lower than the expected allocated time for paid work, by creating the individuals being time poverty. Allocatable time is the aggregation of the estimated time that is used for paid work and available time for leisure. If the individuals are suffering from a lack of available leisure time and a low level of time for the physical and mental well-being, those individuals can be time-poor.

Time poverty has become a serious issue rather than income poverty (Giurge and Whillans, 2019; Urakawa *et al.,* 2020). Because it directly affects for the overall productivity and working efficiency of the food production of individuals. In addition to that, time poverty has influenced on the physical and mental health of people and their wellbeing (Arora and Rada, 2016). Further, in the case of women farmers who live in rural areas, they are suffering from a conspicuous level of time poverty as child caring, household activities, agricultural activities, and many other works regarding self-employment are performed by them.

Imbulpe DS division is a rural farming area where most of the women farmers are performing agricultural activities. In addition, a considerable share of men is working in urban areas. Therefore, lots of women are engaged in agriculture and allied activities. However, women farmers have to do both domestic activities and also agricultural activities in the study area. In addition to that, child caring and self-employment related activities cause to reduce the leisure time of women farmers in this area. Based on theories of time poverty, it may lead to minimize their food production by the impact of the increasing physical and mental stress of women farmers and also the decreasing of working hours related to the agricultural activities of women farmers in the study area.

Therefore, it is timely important to assess the level of time poverty of women farmers and identify the impact of time poverty on food production of them in the Imbulpe DS division, as it is hard to find literature on such type of a study yet.

MATERIALS AND METHODS

This research was conducted in the Imbulpe DS division of Sri Lanka where many agricultural activities are performed by women farmers. There are 50 Grama Niladhari (GN) divisions in the Imbulpe DS division and about 650 women farmers are living in this area. Based on a simple random sampling method, 300 women farmers were selected to conduct the study from five selected GN divisions of the study area. A pre-tested, self-administered questionnaire survey was conducted as the primary data collection method from April to July 2019. The survey was conducted as a field interview of women farmers. Descriptive statistics and regression analysis were used as the data analysis method of the study.

Areas of time allocation of women farmers were identified according to the piolet survey within the study area. Such as caring family members, household activities, agricultural activities, and different kinds of paid works.

In order to make a comparison among the two determinants of the time poverty, paid work (TW) and available time for leisure activities (TL) with the allocable time (TA) represent by the following formula,

Formula 1: Time comparison between the paid work and leisure with the allocable time.

Time for leisure (TL) = Allocatable time (TA) – Time for paid work (TW)
According to the model of Harvey and Mukhopadhyay (2007),

Formula 2: Remaining time period for the allocable time with the selected dimensions

Allocatable time (TA) = 24 - Time required to physical and mental well-being (TN) - Time required to domestic activities (T1)

These formulas 1 and 2 were used to assess the level of time poverty of women farmers with the necessary modifications according to the study. The headcount index of time poverty was assessed as follows.

Formula 3: Headcount index of time poverty (Elena and Quentin, 2006)

$$\text{Headcount index of time poverty} = \frac{\text{Individuals who are time-poor (q)}}{\text{Population size (n)}}$$

"Individuals which are time poor (q)" was calculated by identifying who are the individuals time-poor considering about the upper level of 70% of time poverty within the study area. Beyond the 70% of time poverty was taken as the marginal group of time-poor (Elena and Quentin, 2006). In addition to that, 300 of the respondents were considered as the population size of the study area.

The impact of time poverty on food production was measured by using the model of Arora and Rada (2016) with necessary modifications according to the study area. The independent variable was the time poverty of women farmers and food production was considered as the dependent variable of the study. The level of time poverty of each respondent was assessed by the model of Harvey and Mukhopadhyay 2007 with necessary modifications and based on the study of Elena and Quentin (2006). The food production of individuals was calculated as kg/acre. Because the level of food production of the study area may differ based on the size of the farmland. Primary data were analyzed with the use of descriptive statistics and regression analysis using SPSS software version 23.

RESULTS AND DISCUSSION

Socio-demographic profile of respondents

The socio-demographic factors of the women farmers are presented in Table 1. All the respondents were women; therefore, the gender variable was missed in the data. Based on the results of Table 1, the mean age range of the respondents was 40 - 49 years indicating that they were obtained in middle age category. Therefore, they have adequate power of decision-taking related to household matters and farming activities (Ibharhokanrhowa, 2016). A share of 19.7% of the respondents was reported as below 40 years whereas 4.7% of women farmers belonged to the age group of 20-29 years. The young age category (less than 30 years) constituted 4.7% of respondents and 46% of women farmers were in the middle age range (30- 50 years). In addition, 49.3% of respondents were in the age of more than 50 years. Therefore, these findings concluded that the majority of the respondents are in adult age range. According to the results of the study, 2.7% of respondents were single in their marital status, while the majority of the respondents (93%) were married.

Table 1: Socio-demographic profile of respondents (n = 300)

Selected variable	Freq.	%	Selected variable	Freq.	%
Age			No. of children		
20 – 29	14	04.7	0 child	09	03.0
30 – 39	45	15.0	1 child	56	18.7
40 – 49	93	31.0	2 children	133	44.3
50 – 59	81	27.0	3 children	85	28.3
60 – 69	54	18.0	4 children	27	09.0
70 – 79	13	04.3	5 children	05	01.7
Marital status			Level of education		
Single	08	02.7	No formal education	06	02.0
Married	279	93.0	Primary education	47	15.7
Widowed	13	04.3	Secondary education	242	80.7
Divorced	00	0.0	Tertiary education	05	01.7
Farmland size (acres)			Family size		
0 – 0.5	73	24.3	Less than 3	158	52.7
0.5 - 1	56	18.6	4 - 6	135	45.0
1 – 1.5	95	31.7	more than 6	07	02.3
1.5 - 2	76	25.3			
Monthly income			Monthly income from agriculture		
0 - 20000	25	08.3	0 – 20000	27	09.0
20001 – 40000	208	69.3	20001 – 40000	273	91.0
40001 - 60000	67	22.3	40001 - 60000	00	0.0
Number of trainings participated			Savings (to purchase inputs for next cultivation)		
0 - 10	101	33.7	0 - 1500	09	03.0
11 - 20	168	56.0	1501 – 3000	13	04.3
21 - 30	69	23.0	3001 – 4500	187	62.3
31 - 40	52	17.3	4501 - 6000	91	30.3

(Source: Field survey, April-July 2019)

The majority of the women farmers have only 2 or 3 children. Only 3% of respondents were reported that they do not have children. When respondents' level of education is concerned, while 80.7% of women farmers had gained secondary education as their level of education, there were 2% of the respondents without having any formal education. When consider the family size of the respondents, 29.7% of them had only 4 family members, 10.3% of the respondents had 5 members and 5% of respondents had 6 members in their family. Furthermore, 91% of the respondents were earning LKR in between 20001-40000 as the monthly average income while 9% of them were receiving LKR in between 0-20000.

Time allocation of the women farmers

The time allocation of women farmers for different activities is presented in Table 2. Basically, respondents allocated time according to the requirements for the day to day lives such as caring family members, household activities, agricultural activities, and different kinds of paid works.

Table 2: Time allocation of women farmers (hours per day) (n = 300)

Pattern of time allocation	Category (hours)	Frequency	Percentage
Domestic activities	5 – 10	281	93.7
	11 - 15	19	6.3
Family caring activities	5 – 10	30	10.0
	11 – 15	65	21.7
	16 – 20	205	68.3
Agricultural activities	0 – 4	47	15.7
	5 – 10	169	63.0
	11 – 15	64	21.3
Paid work	0 – 4	171	57.0
	5 – 10	129	43.0
Leisure activities	0 – 4	196	65.3
	5 – 10	104	34.7

(Source: Field survey, April-July 2019)

As per the results of Table 2, most of the respondents (93.7%) have allocated 5-10 hours per day for domestic activities. Also, a least number of women farmers (6.3%) have allocated 11 – 15 hours per day for domestic activities. When consider the family caring activities, the majority of the respondents (68%) has devoted 16 – 20 hours per day, whereas, 30% of the respondents have devoted 5 – 10 hours per day to the family caring activities. Thus, they perform fewer amounts of family caring activities, because 5 – 10 hours per day for the family caring activities were reported by most of the respondents who are widowed or adults among other respondents of the study area.

The time allocation for the agricultural activities has come under 5 – 10 hours per day by the majority of the women farmers. Also, the lowest percentage of women farmers (15.7%) has spent 1 – 4 hours per day for their agricultural activities. Because they have a higher degree of family caring and household activities. Most of the respondents have carried out self-employment activities as economic activity. Moreover, 57% of women farmers have spent 1–4 hours per day for paid work or economic activity. When consider the time allocation for leisure activities by the women farmers in the study area, the majority of the respondents (65.3%) reported that they have 0 – 4 hours per day for the leisure activities.

When consider the marginal group of time poverty, 239 respondents were selected as individuals who were time poor within the study area. According to the findings of the study, calculation of Head Count Index of Time Poverty in this area is as follows,

$$\text{Head count index of time poverty} = \frac{\text{Individuals which are time-poor (q)}}{\text{Population size (n)}}$$

$$= 0.79$$

This study reveals that women farmers in Imbulpe DS division have obtained a considerably higher headcount index of time poverty (0.79) in their efforts in food production. Therefore, it can be concluded that women farmers who lived in the Imbulpe DS division consist of a low level of time for their leisure activities. Further, the average level of time poverty was represented as 78.9% among these women farmers.

According to the studies of Bardasi and Wodon (2010), 0.735 is the level of time poverty of the rural women farmers in Guinea. When consider the women farmers in Guinea, generally allocated their time for self-

employment, paid work and unpaid work, domestic activities, and also agricultural activities. Therefore, they were showed a considerable level of time poverty than the women who lived in developed countries.

As per the results of Williams *et al.* (2015) and Zilanawala (2014), medium discretionary time was noted as 60% in relative terms of threshold time poverty of women farmers. But this study revealed that 78.9% of threshold time poverty in relative terms. However, 60% of the time poverty is represented by the studies conducted in the United States of America and the United Kingdom. Those countries were developed in their economic and social status. Most of the agricultural operations are mechanized and women's involvement in farming activities is at a considerably lower level. Therefore, women who lived in developed countries, usually perform activities in the service sector rather than the agricultural sector. The findings of Arora and Rada (2016) demonstrated that 0.72 is the level of headcount index of time poverty in rural Mozambique area. This figure little bit closer to the value of the time poverty index of the Imbulpe DS division. As Sri Lanka is a still developing country, the agricultural activities are not adequately mechanized, and a considerable level of women who lived in rural areas are engaging in farming activities rather than the service sector. In addition to that, rural women who live in Sri Lanka have to perform self-employment, paid work and un-paid work, domestic activities, and also agricultural activities generally. Therefore, women, farmers showed a higher value of time poverty within the study area.

Impact of time poverty on food production

The impact of time poverty of women farmers on food production was analyzed through the regression analysis and the related results are presented through Table 3 and 4. In here, food production was considered as the dependent variable, and time-poverty was utilized as the independent variable of the study.

As per the results of Table 3, R value denotes the higher degree of correlation which is expressed as 0.807. In addition to that, 65.2% of the total variation in the dependent variable is explained by the independent variable. The $P < 0.05$ indicates the relationship between time poverty and food production. Based on the results of the Table 4, the standard error (18.8) represents the degree of deviation of observed values from the regression line in 95% confidence interval. However, this value should

be below or approximately equal to 2.5 for the increment of the model preciseness. The coefficient was denoted as (-) 0.807 and it presents the strong, inverse relationship between the time poverty of women farmers and food production within the study area. Therefore, these findings conclude that when the time poverty of women farmers increased, food production goes down.

Table 3: Model summary of the impact analysis of the time poverty and food production

Model	R	R Square	Std. Error of the Estimate	Change Statistics		
				R Square Change	F Change	Sig. F Change
1	.807[a]	.652	899.202	.652	557.232	.000

Table 4: Coefficients of the impact analysis of the time poverty and food production

Coefficients						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	10026.89	360.53		27.81	.000
	Time poverty of respondents	-444.75	18.84	-.807	-23.60	.000
a. Dependent Variable: What is your total food production?						

According to the studies of Arora and Rada (2016), time poverty of women farmers has an adverse effect on their agricultural production. Because they respond to increase domestic activities and family caring activities by minimizing the time duration for agricultural activities and leisure activities. Moreover, when the level of time poverty increases, it generates a negative effect on women's physical and mental status, which causes to reduce the productivity of the farm. Further, a study by Nichols (2016) revealed that time poverty creates a considerable negative impact on the food production of women farmers. In addition to that, according to FAO (2015), Women's triple working aspects of productive, reproductive, and social spheres buildup considerable impact on their food production, working efficiency, and well-being, and health. Women's reproductive and

productive workload creates a negative effect on their coffee production in Mexico based on the study of the impact of time poverty on women's participation in coffee producer organizations (Lyon *et al.,* 2017). Therefore, formulation of timely important policies to avoid time poverty of women farmers, educative approach to manage the stress conditions of the women farmers, enhance participation of family members to the farming activities, enhance market information accessibility and directed to use new farming technologies and empower women through diversification of employment activities to enhance the level of food production of women farmers in this area are highly important.

CONCLUSIONS

Most of the respondents represented an economically active range population and they have considerable educational level same as the male counterpart of the study area. The majority of the respondents were married. Therefore, they have to do child caring, household activities as well as agricultural activities. Respondents were showed about their lower level of leisure time duration due to the social responsibilities as a mother or housewife. Imbulpe area is based on rural culture and they have enough land area for the farming activities. Because their average farmland size was 1.25 acres. Most of the respondents mentioned LKR 25,000 as their average monthly income which is earning from farming activities. The time allocation for the agricultural activities has been categorized as 5 – 10 hours per day by the majority of the women farmers. Because they have a higher degree of family caring and household activities. Less than 4 hours per day was devoted by the majority of the women farmers as their time allocation for the paid performance because they have a higher degree of family caring activities and also the domestic activities. When consider the time allocation for the leisure activities of the women farmers, majority of them was prioritized domestic activities, family caring activities, agricultural activities, and paid work when allocating their time durations per day. The rest of the time duration per day was utilized for their leisure activities.

There is an impact of time poverty on food production of the women farmers because when the level of time poverty increases through physical and mental stress, and also the labor input reduction causes the lower productivity of the women farmers. Lower productivity of the respondents decreases the level of food production of the women farmers.

This study revealed that women farmers in the Imbulpe DS division obtain a considerably higher level of time poverty headcount index in their efforts in food production. Therefore, it can be concluded that women farmers who lived in the Imbulpe DS division consist with a lower level of time duration for their leisure activities and thus decreases their level of food production.

Therefore, the establishment of child daycare centers for caring for their children, allow to engaging the knowledge and skill development programs for the efficient utilization of time, conducting awareness programs for the family members especially husbands, about the time spend of women farmers to decentralize the workload of them, persuade to engaging in any kind of leisure activity by the women farmers and enhance the participation of stress management programs are timely important to enhance the women farmers lifestyle. And also, enhancement of participation of extension programs and workshops related to the application of modern farming technology and environmentally friendly farming activities and enhance market information accessibility to reduce the time consume when marketing of their agricultural products are the timely important activities that can be used to help these women farmers.

DECLARATION OF CONFLICT OF INTEREST

Authors have no conflict of interest to declare.

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Impact of different border crops on growth and yield performance of cauliflower (*Brassica oleracea* var *botrytis* L.) varieties

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Abstract

The use of border crops in cauliflower was an eco-friendly method for the management of pests. The present study was conducted at the Faculty of Agriculture, Kilinochchi from December 2018 to April 2019. The experiment was carried out in a split-plot design with three replicates. Four different borders, such as sunflower (T_1), lemongrass (T_2), chrysanthemum (T_3), and no border (T_4) were selected as the main plot treatments, and two different cauliflower varieties such as Mareet (V_1) and White Shot (V_2) were used as subplot treatments. The cauliflower varieties were planted at the spacing of 60 cm × 45 cm. All the agronomic practices were done according to the recommendations of the Department of Agriculture except plant protection methods. The growth, plant protection measures, and yield parameters were recorded. ANOVA and Duncan's Multiple Range Test (DMRT) were used for data analysis. There was no interaction effect between the type

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of border crops and varieties in all measured parameters. The border and the variety were not significant for plant height and the number of leaves per plant. The curd weight, circumference, diameter, total yield, and marketable yield were significantly different among the border crops, while the greater performances were observed in the lemongrass border (T_2). The varieties of cauliflower showed a non-significant effect on the yield parameters, and the highest was recorded in the white shot variety. Marketable yield and infested yield have significantly (p=0.05) differed among the different border crop treatments and the highest marketable yield was obtained from lemongrass border (T_2) in both varieties. The plant protection parameters such as the number of damaged leaves per plant and damaged curds significantly differed among the border crops. The highest was recorded in the control (T_4) treatment in Mareet variety. It can be concluded that lemongrass border and white shot variety can be recommended as the best treatment combination for cauliflower cultivation in the Kilinochchi district of Sri Lanka during the *Maha* season.

Keywords: border crops, cauliflower, curd, growth and yield, plant protection parameters

INTRODUCTION

In agriculture, the vegetable sector is one of the most important, next to the rice. Most farmers are committed to vegetable cultivation throughout the country in both *Maha* and *Yala* seasons (Rupasena, 1999). The temperate vegetables (exotic) grow well in the hill country, which has cool and healthy climatic, and tropical vegetables that are suitable for the low- and mid-country area.

Cauliflower (*Brassica Oleracea* var. *botrytis* L.) belongs to the Brassicaceae family from Europe and Africa (Ajithkumar *et al*., 2014). It is one of the essential vegetables in the world and is consumed daily. It also has good demand in Sri Lanka. Cauliflower is naturally high in fiber and B-vitamins. It provides antioxidants and phytonutrients that can protect against cancer. It also contains fiber to enhance weight loss and digestion, choline essential for learning and memory, and many other important nutrients. In cauliflower, the curd is made up of abortive flowers (Shanmugavelu, 1989). Under a protective environment, the growers can cultivate this crop all season (Yasoda *et al*., 2018).

In brassica vegetable production, the number of insect species is the major limiting factor. The most common cauliflower pests are aphids, flea beetles, slugs and snails, leafhoppers, and several insect larvae. Commercial vegetable growers regard insecticides as a simple, effective, and reliable means of control despite their cost and the need for frequent applications whether or pests are not present (Alishah, 1987). Therefore, there is an urgent requirement to find out an alternative and non-chemical method for pest control. The vegetables are becoming poisonous, ecologically unsafe, and economically unviable due to the frequent use of systemic insecticides (Mannan *et al*., 2015).

Border crops are utilized as a cultural strategy to avoid the pests attack of economically important crops. The use of border crops to form a screen around the cultivated crop provides protection against several virus diseases. Border cropping can control pest populations and limit the damage caused to the crop via pest diversion process (Saha *et al*., 2016).

There are several limitations found in the cultivation of cauliflower in the Dry zone of Sri Lanka. one of the important limitations is high temperature. Due to high temperature, cauliflower plant remains vegetative and continues to form new foliage (Chatterjee and Kabir, 2002), a temperature higher than the optimum level (15 – 20 °C) affect the curd formation due to that cultivars may show physiological disorder viz. riceyness, leafy curd, and blindness (Wheeler *et al*., 1995). Cauliflower plant and curd are easily affected by severe pest and disease attacks, due to which farmers use more chemicals to control pests in open fields to get the optimum yield.

Even though several studies are available regarding border crops effect on growth and yield performances of vegetable cultivation in the world, the information on research studies conducted in Sri Lanka is limited on the growth and yield performance of cauliflower, especially in the Northern Province. By considering this gap, the research was conducted to evaluate the impact of different border crops on the growth and yield performance of cauliflower varieties in Kilinochchi District with the objectives of finding the suitable border crop for cauliflower cultivation and evaluating the varietal performance of cauliflower under different border crops.

MATERIALS AND METHODS

A field experiment was carried out at the Faculty of Agriculture, Ariviyal Nagar, Kilinochchi which is located in the Northern Province of Sri Lanka belongs to the agro-ecological region of Low Country (DL_3) to evaluate the impact of different border crops on the growth and yield performance of cauliflower (*Brassica oleracea* var *botrytis* L.) varieties during December 2018 to April 2019.

The experiment was conducted in split-plot design, including four main plots and six sub-plots. The main plots contained different types of borders. Each main plot was divided into six sub-plots that include two cauliflower varieties with 3 replicates. The cauliflower varieties Mareet and white-shot were selected due to their excellent performance in warm conditions. The main plot factors were T_1 – Sunflower border, T_2 – Lemongrass border, T_3 – Chrysanthemum border, and T_4 – No border (control) (Figure 1). The treatments and their combinations are given in Table 1.

Table 1: Treatment Combinations of Cauliflower Varieties

Varieties	Sunflower (T_1)	Lemongrass (T_2)	Chrysanthemum (T_3)	Control (T_4)
Mareet (V_1)	T_1V_1	T_2V_1	T_3V_1	T_4V_1
Whiteshot (V_2)	T_1V_2	T_2V_2	T_3V_2	T_4V_2

Seeds were treated with fungicide captan (4 g/kg) for nursery preparation and were sown in a nursery tray. Rooting media was prepared by using 1:1:1 ratio of topsoil, compost, and cattle manure treated with fungicide captan, and media was kept for incubation for seven days. Two seeds were planted in a nursery tray per cell. In the field, four blocks were made parallel to each other with a spacing of 1.2 m. Each block was further divided into six plots. The size of each plot was 1.8 m × 1.8 m with a spacing of 0.5 m. The cow dung was incorporated at the rate of 10 kg/ plot before the preparation of the ridges. Three ridges were prepared in each plot with a spacing of 60 cm for planting. Irrigation channels were prepared around the plots.

Figure 1: Borders for cabbage; (A) Sunflower, (B) Lemongrass, (C) Chrysanthemum, (D) Control

The border crops (treatments) such as sunflower (T_1), lemongrass (T_2), and chrysanthemum (T_3) were grown in bags and planted around the plots in each block two weeks before transplanting cauliflower seedlings. Each border crop was planted as a double row cropping system. As a treatment, all border crop seedlings were transplanted at the spacing of 20 cm within a row. Thirty days old cauliflower seedlings were transplanted with a spacing of 60 cm x 45 cm. After planting, watering was done by a water bucket and the soil was kept in wet condition while avoiding excess watering. All management practices were done as a recommendation made by the Department of Agriculture except for plant protection. Blanching is an important operation for getting quality curd to protect the curds from yellowing due to direct exposure to the sun. Leaves were tied up with twine when curd started to protect the curd from sun burning and browning (Figure 2).

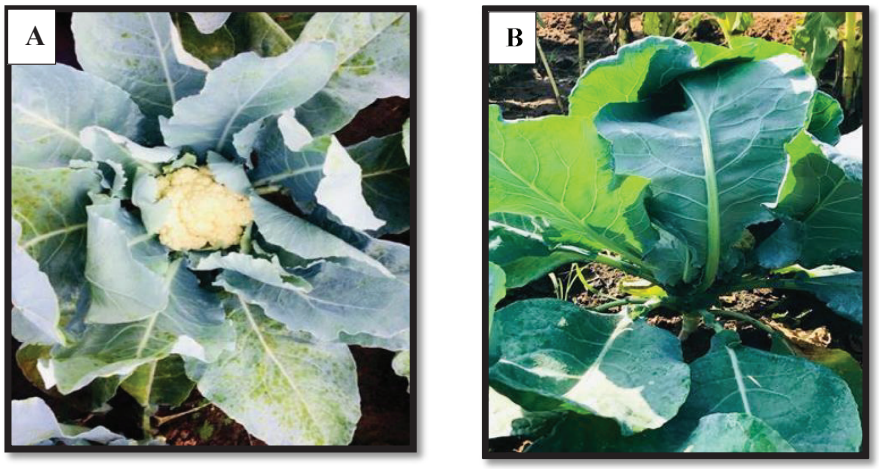

Figure 2: (A) Curd initiation (B) Blanching of cauliflower

Cauliflower was harvested 55 - 65 days after transplanting when the curd reaches proper size, bright white colour, and compactness. The harvesting was done by using a sharp knife in the morning.

Figure 3: Harvested Cauliflower

The growth parameters such as plant height and number of leaves/ plants were recorded at biweekly intervals started from two weeks after transplanting. The yield components of cauliflower such as curd weight, diameter, circumference, and total yield (t/ha) were measured at harvesting. The protection parameters such as the number of damaged leaves and curds were counted every data collection time**.** Data were analyzed by using the SAS 9.1 computer software package and mean separation was done by using Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Growth parameters

Plant height

There was no significant difference in plant height among the treatments in both varieties and there is no interaction effect between border crops and varieties at 6th week after planting. At 6th weeks after planting, the maximum plant height (31 cm) was recorded from sunflower border crop treatment (T_1) in Mareet variety and the minimum plant height (27.6 cm) was observed in the no border crop treatment that is control (T_4) in White Shot variety. The shade level in the sunflower treatment was higher than other border crop treatments. Due to the shade effect cauliflower plants may increase the height (Haque *et al.,* 2009 and Rajasekar *et al.*, 2013) in that treatment. The height was non-significant among the varieties within the same border; this may be due to the genetic character of the cauliflower crop.

Number of leaves per plant

There was no significant difference among the treatments in both varieties at all weeks after planting. The number of leaves per plant was not significantly influenced by the interaction between border crops and varieties at 6th week after planting. The maximum number of leaves was obtained in no border treatment (T_4) in both cauliflower varieties. In Mareet, the maximum number of leaves (22) was recorded at the 6th week after planting. In the White shot variety, the maximum number of leaves (20) was recorded at the 6th week after planting. It may be due to more exposure to sunlight in the control treatment. The number of leaves per plant was non-significant among the varieties within the same border.

Plant protection measures

Number of damaged leaves

The number of damaged leaves is influenced by different border treatments. The number of damaged leaves was significantly differed in control compared to other border crop treatments in both varieties. There is no interaction effect between border crops and varieties. The minimum and the maximum number of damaged leaves were recorded from lemongrass border treatment (T_2) and the control (T_4) in both varieties. Damaged leaves were minimum under lemon grass border (T_2) due to the repellent effect of the border. The damaged leaves were maximum under control treatment due to the absence of any border facilitating the laying of eggs by caterpillars on cauliflower leaves. The number of damaged leaves per plant was non-significant among the varieties within the same border. Hasheela *et al*. (2010) reported that the damaged percentage of diamondback moth on cabbage had significantly reduced by border cropping compared to control without border cropping. Fouche and Mitchell (2000) had reported that field borders or stripes within border crops act as a habitat and slow down the spread of insect pests to the field.

Number of damaged curds

The number of damaged curds is influenced by different border treatments. There is no interaction effect between border crops and varieties. The lemongrass border treatment significantly differed for the number of damaged curds from other border crop treatments in both varieties. The sunflower and chrysanthemum borders were non-significant and the control treatment (T_4) had the maximum number of damaged curds in both varieties. The maximum number of damaged curds (14 and 13) were recorded from Mareet and White Shot varieties, respectively. The minimum damaged curds were observed in the lemongrass border crop treatment (T_2) in both varieties. The minimum number of damaged curds (5 and 4) were recorded from Mareet and White Shot varieties, respectively. In the number of damaged curds parameter, there was a non-significant difference among the varieties within the same border (Figure 4).

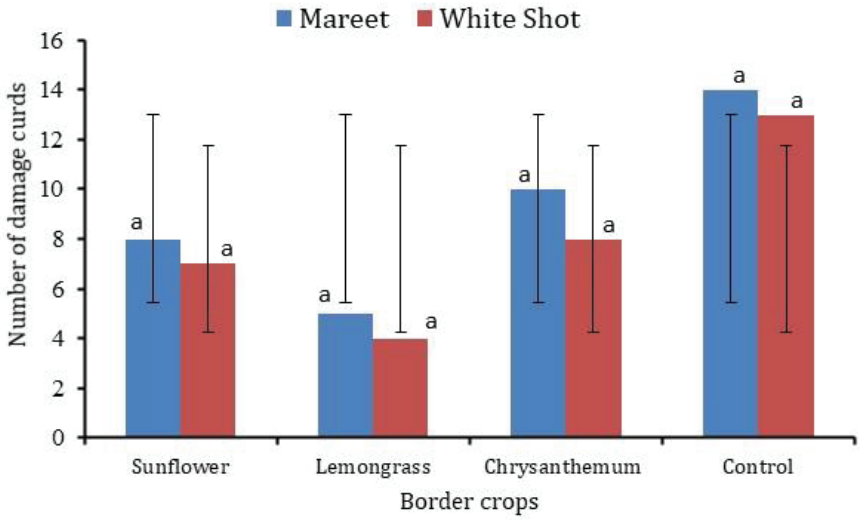

Figure 4: Number of damaged curds of different cauliflower varieties within same border crop treatment. Means with the same letter within a given border crop are not significantly different at p=0.05.

Yield components

Curd weight

There was a significant difference between the border crop treatments (Figure 5). There is no interaction effect between border crops and varieties. In both varieties, the highest average curd weight was recorded in the lemongrass border (T_2). The highest average curd weight (654.5 g and 723.3 g) was recorded from Mareet and White shot varieties, respectively. In Mareet variety there was non-significant difference between sunflower border (T_1) and no border treatment (T_4). In the White shot variety, there was a non-significant difference between sunflower (T_1) and the chrysanthemum border (T_3). The lowest curd weight was recorded in no border treatment (T_4) in both varieties. The lowest average curd weight (458.3 g and 432.2 g) was recorded from Mareet and White shot varieties, respectively. There is a non-significant difference between the varieties of cauliflower within the same border.

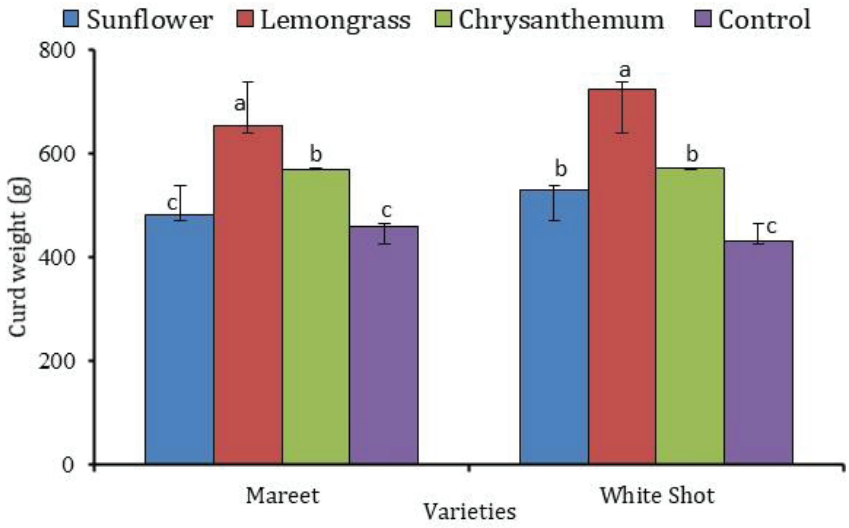

Figure 5: Average curd weight of different varieties of cauliflower under different border crop treatments. Means with the same letter within a given variety are not significantly different at p=0.05.

Curd circumference

There was a significant difference among the border crops but there was a non-significant effect in sunflower (T_1) and chrysanthemum (T_3) border in the White shot variety (Figure 6). There is no interaction effect between border crops and varieties. In both varieties, the highest average curd circumference was recorded in the lemongrass border (T_2), because of favorable micro-climate around the cauliflower plants. The highest curd circumference (47.94 cm and 51.03 cm) was recorded from Mareet and White shot varieties, respectively. The lowest average curd circumference was recorded in the control treatment (T_4) in both varieties. The lowest curd circumference (44.19 cm and 41.83 cm) was recorded from Mareet and White shot varieties, respectively. The average curd circumference was not significantly differed among the varieties within the same border.

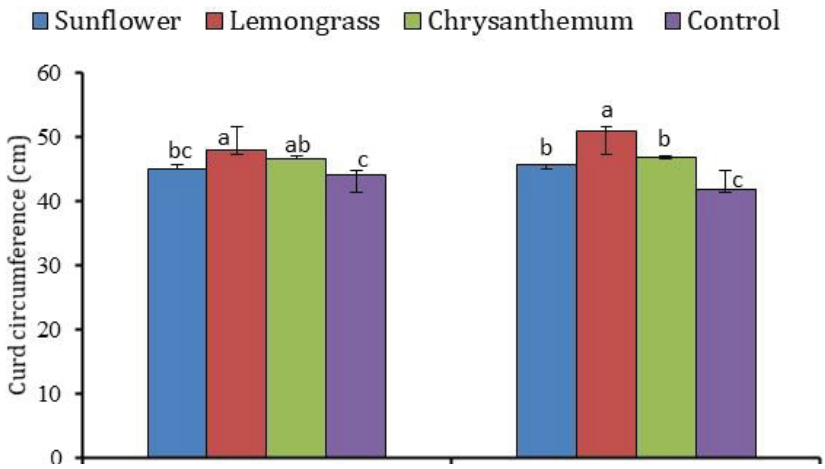

Figure 6: Average curd circumference of different cauliflower varieties under different border crop treatments. Means with the same letter within a given variety are not significantly different at p=0.05.

Curd diameter

The curd diameter was significantly different among the border crops. But no significant difference in sunflower and chrysanthemum border in the White shot variety (Figure 7). There is no interaction effect between border crops and varieties. The highest curd diameter was recorded in the lemongrass border (T_2) in both varieties. The highest curd diameter of 30.54 cm and 32.5 cm was recorded from Mareet and White shot varieties, respectively. The lowest average curd diameter was recorded in the control treatment (T_4) in both varieties. The lowest curd diameter of 28.15 cm and 26.65 cm was recorded from Mareet and White shot varieties, respectively. There was a non-significant difference among the varieties within the same border treatment.

Total yield

The total yield significantly differed among the border crop treatments (Figure 8). There is no interaction effect between border crops and varieties. In Mareet variety, the highest total yield (32.7 t/ha) was obtained

in the lemongrass border (T_2) and the lowest (21.6 t/ha) was obtained from the control (T_4). The yield obtained in the chrysanthemum border and sunflower border was 28.5 t/ha and 24.1 t/ha, respectively. Similarly, in the White shot variety, the highest total yield (36.2 t/ha) was obtained

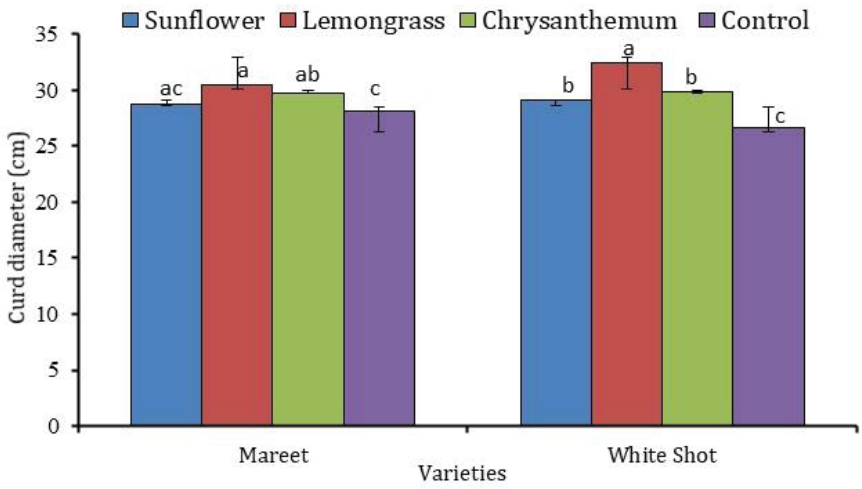

Figure 7: Average curd diameter of different varieties of cauliflower under different border crop treatments. Means with the same letter within a given variety are not significantly different at p=0.05.

in the lemongrass border (T_2) and the lowest (22.9 t/ha) was obtained from the control (T_4). The yield obtained in the chrysanthemum border and sunflower border was 28.6 t/ha and 26.5 t/ha, respectively. Total yield was not significantly differed among the cauliflower varieties within the same border (Figure 9). Tatgar *et al*. (2011) reported that border cropping significantly increased the yield on different crops such as chilli and onion by reducing the impact of leaf curl complex damage and thrips attack.

Marketable and infested yield

Marketable yield and infested yield significantly differed among the different border crop treatments (Figure 10). The highest number of quality curds without holes was obtained from the lemongrass border (T_2) in both varieties. In Mareet variety, the highest marketable yield (29.1 t/ha) and the lowest infested yield (3.6 t/ha) were recorded in lemongrass border crop treatment. Similarly, in the White shot variety, the highest

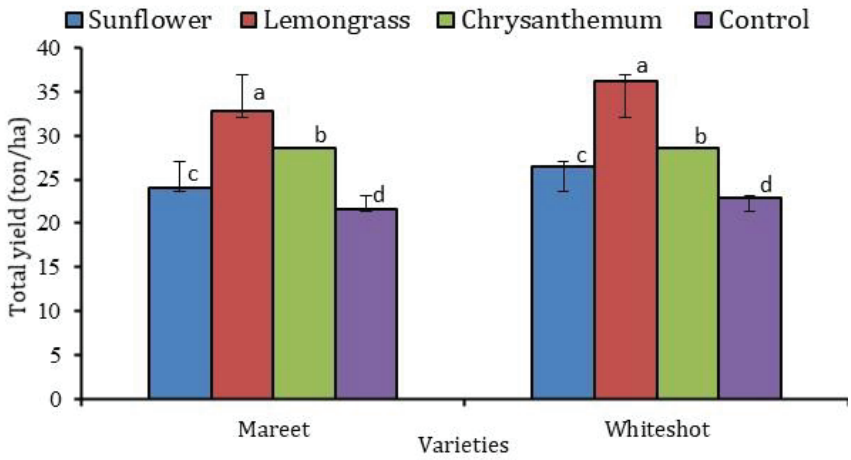

Figure 8: Total yield of different varieties of cauliflower under different border crop treatments. Means with the same letter within a given variety are not significantly different at p=0.05.

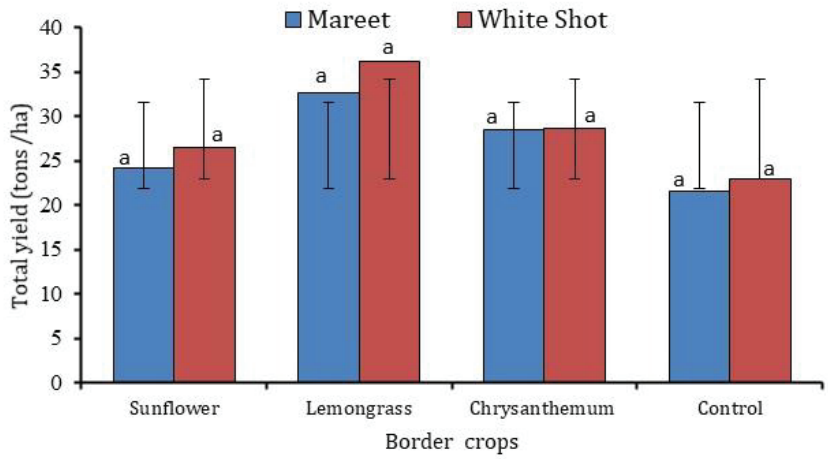

Figure 9: Total yield of different cauliflower varieties within the same border treatment. Means with the same letter within a given variety are not significantly different at p=0.05.

marketable yield (32.5 t/ha) and the lowest infested yield (3.7 t/ha) were recorded in lemongrass border. In Mareet variety, the maximum infested yield (8.4 t/ha) and the minimum marketable yield (14.6 t/ha) were recorded in the control treatment. Similarly, in the White shot variety, the

maximum infested yield (7.9 t/ha) and the minimum marketable yield (13.7 t/ha) were recorded in the control treatment. Cauliflower crop can be easily attacked by pests in control treatment because of the absence of physical barriers in the control treatment.

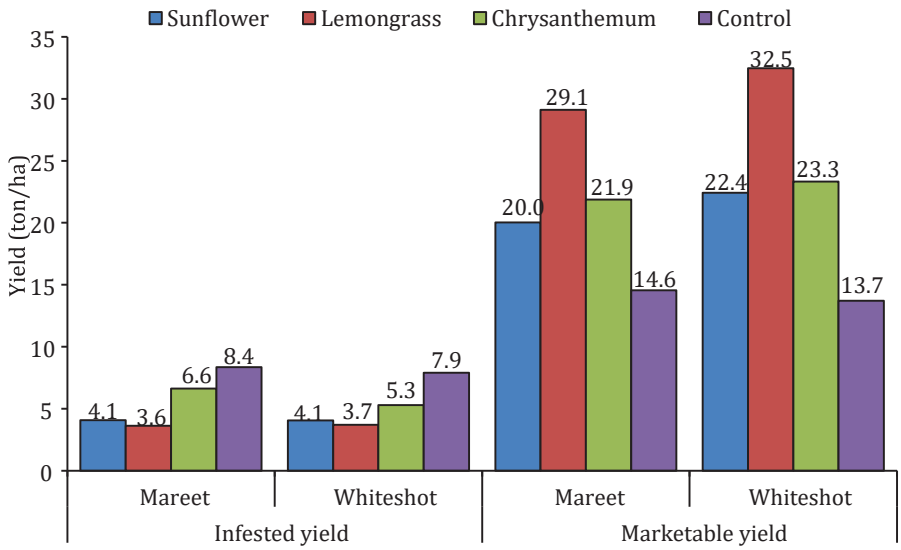

Figure 10: Effect of different treatments on the marketable and infested yield of different cauliflower varieties.

CONCLUSIONS

The experiment confirmed that different border crop treatments have influenced on growth and yield performance of cauliflower varieties. The highest mean curd weight, curd circumference, curd diameter, total yield, and marketable yield were obtained in lemongrass border treatment in both cauliflower varieties. White shot variety showed the highest curd diameter, curd circumference, curd weight, total yield, and marketable yield than Mareet cauliflower variety. It can be concluded that White shot cauliflower variety can be cultivated under lemon grass border to obtain the highest yield in the Kilinochchi district.

LIMITATIONS AND SUGGESTIONS

The high temperature in the dry zone is the limitation for the quality curd formation and causes severe pest and disease attacks. To bring down the temperature effect in the field, cauliflower can be cultivated under alley cropping.

This experiment should be carried out during the *Yala* season for evaluating the performance under different weather conditions. This experiment should be repeated with the same season to confirm results. This experiment also can be repeated with different border crops to evaluate the growth and yield performance of cauliflower varieties and with different varieties of cauliflower.

DECLARATION OF CONFLICT OF INTEREST

Authors have no conflict of interest to declare.

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Production and optimization of bioethanol from over ripen sour banana fruit wastes (*Musa sapientum)* using *Saccharomyces cerevisiae*

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Abstract

This study was carried out to produce bioethanol from low quality over ripen *Musa sapientum* (sour banana) fruit wastes to enhance the yield of bioethanol. When the sour banana juice was inoculated with *Saccharomyces cerevisiae* (2 g/L) in the fermentation media (100 mL, 8° Brix) composed of 10 g/L yeast extract, 10 g/L KH_2PO_4, 2 g/L $(NH_4)_2SO_4$, 2 g/L peptone, and 0.5 g/L $MgSO_4 \cdot 7H_2O$ and fermented for 24h at 30 °C and 100 rpm, the ethanol yield was 0.8% v/v. When nitrogen sources urea, ammonium sulphate, ammonium carbonate, and ammonium nitrate were used in the fermentation media (2.0 g/100mL), significantly higher ethanol yield ($p<0.05$, 0.90%) was produced with ammonium carbonate. When yeast inoculum was increased to 5 g/L, the ethanol yield was significantly higher ($p<0.05$, 1.00%, 1.11 times) than the control. When the temperature was 25 °C, the ethanol yield was significantly increased ($p<0.05$) by 1.2 times the control temperature of 30 °C. When the rotation speed was 150 rpm, the ethanol yield was significantly higher ($p<0.05$) than the control (100 rpm). Ethanol yield was significantly higher ($p<0.05$, .15 times - 4.10 %)

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with 90% of banana juice. With 0.1 g/100mL of ammonium carbonate, ethanol yield was significantly increased by 1.1 times ($p<0.05$, 40 %) than the non-optimized control (0.2 g/100mL). Sucrose significantly stimulated ethanol yield than the other sugars. Fifteen grams per hundred milliliters of sucrose yielded significantly higher ethanol ($p<0.05$, 2.33 times) than the non-optimized control (2 g/100mL). When the pH of the medium was optimized at 6.0, the ethanol yield was significantly higher ($p<0.05$, 12.60%). Therefore, *Musa sapientum* could be an effective substrate for bioethanol production and optimization process increased the bioethanol yield significantly by 15.75 times (12.60% - 1.6°Brix).

Keywords: baker's yeast, bioethanol, sour banana fruit waste, fermentation, incubation period

INTRODUCTION

Since petroleum-based fossil fuels are exhausted super-fast to meet the demands of the rapidly increasing human population, the energy crisis has become an important global concern nowadays (Prasad *et al*., 2007). Greenhouse gas emissions from fossils fuels cause adverse effects on the nature. Increase in the CO_2 level by the burning of petroleum-based fuels causes global warming (Naik *et al*., 2010). Disruption of oil supply in the Middle East countries where major field of petroleum-based fossil fuels are found would cause a huge struggle for fuel consumption and fuel-based essential sectors (Nagashima *et al*., 1984; Ogbonna *et al*., 2001). Scientists have shown great interest in finding out a sustainable and environmentally friendly energy sources for our industrial needs and for regular consumption for the vehicles of public all over the world (Mabee *et al*., 2005). As a solution, bioethanol is considered as one of the best options as a sustainable and renewable energy source.

The merits of bioethanol are higher octane number, evaporation enthalpy, flame speed and wider range of flammability, that make them suitable as a fuel source (Balat, 2007; Balat *et al*., 2009; Dias de Oliveira *et al*., 2005). Since the bioethanol is an eco-friendly oxygenated fuel containing oxygen of more than 35%, it is highly suitable to reduce the emission of particulate and other greenhouse gases during combustion (Demirbas, 2008; Malca *et al*., 2006; Searchinger *et al*., 2008). In addition to the above, bioethanol reduces the interference on ozone due to its lower ambient photochemical reactivity (Lynd *et al*., 1991; McCarthy *et al*., 2006).

Bioethanol can compete with petroleum in terms of sustainability and economic viability, only when it is produced from cheaper natural sources (Cysewski *et al.,*1978; Maiorella *et al*., 1984). At present, starch from cereal crops and juice and molasses from a wide range of crops are the two types of primary feed stocks employed in large scale biofuel production (Balat *et al.,* 2009; Mojovic *et al*., 2006; Salassi *et al*., 2007; Wilkie *et al*., 2000). Bioethanol production from diverse lignocellulosic biomasses has been studied widely but this type of research study is confined to the laboratory level. Usage of free sugar containing juice as feedstock for ethanol production than starch or lignocellulosic biomass has been cheaper and easily available. This may be due to the non-requirement of costly steps such as pretreatment of the lignocellulosic biomasses and hydrolysis step to obtain fermentable sugars (Bryan *et al*.,1990; Ganesh *et al*., 1995; Nilkolovv *et al*., 2000; Rolz *et al*., 1980). Microbial involvement in fermentation of sugars would be sometimes possible in the absence of oxygen with glucose and this results in ethanol and carbon dioxide (Deesuth *et al*., 2012; Ingram *et al*., 1998). Fermentation of yeast to produce alcoholic beverages such as beer and wine has been a prominent practice in the past, and this step is still efficiently used to produce bioethanol from renewable energy sources (Dien *et al*., 2003; Kosaric *et al*., 1995). *Saccharomyces cerevisiae* (de Mancilha *et al*., 1984; Liang *et al*., 2008; Sheoran *et al*., 1998; Yu *et al*., 2009). *Saccharomyces diastaticus* (Maruthai *et al*.,2012), *Kluyveromyces marxianus* (Limtong *et al*., 2007; Nonklang *et al*., 2008). *Escherichia coli* and *Klebsiella oxytocastrain* (Da silva *et al*., 2005) and *Zymomonas mobilis* (Cazetta *et al*., 2007; Gunasekaran *et al*., 1999; Rogers *et al*., 1982; Rodriguez *et al*., 1986) have been widely used for ethanol production from sweet sugary juices. Among these, *S. cerevisiae* has been the best choice for alcoholic fermentation because of the following reasons: efficient capacity to convert sugar into alcohol, capability of producing loosely clumped mass of fine particles during growth, easier to settle or suspend in the fermentation chamber (Kosaric *et al*., 1995) and higher tolerance to the ethanol present in the growing media (Olsson *et al*., 1993).

The optimum temperature range for the efficient function of *S. cerevisiae* for ethanol production is 30–35 °C and slightly alkaline media is highly preferable for effective fermentation. The heterotrophic microorganisms are generally used in fermentation process, they need at least a carbon and a nitrogen source for their survival and their growth. The direct bioethanol production from the free sugar containing juices of some plants is conducted by this yeast and they convert sucrose or mono

saccharides present in the raw materials into ethanol through the direct fermentation process (Cardona *et al*., 2007; Hossain *et al*., 2010). Banana, pineapple, orange, mango, sugarcane, and some fruits are the potential crops yield free sugar containing juices (Ensinas *et al*., 2009). These plants contain free sugars such as sucrose, glucose, and fructose (Dhaliwal *et al*., 2011). Sucrose is the major sugar in fermentable juices and it can be easily converted into glucose and fructose during fermentation process by using the enzyme invertase, found in yeast (Dodic *et al*., 2009; Sanchez *et al*., 2008).

A trend of converting staple paddy fields into banana cultivations has been increasing during the last decades due to the advantage that diverse banana plants grow very well in the dry zones of Sri Lanka. Among the different types of banana cultivars grown in Sri Lanka, most varieties are very popular because of their taste, low price, and nutritional qualities. Sour type banana is one of the very unpopular types of banana fruits produced in excessive quantities in northern Sri Lanka due to its sour taste. Large quantities of this variety of banana type are wasted without human consumption and considerable amount is allowed to deteriorate due to lower human attention and very poor taste. The shelf-life of this type of banana is also very short and it is easily susceptible to microbial invasion. Due to its small size, irregular-shaped black lesions formed frequently on the skin and poor taste, it is discarded into the garbage or used as feed for cows in large farms in the Jaffna peninsula. Sometimes, farmers choose not to harvest this type of banana from their cultivation land. Usage of plant juices as feedstocks would cause low storability and subjected to microbial decomposition and these are the demerits of the usage of sugary juices for fermentation (Dodic *et al*., 2009). To purify the juices, the conventional liming-carbonation method that uses more energy and produce waste and $CO_2$is replaced by the usage of membrane technology nowadays (Lipnizki *et al*., 2006). Method using membrane filtration of sugar juice is highly preferred over the conventional liming-carbonation method for yielding higher sucrose concentration (Hakimzadeh *et al*., 2006; Kawa-Rygielska *et al*., 2013; Regiec *et al*., 2004; Shahidi *et al*., 2006). Further, the sour variety of banana is very cheap, easily available, and grows excessively all over Sri Lanka. Therefore, the objective of the study was to determine the bioethanol production from the poor quality sour type banana fruit waste and to optimize the conditions to enhance the yield.

MATERIALS AND METHODS

Source of microbial strain and fruit

Baker's yeast (*Saccharomyces cerevisiae*) was purchased from the local market. Sour banana fruits (*Musa sapientum*) were grabbed from the Botanical Garden of the Department of Botany, University of Jaffna, and juice was prepared. Compared to other types of microorganisms, yeasts especially *Saccharomyces cerevisiae* is the common microbe employed in ethanol production due to its high ethanol productivity, high ethanol tolerance and ability to ferment a wide range of sugars (Azhar *et al*., 2017)

Chemicals and media

All the chemicals used were obtained from Sigma-Aldrich Chemicals PVT LTD, 301/2, Galle Road, Colombo-00300, Western province, Sri Lanka. Basal medium containing 10 g/L yeast extract, 10 g/L KH_2PO_4, 2 g/L $(NH_4)_2SO_4$, 2 g/L Peptone, and 0.5 g/L $MgSO_4 \cdot 7H_2O$ was prepared. After the autoclaving of the conical flask containing 100 mL media, it was inoculated with 0.2 g of *Saccharomyces cerevisiae* (2 g/L).

Production of biofuel and measurement

To the fermentation medium (100 mL), (2 g/L) inoculum was added and incubated at room temperature (30 °C) in a rotatory shaker (100 rpm), provide a smooth uniform circular motion with an orbit of 16mm, speed range 30-300 rpm, load bearing capacity 10 kg, depth (metric) 420 mm, height (metric) 270 mm. Each flask was cultured at room temperature (30 °C) under oxygen limited condition up to 24 h. The oxygen limited condition was provided by sealing the flask tightly with parafilm and keeping it in an Himedia glass anaerobic chamber, supplied with transparent, unbreakable polycarbonate jar of 3.5 L capacity with sturdy, aluminium lid clamp and sealing ring. Medium was mixed with distilled water and the suspension was mixed and the extract was centrifuged in Hermle. Z 306 model centrifuge with rotor, rotor's radius 8 cm, speed range: 200 to 14,000 rpm, max. capacity 4x100 mL. The supernatant was used for bioethanol measurement.

Analytical methods

Sugar concentration was measured by using dinitrosalicylic acid method (Miller, 1959) and refractometer method before and after the fermentation process. The suspension was mixed and the extract was centrifuged for 20 min at 3000 rpm (Relative centrifugal force = 805 x g) in a Hermle. Z 306 model centrifuge with rotor, rotor's radius 8 cm, speed range :200 to 14,000 rpm, Max. capacity 4x100 mL. The supernatant was used for bioethanol measurement in percentage using ebulliometer (Wahab *et al*., 2005).

Optimization of conditions for bioethanol production

Production of bioethanol in sour banana medium

Fermentation medium (100 mL) was inoculated with *Saccharomyces cerevisiae* (0.2 g) and incubated at 30 °C for 24 h. Ethanol production was measured by using Salleron ebulliometer, electric heating system 220V-125W, Analysis time 5 minutes approximately, range 0-18% alcohol.

Effect of nitrogen source

Fermentation media were prepared by taking different nitrogen sources (ammonium sulphate, ammonium nitrate, ammonium carbonate and urea) in a concentration of 0.2 g/100mL. The experiment was continued and ethanol production was measured by using Salleron ebulliometer electric heating system 220V-125W, Analysis time 5 minutes approximately, range 0-18% alcohol.

Effect of inoculum size

Media were prepared by mixing the optimized nitrogen source (ammonium carbonate) with liquid fermentation media. Different amounts of yeast inoculum (0.4, 0.5, 0.6, 0.8, 1.0 g/100 mL) was added in the media and incubated at room temperature (30 °C).

Effect of temperature

Media were prepared by mixing the optimized nitrogen source (ammonium carbonate) with liquid fermentation media. Optimized amount of yeast

inoculum (5 g/L) was added to the media and incubated at different temperatures (10, 20, 25, 30, 35, 40 °C) ranging from 10 – 40 °C.

Effect of rotation speed

Media were prepared by mixing the ammonium carbonate with liquid fermentation media. Yeast inoculum (5 g/L) was added to the media and incubated at the optimized temperature (25 °C) at different rotation speeds (50, 100, 150, 200, 250 rpm) by using Stuart orbital shaker, provide a smooth uniform circular motion with an orbit of 16 mm, speed range 30-300 rpm, load bearing capacity 10 kg, depth (metric) 420 mm, height (metric) 270 mm.

Effect of substrate concentration

Fermentation media were prepared by mixing all the substances with different concentration of substrate (5%, 10%, 25%, 50%, and 90%) of liquid fermentation media. The fermentation medium was inoculated with yeast inoculum (0.5 g/100mL) and incubated at 25 °C at 150 rpm.

Effect of amount of nitrogen source (ammonium carbonate)

Media were prepared by mixing all the substances with different amount of ammonium carbonate (0.1, 0.2, 0.5, 1.0, 1.5, and 2.0 g/100 mL) with 90% of banana juice concentration of liquid fermentation media. The medium was inoculated with yeast inoculum (0.5 g/100mL) and incubated at 25 °C at 150 rpm.

Effect of carbon source

Fermentation media were prepared by mixing all the substances with 90% of banana juice concentration and 0.1 g/100mL of ammonium carbonate of liquid fermentation media. Different carbon sources such as glucose, sucrose, maltose, and dextrose (2 g/100mL) were added to the media and inoculated with yeast inoculum (0.5 g/100mL) and incubated at 25 °C at 150 rpm.

Effect of amount of carbon source

Media were prepared by mixing already optimized substances at the appropriate level in the liquid fermentation media. Different amount of

carbon source (sucrose – 1 g, 2 g, 4 g, 6 g, 8 g, 10 g, 15 g and 20 g) was added to the media and inoculated with yeast inoculum (0.5 g/100mL) and incubated at 25 °C at 150 rpm.

Effect of pH of the medium

Media were prepared by mixing already optimized substances at the appropriate level in the liquid fermentation media. The medium was set at different pH values such as 4.0, 5.0, 6.0, 7.0, and 8.0 and inoculated with yeast inoculum (0.5 g/100mL) and incubated at 25 °C at 150 rpm.

Effect of incubation period

Media were prepared by mixing already optimized substances at the appropriate level in the liquid fermentation media. The medium was set at pH 6.0 and inoculated with yeast inoculums (0.5 g/100mL) and incubated at 25 °C at 150 rpm. The set ups were incubated at different incubation periods (24 h, 48 h, 72 h and 96 h).

Statistical analysis

All the experiments were carried out in triplicate and the average values were used to plot the graphical representation. Statistical analyses were performed using Minitab 16.0 Version. The data were analyzed using one way ANOVA. Tukey's multiple comparison test was used to determine significant differences at $p < 0.05$.

RESULTS AND DISCUSSION

Production of bioethanol in sour banana medium

The amount of ethanol produced from the banana juice was 0.8% under non- optimized conditions initially at room temperature after 24 h of fermentation. There were significant differences in the sugar content values obtained before fermentation and after the optimization of fermentation (Table 1).

Effect of nitrogen source

When different nitrogen sources such as urea, ammonium sulphate, ammonium carbonate, and ammonium nitrate were used in the

fermentation media, significantly higher ethanol production ($p<0.05$, 0.90%) was obtained in the medium containing ammonium carbonate (Figure 1) than the other nitrogen sources. Ammonium carbonate as a weak base can provide alkaline environment that facilitates the fermentation process. Hence, ammonium carbonate was chosen as nitrogen source for further studies.

Table 1: Sugar concentrations before and after the fermentation using dinitrosalicylic acid method (Miller,1959) and refractometer method.

	Sugar concentration	
	Before the fermentation	After the optimization of fermentation conditions
Dinitrosalicylic acid method (at 540nm)	0.55 ± 0.011 moldm^{-3}	0.08 ± 0.005 moldm^{-3}
Refractometer method	8 ± 0.577 ^{o} Brix	1.6 ± 0.057 ^{o} Brix

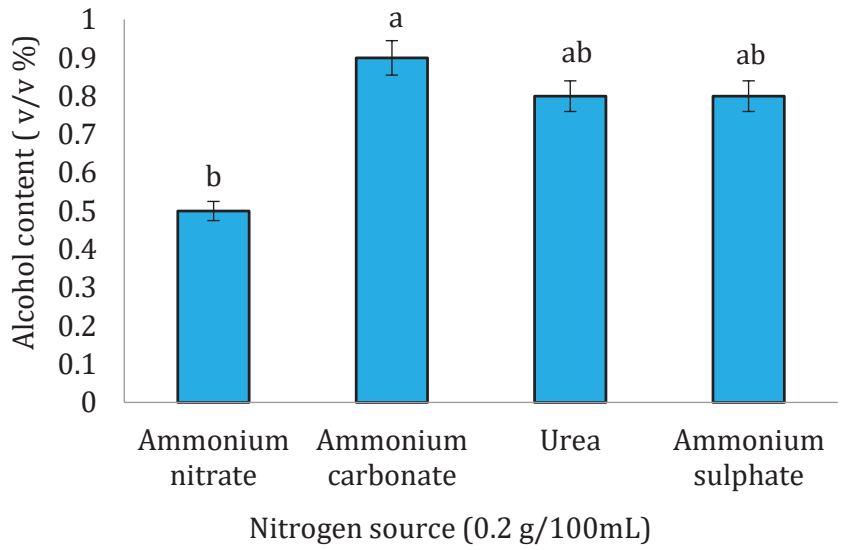

Figure 1: Effect of different nitrogen sources on bioethanol production from banana fruit juice using *Saccharomyces cerevisiae.* Different alphabets show significant differences between the mean values.

Effect of inoculum size

When the size of yeast inoculum was 0.5 g/100mL, ethanol yield was significantly increased by 1.11 times (0.90% to 1.00 %, $p<0.05$) than the non-optimized control (0.2 g/100mL) (Figure 2). Hence 0.5 g/100mL of yeast inoculum was chosen for further studies. The concentration) of added inoculum in the fermentation media does not have a significant influence ($p<0.05$) on final ethanol production but also it affects sugar consumption rate (Laopaiboon *et al*., 2007). When the inoculum concentration increased within a certain range that can causes a reduction in the fermentation time due to the rapid growth of the yeast cells in the fermentation media they immediately consume fed sugars producing ethanol.

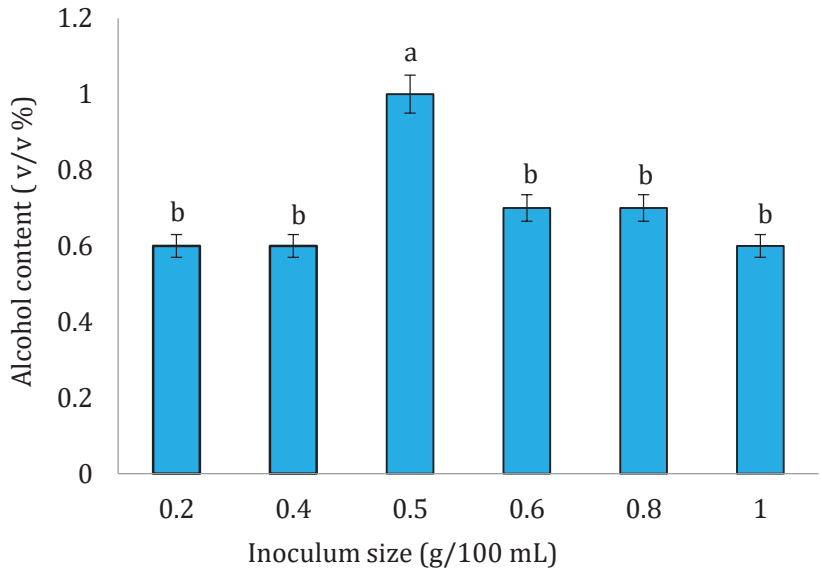

Figure 2: Effect of different size of inoculum on bioethanol production from banana fruit juice using *Saccharomyces cerevisiae*. Different alphabets show the significant differences between the mean values.

Effect of temperature

The bioethanol production after 24 hours at 10, 20, 25, 30, 35 and 40 °C was 0.60%, 1.00%, 1.20%, 0.90%, 0.70% and 0.60% respectively (Figure 3). Even though yeast grew well at temperatures between 30 – 60 °C, the bioethanol production was significantly higher at 25 °C (1.20%,

p<0.05) than the non-optimized temperature 30 °C. When the culturing temperature was optimized as 25 °C, ethanol production was increased by 1.20 times (from 1.00% to 1.20%) than the non-optimized condition (30 °C). At 30 °C and above the bioethanol yield showed a decreasing trend and this decrease may be due to the stress factor on microorganisms, which is unfavorable for their growth. Microorganisms produce heat-shock proteins in response to the high temperature and inactivate their ribosomes. In addition, microbial activity and fermentation process are regulated by different enzymes which are also sensitive to high temperature since it denatures their tertiary structure eventually inactivating them (McMeekin *et al*., 2002; Phisalaphong *et al*., 2006). Microorganisms employed in the fermentation method have optimum temperature range for their better growth. Therefore, it is necessary to predetermine an optimum temperature during fermentation for proper microbial growth as well as a higher yield of ethanol. It is generally believed that the ideal fermentation temperature range is between 20 and 35 °C and high temperature in almost all fermentation processes creates uncontrollable issues (Ballesteros *et al*., 2004; Phisalaphong *et al*., 2006). Hence 25 °C temperature was chosen for further studies.

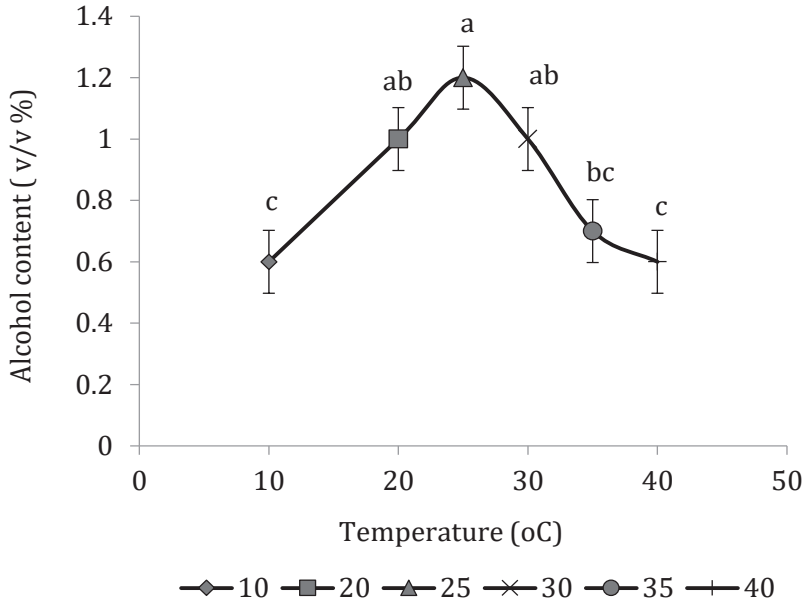

Figure 3: Effect of different temperatures on bioethanol production from banana fruit juice using *Saccharomyces cerevisiae*. Different alphabets show the significant differences between the mean values.

Effect of rotation speed

When different rotation speeds (50, 100, 150, 200, 250 rpm) were used, significantly higher ethanol production (1.30 %, $p<0.05$, Figure 4) was obtained when 150rpm was used. When the rotation speed of the media was optimized as 150 rpm, ethanol yield was increased by 1.08 times than the speed at non-optimized condition (100 rpm). Agitation enlarged the porosity of nutrients from the fermentation broth to inside the cells and in the same way removing ethanol from the cell interior to the fermentation broth. It conjointly will increase the sugar consumption of microbial cells and reduces the inhibition of ethanol on cells. Commonly 150–200 rpm is usually rotation speed is employed for the surplus bioethanol production by yeast cells (Liu *et al*., 2008). Once the surplus agitation is given it ends up in the restricted metabolic activities of microbial cells within the media. Hence 150 rpm rotation speed was chosen for further studies.

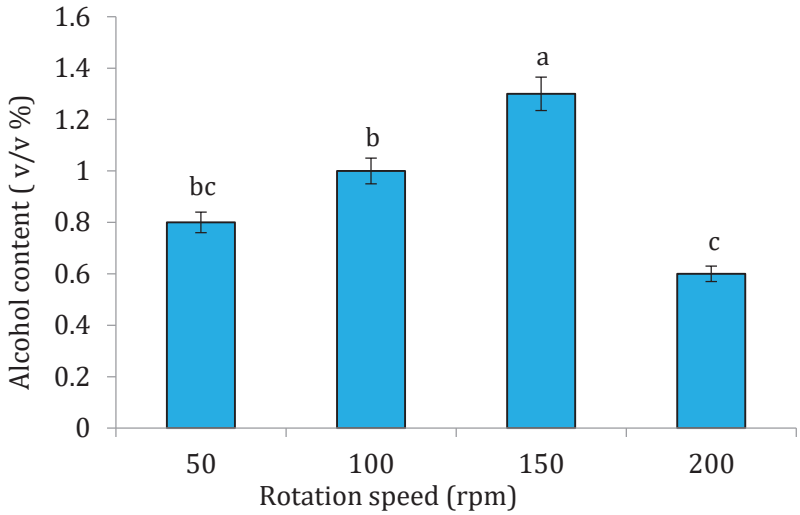

Figure 4: Effect of different rotation speeds on bioethanol production from banana fruit juice using *Saccharomyces cerevisiae*. Different alphabets show the significant differences between the mean values.

Effect of substrate concentration (raw fruit juice)

When different concentrations of raw fruit juice (5%, 10%, 25%, 50%, and 90%) were chosen, significantly higher ethanol production was obtained at 90% of substrate concentration (3.15 times, from 1.30% to 4.10%,

p<0.05) than the non-optimized substrate concentration of 25% (Figure 5). Substrate concentration has the direct effect on fermentation rate and microbial cells. Generally, fermentation rates are going to be enlarged with the rise in substrate concentration up to a definite level. However, the surplus sugar concentration can exceed the uptake capability of the microorganisms cells resulting in a gradual rate of fermentation. Higher ethanol production can get at higher initial sugar concentration (Laopaiboon *et al*., 2007). Hence 90% substrate concentration in the fermentation media was chosen for further studies.

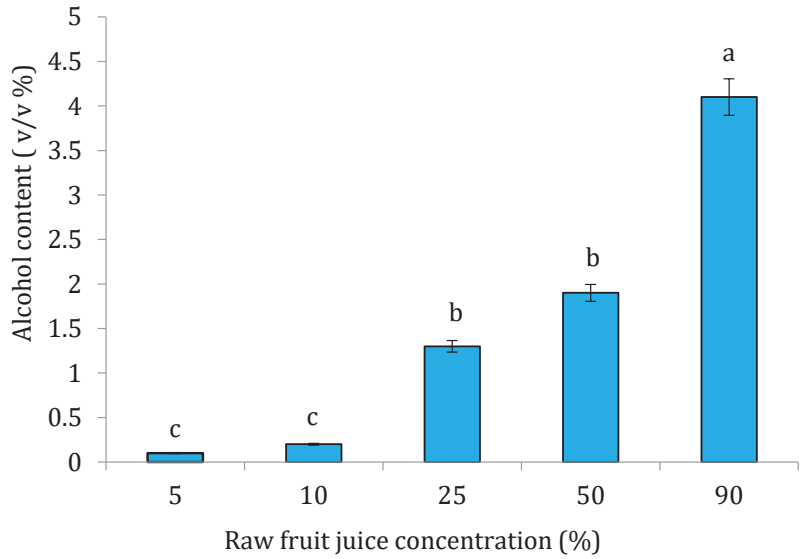

Figure 5: Effect of different concentrations of raw fruit juice on bioethanol production from banana fruit juice using *Saccharomyces cerevisiae*. Different alphabets show the significant differences between the mean values.

Effect of amount of ammonium carbonate

When the amount of ammonium carbonate was used as 0.1 g/100mL, the ethanol yield was significantly increased by 1.07 times (from 4.10% to 4.40%, Figure 6, p<0.05) than the non-optimized amount of ammonium carbonate (0.2 g/100mL). Fermentation medium containing 0.1g of ammonium carbonate yielded significantly higher ethanol production than the other concentrations except for 0.2 g/100 mL. Higher concentration of nitrogen sources may inhibit the growth of yeast in the fermentation

medium and this will lead to a decrease in the ethanol production. Hence 0.1 g/100mL of nitrogen source (ammonium carbonate) in the fermentation media was chosen for further studies.

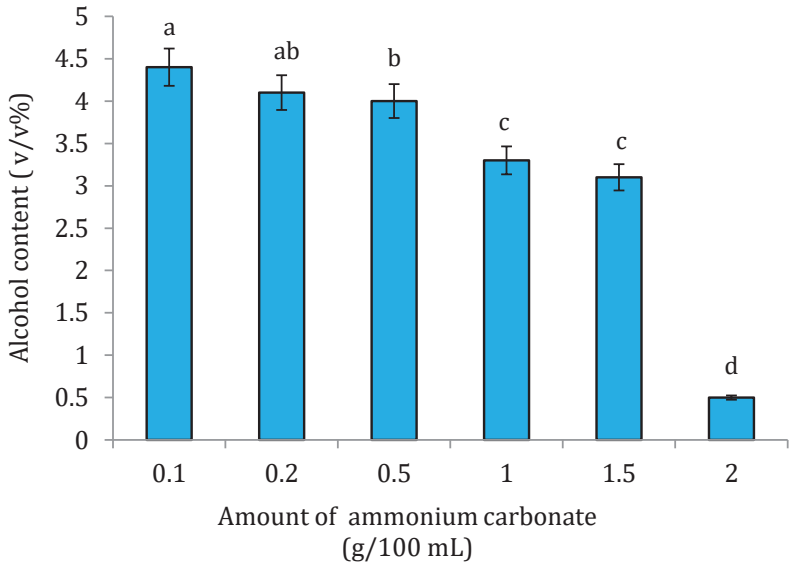

Figure 6: Effect of different amounts of nitrogen sources on bioethanol production from banana fruit juice using *Saccharomyces cerevisiae.* Different alphabets show the significant differences between the mean values.

Effect of carbon source

When different carbon sources such as glucose, sucrose, maltose, and dextrose (2 g/100mL) were separately added in the media setups, significantly higher ethanol production (4.80%, $p<0.05$) was obtained in the medium containing sucrose (Figure 7) than the other media. Sucrose was the best among the carbon sources used for bioethanol production and it may be due to its ability to make the yeast cells develop a foam surface for efficient fermentation than the other carbon sources. Hence sucrose was chosen as the carbon source for further studies.

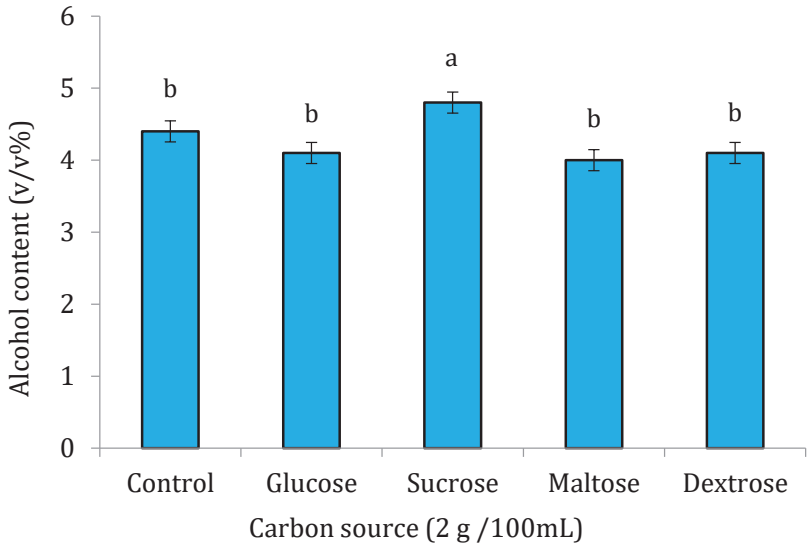

Figure 7: Effect of different carbon sources on bioethanol production from banana fruit juice using *Saccharomyces cerevisiae*. Different alphabets show the significant differences between the mean values.

Effect of amount of carbon source (sucrose)

When the amount of sucrose in the media was optimized as 15 g/100mL, the ethanol yield was significantly increased by 2.33 times (from 4.80% to 11.20%, $p<0.05$) than the non-optimized amount 2 g/100mL (Figure 8). An increase in the concentration of sucrose increases the rate of anaerobic respiration in the yeast cells. An increase in substrate availability allows more cells to use up the substrate for respiration, thereby increasing the amount of its by-product CO_2, High concentration of ethanol is toxic to yeast and it can retard the rate of cell respiration in yeast, or even lead to cell death. Higher concentrations of sucrose in the fermentation media might lead to decrease in the bioethanol production. Hence 15 g/100mL of sucrose in the fermentation media was chosen for further studies.

Effect of pH of the medium

When the pH of the media was kept at6.0, ethanol yield was significantly increased by 1.13 times (from 11.20% to 12.60%, $p<0.05$) than the non-optimized control pH 7.0 (Figure 9). The management of pH has a direct influence on the growth of microorganisms used for fermentation process and co-jointly on their cellular processes (Kasemets *et al*., 2007; Pirselove

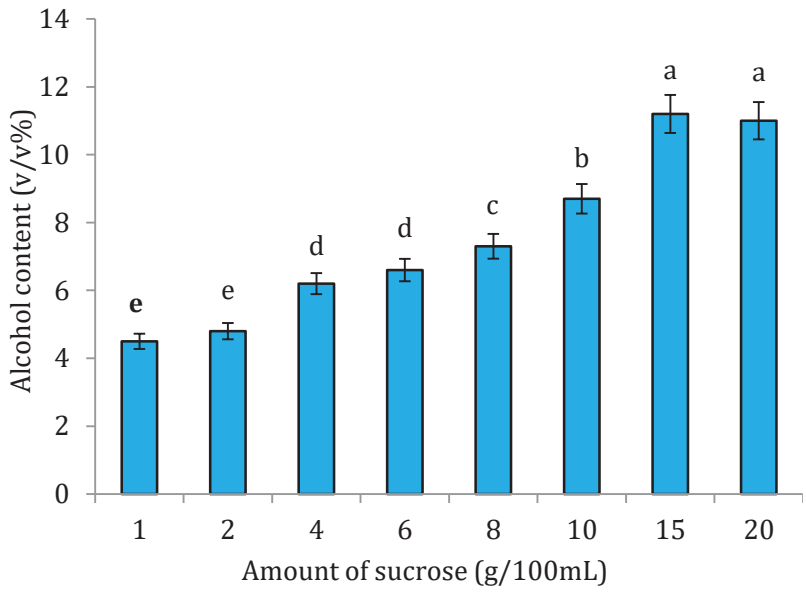

Figure 8: Effect of amount of carbon sources used in the fermentation media on bioethanol production from banana fruit juice using *Saccharomyces cerevisiae.* Different alphabets show significant differences between the mean values.

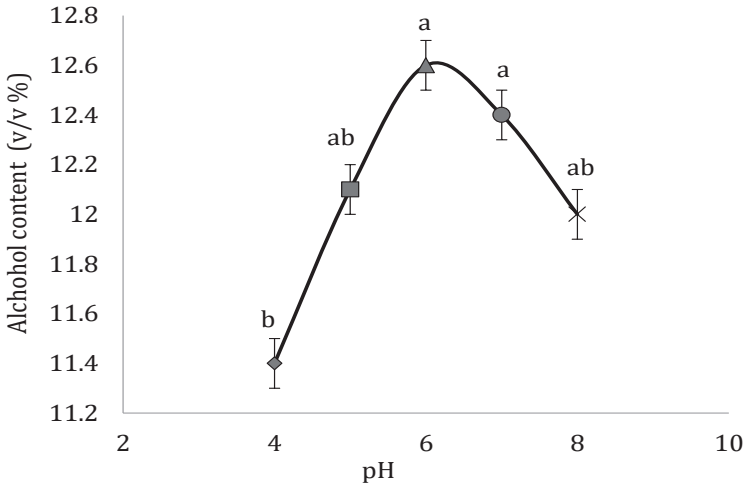

Figure 9: Effect of different pH on bioethanol production from banana fruit juice using *Saccharomyces cerevisiae*. Different alphabets show significant differences between the mean values.

et al., 1993). The H^+ concentrations in fermentation broth will be ready to amendment the entire charge of plasma membrane so moving the porosity of some essential nutrients into the cells. Once fermentation medium becomes more acidic, the fermentation rate conjointly will increase. This might ensue to enzymes made by yeast to ferment aldohexose and these enzymes might need custom made to acidic conditions. Yeast cells are more tolerant to acidic conditions than basic conditions. The organic and inorganic chemicals employed in the media may be responsible for the change in the pH of the media due to the different ions released. Hence pH of the fermentation media was chosen as 6.0 for further studies.

Effect of incubation period

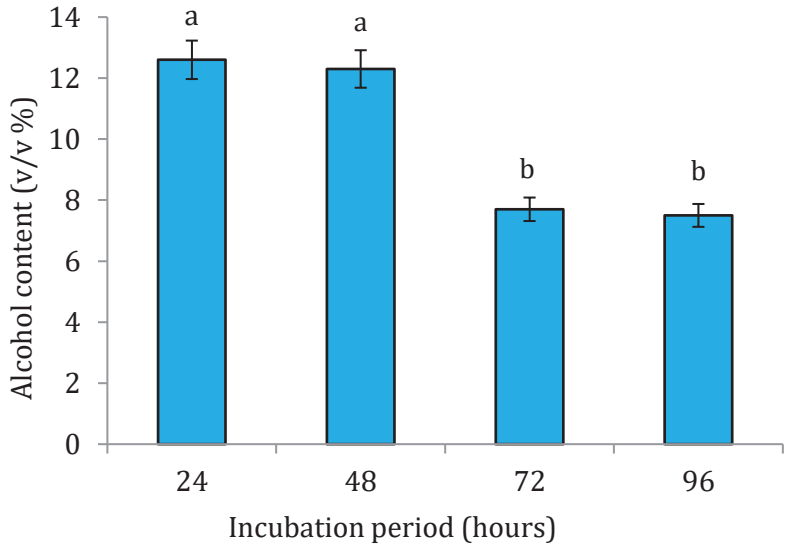

Figure 10: Effect of different incubation periods on bioethanol production from banana fruit juice using *Saccharomyces cerevisiae.* Different alphabets show significant differences between the mean values.

The bioethanol production after 24, 48, 72 and 96 hours of fermentation were 12.6%, 12.3%, 7.7% and 7.5% respectively (Figure 10). Since there was no significant difference in the alcohol yield between the different incubation periods of the media, it was decided to use 24 h as the incubation period for future experiments. Short fermentation time causes inadequate growth of microorganisms within the fermentation media that ends up in inefficient fermentation. Long fermentation time causes toxic

impact on microorganisms growth particularly in batch fermentation due to the presence of a higher concentration of ethanol in the fermented broth (Asmamaw *et al*., 22014; Hossain *et al*., 2011; Nadir *et al*., 2009).

CONCLUSIONS

The *Musa sapientum* (sour) banana juice is an effective substrate for ethanol production using yeast. After optimization of carbon and nitrogen sources, culture conditions, and media composition, the bioethanol yield was significantly increased (15.75 times, from 0.8% to 12.60%) than the non-optimized conditions. Large scale fermentation study should be carried out in order to determine whether this finding could be commercialized.

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DECLARATION OF CONFLICT OF INTEREST

Authors have no conflict of interest to declare.

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Formulation of organic liquid fertilizers and their effects on germination of selected seeds and growth and yield of chilli (*Capsicum frutescens* L.)

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Abstract

The present study was aimed to formulate organic liquid fertilizers using banana pseudostem and to assess their potential use in the germination of selected seeds (i.e., chilli, curry chilli, lettuce, and water spinach), and growth and yield of chilli (*Capsicum frutescens* L.), in combination with either organic (cattle manure - CM) or inorganic fertilizers (IF). The formulations were banana pseudostem extract with decomposed solution (banana formulation- BF) and banana pseudostem extract with 2% Panchagavya (BP). The nutrient content (NPK) of formulations were analyzed. In the germination test, control (distilled water T1) was compared with BF (T2) and BP (T3). The pot experiment was conducted in a complete randomized design with six treatments and four replicates. The treatments were T1 (100% IF), T2 (100% CM), T3 (50% IF + 50% BF), T4 (50% CM + 50% BF), T5 (50% IF + 50% BP) and T6 (50% CM + 50% BP). The liquid formulations were applied at the rate of 250 Lha^{-1}. Growth

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parameters namely the number of leaves per plant, plant height and yield were measured. Results of nutrient analysis of formulations indicate that BF had 365 ppm N, 1320 ppm P, and 8097 ppm K, while BP had 601 ppm N, 1930 ppm P, and 8619 ppm K. The results indicated that the highest germination percentage was recorded in T2 (BF) in all selected seeds. Vigour index was higher in T2 (BF) and T3 (BP) treatments than in the control. Significant differences among treatments in plant height of chilli were only observed at the second and sixth week. However, the number of leaves showed significant differences during the second, fourth and sixth weeks. Among the treatments, the highest yield was recorded in T6. Moreover, all foliar treatments T3, T4, T5, and T6 performed better than T1.

Keywords: banana formulation, banana pseudostem extract, *Capsicum frutescens*, Panchagavya

INTRODUCTION

The current farming system mostly depends on chemical fertilizers, which may negatively affect soil health, soil organisms, environment, and human health. The Sri Lankan government spends almost US$ 13,200 for the importation of inorganic fertilizer (Central Bank of Sri Lanka, 2020). In the present agricultural system, improving crop production on a sustainable basis is a quite challenging issue. To address this problem, integrated nutrient management is an attractive alternative where organic and inorganic nutrients are applied in combination to get ecological as well as economic benefits in farming systems (Gruhn *et al*., 2000).

The availability of organic fertilizers is very limited in the local market. However, the organic sources (i.e., plant residues and animal wastes) are abundantly available in the environment. With increasing environmental awareness, agricultural wastes can be used for efficient conversion into biomaterials. Using fresh animal waste as fertilizer may cause undesirable effects because it can damage the plants and environment (Millner *et al*., 2014). Therefore, it is advisable to add partially decomposed waste in the form of decomposed solution and Panchagavya. It has been reported that decomposed solution of cow dung and cow urine was an effective nutrient source when used in combination with other organic sources (Thamilini *et al.*, 2020).

Another waste material that is underutilized in Sri Lanka is banana Pseudostem. Banana is one of the important tropical fruit crops widely grown all-around the country. The banana tree is a non-seasonal crop and their cultivated extent in Sri Lanka is around 45,497 ha (Department of Census and Statistics, 2017). In addition to the banana fruit, a large volume of biomass in the form of pseudostem is generated as waste. Banana pseudostem consists of macronutrients, micronutrients, and growth hormones such as cytokinin and gibberellins (Kolambe *et al.*, 2013). Using pseudostem, products like fibre, fabrics, paper, organic liquid fertilizer, candy, vermi-compost, etc., have been developed in other countries, especially in India (Mohapatra *et al*., 2010). In the northern region of Sri Lanka where banana is commonly cultivated, however, the pseudostem is underutilized. Currently the challenges faced by the farmers and households is the disposal of pseudostem. Huge amount of pseudostems are dumped in roadsides, which leads to environmental problems. As banana pseudostem is rich in macro and micronutrients, it can be incorporated to enhance the quality of organic fertilizer.

Meanwhile, Panchagavya comprises five products obtained from cow, namely dung, urine, milk, curd, and ghee. When the above five bovine products are reasonably blended and utilized, these have an inexplicable positive influence on crops (Swaminathan *et al.*, 2007). Panchagavya plays a vital role in organic agriculture. It consists of almost all the macronutrients, micronutrients, and growth hormones, and also numerous kinds of microorganisms which would help to improve soil quality (Maheshwari *et al*., 2007). The use of these organic inputs can be helpful to obtain higher nutrient content and uptake by crop and good soil health for the subsequent crops.

Foliar fertilization provides benefits when absorption by the plant root is not to the required level, or soil nutrient level is less than the optimum for plant growth. Foliar application is also recommended when soil pH is either highly acidic or alkaline which limits the nutrient uptake by roots, high weed invasion, or nematode infestation. Foliar application is also useful as a preventive method to avoid nutrient deficiencies, especially, micronutrients by using a minute amount of fertilizer (Patil *et al*., 2010). In addition, it is also possible to combine fertilizers with other agrochemicals which could reduce the cost of application (Oosterhuis, 2009).

The importance of organic fertilizers has long been realized, however, very few research has been conducted in Sri Lanka to study the usage

of different underutilized nutrient sources. In Sri Lanka, a strong move towards organic farming has been taken. However, the availability of organic fertilizers is not adequately available in the market. Therefore, it is important to find alternative organic sources of nutrients and fertilizer products. Though banana pseudostem, has high potential as a nutrient source, no study has been reported in Sri Lanka regarding this. Therefore, this experimental study was conducted at the Department of Agricultural Chemistry, Faculty of Agriculture, University of Jaffna to formulate different types of liquid fertilizers using Banana pseudostem extract, panchagavya, and decomposed solution and compare their effects on the performance of chilli (*Capsicum frutescens* L.). Chilli was selected as a test crop because it is one of the important cash crops grown in Sri Lanka. It is a main spice yielding plant and belongs to the family Solanaceae. It is a valuable and important spice in our daily diet. Though the potential yield of green chilli is approximately 12-15 t/ha, the national average yield is only 4.74 t/ha in 2015 (Department of Agriculture, 2015). The overall objective of this study was to assess the suitability of banana pseudostem sap enriched formulations in enhancing crop productivity and role as an organic fertilizer. The specific objectives were

- to assess the nutrient composition of banana pseudostem sap, decomposed solution, and panchagavya.
- to formulate the organic liquid fertilizer in combination with different levels of banana pseudostem sap, decomposed solution, and panchagavya solution.
- to study the efficiency of liquid fertilizer formulation in germination of selected seeds.
- to assess the efficiency of different levels of formulated liquid fertilizer on the growth and yield of green chilli.

MATERIALS AND METHODS

Study location

This study was conducted at the Faculty of Agriculture, University of Jaffna, Kilinochchi from January 2020 to July 2020. The pot experiment was conducted in the net house of the JICA training farm. Laboratory analysis was carried out at the Department of Agricultural Chemistry, Faculty of Agriculture, University of Jaffna.

The raw materials used for liquid fertilizer were banana pseudostem, cow dung, cow urine and panchagavya solution. Banana pseudostems were collected from farmer's field at Inuvil. Fresh cow dung and cow urine were collected from the Animal Farm, Faculty of Agriculture, University of Jaffna.

Two organic liquid fertilizers were prepared namely Banana formulation and Banana pseudostem extract with 2% Panchagavya. The banana formulation was prepared by using banana pseudostem extract and decomposed solution.

Preparation of banana pseudostem extract

About 75 cm of pseudostem was cut from a bottom part of the banana tree (variety: *Itharai*) after the harvest of the bunch. It was cleaned using a cloth to remove dirt materials on the surface. Blades and the inner core of the pseudostem were separated carefully. They were chopped into small pieces by using stainless steel liquidizer and strained through a clean muslin cloth to obtain the extract. During this process, from 100 grams of chopped outer blade banana pseudostem, 75 mL of extract was obtained, while from 100 grams of chopped inner core banana pseudostem 90 mL of extract was obtained. Outer blade banana pseudostem extract and inner core extract were mixed in one is to one ratio. This extract was considered as 100% level. The extract was diluted according to the treatments.

Preparation of banana formulation

Ten kilograms of fresh cow dung and 500 mL of cow urine were taken and it was mixed with ten liter of water (Thamilini *et al.*, 2020). This mixture was allowed to decompose for two weeks, filtered and preserved in refrigerator.

Ten liters of banana formulation was prepared by mixing 2 L of decomposed solution, 650 mL banana pseudostem extract, and 7.35 L of water. One liter of the banana formulation was prepared by mixing 200 mL of the above decomposed solution, 65 mL banana pseudostem extract, and 735 mL of water.

During the preparation of banana pseudostem extract with 2% Panchagavya formulation, 2% of panchagavya solution was replaced for decomposed solution of above mentioned banana formulation. Two

milliliters of panchagavya solution was diluted with 98 mL of distilled water. One liter of banana pseudostem extract with 2% Panchagavya solution was prepared by mixing 200 mL of diluted panchagavya solution, 65 mL banana pseudostem extract, and 735 mL of water.

Chemical analysis of raw materials

Nutrient contents such as N, P, and K were analyzed for making a liquid fertilizer mix recipe. Total nitrogen was estimated by Kjeldhal method, as explained by Haluschak (2006). Phosphorus content was determined by Vanadomolybdate method as described by Kalra (1971), and potassium content was measured by using flame photometer as described by Kalra (1971).

Efficiency of liquid fertilizer in germination of different seeds

Three different treatments were applied to four different seeds to assess the efficiency of fertilizer formulation of organic sources in germination. In the germination test, control (distilled water T1) was compared with BF (T2) and BP (T3). Table 1 shows the treatment schedule for soaking.

Table 1: Treatment schedule for soaking

Seed name	30 SW (mg)	100 SW (mg)	Volume needed (mL)
Lettuce	32.20	107.33	3.22
Green chilli	170.00	566.67	1.70
Water spinach	1410.40	4701.33	1.41
Curry chilli	193.00	643.33	1.93
Sugar graze	1210.00	4033.33	1.21

SW- Seeds weight

Thirty seeds were soaked in different fertilizer formulations for 3 hours. Seeds were soaked in 1/10 times volume of seed's weight (Arancon *et al.,* 2012). Thereafter selected seeds (curry chilli, lettuce, green chilli) were placed in filter paper on petric dish and other type of seeds (water spinach) was placed on pots with sand. The day onward growth parameters including the percentage of germination, seedling height were measured.

Vigour index value was calculated using the following formula proposed by Abdul-Baki and Anderson (1973).

Vigour index = Germination (%) x Total seedling length (cm)

Preparation of pots

Black polythene bags were used as pots and ten kilograms of air-dried, sieved (<2 mm) soil was added to each pot. According to the treatment schedule, inorganic fertilizers were mixed with the topsoil one day prior to transplanting. Organic Fertilizer (Cow manure) was applied two weeks before transplanting. The pots were labeled according to the number of treatments and number of replicates. *Capsicum frutescens* L. KA-2 (Karadhiyan Aru-2) variety was used as a test crop. One seedling was transplanted in each pot.

Treatments and experimental design

The experiment was arranged in a completely randomized design with four replicates. Six different treatments were applied to pots. Table 2 shows the treatment schedule.

Table 2: Treatments in experiment

Treatment number	Fertilizer formulation
T1	100% IF
T2	100% CM
T3	50% IF + 50% BF
T4	50% CM + 50% BF
T5	50% IF + 50% BP
T6	50% CM + 50% BP

BF: Banana formulation BP: Banana extract + 2% Panchagavya CM-Cattle manure IF-Inorganic fertilizer

For organic treatments cow manure was applied to the soil at the rate of 10 tons/ha. For inorganic treatments, fertilizers were applied according to the department of agriculture recommended rates. Urea (475 kg/ ha) at top dressing was applied in four splits at 2, 4, 8, 12 weeks after planting. MOP at the rate of 50 kg/ha was applied with the third top dressing (Department of Agriculture, 2015). Table 3 shows the amount of fertilizers applied to a pot. The liquid fertilizer formulations were applied as foliar spray at every two weeks at the rate of 250 liters/ha (Salunkhe *et al*., 2013).

Table 3: Inorganic Fertilizer Recommendation

	Urea	TSP	MOP
Basal	-	2.700 g	1.350 g
Top dressing 100% (Per pot)			
2 WAP	3.375 g	-	-
4 WAP	2.565 g	-	-
8 WAP	3.645 g	-	1.350 g
12 WAP	3.240 g	-	-
Top dressing 50% (Per pot)			
2 WAP	1.688 g	-	
4 WAP	1.283 g	-	
8 WAP	1.823 g	-	0.675 g
12 WAP	1.620 g	-	

WAP – Weeks After Planting, TSP - Triple Super Phosphate, MOP - Muriate of Potash

Data collection and statistical analysis

Plant height and leaf number per plant were recorded every two weeks. In each treatment height of four plants was recorded in two weeks intervals. Measurements were made from ground level to extreme growing tip using a meter scale. The matured pods were harvested from the 17th of April to 7th of July at 10 - 14 days intervals. Harvested pods were measured separately as per treatments. An electronic scale balance was used to

measure the weight of harvested pod of each pot. After 180 days plants were uprooted and final fresh and dry weights were quantified. The data were statistically analyzed using a statistical analytical system (University version) and Duncan's multiple range test was used to compare means at significance level of 0.05.

RESULTS AND DISCUSSION

Physico chemical properties of soil

Collected soil had 6.77 pH, sandy clay loam in texture and was non-saline (EC: 67.37 **µ**S/cm). The organic matter content of the soil was 0.82% and the bulk density was 1.55 g/cm^3. Soil has 25 ppm of available nitrogen, 31.8 ppm of available phosphorus, and 61.3 ppm of available potassium.

Nutrient content of raw materials and formulations

Table 4: Nutrient content of raw materials and organic fertilizer formulations

	Nitrogen	Phosphorus	Potassium
Banana pseudostem extract	3600 ppm	450 ppm	9696 ppm
Panchagavya	7500 ppm	2976 ppm	7576 ppm
Decomposed solution	1025 ppm	4899 ppm	4445 ppm
Cattle manure	2770 ppm	24010 ppm	4862 ppm
Banana Formulation	365 ppm	1320 ppm	8097 ppm
Banana sap with 2% Panchagavya	601 ppm	1930 ppm	8619 ppm

Table 4 displays the total nutrients available in raw materials and total nutrient availability in organic liquid fertilizer formulations. Panchagavya

had the highest N content (7500 ppm) while the lowest was recorded in decomposed solution (1025 ppm). The highest and lowest P was observed in cattle manure (24010 ppm) and banana pseudostem extract (450 ppm), respectively. On the other hand, the highest K was found in banana pseudostem extract. The decomposed solution had the lowest K (4445 ppm). Table 4 shows that the BP formulation had comparatively much higher N and P content than BF, however, both formulations had similar P contents.

Germination test and vigour index

Figure1 displays the effect of different organic liquid fertilizer formulations on the germination of selected seeds. Among all seeds, the highest germination percentage was recorded in T2 (Banana Formulation). In water spinach T2 (Banana Formulation) and T3 (Banana pseudostem extract with 2% Panchagavya) were higher in germination than T1 (Control). In Lettuce T2 (Banana Formulation) had the highest germination percentage among the treatments. In chilli and curry chilli, T2 (Banana Formulation) was higher in germination than T1 (Control).

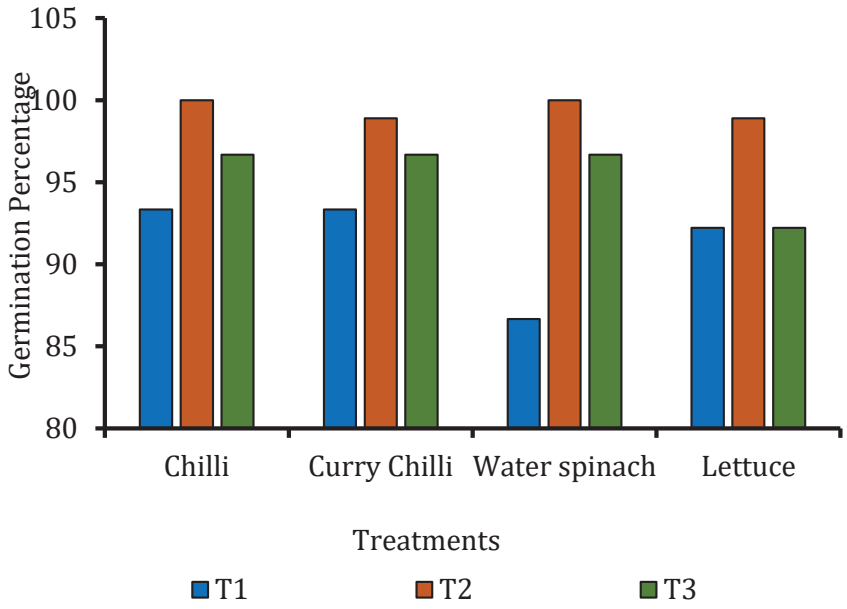

Figure 1: Germination percentage of selected seeds. T1-Control, T2-Banana Formulation, T3-Banana pseudo stem extract with 2% Panchagavya.

Organic liquid fertilizers (Cow dung slurry, Banana pseudostem sap) contain macro and micro-nutrients and growth promoting substances like Indole Acetic Acid (IAA), Giberrilic Acid (GA), etc. These growth hormones help in the germination of seeds and improve cell growth (Natarajan, 2007). It was reported that application of enriched sap to the nursery of eggplant and chilli, advanced the seedlings to transplantable stage 8 to 9 days earlier than the control, however, when the sap was applied as foliar spray to the nursery, advancement was only 3 days (Kolambe *et al*., 2013). Figure 2 shows the effect of different organic liquid fertilizer formulations on the vigour index of selected seeds.

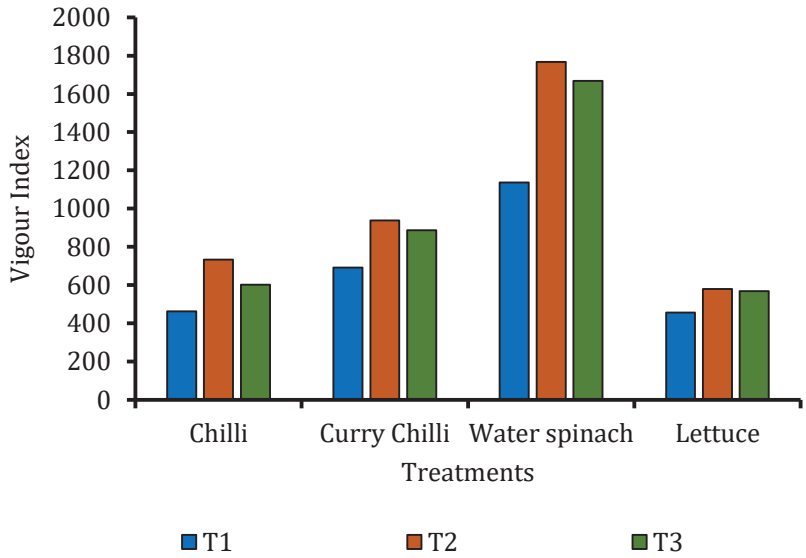

Figure 2: Vigour Index of selected seeds. T1- Control, T2 - Banana Formulation, T3 - Banana pseudo stem extract with 2% Panchagavya.

Vigour index in T2 (Banana formulation) was significantly higher than the other treatments in chilli and water spinach. In all seeds, vigour index of T2 (Banana formulation) and T3 (Banana pseudostem extract with 2% Panchagavya) were higher than T1 (control).

Growth parameters

Table 5 displays the effect of different organic liquid fertilizer formulations on plant height. At the second week after transplanting, the highest height

Table 5: Plant height with different treatments

Treatments	On transplanting	After 2 weeks	After 4 weeks	After 6 weeks	After 8 weeks	After 10 weeks
100% IF	8.50[a]	12.63[a]	26.20[a]	48.98[ab]	65.08[a]	72.40[a]
100%CM	7.50[a]	10.50[ab]	23.13[a]	47.95[ab]	70.23[a]	83.83[a]
50% IF+ 50%BF	7.95[a]	11.38[a]	23.50[a]	45.50[ab]	67.50[a]	80.68[a]
50%CM+ 50%BF	8.40[a]	7.75[b]	21.95[a]	41.00[b]	62.75[a]	83.83[a]
50% IF+ 50%BP	7.63[a]	11.13[a]	22.75[a]	44.50[ab]	73.50[a]	86.98[a]
50%CM+50%BP	7.88[a]	9.63[ab]	22.25[a]	51.68[a]	70.60[a]	89.98[a]

IF - Inorganic fertilizer, CM-Cattle manure, BF-Banana Formulation, BP-Banana pseudostem extract with 2% Panchagavya. Means followed by the same letter in each column are not significantly different at the 5% level.

was recorded in T1 (100% IF), however, it was not significantly different with other treatments except T4 (50% CM + 50% BF). At 4th week after transplanting, there was no significant difference in height among the treatments. However, the height of T1 (100% IF) was higher than the other treatments. Six weeks after transplanting, the highest height was recorded in T6 (50% CM+50% BP) while the lowest in T4 (50% CM+50% BF). There were no significant differences in height between T1 (100% IF), T2 (100% CM), T3 (50% IF + 50% BF) and T5 (50% IF + 50% BP). At eighth and tenth weeks after transplanting there was no any significant difference in plant height among the treatments.

According to Misal *et al.* (2015), the application of two sprays of banana pseudostem enriched sap (2%) increased the plant height in fenugreek compared to no sap application. The noticeable influence of liquid organics on growth aspects of fenugreek might be due to their rapidly available form of nutrients, which are easily absorbed, leading to faster growth and development of fenugreek components. Salunkhe *et al.* (2013) reported that the application of banana pseudostem sap at 2000 L/ha through a micro-irrigation system to onion gave significantly higher plant height. However, in the present study, plant height was not significantly increased than fertilizer treatment, possibly due to the dilution of the extract.

Table 6: Number of leaves per plant with different treatments

Treatments	On transplanting day	After 6 weeks	After 4 weeks	After 6 weeks
100% IF	6[a]	15[a]	52[a]	157[a]
100% CM	6[a]	11[b]	41[b]	140[a]
50% IF+50% BF	6[a]	11[b]	38[b]	114[b]
50% CM+50% BF	6[a]	12[b]	43[b]	143[a]
50% IF+50% BP	6[a]	10[b]	36[b]	108[b]
50% CM+50% BP	6[a]	10[b]	40[b]	117[b]

IF - Inorganic fertilizer, CM-Cattle Manure, BF-Banana Formulation, BP-Banana pseudostem extract with 2% Panchagavya. Means followed by the same letter in each column are not significantly different at the 5% level.

Table 6 displays the effect of different organic liquid fertilizer formulations on the number of leaves per plant. The number of leaves per plant in T1 (100% IF) was significantly higher than other treatments until four weeks after transplanting. However, there was no any significant difference in the number of leaves per plant when transplanting.

Crop yield

The weight of green chilli was recorded in 7-14 days intervals. The crop yield of each treatment at different time interval is illustrated in Table 7. First harvesting was done after 100 days from transplanting. The yield of first harvest for a treatment ranged between 196 g (T4-50% CM + 50% BF) to 256 g (T2- 100% CM). The average Yield from T2 (100% CM) was significantly higher than other treatments. However, there was no any significant difference in yield among T3 (50% IF + 50% BF), T5 (50% IF + 50% BP) and T6 (50% CM + 50% BP). All other treatments, except T4 (50% CM + 50% BF) gave a significantly higher yield than T1 (100% IF).

In the second picking, no significant difference was observed in yield among the treatments. T5 (50% IF +50% BP) had the highest yield (220 g) compared to all other treatments. The lowest yield (100 g) was obtained from T3 (50% IF + 50% BF). In third picking, the highest and lowest yield were obtained from T6 (50% CM + 50% BP) and T2 (T2- 100% CM) respectively. The yield of T6 (50% CM + 50% BP) was significantly higher than other treatments. There was no significant difference in yield among T1 (100% Inorganic) T3 (50% IF + 50% BF) T4 (50% CM + 50% BF) and T5 (50% Inorganic + 50% BP). The yield of T2 (100% CM) treatment had the lowest yield from third picking. However, the yield of T5 (50% IF + 50% BP) and T1 (100% IF) were significantly higher than T2 (100% CM).

In the fourth picking, the yield from T5 (50% IF +50% BP) was significantly higher than the yield from T1 (100% IF). Yield ranged from 58 g (T1 -100% IF) to 280 g (T5- 50% IF +50% BP). The yield of foliar applied treatments was higher than the yield of T1 (100% IF). In fifth picking, the highest yield and lowest yield were obtained from T6 (50% CM + 50% BP) and T1 (100% IF) respectively. Yield ranged from 18.5 g (T1- 100% IF) to 231 g (T6-50% CM + 50% BP). There was no significant difference in yield among T1 (100% IF), T2 (100% CM), and T3 (50% IF + 50% BF). However, the yield from all these three treatments (T1, T2, and T3) were significantly lower than the T6 (50% CM + 50% BP).

Table 7: Weight of green chilli pods in different pickings

Treatments	First picking	Second picking	Third picking	Fourth picking	Fifth picking	Sixth picking
100% IF	50.75±1.35^{c}	27.50±15.55^{a}	18.50±9.95^{b}	14.50±9.00^{b}	4.63±4.61^{b}	7.12±7.23^{c}
100% CM	64.00±1.35^{a}	42.50±22.17^{a}	10.45±0.42^{c}	21.25±26.31^{ab}	7.50±2.80^{b}	18.12±4.93^{bc}
50% IF+ 50% BF	57.50±1.61^{b}	25.00±19.15^{a}	16.50±1.29^{bc}	29.25±1.50^{ab}	18.00±15.71^{b}	23.30±3.12^{b}
50% CM+ 50% BF	49.00±4.43^{d}	41.25±15.48^{a}	13.75±4.79^{bc}	37.00±0.65^{ab}	38.75±17.35^{ab}	40.44±1.16^{a}
50% IF+ 50% BP	50.75±1.00^{b}	55.00±20.41^{a}	18.75±1.90^{b}	70.00±68.43^{a}	38.75±34.01^{ab}	9.88±7.27^{c}
50% CM+ 50% BP	55.725±2.03^{b}	42.50±33.04^{a}	39.00±1.31^{a}	57.00±34.05^{ab}	57.75±40.03^{a}	17.99±15.55^{bc}

Means with the same letter within a given column are not significantly different at the 5% level.

In the sixth picking, yield ranged from 28.47 g (T1- 100% IF) to 161.75 g (T4- 50% CM + 50% BF). Yield from T4 (50% CM + 50% BF) was significantly higher than all other treatments. However, there was no significant difference in yield among T1 (IF), T3 (50% IF + 50% BF) and T5 (50% CM + 50% BP). Total yield from T6 (50% CM + 50% BP) was significantly higher than T1 (100% Inorganic), T2 (100% CM) and T3 (50% Inorganic + 50% BF). The yield of T4 (50% CM + 50% BF) and T5 (50% Inorganic + 50% BP) were higher than T1 (100% Inorganic), however, a significant difference was not observed. Total yield for the treatments ranged from 491.97 g (T1- 100% Inorganic) to 1079.87 g (T6- 50% CM + 50% BP). The total yield variation is shown in Figure 9. It is interesting to note that total yield was higher in T6 (50% CM + 50% BP) than the T1 (100% Inorganic). However, the vegetative parameters were high in T1 (100% Inorganic). Through the foliar application of organic liquid fertilizers, plants utilized the maximum amount of macro and micronutrients. Nutrient leaching losses are also less in foliar application compared to the soil application (Fageria *et al*., 2009).

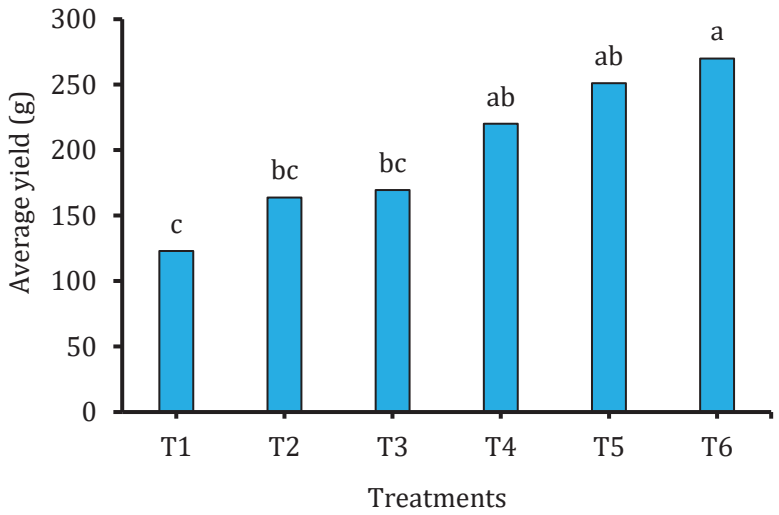

Figure 3: Total yield of chilli. T1- 100% IF, T2- 100% CM, T3- 50% IF + 50% BF, T4- 50% CM + 50% BF, T5- 50% IF +50% BP, T6- 50% CM + 50% BP. Means with the same letter within a given treatment are not significantly different at p= 0.05.

Organic formulations used in this study consist higher amount of phosphorus and potassium. It has been reported that phosphorus enhances the synthesis and translocation of carbohydrates, roots development and growth. Phosphorus induces earliness in flowering and fruiting including seed formation (Brady and Weil, 2008). In addition, the application of higher amount of K increased vitamin C content in chilli (Mary and Balakrishnan, 1990). Fruit weight of pomegranate was significantly increased in treatments applied with enriched banana pseudostem sap at 1% (Rathod *et al*., 2017) which was possibly due to the higher nitrogen and potassium in the sap improved the metabolic process enhanced the growth. In the same study, 1% enriched banana pseudostem sap reported significantly lower fruit drop (16.22%), early harvesting, highest fruits/plant, fruit set percentage, percentage fruit retention, and fruit yield. Similar findings of higher yield were reported in garlic (Patil *et al.*, 2014). In another study in chilli foliar application of a novel organic liquid fertilizer at 2% gave the highest fruit weight (Deore *et al*., 2010). Liquid organic manures contain macro and micro-nutrients, many vitamins, essential amino acids, numerable microorganisms, and growth promoting substances like IAA, GA etc. (Natarajan, 2007) which could have contributed to the positive response in plants.

CONCLUSIONS

The results of the study revealed that the highest germination percentage was recorded in T2 (Banana Formulation), in selected seeds namely, chilli, curry chilli, water spinach, and lettuce. In water spinach T2 (Banana Formulation) and T3 (Banana pseudostem extract with 2% Panchagavya) showed a higher germination percentage than T1 (Control). In all the crops tested, the seedling vigour index of T2 (Banana Formulation) and T3 (Banana pseudostem extract with 2% Panchagavya) were higher than the control. Considering both germination percentage and seedling vigour, T2 is the best treatment to enhance seedling quality. Among six different fertilizer treatments, the highest total yield was recorded in T6 (50% CM + 50% Banana pseudostem extract with 2% Panchagavya), which was significantly higher than T1 (100% IF), T2 (100% CM), and T3 (50% IF + 50% BF). Moreover, all foliar sprayed treatments T3 (50% IF + 50% BF), T4 (50% CM + 50% BF), T5 (50% IF + 50% BP) and T6 (50% CM + 50% BP) performed equal or better than T1 (100% IF). By substituting 50% of inorganic fertilizer with enriched Banana formulation, yield of chilli was increased by 46%. This study has verified that the quality organic liquid fertilizer can be produced from Banana pseudostem sap with decomposed

solution and panchagavya. The use of organic liquid fertilizer helps to decrease the inorganic fertilizer usage without affecting the yield of chilli.

DECLARATION OF CONFLICT OF INTEREST

Authors have no conflict of interest to declare.

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Development of jackfruit (*Artocarpus heterophyllus*) bulb and seed flour-based pasta

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Abstract

Jackfruit (*Artocarpus heterophyllus*) is one of the major edible foodstuffs rich in carbohydrates and fiber. This study investigated the reduction of postharvest losses of jackfruits by value addition. Jack fruit seeds (JFS) flour and Jackfruit bulbs (JFB) flour were used as raw material. JFB and JFS were subjected to mechanical drying, grinding and sieving (particle size <200µm) to yield the JFS flour and JFB flour. The composite flour consists of different ratio of JFS, JFB, and cassava flour (CF), corn flour and semolina. The proximate composition, physical properties and cooking characteristics of developed pasta were determined. Sensory attributes of the pasta were evaluated using Hedonic scale (7-points) with 36 semi-trained panelists. The best composite flour formulation was JFS: JFB: semolina: CF: corn flour, at the ratio of 40:40:10:5:5. Crude protein (13.26±0.18%), crude fiber (4.91±0.61%) and ash (3.35±0.04%) were

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higher in the best selected composite flour than the other treatments. Carbohydrate content (71.28%) was the lowest in T3 formulation. However, there was no significant difference ($p>0.05$) in moisture content among the treatments, whereas, hardness and water activity differed significantly ($p<0.05$) among the treatments. The best selected formulation exhibited higher water absorption (1.20±0.02 g/g) and cooking time (8.6±0.2 min) than the other treatments while cooking loss (13.3±0.4%) was lower than the other treatments except the control. Lightness value of pasta was decreased with increasing the amount of JFS and JFB flour. In conclusion, value added jackfruit flour pasta has a higher potential for commercialization as a convenient food for the consumers with busy lifestyles.

Keywords: cassava, composite flour, convenient food, jackfruit seed, pasta

INTRODUCTION

Jackfruit tree (*Artocarpus heterophyllus*) belonging to genus Artocarpus is a well-known perennial tree in Sri Lanka (Boning, 2006; Peiris, 2015). The tree originated in India and is commonly known as "*Kos*" (Sinhala) and "*Pala*" (Tamil) in Sri Lanka (Prakash *et al*., 2009). Edible parts of jackfruit tree consist of immature, mature and ripe fruits. Jack fruit is one of the popular staples during scarcity of food in Sri Lanka (Ranasinghe *et al.*, 2019). Mature fruit is the largest tree-borne fruit, having up to 35 kg weight, 90 cm length, and 50 cm diameter (Nair *et al.,* 2017). The fruit contains a large number of fleshy bulbs, spikes and seeds which is covered by the fleshy white cotyledon (Ranasinghe *et al*., 2019).

Jackfruit is a good source of digestible carbohydrate (bulb-10%, seeds - 22%), vitamin A and protein (1.6%) (Hettiaratchi *et al*., 2011). The fiber content of immature and ripe jackfruit is 2.6% and 0.8%, respectively (Ranasinghe *et al.,* 2019). Jackfruit meal has low glycaemic index (GI) due to presence of higher fiber content, slowly available glucose, intact starch granules in seeds and influence of different sources of carbohydrates (Hettiaratchi *et al*., 2011). Further, jackfruit is rich in minerals, bioactive phytochemicals, polyphenols, carotenoids, flavonoids and it is devoid of saturated fats and cholesterol (Nair *et al.,* 2017; Swathi *et al., 2019*). According to Priya Devi *et al*, (2014), 100g of jackfruit contains potassium (107 mg), calcium (20 mg), phosphorous (41 mg), iron (0.56 mg), β-carotene (175 mg), thiamine (0.03 mg), riboflavin (0.13 mg), niacin (0.40 mg) and vitamin

C (7 mg). Antimicrobial, anti-diabetic, anti-inflammatory and antioxidant properties were also reported by Waghmare *et al*. (2019). Jackfruit is also having a chemical "Jacalin" which is useful in preventing colon cancer, AIDS etc. (Waghmare *et al*., 2019).

Utilization of jack fruits has gained only little attention during the past decades. Jackfruits are abundant during the season and substantial postharvest losses are experienced. At present, there is a higher consumer preference and demand for value added convenient food products. Therefore, the value-added products of jackfruit would be a good source of income for the industry as well as a nutritional meal for the people. Therefore, this study was designed to evaluate the potential of producing value added food products using the jackfruit. For this purpose, some other plant raw materials such as CF, corn flour and semolina were selected.

Cassava (*Manihot esculenta* Crantz) is one of the most cultivated and consumed plants after maize, rice and wheat in the world (Mombo *et al*., 2016). The root of cassava is composed of 85- 90% of carbohydrate, 1 - 3% of crude protein and lesser content of vitamins and minerals (Stupak *et al.,* 2006). Several medicinal properties in cassava due to presence of different phytochemicals were reported (Zekarias *et al*., 2019). In Sri Lanka, surplus cassava is available during the season. Therefore, utilization of cassava also benefits the farmers. Hard durum winter wheat is used to make semolina. Semolina contains high protein content and possesses favorable cooking quality. Thus, the presence of semolina as an ingredient in pasta is responsible for better appearance with smooth clear surface, high resistance to breakage, flexible and dry finished product. Corn starch, a thickening agent improves the textural quality of pasta and prevents stickiness and reduces the cooking loss (Fuad and Prabhasankar, 2010).

Pasta is an extruded dough product of Italian style food similar to spaghetti. The demand for pasta is increasing because of the convenience for cooking, palatability and extended shelf life (Nilusha *et al*., 2019). The World Health Organization (WHO) and Food and Drug Administration (FDA) identified pasta as a suitable vehicle for incorporation of nutrient supplements (Chillo *et al.,* 2008). Pasta enrichment with minerals, vitamins, fiber provides additional health benefits to the consumers. Despite the availability and nutritional benefits of jackfruit, the consumer products of jackfruit available in the market are limited. Therefore, the objectives of this study were to formulate composite flour mixtures using

JFS: JFB: semolina: CF: corn flour, to produce jackfruit flour based pasta and to minimize the postharvest losses of jackfruits during the season.

MATERIALS AND METHODS

Sample collection

Mature jack fruits (cultivar *Waraka*) were collected without damage from the fruit from Peradeniya, Sri Lanka, while cassava roots were collected from the open market in Kandy, Sri Lanka.

Preparation of flour samples

Jackfruit bulbs and jackfruit seeds were separated from mature jackfruits by removing the surrounding hard outer layer and fleshy white bulbs. The cotyledons of the seeds were separated and washed thoroughly. JFB, JFS and cassava roots were blanched in boiling water for 8 minutes and drained. The blanched samples were cut into small pieces and dehydrated in a hot air circulation tray dryer (Model No. stdq-2, China) at 55 ^{o}C for 6 hours. Subsequently, JFB flour, JFS flour, and CF were ground and sieved to receive uniform particle size (ASTM E11:87, mesh No 50 for 300µm). The ground flour samples were packed in high-density polyethylene (HDPE, 300 gauge) bags and stored at ambient temperature (28±2 ^{o}C).

Production of pasta

Initially experimental trials were conducted using JFS, JFB (*Madullu*) flour and CF formulations using the pasta machine (Pasta maker DOLLY-La Monferrina, Italy). The JFB:JFS flour ratio of 1:1 was selected based on the results of the pre-trials. Further experiments were conducted using four composite flour formulations of JFS:JFB:CF: corn starch: semolina, as treatments, T1 - 30:30:10:10:20, T2 - 35:35:7.5:7.5:15, T3 - 40:40:5:5:10, T4 - 35:35:0:0:30 and the control (0:0:0:0:100). Egg, salt and water were added into the flour mixture and all the ingredients were mixed in the extruder properly. Then pasta was made by extruding through a selected molding disk (for shape) in the extruder. The pasta was collected from the extruder and steamed for 10 minutes. The steamed pasta was dehydrated using the tray dryer (Model No. stdq-2, China) at 50 C for 3 hours. Finally, the samples of jackfruit pasta were air cooled, packed in HDPE (300 gauge) bags and stored at the ambient temperature (28±2 ^{o}C) for further experiments.

Sensory evaluation

Sensory evaluation of developed pasta samples was conducted using Hedonic scale (1-extremely dislike, 7-extremely like), with a panel of 36 semi-trained panelists on colour, aroma, taste, texture, and overall acceptability. The collected data was analyzed by non-parametric analysis, Friedman test using MNITAB (version 17).

Figure 1. Pasta produced from the composite flour formulations.

Ratio of JFS flour: JFB flour: semolina: CF: corn flour. Treatment 1. T1- 30:30:20:10:10, Treatment 2. T2 - 35:35:15:7.5:7.5, Treatment 3. T3 - 40:40:10:5:5, Treatment 4. T4 - 35:35:30:0:0, and the control - 0:0:0:0:100.

Determination of proximate composition

Moisture content (MC), crude protein (CP), crude fat (CF), crude fiber (CFb) and ash contents of different treatments were determined using the methodology, AOAC 934.01, 984.13, 920.39, 962.09 and 942.05, respectively (AOAC, 2006). Total carbohydrate content was calculated using formula 1 (FAO, 2003).

Total carbohydrate (%) = [100 – (moisture + crude protein + fat + crude fiber + ash)] (1)

Determination of hardness, water activity and colour

Hardness: Hardness of the pasta samples was determined using a texture analyzer (SHIMADZU EZ-X series) under compression mode with a sharp cutting blade probe. The peak force at the point the cutting blade snaps the piece of pasta under compression was measured as the fracture force in N.

Water activity: Water activity of the pasta samples was measured using the water activity meter (Hydrolack3 ROTHRONIC).

Colour: Colour of the pasta samples was measured using a colorimeter (CS-10, China). Colour measurement was expressed as lightness (L*), a* and b* values.

Determination of cooking characteristics

Water absorption

Water absorption is the amount of water absorbed by the pasta during cooking. Water absorption was determined using the method described by Ojure and Quadri's (2012) with minor modifications. Pasta (50 g) was cooked, rinsed with water and drained. Then weighted the cooked pasta sample and calculated the water absorption (g/g) using the formula (2).

$$\text{Water absorption } \left(\frac{\text{g}}{\text{g}}\right) = \frac{(\text{Final weight} - \text{Initial weight})}{\text{Initial weight}} \qquad (2)$$

Cooking time

A sample of pasta (10 g) was cooked in a covered glass beaker with 300 mL of boiling water. Cooking time was measured when the pasta in the center of container became transparent or fully hydrated (Ojure and Quadri, 2012).

Cooking loss

Cooking loss of the pasta samples was determined using the method described by Ojure and Quadri (2012) with minor modifications. A pasta sample (10 g) was cooked in 300 mL of boiling water. The dissolved solid content of the pasta sample during cooking was determined by evaporating the cooking water without pieces of pasta using oven dry method at 100 °C. Weight of the dried residue was measured and cooking loss (%) was determined using the formula (3).

$$\text{Cooking loss (\%)} = \frac{\text{Weight of dried residue in cooking water (g)}}{\text{Initial weightt of pasta (g)}} \text{ X } 100 \quad (3)$$

Statistical analysis

One-way Analysis of Variance (ANOVA) was used to determine significant differences ($p \geq 0.05$) between the treatments of the parametric data, and means separation was done using the Tukey test using Minitab 17 Statistical Software. Data of the sensory evaluation were analyzed by non-parametric Friedman test. Means separation was conducted using Wilcoxon Signed Ranks Test using SPSS Statistics 20 Software. All the data were expressed as the mean of three independent measurements as mean± standard deviation.

RESULTS AND DISCUSSION

Sensory evaluation

Pasta produced using the formulation T3 (40:40:10:5:5, JFS:JFB :semolina:CF:corn flour) was scored the highest mean score for all the sensory attributes (Figure 2). The highest ratio (40 %) of JFS and JFB flour was in the T-3 composite flour mixture, thus consumer preference of pasta was scored as the highest for all sensory attributes. In a similar study on

noodles, Kumari *et al*. (2018) reported the sensory scores were increased while adding JFS flour in flour formulation for noodles. However, there was no significant difference ($p>0.05$) between the pasta produced from T3 and T2 treatment formulations with respect to flavour and aroma. Treatment formulation T1 was scored for the least means for texture, aroma and overall acceptability (Figure 2). This indicates that as lower percentages (30 %) of JFS flour and JFB flour decreases the consumer preference over the sensory attributes of pasta. The control past sample without JFB and JFS flour was scored the lowest mean scores for colour and flavor. The incorporation of JSF flour and JFB flour has improved the colour and flavour of pasta. Treatment -3 formulation was significantly different ($p<0.05$) from the other treatments in terms of colour, texture and overall acceptability. There was a significant difference ($p<0.05$) for overall acceptability of treatments T3 and T2 with the other three formulations (T1, T4 and the control). Similarly, there was a significant difference ($p<0.05$) for flavour in-between both T3 and T2 verses T1, T4 and the control. The best formulation, T3 was selected based on the nonparametric statistical analysis of mean scores of the sensory panel.

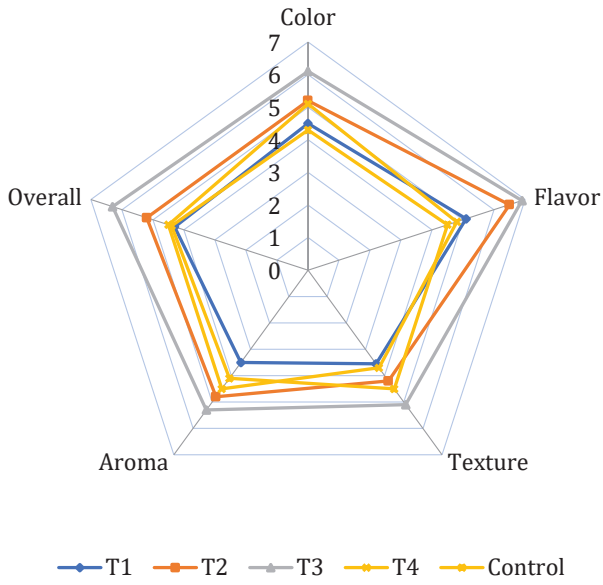

Figure 2: Mean scores of sensory attributes of jackfruit flour based pasta.

Proximate composition

The proximate composition of developed pasta formulations is given in Table 1. The best selected composite formulation-T3 possessed the highest quantity of jackfruit seed and bulb flour. Therefore, the highest percentages of crude protein, crude fiber, and ash were determined, and the values were significantly different ($p<0.05$) compared to the other treatments. Hettiaratchi *et al*. (2011) reported that a considerable amount of protein, fiber and minerals are present in jackfruit bulbs and seeds. Thus, higher contents of protein, dietary fiber and ash were determined in pasta developed from composite formulation of treatment 3 than the other treatments. The lowest percentages of crude protein and crude fiber were measured in pasta developed using treatment 1 (T1) formulation because of the lowest percentage of JFB and JFS flour (60 %) in the formulation. There was no significant difference ($p>0.05$) in moisture content among the pasta samples of all treatments except the control sample. Moisture content of the control pasta sample was the highest and significantly different ($p>0.05$) against the treatment formulations. Protein and ash content was increased significantly while incorporation of JFS flour, however moisture content of pasta was not significantly different ($p \leq 0.05$) (Waghmare *et al*., 2019).

Carbohydrate content was reduced by 5.39%, 6.16%, 8.13% and 5.35% in T1, T2, T3 and T4, respectively, compared to the control sample. The reason was that JFS flour and JFB flour contain lesser quantities of carbohydrate compared to semolina. Therefore, the highest amount of carbohydrates was determined in the control sample. Similar observation was reported on carbohydrate content of jackfruit seed flour incorporated biscuit formulation (Islam *et al.,* 2015).

Hardness, water activity and colour of pasta

Hardness is an important parameter of pasta for both the processors and the consumers. Harder or tougher the pasta, mouth feel during the bite or eating is not preferred by the consumers. Disintegration and breakages of pasta during packaging and distribution is comparatively high in pasta with softer or lesser hardness (Kumari *et al.,* 2017). The hardness and water activity values of pasta formulations are given in Table 2. The lowest hardness value and water activity were measured in the control sample due to the lowest protein content while hardness and water activity values were not significantly different ($p<0.05$) in jackfruit flour

Table 1: Proximate composition of pasta developed using composite flour formulations

Treatment	Moisture content (w/w)%	ash (w/w)%	Crude protein (w/w)%	Crude Fat (w/w)%	Crude fiber (w/w)%	Carbohydrate*
T1	6.04±0.05^{b}	3.02±0.24^{ab}	11.90±0.21^{b}	1.52±0.02^{b}	3.50±0.28^{b}	74.02
T2	5.76±0.01^{b}	3.19±0.05^{ab}	12.40±0.14^{b}	1.30±0.01^{c}	4.10±0.28^{ab}	73.25
T3	5.99±0.04^{b}	3.35±0.04^{a}	13.26±0.18^{a}	1.21±0.02^{c}	4.91±0.61^{a}	71.28
T4	5.43±0.71^{b}	2.79±0.06^{b}	12.25±0.07^{b}	1.72±0.03^{a}	3.75±0.21^{b}	74.06
Control	7.65±0.26^{a}	0.62±0.03^{c}	9.86±0.18^{c}	1.04±0.04^{d}	1.42±0.05^{b}	79.41

Values with same letters within a column are not significantly different at p> 0.05., n= 3.

* Obtained from subtraction method

Table 2: Hardness, water activity, cooking time, cooking loss and water absorption values of developed pasta

Treatment	Hardness (N)	Water activity	Cooking time (minutes)	Cooking loss (%)	Water absorption (g/g)
T1	64.50±3.25^{a}	0.57±0.01^{a}	8.10±0.07^{b}	15.04±0.17^{a}	1.10±0.07^{a}
T2	63.29±5.93^{a}	0.53±0.00^{ab}	8.32±0.10^{ab}	14.31±0.28^{ab}	1.08±0.01^{a}
T3	68.60±4.30^{a}	0.55±0.01^{ab}	8.65±0.18^{a}	13.25±0.35^{b}	1.20±0.02^{a}
T4	51.81±6.84^{ab}	0.53±0.01^{ab}	8.40±0.14^{ab}	14.58±0.31^{a}	1.12±0.07^{a}
Control	39.40±2.51^{b}	0.52±0.02^{b}	7.11±0.14^{c}	11.31±0.15^{c}	0.90±0.02^{b}

Values with same letters within a column are not significantly different at p> 0.05., n = 3.

incorporated pasta samples. The highest hardness value, 68.60±4.30 N was reported from T3 formulation with 80 % JFS and JFB flours and the highest among the four treatments. Thus, T3 contains the highest amount of protein and performs the highest hardness value. Kumari *et al*. (2017) reported flour protein content has a positive correlation with hardness in noodles. Therefore, a similar trend, a positive correlation with hardness of pasta against protein content of JFS and JFB flour content was observed. Pasta developed from T4 with 70% jackfruit flour possessed the lowest hardness value (51.81±6.84 N) among treatment formulations and not significantly different ($p>0.05$) among the treatments T1, T2 and T3 samples.

Noodle was produced using JFB and JFS flour with good firmness quality because of higher protein and fiber contents in jackfruits bulb flour (Kumari *et al*., 2017). In our experiment on pasta using JFS and JFB flour was also performed the similar result. The best textural quality and hardness was yielded from 80 % of JFB:JFS, 1:1 formulation.

Lightness ('L' value), yellowness ('b' value) and 'a' values of pasta formulations are given in Figure 3. There was no significant difference ($p>0.05$) among the jackfruit flour incorporated samples for the 'L' value. However, the control sample possessed the highest lightness value and significantly different from jackfruit flour incorporated pasta samples. Lightness value of pasta was decreasing by increasing JFS and JFB flour. The reason was higher protein content JFS and JFB flour subjected to a browning reaction during drying of pasta. Thus, lightness value was decreased. T1 formulation with the lowest JFB flour (30 %) and JFS flour (30 %) possessed the highest lightness value among four composite flour treatments. A similar observation, a negative correlation of brightness of noodle versus flour protein content was reported by Kumari *et al*. (2017). Therefore, addition of jackfruit flour in composite flour formulation is a limitation due to reduction of lightness compared to the control. Lightness of pasta can be a visual perception or preference of pasta by the consumers compared to the ordinary pasta available in the market. Higher protein content in jackfruit flour and bulb flour is responsible for such colour changes.

There was a significant difference ($p<0.05$) of 'a' and 'b' colour values among the pasta samples. Yellowness was increased by increasing JFS and JFB flour because of carotenoid pigments in JFB flour. Carotenoids are the main compounds that contribute to the yellow color of jackfruits (Yi *et al.,* 2016).

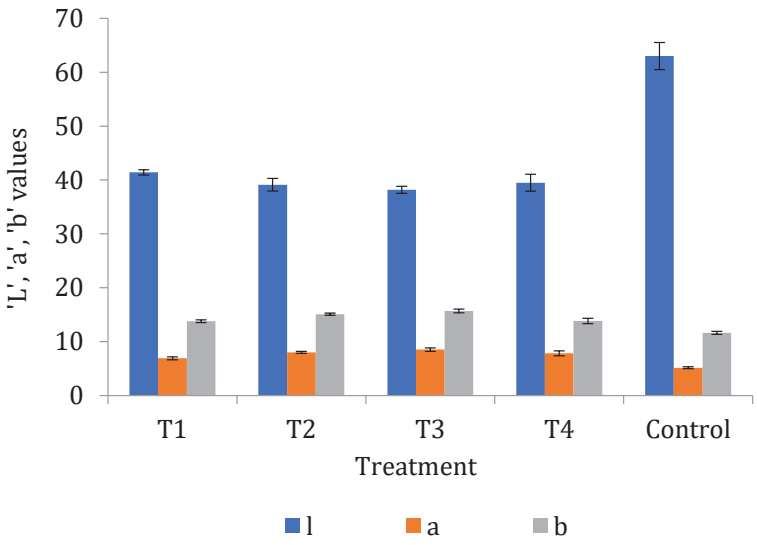

Figure 3: Lightness ('L' value), yellowness ('b' value) and 'a' value of Jackfruit pasta

Cooking characteristics of pasta

The cooking characteristics of the developed four pasta formulations are given in Table 2. There was a significant difference ($p<0.05$) on cooking time and cooking loss among the treatments (Table 2). The highest cooking time, 8.65±0.18 minutes, was measured in pasta (Treatment T3) with the highest percentage of JFB and JFS flours. The gelatinization efficiency reduces due to higher amount of fiber in higher content of JFB and JFS flour, added composite formulation and resulted in a lengthy cooking time (Kumari *et al.*, 2017). Leached out pasta particles quantity to the cooking water is represented by cooking loss value. The lowest cooking loss value was measured in T3 treatment, while the highest measured in T1 treatment with the lowest quantity of JFB and JFS flour. Availability of a substantial amount of fiber in JFB flour and protein in JFS flour is the reason to reduce the cooking loss of pasta produced from T3 formulation. Therefore, a negative relationship in-between the quantity of JFS and JFB flour verses cooking loss was evident from the experiments. The control with semolina possesses the lowest cooking loss value than all four treatments due to lower contents of fiber and protein in semolina than the pasta developed using other four composite flour formulations.

There was no significant difference ($p>0.05$) among jackfruit flour incorporated treatment samples for water absorption (Table 2). However, T3 formulation shows the highest water absorption value than T1, T2 and T4. Control sample possessed the lowest water absorption value than all the treatment samples. JFS flour has a good water holding and binding ability (Abraham and Jayamuthunagai, 2014). The water absorption of pasta is determined by the openness in the gluten structure of pasta (Sun-Waterhouse *et al*., 2013).

CONCLUSIONS

Development of composite flour formulations using JFB and JFS flour was successful and the composite flour formulation treatment 3 (T3), consists with JFS flour: JFB flour: semolina: CF: corn flour, 40:40:10:5:5, was selected as the best composite flour for jack fruit based pasta production. The best formulation was further tested and confirmed as the most suitable formulation using proximate composition, physical properties, cooking characteristics and consumer acceptability test. T3 formulation contains comparatively higher nutrient content and consumer acceptability than other formulations. The developed JFS and JFB composite pasta formulation has a higher commercial potential for mass scale production as a convenient food for the consumers with busy lifestyles in the urban areas.

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DECLARATION OF CONFLICT OF INTEREST

Authors have no conflict of interest to declare

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WHO. 2015. Eliminating *trans* fats in Europe: A policy brief. http://www.euro.who.int/__data/assets/pdf_file/0010/288442/Eliminating-trans-fats-in-Europe-A-policy-brief.pdf. Accessed January 30 2021

Abbreviations and symbols
Unless common, these should be defined when first used, and not included in the abstract. The SI system of units should be used wherever possible. If measurements were made in units other than SI, the data should be reported in the same units followed by SI units in brackets. E.g. 5290 ft (1610 m)

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