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EVALUATION OF GROWTH AND YIELD PERFORMANCES OF NAPIER GRASS CULTIVAR PAKCHONG-1 UNDER DIFFERENT SPACIAL PATTERNS IN THE KILINOCHCHI DISTRICT, SRI LANKA

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ABSTRACT

Inadequacy of quality forage production is a major limiting factor for dairy production in the Sri Lankan dry zone. Napier grass cv Pakchong-1 (Pennisetum purpureum x Pennisetum glaucum) is a tropical grass with fast-growing and high yielding ability. The study aims to determine the growth parameters and yield performance of Pakchong-1 grass under three different spacing of 30cm x 30cm, 90cm x 90cm and 120cm x 90cm in the Kilinochchi district, dry zone of Sri Lanka, from April 2019 to March 2020. A complete randomized design with three replicates was used in this study. Growth parameters were measured bi-weekly up to the 8th week and harvested the foliage after the 8th week in 56 days intervals. Plants at 30cm x 30cm spacing have shown the highest plant height of (153.00cm), the higher number of leaves (93.67), longer leaf length (95.33cm), wider leaf width (3.82cm)and higher leaves per tiller (11.33) at 8 weeks after planting (P<0.05). While the highest (P<0.05) the number of tillers (10.00) was recorded at 120cm× 90cm spacing. Fresh matter yields were highest (P<0.05) at 30cm x 30cm spacing in all cutting frequencies. The second cutting at the 14th week has shown the highest fresh matter yield(P<0.05) in all spacing. Pakchong – 1 can be suggested for the Sri Lankan dry zone regions at 30cm x 30cm spacing to provide the highest fresh matter output and optimal growth performance.

Keywords: Dry Matter, Growth parameters, Kilinochchi district, Pakchong-1 (Pennisetum purpureum × Pennisetumglaucum)

INTRODUCTION

Successful forage production is one of the crucial factors for any ruminant production. Still, some problems need to be addressed concerning the feed for livestock in Sri Lanka(Pushparajah and Sinniah, 2018a). Especially, the availability of forage crop fields amongst all other agricultural fields as farmers so concerned about the cultivation of cereals and industrial crops (Gnanagobal and Sinniah, 2018). One of the reasons for the lesser dairy productivity of livestock in Sri Lanka could be the lack of quality forages and their availability. Feeding with good quality and adequate quantity of green fodder materials for dairy animals is essential to maximize milk production(Premaratne and Premalal, 2006).

At present, the Sri Lanka dairy industry predominantly depends on forage materials from natural pasture fields and fodder collected from on the roadside, mountain slopes, tank banks, uncultivated public and private lands. Only a handful of farmers turned to grow quality pasture and fodder solely for their dairy animals in Sri Lanka. Lack of availability, accessibility of quality improved pasture, fodder and availability of cultivable lands for pasture and fodder are some of the major constraints prevailing in dairy production of Sri Lanka.

Inadequate quality forage and the lower availability of forage materials is the critical limiting factor for livestock production in many developing countries. The introduction of high yielding forages will overcome these problems. King Napier Grass (P. purpureum X P.americanum) is a well known perennial forage crop, having a higher growth rate, higher green matter productivity and desirable nutritive value. The development of new hybrid Napier grasses is undergoing to increase its agronomic performance suiting the demand of high performing dairy cows. One such hybrid Napier grass cultivar is Pakchong– 1, which was developed by crossing P.purpureum and P. glaucum in Thailand.

Pakchong–1 showed a faster growth rate, resulting in a higher yield with an elevated Phosphorus content to adopt a wide range of environmental conditions. Until this time, very little research has been done in Pakchong – 1 in Sri Lanka and very

little data are available for Pakchong – 1 cultivation in the northern regions of Sri Lanka. Moreover, yield, digestibility and nutrient composition must be taken into consideration for selecting forage species. Therefore, this study was developed to investigate the performances of growth and yield of Pakchong-1 under selected three different plant spacing in the Kilinochchi district, the northern part of Sri Lanka.

METHODOLOGY

This experiment was carried out at the Faculty of Technology, University of Jaffna, Ariviyal Nagar, Kilinochchi from April 2019 to March 2020. This area lies in the dry zone of Sri Lanka and the latitudinal and the longitude coordinates of the field location are 9031'40" N and 80039'82" E respectively. The soil type is red yellow latosol.

The field experiment was carried out using a randomized complete block design (RCBD) with the selected three plant spacings of 30cm×30cm, 90cm×90cm and 120cm× 90cm that commonly farmers practised in this region. Each treatment was replicated three times. Pakchong – 1 cuttings were obtained from the Livestock and Poultry Farm, Department of Animal Science, Faculty of Agriculture, Ariviyal Nagar, Kilinochchi. Single nodal cuttings were planted per planting hole and irrigation was done at weekly intervals. After 30 days of planting manual weeding was done

From each plot randomly three plants avaoiding the border lines of the experiment plots were selected at the field for taking measurements. The number of tillers per clump, the total number of leaves, number of leaves per tiller, length of the standard leaf of a tiller and its width and basal stem diameter were recorded at weekly intervals from two weeks after planting. After 60 days of planting plants were cut at 15cm from ground level and ratoon crop was maintained.

Immediately after harvesting the fresh weight of forage, was taken using a spring balance. Harvested fresh forage (2kg of the sample) from each plot were allowed to be air-dried for 24 hours. Then the air-dried samples were allowed to be oven-dried at 75oC for 72 hours to obtain a constant dry matter weight. Similarly, the harvested forage yield was obtained at 60 days intervals between the 2nd, 3rd, 4th and 5th harvests and the fresh matter yield was calculated nearly calendar cycle.

Data were analyzed statistically using the statistical software SAS 9.1.3. Mean separation was done using Duncan's multiple ranges test with a p-value of <0.05.

RESULTS AND DISCUSSION

Growth characteristics

The effects of row spacing and on plant height, number of leaves per plant, leaf length & leaf width of a standard leaf on the tiller, tiller number and diameter and leaf number per tiller are presented in Table 1, Table 2, Table 3, Table 4 and Table 5 respectively per plant at 14 days,28 days, 42 days and 56 days after planting.

For plant height followed the order 30cm × 30cm > 90cm × 90cm > 120cm × 90cm row spacing, while number of leaves and standard leaf with for the spacing 30cm × 30cm greater than for 90cm × 90cm and 120cm × 90cm spacing ($P<0.05$). Row spacing had significant effects on plant height, number of leaves per plant, leaf length & leaf width of a standard leaf on the tiller, tiller number and diameter and leaf number per tiller with reduced spacing ($P<0.05$).

Reduced row spacing had a significant effect on number of leaves/tiller (30cm × 30cm > 90cm × 90cm > 120cm × 90cm, $P<0.05$) and leaves/plant (30cm × 30cm > 90cm × 90cm > 120cm × 90cm, $P<0.05$.According to table 1 the height of the Pakchong -1 was higher ($P<0.05$) in the 90cm× 90cm spacing at the 14 daysafter planting but by the 56 daysafter planting the height at 30cm×30cm spacing was the highest ($P<0.05$). The results obtained by (Wangchuk et al., 2015) indicated that the height at 60 days after planting was 218 cm. The difference may be due to the climatic conditions prevailing in the areas.

Table 2 presents the number of leaves per plant at different spacing on at 14 days,28 days, 42 days and56 days after planting.The highest number of leaves per plant was obtained for 30cm × 30cm at 56 days after planting in respect to the other two spacing. A field study(Samarawickrama et al., 2018)in Peradeniyaat the 42 days after planting reported a lower number of leaves (51) with different spacing. The leaves count per plant are very important as the leaves have a higher nutritive value than the stem (Sarmini and Premaratne, 2017).

The average length of the Pakchong-1 was not different among the spacing at 28 days and 42 daysafter planting. The highest ($P<0.05$) leaf length was observed at the 56 daysafter planting for spacing 30cm × 30cm.Individual plant survival is influenced by large leave length within a sward. On the other hand, plant growth is also interpreted

by an increased leaf length of the plants. (Pushparajah and Sinniah, 2018b). In the present study the highest (P<0.05) leaf width was observed at 30cm × 30cm spacing at the 56 days after planting.

Table 5 presents the number of tillers per plant at 14 days,28 days, 42 days and56 daysafter planting. There is no significant difference between the spacing at 14 days but 28 daysand 42 days have a significant difference between the three spacing. The number of tillers at 120cm × 90cm was higher (P<0.05) at the 14 days,28 days, 42 days and56 daysafter planting. The number of tillers per clump observed in the current studyat 90cm × 90cmas per the values obtained by (Samarawickrama et al., 2018).

Table 1: Reasons for abandoning paddy farming

	Height of the Plant (cm)			
Spacing	14 days	28 days	42 days	56 days
30cm × 30cm	40.55±0.39^{b}	57.11±0.38^{b}	79.22±0.51^{a}	153.00±1.76^{a}
90cm × 90cm	42.11±0.77^{d}	57.11±0.84^{b}	75.56±1.35^{b}	143.56±1.35^{b}
120cm × 90cm	39.22±0.39^{b}	58.67±0.67^{a}	68.78±0.38^{c}	131.44±3.53^{c}

Means (Mean ± SD) in the same column followed by different superscripts differ significantly at P<0.05

Table 2: Effect of row spacing on the number of leaves per plant at 14 days,28 days, 42 days and56 days after planting.

	Number of leaves			
Spacing	14 days	28 days	42 days	56 days
30cm × 30cm	25.44±0.7^{a}	37.11±1.35^{a}	64.78±0.84^{a}	93.67±0.33^{a}
90cm × 90cm	25.97±0.95^{a}	37.78±2.17^{a}	62.67±2.00^{a}	89.00±1.73^{b}
120cm × 90cm	27.85±0.27^{a}	39.44±1.28^{a}	63.33±2.65^{a}	89.11±1.13^{b}

Means (Mean ± SD) in the same column followed by different superscripts differ significantly at P<0.05

Table 3: Effect of row spacing on leaf length at 14 days,28 days, 42 days and56 days after planting.

	Leaf length (cm)			
Spacing	14 days	28 days	42 days	56 days
30cm × 30cm	12.86±0.51^{b}	38.0±0.58^{a}	59.67±1.00^{a}	95.33±1.76^{a}
90cm × 90cm	14.02±0.43^{b}	37.56±0.19^{a}	59.33±1.15^{a}	90.78±0.51^{b}
120cm × 90cm	16.08±0.94^{a}	39.22±1.35^{a}	59.22±0.69^{a}	90.56±0.69^{b}

Means (Mean ± SD) in the same column followed by different superscripts differ significantly at P<0.05

Table 4: Effect of row spacing on leaf width at 14 days,28 days, 42 days and56 daysafter planting.

	Leaf width (cm)			
Spacing	14 days	28 days	42 days	56 days
30cm × 30cm	0.7±0.1^{b}	2.63±0.06^{a}	3.31±0.13^{a}	3.82±0.05^{a}
90cm × 90cm	1.17±0.15^{a}	2.61±0.07^{a}	3.30±0.06^{a}	3.52±0.04^{b}
120cm × 90cm	1.10±0.10^{a}	2.64±0.02^{a}	3.29±0.05^{a}	3.57±0.06^{b}

Means (Mean ± SD) in the same column followed by different superscripts differ significantly at P<0.05

Table 5: Effect of row spacing on the number of tillers per plantat 14 days,28 days, 42 days and 56 daysafter planting.

	Number of tillers per plant			
	14 days	28 days	42 days	56 days
30cm × 30cm	1.56±0.2^{a}	4.22±0.51^{c}	5.89±0.19^{c}	8.44±0.19^{b}
90cm × 90cm	1.53±0.35^{a}	4.67±0.33^{b}	6.89±0.39^{b}	8.56±0.19^{b}
120cm × 90cm	2.02±0.07^{a}	5.22±0.19^{a}	7.78±0.19^{a}	10.0±0.58^{a}

Means (Mean ± SD) in the same column followed by different superscripts differ significantly at P<0.05

Table 6: Effect of row spacing on leaves per tiller at 14 days,28 days, 42 days and 56 daysafter planting.

	Number of leaves per tiller			
Spacing	14 days	28 days	42 days	56 days
30cm × 30cm	3.33±0.58^{b}	9.11±1.35^{a}	11.22±0.38^{a}	11.33±0.33^{a}
90cm × 90cm	1.67±0.58^{c}	8.22±0.19^{a}	9.22±0.38^{b}	10.56±0.19^{b}
120cm × 90cm	5.0. ±0.00^{a}	7.78±0.19^{a}	8.33±0.33^{c}	9.11±0.69^{c}

Means (Mean ± SD) in the same column followed by different superscripts differ significantly at P<0.05

Forage yield production

The effects of row spacing on leaf and stem fresh matter yield production are presented in Table 7. Fresh matter yield at 3rd cutting was greater for Pak-chong-1 but declined sharply as the row space increased with the greatest effect for Pakchong-1 (P<0.05). Amongst the main effects, row spacing had a significant effect on fresh matter production (30cm × 30cm > 90cm × 90cm > 120cm × 90cm).

As complementary information, correlations between growth parameters are presented in Table 7. While fresh matter yield was positively correlated with plant height, tiller number, leaf number and width, plant height . On the other hand, fresh matter yield was negatively correlated with row spacing.

When considering the fresh matter yields, the highest yields were obtained at the third harvest for the 30cm × 30cm spacing.

Table 7: Effect of row spacing on fresh matter yield (ton/ha/year) at different cutting frequencies.

	Number of harvests				
Spacing	1	2	3	4	5
30cm × 30cm	63.00±2.00^{a}	89.33±2.52^{a}	107.33±2.52^{a}	85.67±1.53^{b}	71.33±1.53^{a}
90cm × 90cm	60.67±1.53^{a}	80.33±2.08^{b}	95.00±1.00^{b}	82.00±1.00^{ab}	71.33±1.53^{a}
120cm × 90cm	59.20±2.00^{a}	75.00±1.00^{b}	91.33±2.08^{b}	79.33±1.53^{c}	71.00±1.00^{a}

Means (Mean ± SD) in the same column followed by different superscripts differ significantly at P<0.05

Discussion

Plant height as a growth parameter is a result of elongation of the stem internodes, which is influenced by the environment as suggested by Hozumi et al. . In the current study, taller plants were observed with narrow spacing, which is in agreement with reports in the literature that narrower spacing will give taller plants as a result of competition for sunlight (Lamana M.C.L., 2003) . Taller plants led to narrower stem diameter as well.

Leaf development has been described extensively for fodders, as growth is mostly reflected in large increase in leaf length as plants grow to maturity, accompanied by relatively small increase in width and thickness (Skinner R.H. et al 1994). Large leave lengths are also important for the survival of individual plants within a sward (Barre P. et al 2015).

Significant reduction in dry matter yield with increasing plant spacing may be due to decreasing plant density with increasing spacing. In a study conducted at Kemptville Research Station, Canada (Ashraf T. et al 2014)., planting density had a significant effect on fresh and dry matter production and two higher densities had significantly higher production than the 2 lower densities for 3 sweet sorghum hybrids including Sugar graze.

Plant spacing has a marked impact on the efficiency of use of land, light, water and nutrients. By optimising plant spacing, highest yield potential can be achieved from the smallest possible area (Oseni T.O. et al 1986).

CONCLUSIONS

The study suggests that the growth parameters and yield of Pakchong-1 grass under three different spacing in the Kilinochchi district, dry zone of Sri Lanka showed that 30cm×30cm spacing has shown the highest (P<0.05) plant height of 153.00cm, higher number of leaves (93.67), longer leaf length of 95.33cm, wider leaf width of 3.82cm and higher leaves per tiller (11.33) at 56 days after planting. While the highest (P<0.05) the number of tillers (10.00) was recorded at 120cm× 90cm spacing. Fresh matter yields were highest (P<0.05) at 30cm× 30cm spacing in all cutting frequencies. The second cutting at the 98 days has shown the highest (P<0.05)fresh matter yield in all spacing. Thus, Pakchong – 1 can be recommended to dry zone of Sri Lanka at the spacing of 30cm×30cm to obtain a higher fresh matter yield and best growth performance.

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ANALYSIS OF THE PADDY CULTIVATION PATTERN IN GALLE AND MATARA DISTRICTS IN THE SOUTHERN PROVINCE OF SRI LANKA

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ABSTRACT

This study aims to determine the current trends of paddy cultivation in the Galle and Matara districts in the southern province of Sri Lanka. Moreover, constraining factors for paddy cultivation and the role of extension services to promote paddy farming are also analyzed. The required data was gathered from the field survey carried out using 400 farmers in Galle and Matara districts. The majority of paddy lands have single ownership in both districts while shallow and bog soil was dominant soil types in the paddy fields. Among the factors affecting paddy cultivation patterns, poor water drainage conditions and labor scarcity were the main reasons for the decreasing trend. Bog and shallow soil conditions of paddy lands have created the water drainage issue. The average cost of paddy farming in the Galle and Matara districts was Rs.39444 and Rs.39374 per acre respectively. The highest percentage of the cost is incurred for land preparation while the next highest cost is for paddy harvesting. The government farmer training programs were not sufficiently addressing the farmers' needs and did not contribute to increasing paddy farming in these districts. The frequency of farmer visits by advisory services was 2-3 visits per season, while farmers prefer to meet them at least once a week. Agrarian service centers and community-based organizations were the main farmer assistance services. Farmers expect government assistance mainly for the irrigation facilities to promote paddy farming in Galle and Matara districts.

Keywords: Advisory service, Cost of Production, Decreasing trend, Extension Services, Paddy farming

INTRODUCTION

Sri Lankan agricultural sector plays an important role in the rural economy despite the low GDP contribution compared to the service and industrial sectors. Since rice is the staple food of Sri Lanka providing half of the daily calorie requirement, and every government has given priority to the development of the paddy/rice industry at a national level. The land extent under paddy cultivation during the 2019 Yala season was 368,906 hectares, and the yield of paddy estimated for the 2019 Yala season was 4,896 Kg/ha. The largest extent of paddy cultivated in the Yala season was reported in Polonnaruwa district (61,624 hectares) which is 16.7% of the total extent of paddy cultivated in the country. The extent harvested during this season was estimated to be 346,010 hectares, and it is about 94% of the total cultivation. The highest average yield of 5,726 kg per hectare was reported during this season in the Hambantota district (Department of Census and Statistics, 2019). Among the total permanent agricultural land, 45 percent is used for paddy cultivation and the majority of the farmers (70%) are small landholders who are cultivating less than 1 ha (Wijetunga et al., 2008). Moreover, in the year 2019, the paddy sector contributes nearly 3.5 % of the GDP (CBSL, 2019). In the global context, rice is the second most widely grown cereal crop and the staple food for more than half the world's population. More than 3 billion people, the per capita consumption of rice is more than 100 kg per year. Rice is cultivated on 155.5 million ha with an average growth rate of 0.39% a year, in the last 30 years.

In the near future, the possibility for expanding areas under rice-based systems will remain very limited because of the scarcity of global water resources for agriculture. The expansion of urban and industrial sectors in Asia where land is already limited and the high costs of developing new lands that are suited for rice production in Sub-Saharan Africa and Latin America (Van Nguyen and Ferrero, 2006).

About 45% of total permanent agricultural land is utilized for paddy cultivation in Sri Lanka. Nevertheless, at present, the paddy sector is facing an unparalleled crisis due to the decreasing trend of

paddy farming. As cited by many studies, one of the core issues is the slimming down of the net returns of paddy farming due to the discriminatory price offered to the paddy producers at the paddy market (Gunawardene and Somarathna, 2001). According to Wijetunga et al. (2008), this has led some farmers to move away from paddy farming.

According to the aforementioned facts, the Government of Sri Lanka has introduced several policies and programs to increase paddy production. In the context of the southern province in Sri Lanka, Galle, Matara, and Hambantota districts are mainly cultivating paddy as their major economic crop. Since 2008, the paddy sown extent in Galle district shows a tremendous decline despite its paddy land extent due to various socio-economic and political reasons. Production in Galle and Matara was well up to average, with harvests estimated at 37 000 tons and 40 000 tons, respectively (FAO, 2014). Statistically, paddy cultivation in the Galle district was rapidly declining every year due to several obstacles faced by the farmers. According to the district agricultural committee report, in Galle district, there is a significant number of abandoned paddy lands in Galle district. According to that, increasing cost of production, poor prices of paddy, filling of paddy land for road development projects, and facing hardship for water drainage issues and poor irrigation facilities were identified as key constraining factors. Therefore, this study intends to analyze the present situation of paddy farmers in the Galle and Matara districts, the nature of paddy lands, cost of production and key cost component, and farmers' need assessment in terms of paddy cultivation. In addition, this research will contrast the research findings with the national data issued by the Socio-Economic and Planning Division, Department of Agriculture in the year 2019.

METHODOLOGY

Selection of farmers

All farmers in each Agrarian Service Center's (ASCs) division are registered in the Agrarian Services Department Office established. Agricultural Instructors of each division maintain a register of farmers with whom they have close contacts on paddy cultivation. In the project area of the Galle district, a list of 20 farmers was randomly obtained from the relevant 20 ASCs. In order to compare the farming practices and problems in the other areas of the same geographical area, 100 farmers from the Matara district were selected. A team of three graduate research students were trained in collecting data and information from farmers by interviewing.

Method of data collection

To collect data and information, it was investigated the prevailing problems of the farmers, and a questionnaire was designed and pre-tested for appropriateness. It was designed to obtain the following information.

a. Basic information of the farming system, general information about the farmer, size of the paddy field, farming experiences, soil characteristics of paddy field and nature of paddy land ownership,

b. Information on the constraining factors of paddy production, each cost component of the paddy cultivation, which includes the operations of land preparation, the establishment of paddy, cultural practices, harvesting of the crop, threshing, storage, processing, and marketing, including expenses and income,

c. Role of the Extension and Advisory Services in the paddy cultivation process and analysis the expectations of farmers from Extension and advisory services

Basic descriptive and inferential analytical tools were used to analyze the collected data.

RESULTS AND DISCUSSION

The following table summarizes the basic characteristics of the farming community of Galle and Matara Districts, representing farmers' age, farming experiences, size of paddy land and land extend of other cultivations.

According to Table 01, farmers have an average of 30 years of experience in farming in both districts. In addition, as obvious in many recent researches in the agriculture sector, farmers, aged over 50, have dominated in these two districts implying less youth involvement in paddy farming. Average paddy land belonging to the farmers was 2 acres of tea and cinnamon cultivations are other prominent cultivations in both districts.

Information related to paddy farming

According to the paddy land ownership, the majority of the farmers (84% & 85.06%) have the single owned ownership type. The second highest (21% & 21.27%) ownership type is the rental system and these two districts do not have Thattu maru and Katti maru ownership types. In the Katti Maru system, the specific land area is divided into no of farmers & they cultivate those land blocks

Table 1: General profile of the paddy farmers in Galle and Matara Districts

	Minimum		Maximum		Mean	
	Galle	Matara	Galle	Matara	Galle	Matara
Age (years)	29	30	90	85	58	59
Farming experiences (years)	4	4	40	40	30	35
Paddy land size (Acre)	2	1.3	3.5	2.2	2.15	1.9
Other land areas (Acre/farmer)						
Coconut	0	0.1	8	1.25	0.81	0.84
Rubber	0	01	3	2	1.13	0.65
Cinnamon	0	0.2	30	3	1.80	1.42
Vegetable	0	0.01	3	1.5	0.27	0.52
Tea	0	0.01	100	2	3.42	2.34

Source: Author's own data, 2019

with a seasonal rotation. In the Thattu Maru system, the specific whole land area cultivates by one farmer but the cultivation right will change year-wise with known farmers of that land area.

Furthermore, this research found that the last cultivations season and year were the year by the farmers in Galle and Matara District. According to the research findings, the last season of cultivation ranges from 1978 to 2017 in Galle District while ranging from 1969 to 2017 in Matara District. Accordingly, it seems that some land has been abandoned for more than 40 years. Many reasons are being affected for the paddy land abandoned in Galle districts. Therefore, the possible reasons for abandoning paddy lands were investigated.

According to the reason for abandoning paddy farming (Figure 01), the water drainage issue was the main reason in both Galle and Matara districts.

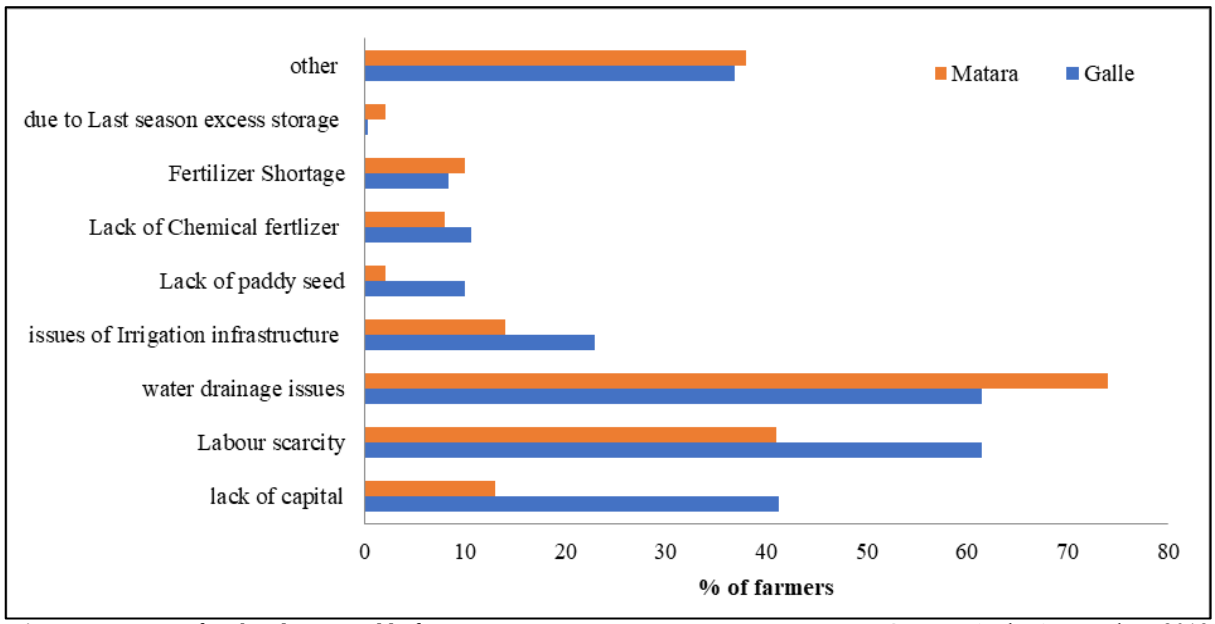

Figure 1: Reasons for abandoning paddy farming **Source:** Author's own data, 2019

However, these two districts showed labor scarcity as the second important reason for abandoning paddy farming. The lack of capital is another important reason in Galle district. The least affected reason for the abandonment of paddy lands in both districts was the availability of excess storage stored in the last season.

Constraints for paddy farming

Moreover, farmers of the study area were asked to prioritize the most affecting constraining factors for paddy farming in their area. Accordingly, poor water drainage condition was the most prominent constraining factor in the Galle district (at 1.33) (Figure 02). Lack of labor availability was the

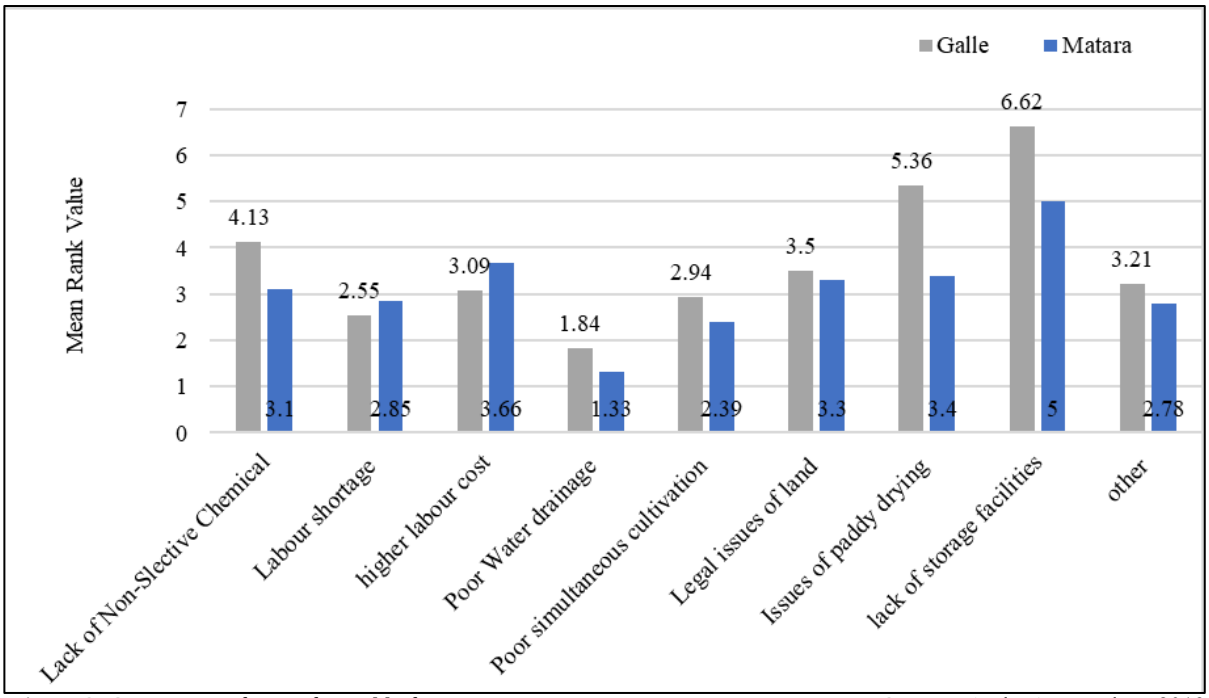

Figure 2: Constraining factors for paddy farming **Source:** Author's own data, 2019

second important constraining factor in Galle district. Second Matara district also showed the lowest mean rank value (1.84) for poor water drainage factor, implying that poor drainage condition is the main constraining factor for paddy farming. Further, lack or poor simultaneous practices have been recorded as the second important constraining factor in the Matara district (2.85).

Characteristics of paddy farming in Galle and Matara district

Soil types in paddy field

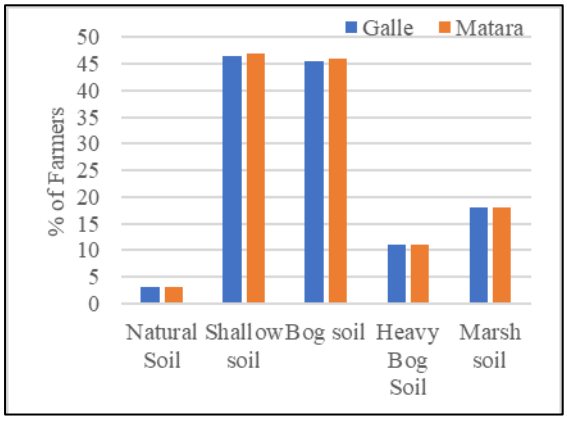

Figure 3: Different soil types in paddy fields
Source: Author's own data, 2019

This study has investigated the impact of soil types on the decreasing trend of paddy farming, and figure 03 shows the existing soil types in the paddy field in the study areas.

According to Figure 03, the majority of the soil types in the paddy fields are shallow and bog soil types in both Galle and Matara districts. The availability of natural soil in the paddy field was hardly observed in both districts. The soil type of the paddy field has a great impact on poor water drainage conditions.

Cost of paddy production

According to Table 02, the total cost of production of paddy farming in Galle District was Rs. 39444.12 per acre and Rs.39375.00 per acre in Matara District. When comparing these cost components with the national average cost of production, it was not identified any significant changes with the figures of the reports issued in 2019 by the Socioeconomic and planning center in Sri Lanka.

According to Table 02, both districts show similar total cost and % of TCP. However, Galle district has a higher cost for manual weed control (13%), land preparation (32%), and organic fertilizer (5%) activities than the Matara district. Both districts showed similar costs in pesticides (6%). However, the Matara district showed higher costs in chemical fertilizer (14%), weedicide cost (8%), harvesting cost (23%), and storage cost than the Galle district.

Table 2: Cost of paddy production in Galle and Matara District

Cost factor	Method	Galle		Matara	
		Cost (Rs/Ac)	% of TCP	Cost (Rs/Ac)	% of TCP
Weed control-Manual	water management, by tillage, chemical,	5180.93	(13%)	4145.31	(11%)
Land Preparation	tractor, manual, using cow	12407.73	(32%)	9436.86	(24%)
Organic fertilizer	paddy husk, compost	2020.59	(5%)	560	(1%)
chemical fertilizer	chemical	4787.27	(12%)	5530.43	(14%)
Pesticide	weedicide, traditional methods, manual weeding	2479.31	(6 %)	2500	(6%)
Weedicide	sowing	2631.97	(7 %)	3025	(8%)
Harvesting	tractor, combined harvester, manual	8150.43	(21%)	8879	(23%)
Processing	tractor	3840.22	(10%)	5664.55	(14%)
Storage		1570	(4%)	4500	(11%)
Total		**39444.12**		**39375.00**	**39375.00**

Based on the cost of cultivation of crops, 2018/2019 Maha, we contrast the cost-production of Galle and Matara districts with the other paddy cultivating districts under a rain-fed system (RF). Furthermore, the agricultural-ecological factors of the Galle and Matara districts are much more similar to Kalutara District. Therefore, we can contrast our research findings with the Kalutara district figure as well. The estimated cost of cultivating an acre of paddy under a rain-fed system is about Rs. 39, 572.00, and the cost of production of a kilo of paddy is Rs. 36.00. However, the present guaranteed price of a kilo of paddy is varied from Rs.39.00 to Rs. 41.00. Anyhow, paddy farmers in Matara and Galle districts do not intend to sell their products. According to this study, only 27 percent of the farmers in Matara district sell their paddy production while only 24 percent of the farmers in Galle district sell their production. Accordingly, the majority of farmers in both districts are doing paddy farming basically for their consumption purpose rather than a commercial purpose.

Furthermore, this study investigated the recent farm gate price for paddy they received, the maximum price they have received so far. Table 03 shows the information on paddy prices in Matara and Galle districts.

The farmers in Galle districts have received a relatively higher unit price for paddy compared to the farmers in Matara. The possible reason for these observed differences could be due to different sample sizes in this study. Otherwise, there wouldn't be such remarkable price differences between the two districts in the Southern province.

Table 3: Paddy Farm gate price in Galle and Matara District

	Galle	Matara
	(Average prices Rs/Kg)	
Price of 1 kg of paddy at the last time of selling	Rs.39.74	Rs.31.00
Highest farm gate prices received so far	Rs. 41.80	Rs.36.39

Source: Authors own data, 2019

Fertilizer application for paddy farming

This study intends to analyze whether farmers are heavily relying on chemical fertilizer and how many farmers follow the recommendation given by the Department of Agriculture. Anyhow, we were unable to gather information on the amount of applied fertilizer due to inadequate information available with the farmers in this study. Table 04 shows the percentage of farmers who apply NPK (Nitrogen, Phosphorous, K for Potassium) fertilizer Basal, Top I, II, and III application regularly to their paddy lands.

According to Table 04, though the higher percentage of farmers in both districts applies N, P, K application as Basal and Top I, and II, fewer percentages of farmers apply NPCs as Top III application. According to the report, issued by the Department of Socio Economic and Planning

Center (2019), the total average use of fertilizer use was 155 kg/ac in irrigated water regimes, and it was 124 kg/ac in rain-fed water regimes. The usage of the basal mixture was 54 kg/ac in irrigated water regime, whereas it was 29 kg/ac in a rain-fed water regime.

Table 4: Percentage of farmers who applied fertilizer at each stage

	Galle (% of farmers)			Matara (% of farmers)		
	N	**P**	**K**	**N**	**P**	**K**
Basal	13	65	13	10	90	8
Top I	69	10	59	92	3	79
Top II	68	9	61	82	3	80
Top III	15	1	12	8	0	7

Source: Authors own data, 2019

Supporting services and subsidies for promoting paddy farming in Southern province

The department of Agriculture in the Southern province has organized different training and awareness programs with the assistance of the Agrarian extension service center to promote paddy farming. This study has evaluated those training programs exploring the number of the participants as a percentage and analyzing the perception of farmers in regard to the usefulness of the training program for their farming. Table 05 shows the research finding in Galle and Matara districts. The participation of the farmers for the training session is satisfactorily higher (55% & 77%) in both districts. However, the majority of the farmers in both districts don't perceive the training session as useful.

Table 5: Farmers' training program on paddy cultivations

	% of Farmers			
	Galle		Matara	
	Yes	**No**	**Yes**	**No**
Participation	55	45	77	33
Perceived as useful	26	74	25	75

Source: Authors own data, 2019

Role of Extension and Advisory service in the promotion of paddy farming

Meeting with Agriculture Instructors

There is vital role-playing by agriculture extension and advisory services for the development of the agriculture sector. In Galle and Matara districts, extension services insert their effort to promote paddy farming due to the higher percentage of abandoned paddy lands. Table 06 shows the frequency of farmer visits and the purpose of visiting in the Galle and Matara district.

Table 6: visit of agricultural extension and advisory services

	Galle (Average)	**Matara**
Meeting frequency	2-3 times per/season	1-2 time per/season
Purpose of meeting	When necessary	When necessary

Source: Authors own data, 2019

According to Table 06, the farmers meet the agricultural instructors only when necessary, in both districts. The meeting frequency of both districts is 1 to 3 times per season (Yala or Maha). When compared with the other districts, the meeting frequency seems to be inadequate to give necessary information and advice to the paddy farmers. Moreover, farmers were asked to mention their convenient time to meet extension officers to get assistance whenever they required. Table 07 showed that the majority of farmers in both districts preferred to meet extension and advisory services at their office on Wednesday. The possible reason might be the availability of extension officers who are supposed to be at their office every Wednesday. However, the majority of the farmers in the Galle district have shown their preference to meet agricultural advisory services on other weekdays rather than Wednesday (22%) and are also willing to meet them over the phone (54%).

T**able 7:** Most convenient meeting schedule with Agricultural advisory services

	Galle (% of farmers)	**Matara (% of farmers)**
Office Day (Wednesday)	75	84
Other weekdays	22	12
Over the Phone	54	31
Others	30 (meeting, at the field)	44 (meeting, at the field)

Source: Author's own data, 2019

Supporting service providers and institutions for the paddy farming activities

Farmers require frequent supports from particular personal and institutions for their farming activities. Therefore, it was studied the existing supporting services of the paddy farmers in the study areas. This study investigated the most supportive providers or institutions for their farming activities and ranked them according to the importance perceived by farmers. Figure 04 shows

the different service providers and their importance based on the farmers' perceptions. Accordingly, the Agrarian service center and community-based organizations are the most supporting service providers to the paddy farmers in Galle and Matara District.

Moreover, farmers were asked to specify the particular farming activities that they require support from the aforementioned supporting services and ranked them based on the responses. Farmers request supporting services for the rehabilitation of irrigation canals. Thus, labor issues, land preparation problems due to bog soil conditions, and business startup issues have been prioritized by the farmers. Figure 05 shows the different farming activities which were requested as supporting activities by the farmers.

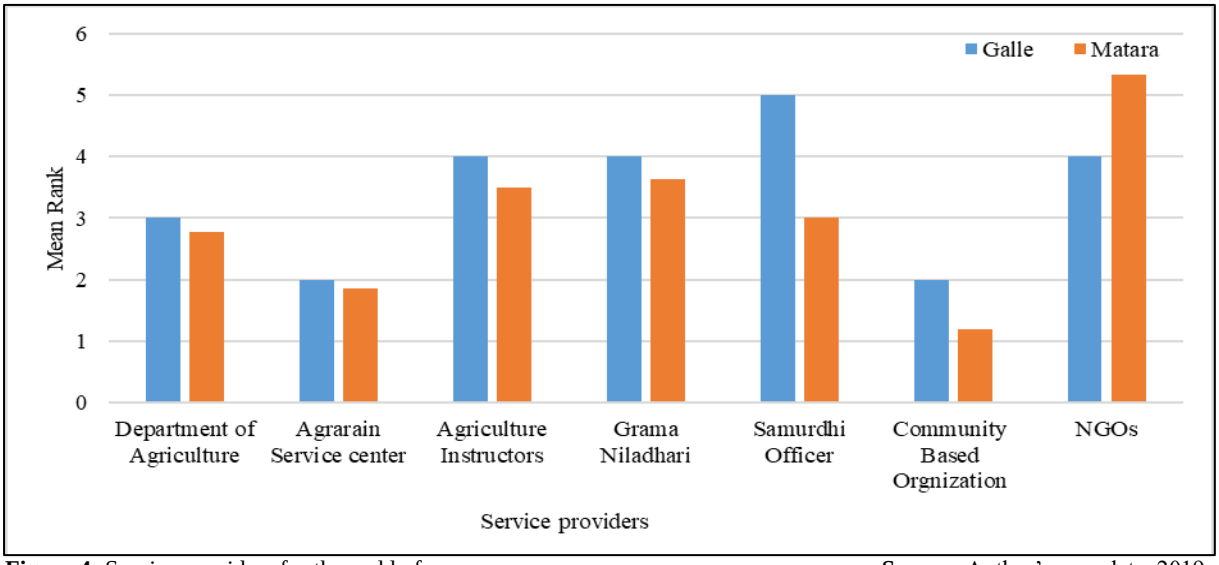

Figure 4: Service providers for the paddy farmers **Source:** Author's own data, 2019

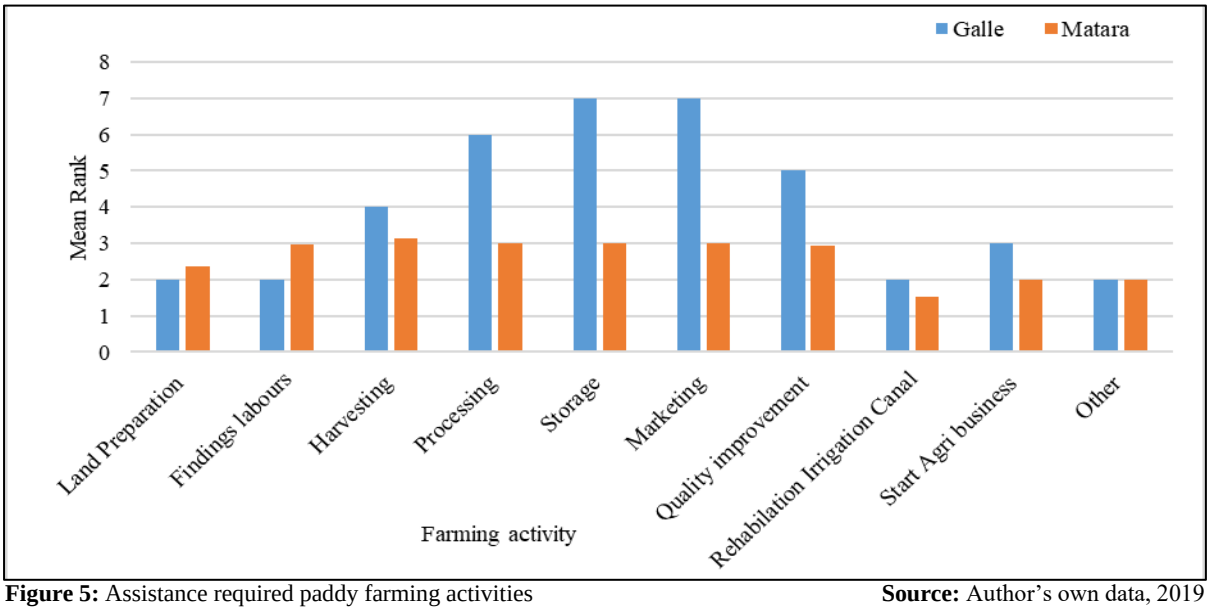

Figure 5: Assistance required paddy farming activities **Source:** Author's own data, 2019

CONCLUSIONS

This research study revealed that paddy farmers in Galle and Matara districts have their paddy fields even though they have neglected farming mainly due to water drainage issues and a few other reasons. Furthermore, this study revealed that paddy farming had been constrained by poor water drainage and scarcity of labor for farming activities. The poor water drainage issues have been affected by the shallow and bog soil conditions of the majority of paddy fields in the Galle and Matara District. Nevertheless, there was no significant gap between the national average cost of production with the cost of production of the Galle and Matara districts. The highest cost components were for the land preparation activities. However, when compared to the national

statistical data on the cost of production, there is no significant difference between the cost values of Galle and Matara, implying cost of production would not be the possible reason for abandoning paddy lands. Farmers in both districts have incurred considerably high costs for fertilizers, and, basically, they are applying NPK as basal dressing and Top 1 and II dressings. Anyhow, this research has a limitation of quantifying the amount of applied fertilizer as NPK due to the poor response rate by farmers.

In context to the marketing of paddy, the majority of farmers in Galle and Matara district do not intend to sell their production to cover their cost of production, and they are mainly cultivating paddy for their family consumption. Moreover, research findings have shown that extension and advisory services visit farmers when only they require it, and it is hardly seen any regular farmer visit system in the study area. Accordingly, the ineffectiveness of extension and advisory services provided by government institutions has shown the poor visiting frequency. Therefore, the majority of farmers are expected to meet advisory and extension officials every Wednesday, which is considered the official meeting date for farmers at the agrarian service center. Even though the participation of farmers in the training and advisory session was satisfied in both districts, many farmers haven't perceived these training sessions as useful training for their farming activities.

The role and functions of community-based organizations and Agrarian service centers were perceived as the most important service providers for the paddy farmers in both districts. Moreover, farmers requested us to assist them to rehabilitate irrigation canals and to find a solution for labor scarcity when introducing new technologies which consume less manpower as well as are suited for the swallow and bog soil conditions. This research will suggest some policy initiatives to motivate paddy farmers to cultivate paddy in their abandoned lands.

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PESTS OF LEAFY VEGETABLES IN SRI LANKA, THEIR DAMAGED SYMPTOMS, HOST RANGE AND BIOLOGY

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ABSTRACT

Detail investigations on pests of leafy vegetables of Sri Lanka were carried out using three representative districts to generate background information required for development of sustainable management technologies. The methods included field sampling, laboratory culturing, and biological studies. Host range and biology of already recorded major pests, flea sap sucking bug, Halticus minitus (Heteroptera: Miridae) and flea beetle Chaetocnema spp. (Coleoptera: Chrysomelidae) under local conditions were described in detail. A new flea weevil pest damaging to Alternanthera sessilislinn linn. was identified as Tachyerges spp. (Coleoptera: Curculinoidae) and its morphology, biology and damage were described. In addition, a new flea beetle, Chaetocnema confinis was identified as a major pest of Ipomoea aqutica. Two leaf folder pests, Psara basalis (Lepidoptera: Crambidae) and beet webworm, Spoladeare recurvalis (Lepidoptera; Pyralidae) in A. sessilis and Amaranthus spp. respectively and a Bracon larval parasitoid of S. recurvalis were identified. Thrips, nematode, mites and plant bug were the other general pests damage to leafy vegetables including Centella asiatica.

Keywords: Biology, Damage, Hosts, Leafy vegetables pests, Sri Lanka

INTRODUCTION

Leafy vegetables are one of the essential components in the Sri Lankan diet and the most popular varieties such as Gotukola (*Centella asiatica*), Mukunuwenna (*Alternanthera sesilis* linn), Kangkun (*Ipomoea aqutica*), Thampala (*Amaranthus candatus*), Nivithi (*Spinacia oleracea*) and Kathurumurunga (*Sesbania grandiflora*) have been commercially cultivated. Intensifying pest problems due to environmental changes and continued commercial cultivations become the major constraint for their production and quality maintenance and compelled farmers to use insecticides creating health and environmental hazards (Lakshani *et al.*, 2018). Therefore, sustainable management technologies were required to mitigate the situation and safeguard the farmers. Sound knowledge of the pest fauna of leafy vegetables is required to develop such management technologies. As the information provided by previous studies (Wijerathne, 1999; Wahundeniya *et al.*, 2005; Marasingha and Nishantha, 2018; Rajshkanna *et al.*, 2017) was not sufficient to meet these requirements, detailed investigation of the pests of leafy vegetables of Sri Lanka, their damage symptoms, host ranges and biology were investigated.

METHODOLOGY

Leafy vegetable cultivations in three representative commercial leafy vegetable cultivating districts, Gampaha (Dompe), Chillaw (Bingiriya), and Kandy (Peradeniya) were surveyed during the period of 2017 to 2020 in this study. The cultivations in the surroundings of Peradeniya were examined in fortnight intervals, whereas in the rest of the areas it was done periodically. The samples were collected by handpicking and using a sweep net and crop damages were visually estimated using 0-4 scale (0= no damaged; 1= up to 10% top three leaves have the damaged; 2= up to 11-25% of top three leaves have damaged; 3= 26 -50% of top three leaves have damaged; above 50% of top three leaves have damaged). The collected samples of suspected pests were separately reared on respective hosts in insect-proof containers / cages in the laboratories of Entomology division, Horticulture Crop Research and Development Institute (HORDI), Gannoruwa, Peradeniya for their identification and biological studies. Morphological identification of pests was done using stereo microscopic observation and then comparing their morphological characteristics of recorded pests. However, identification keys Hackston (2020) were used for identification of the new flea weevil pest. Host preference studies were carried out under choice conditions offering them detached twigs or whole plants of different leafy

vegetables together in a watered plastic cup kept in insect-proof cages having the respective pest. The life cycle studies and host preference studies were carried out in three replications under the prevailing environmental conditions in the laboratory (26-32ºC; 66-88 RH; natural illumination) and averages of 10 observations were made when taking quantitative measurements.

RESULTS AND DISCUSSION

1. **Flea sap sucking bug,** *Halticus minitus* (Heteroptera: Miridae)

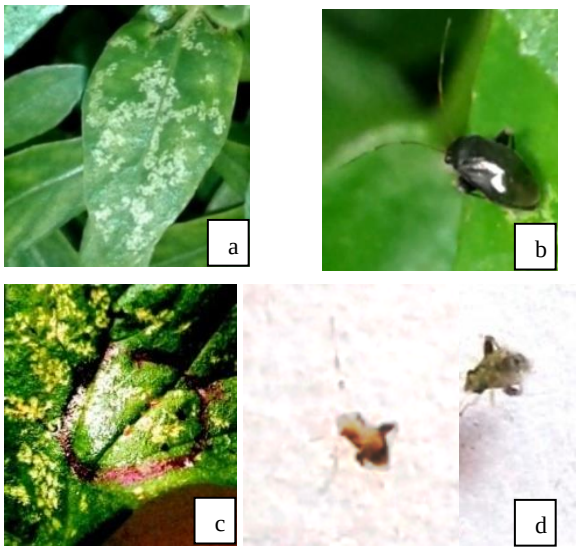

Plate1: Life cycle and damage of flea sap sucking bugs, *Halticus minitus*, a-damaged symptom of Mukunuwenna b-adult c-eggs, d- nymphs

Damage: This was a reported pest of Gotukola and Mukunuwanne in Sri Lanka (Wijerathne, 1999: Wahundeniya *et al*. 2005). The present study revealed that in addition to these two hosts, the pest damage to a number of other vegetables and some weeds, including Kangkun as a preferred host (Table 1). Damaged observations indicated that this pest was a frequently observed major pest of gotukola and mukunuwenna, which optimize its leaf damage exceeding 75% during dry periods in some locations. Both adults and nymphs suck the sap from the leaf tissues producing white stippling or irregular-shaped marks (speckled) on the leaf surface (Plate 1 a). In severe infestations, the leaves become grayish-white or silver color patches. The quality of leafy vegetables gets completely deteriorated due to their feeding, ovipostion and depositing of excreta on the leaves. The excreta were appeared as black spots on the leaves. *Halticus* spp. has been recorded as a widely spread pest of many crops and weeds in the Asia Pacific region (Amalin and Vasquez, 1993; Eyles, 2005).

Biology: The shiny black adults have grayish black posterior wing and about 2 mm long body (Plate 1 b). It has 4 segmented long and slender antennae and the first segment was thick and shorter than the rest, and the fourth segment was dark brown. The well-developed hind femora help them to jump when disturbed. Apical parts of legs were black and rests of the parts were brownish yellow. Eggs were inserted in to the leaves and stems of the plants on which the females feed (Plate 1 c). The whitish, translucent eggs about 0.4±-0.1 mm in length become red mixed creamy appearance towards maturity and it takes 10-12 days to hatch. It has been distributed in the countries of pacific region and reported that the early nymphs were green in color (Tsatsia and Jackson 1999). However, in the present study they were observed in red mix creamy in color with dark red eyes. Antennae of nymphs were creamy yellow in color with two red spots (Plate 1 d). Towards maturity, the nymphs turn to grayish green and finally emerge as shiny black adults. The whole life cycle takes about 3-4 weeks under laboratory conditions.

2. Flea beetle, *Chaetocnema spp.* (Coleoptera: Chrysomelidae)

Flea beetle, *Chaetocnema spp*. has already been reported as a major pest of Mukunuwenna (Wahundeniya *et al*., 2005; Marasinghe and Nishantha, 2018). The present investigation revealed that in addition to Mukunuwenna, this pest could make economic damage to a number of leafy vegetables (Table 1)**.** The adult chew both sides of leaves making small round holes (shotholes) but some damaged spots appears as windows due to the presence of the epidermis (Plate 2 a). The shiny black adult about 2.2 ± 0.2 mm in length had light brown, eleven segmented antennae which gets darker color towards the end (Plate 2 b). Elliptical shape eggs in white color about 0.5 mm were laid in the soil around the base of the host plant and they get hatched within 6-7 days under laboratory conditions (Plate 2 c). The white color young larvae about 1 mm in length grow up to 3 mm in length and head turn to black toward maturity (Plate 2 d). Afterwards, the larvae pupate in the soil and become adults after 7-10 days.

3. Flea weevil, *Tachyerges* spp. (Coleoptera: Curculinoidae)

Damage: A new flea weevil pest causing leaf damage to Mukunuwenna was identified as, *Tachyyerges* spp. (Coleoptera: Curculinoidae) (Hackston, 2020). The adult makes leaf holes similar to the damage caused by flea beetle and therefore could not be differentiated by damaged symptoms (Plate 3 a). Laboratory feeding studies indicated that it could cause damage to a range of other leafy vegetable crops (Table 1). The adult prefers younger leaves for feeding and damage appears as small windows and holes in the leaves. Larvae make mine in mature leaves but not prominent as adult damage (Plate 3 b. Both flea

beetle and flea weevil damages were observed in some instances in the same field and seriously affected the quality of the harvest. The present investigations reveals that this pest as an occasional pest of leafy vegetables present in all three districts. However, the pest caused very high leaf damage to mukunuwenna in Gannourwa area in July-August, 2017.

Morphology & Biology: The adult is about 2.0 ±0.2 mm in length and reddish brown with paler irregular markings on the elytra (Plate 4 c). Thorax was darker than the rest of the body. Rostrum, legs and the body were hairy (Plate 4 d). Eyes were black and large. Body shape is broad and convex. Abdomen consists five segments. The antennae (Geniculate) were inserted to the middle of the rostrum. Adult inserted elliptical shape light yellow color eggs about 0.4 ±0.2 mm in length into the leaves near the veins. The eggs become darker yellow towards maturity and hatch within 2-3 days under the prevailing laboratory conditions (Plate 4 e). The yellow color larva had brown color head. Larvae tunnel through the leaf as they feed, producing a serpentine mine gradually enlarges in diameter as the larvae get mature and darker color excreta appeared in the tunnel (Plate 4 f). Larvae grew up to 3.5 ± 0.2 mm length and the developmental period was about 6-7 days. The pupation occurs in soil and takes about 7 days to emerge as adults (4 g).

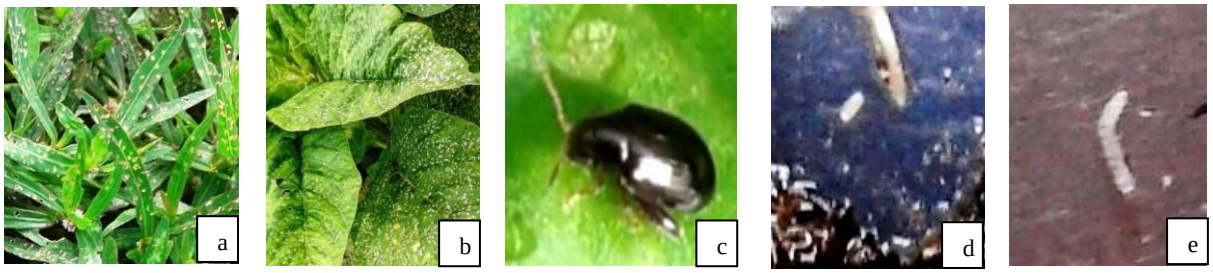

Plate 2: Life cycle and damage of Flea beetles, *Chaetocnema spp*, a-damaged in Mukunuwenne and Thampala b-enlarged adult, c-enlarged egg, d-enlarged larvae

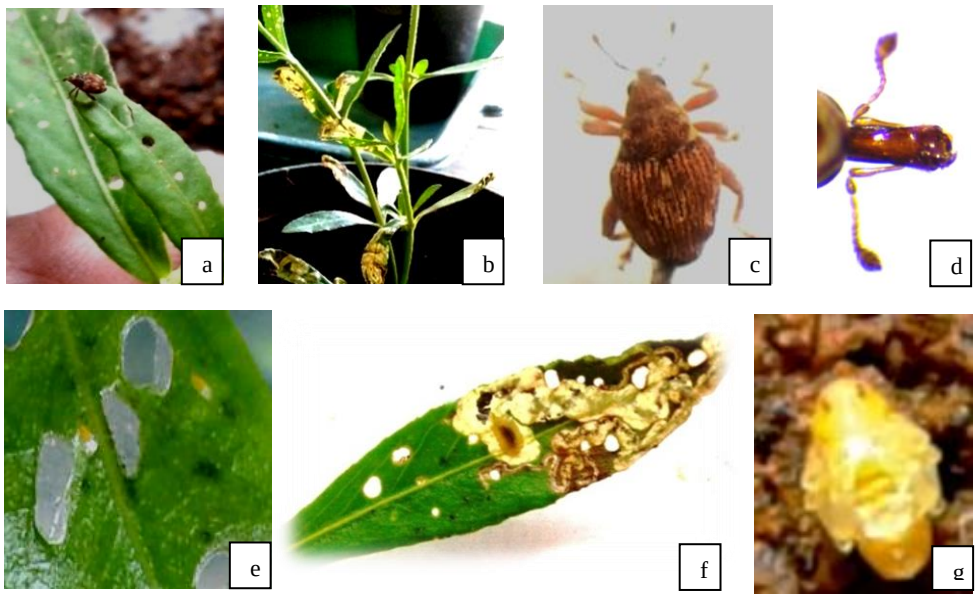

Plate 3: Life cycle and damage of flea weevil, *Tachyyerges* spp, enlarged a-adult damage, b-larvae damage c-adult, d-rostrum, e-eggs f- larvae in a tunnel, g-pupa

4. Sweet potato flea beetle, *Chaetocnema confinis* Crotch (Coleoptera: Chrysomelidae)

A new flea beetle species causing new type of damage to Kankun was observed and its damage reached to 100% in Gannoruwa area during January-February 2018. It appeared as whitish streaks on leaves and they turned to yellow and brownish later completely destroyed the crop. These damage symptoms were completely different from the already recorded flea beetle to Mukunuwenna (Plate 4 a & b). However, it was found that this damage similar to the damage caused by sweet potato flea beetle, *Chaetocnema confinis* to Kankun and Sweet potato Tsatsia and Jackson (2019). Further morphological studies indicated that both species have similar appearance but the new species was smaller (1.4 ± 0.2 mm) than the already recorded flea beetle of Mukunuwenna (2.3-2.5 mm) and feeding studies indicated that it caused no damage to

Mukunuwenna. The adult beetle is black to dark bronze and striae on the elytra were parallel and the Punctures are deep on the pronotum and similar to sweet potato flea beetle, *C. confinis (*Jolivet, 2008; Ruan *et al*., 2019*)* (Plate 4 c). These findings confirm that this new species is the invasive flea beetle species, *C. confinis*, which has not been recorded earlier in Sri Lanka *(*Ruan *et.al.,* 2019).

5. **Leaf webber, *Psara basalis* (Lepidoptera: Crambidae)**

Leaf webber damage was recorded in the all three districts which caused around 5% damage to mukunuwenna as its preferred host. This is a recorded leaf Webber species in *Celosia* spp. in Sri Lanka and the present study identified it as a pest of Mukunuwenna and *Amaranthus* spp. (Wijerathne, 1999). Yellowish green larvae with dark brown heads grew up to 1 cm in length, having two dark spots on the thorax with green stripes running along the body (Plate 5 a) (James *et al*. 2010).

The young caterpillars fold Tampala and Mukunuwenna leaves into shelters and feed and live inside them (Figure 5 b). Morphological characteristics confirm this leaf Webber pest as *Psara basalis* Walker (Lephidopters: Crambidae) (Kumar *et al*., 2008) (Figure 5 c).

6. Beet webworm, *Spoladea recurvalis* (Lepidoptera; Pyralidae)

Spoladea recurvalis has been recorded as a pest of beet and *Amaranthus* spp in Sri Lanka and a pest of *Amaranthus* spp. in India (Wijeratne, 1999; AtanuSeni, 2018). The present study confirmed that the same pest damage to *Amaranthus* spp. and also to Mukunuwenna and its identity was confirmed by morphological comparisons of the study of James *et al*. (2010) (Plate 6 a & b). This pest was present in lower proportions (1 %) when compared with *P. basalis***,** however their leaf damage which fold and skeletonized the leaf caused significant crop damage. A *Bracon* spp. parasitoid found infesting the larvae of *S. recurvalis***.** This orange color Bracon wasp was about 5.5 ±0.5 mm in length has translucent wings with a black and yellow color spot on the fore wings (Plate 6 c). They had three prominent black spots in triangle shape in between two eyes and black antenna (4.0±0.5 mm length) on their head (Ward, 2014). The percentage of parasitism in field collected larvae, where pesticides have not been used was around 30 ± 5 %, which indicates its potential as a biocontrol agent.

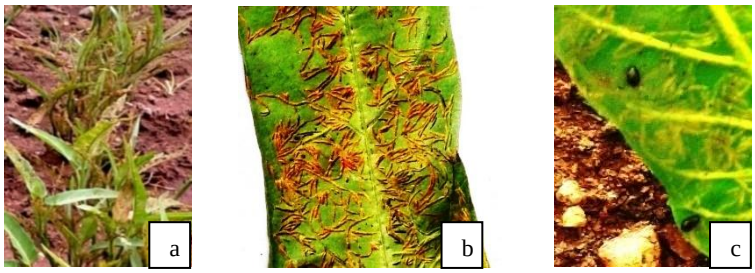

Plate 4: Sweet potato beetle, *Chaetocnema confinis* damage to kankun. a. damaged crop b. enlarged damaged leaf, c. the adult

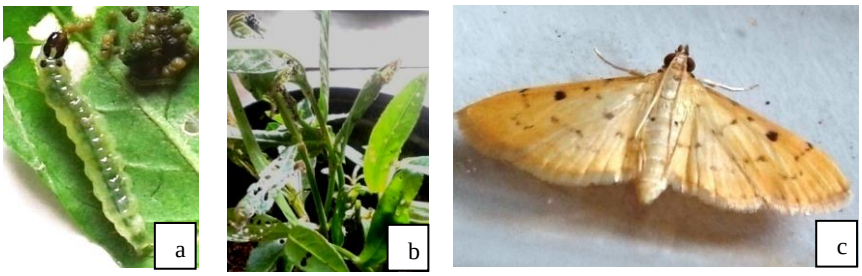

Plate 5: *Psara basalis* a-larva, b. damage, c. adult moth

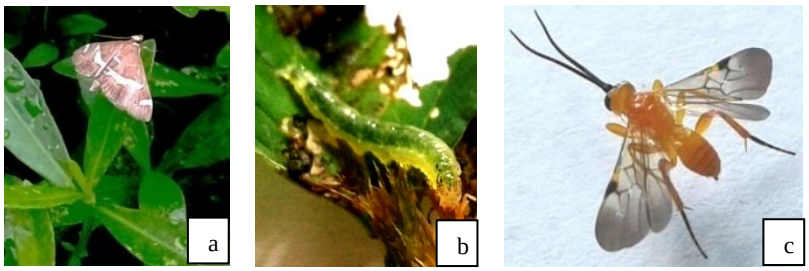

Plate 6: a. Beet webworm, Spoladea recurvalis a. adult b. larvae, c. Adult of Bracon parasitoid of Spoladea recurvalis

Table 1: Hosts of *Halticus minitus, Chaetocnema spp. and Tachyyerges* spp. identified in the study

Pests	Common name	Scientific name
Halticus minitus, Flea sap sucking bugs (Heteroptera: Miridae)	Mukunuwenna	*Alternanthera sessilis linn.*
	Gotukola	*Centella asiatica*
	Kankung	*Ipomoea aqutica*
	Wing bean	*Psophocarpus tatragonolobus*
	Elabatu	*Solanum insamum*
	Centrosema wel	*Centrosem apubescens*
	Wathupalu	*Mikania cordata*
	Sweet potato	*Ipomoea batatas*
	Long bean	*Vigna unguiculate*
	Brinjal	*Solanum melongena*
Chaetocnema spp. Flea beetle (Coleoptera: Chrysomelidae)	Mukunuwenna	*Alternanthera sessilislinn*
	Thampala	*Amaranthus candatus*
	Nivithi	*Spinacia oleracea*
	Mal mukunuwenna	*Alternanthera bettzickiana*
	Katukoora	*Amaranthus spinosus*
	KooraThampala	*Alternanthera viridis*
Tachyyerges spp., Flea weevil (Coleoptera: Curculinoidae)	Mukunuwenna	*Alternantherases silislinn*
	Thampala	*Amaranthus candatus*
	KooraThampala	*Alternanthera viridis*
	Mal mukunuwenna	*Alternanthera bettzickiana*

7.Thrips

Thrips caused a considerable damage to Kankun crop, which appears as scraping mainly on underside of the leaves resulted curling, and deformation of leaves. In some instance, silvery appearance of veins on the upper side of the leaves was also observed (Plate 7 a & b). The species could not be identified.

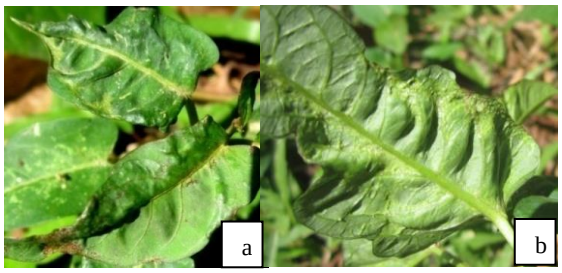

Plate 7: The leaf damage caused by thrips to kankun. a damaged plant b. enlarged leaf

8. Coreid bug, *Cletus trigonus* Thunb

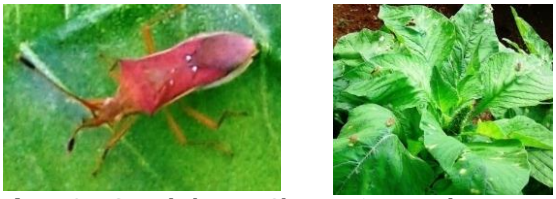

Plate 8: Coreid bugs, *Cletus trigonus* damage in thampala

Coreid bug, *Cletus* spp. is recorded as a pest of *Amaranthus* spp in Sri Lanka (Wijerathne, 1999). The present study identified the pest damage to *Amaranthus* spp. as *C. trigonus* (Heteroptera: Coredae) (Kafle and Lamjung, 2018; Gupta and Sing, 2013). (Plate 8).

9. Mite pests

Plate 9: Red spider mite, *Tetranychus urticae* (Acari:Tetranychidae) damage in Kankun

Mites were another group of pests, which attacked leafy vegetables. The damage of red spider mite, *Tetranychus urticae* (Acari: Tetranychidae) was found as a common pest of a number of leafy vegetables such as Gotukola, Mukunuwenna, Thampala, Kathurumurunga, and Kankun and their damage was observed as a pale color stippling on leaves (Plate 9) (Zhang 2003). This mite was previously reported as a pest of Gotukola (Wahundeniya *et al*. 2005). In addition, the damage of broad mite, *Polyhagotarsonemus latus* (Banks) (Acari: Tarsonemidae) was observed as a minor pest in Mukunuwenna, especially in home gardens in this study. This tiny mite about 0.2 mm with translucent body damage to young leaves which curl downward and turn to coppery or purplish in color (Zhang 2003).

10. Nematodes (*Melodygyne* spp,)

Nematodes were another group of pests' attack to leafy vegetables especially Gotukola, Mukunuwenna and Nivithi in some locations (Plate 10). Their presence in Gotukola has already been reported (Wahundeniya *et al*. 2005). The damaged symptoms include narrowing and necrosis of leaves, growth retardation and when uprooted their root galls appears in the root system.

Plate 10: Nematode damage in Mukunuwanna

In addition, white hopper, white fly, black hopper, soft scales, aphids, mealy bugs, and leaf miner were the other minor pests observed in leafy vegetables during this study. However, Amaranthus stem borer, *Hypolixus truncatulus* (Coleoptera: Curculinoidae), which has been recently reported as a major pest of Thampala in Northern Province of Sri Lanka was not found in the sampled fields (Rajshkanna *et al*., 2017). This pest was earlier reported as a pest of *A. spinosus* Wijeratne (1999).

CONCLUSIONS

Pest problems with increasing trends badly affected the production and quality maintenance of leafy vegetable crops in Sri Lanka. The present investigations discovered a large number of pests damaging to both commercial and home garden grown leafy vegetables in Sri Lanka and some of them were new pests. Flea sap sucking bug, Halticus minitus and flea beetles, Chaetocnema spp. were identified as the most damaging pests of leafy vegetables and their damage, host range and biology were described. Flea weevil, *Tachyyerges* spp. was identified as a new occasional pest of Mukunuwenna and its morphology, biology and damage were described. Sweet potato flea beetle, *Chaetocnema confinis* was a new pest found causing serious damage to Kankun. Two leaf folders *Psara basalis* and beet webworm, *Spoladea recurvalis* were identified as pests of Mukunuwenna and *Amaranths* spp. A larval parasitoid of *S. recurvalis* was identified as a Bracon spp. and its parasitism exceed 30±5 % in pesticide free cultivations indicating its potential as a biocontrol agent. The study confirms the presence of already recorded general pests namely, red spider mite, *Tetranychus urticae*, broad mite, *Polyhagotarsonemus latus* (Banks), nematodes, *Melodygynye* spp, leaf eating caterpillar, *Spodoptera litura* in leafy vegetable cultivations. An undescribed damage caused to the leaves of kankun was identified due to thrips. The study identified a coreid bug, *C. trigonus* as a pest of *Amaranthus* spp. White hopper, white fly, black hopper, soft scales, aphids, mealy bugs, and leaf miner were the other minor pests observed in leafy vegetables in this study.

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PERCEPTION OF CULTURED MEAT AMONG SRI LANKAN COMMUNITY

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ABSTRACT

Production of cultured meat involves synthesizing meat from animal tissue samples in a controlled environment using biotechnology. This study was directed to understand the perception of Sri Lankan consumer on cultured meat consumption. A structural survey was conducted in Sri Lanka using a probability sample of 14200 people from 11 districts and it was selected proportionately to the population in selected divisional secretariat divisions of these districts. The result of the survey revealed that 75% of the population was interested in accepting the cultured meat. The study showed that the meat consumers usually considered the health benefits mostly followed by nutritional properties, sensory properties especially the flavor and texture and meat price. Participants have understood the advantages of cultured meat in terms of animal welfare, environmental aspects, and food security of the country. Therefore, it can be concluded that there will be a substantial market for cultured meat, when it is introduced to the market. Educating people about intrinsic properties of cultured meat will also be important. In addition, the regression analysis showed that the acceptance level of cultured meat increased with the education level of consumers.

Keywords: Animal welfare, Cultured meat, Food security, Lab-grown meat

INTRODUCTION

Meat which is a major source of proteins has seized a dominant position in Western food culture (Holmand and Mohl, 2000) since long ago. Globally, the demand for meat is increasing and even in vegetarian cultures, some dishes are made imitating the properties of meat considering the dominant nature of meat in cookery. But the plant-based meat substitutes known as protein analogues haven't still succeeded in replacing meat in human diet (Holmand and Mohl, 2000; Stephans *et al.,* 2018). According to Rorheim *et al.,* (2016), more than 60 billion animals are nurtured industrially in each year with the purpose of meat production. The global demand for meat is predicted to rise by 73% by year 2050 even though the meat industry is the globe's main cause of human pandemic diseases (Rorheim *et al.,* 2016).

In Sri Lanka, even though the meat industry is having the influence of religious, cultural and economic influence, there is an upward trend in the consumption pattern of meat and meat-based products (Alahakoon *et al.,* 2016). According to statistical data by DAPH (2014), the total meat production has increased from 119,620MT to 185,490MT in 2013. Sri Lanka exports poultry, beef, pork and mutton and poultry exports are recorded to be the highest (DAPH, 2013). Literature reveals that Sri Lanka imports meat from high meat producing countries over years. Poultry meat is the top imported type followed by mutton, beef, and pork (Alahakoon *et al.,* 2016). Recent studies depict that still there is a shortage in the supply of poultry meat and other popular meat types in Sri Lanka (Alahakoon *et al.,* 2016) and actions need to be taken to satisfy the consumer demand on meat.

With the increasing human population, demand for protein foods is also rising. Hence, it is a timely requirement to search for methods for protein production which are more sustainable, nutritious, with more emphasis on animal welfare (Stephans *et al.,* 2018). Although the plant-based meat substitutes are favored by most meat consumers due to the health concerns, the usage is very low due to the less sensory acceptability (Ruzgys and Pickering 2020). The activists of cultured meat present this artificial meat as a potential substitute for consumers who want to be more responsible without changing their dietary pattern (Chriki and Hocquette, 2020; Ruzgys and Pickering, 2020). "In vitro meat production system is the production of meat outside the food animals by culturing the stem cells derived from farm animals inside the bioreactor by using advanced tissue engineering techniques" (Bhat *et al.,* 2015). During culturing, extracted cells from farm animals are transferred to an appropriate medium containing nutrients, energy sources and other growth factors (Chriki and Hocquette, 2020) so that to promote the growth and differentiation of stem cells into mature muscle cells within a bioreactor (Welin, 2013). This involves the production of edible animal muscle by

proliferating a small amount of muscle cells to a large portion of consumable flesh (Bhat *et al.,* 2015). Even a living animal can be used to harvest muscle cells and cells from a single cow could produce 175 million quarter-pounders of meat whereas 440,000 cows are needed to produce the same amount of meat using conventional farming methods (Mancini and Antonioli, 2020).

Concerning the issues created by industrial animal farming the attention of scientists over the world has turned towards the research and development work on mass production of cultured meat (Rorheim *et al.,* 2016). In-vitro meat production is anticipated to be resource efficient than conventional meat animal farming, especially concerning the demand for meat in future, more sustainable as the environmental impact will be low (Verbeke *et al.,* 2015) with eliminating manure disposal problem and by reducing Green House Gas (GHG) emission (Rorheim *et al.,* 2016; Ruzgys and Pickering 2020). It is estimated that cultured meat requires 7-45% less energy than conventional meat while 78-96% less emission of GHG, 99% lesser land use and 82-96% lower water usage (Welin, 2013). Cultured meat is safer than conventional meat considering human health aspects (Verbeke *et al.,* 2015); as aseptic conditions are applied (Chriki and Hocquette, 2020) and antibiotics are not required during production process there is no risk of zoonotic infections (Rorheim *et al.,* 2016). Furthermore, nutritional composition changes, for instance, the ratio of saturated fatty acids to polyunsaturated fatty acids (Chriki and Hocquette, 2020), can be applied on cultured meat during the production procedure which is non-applicable in conventional meat production. Regarding the animal welfare, unnecessary suffering imposed upon animals under human care and in factory farms and extremely brutal slaughtering of food animals are bypassed with this in-vitro meat production (Bhat et al. 2015; Verbeke *et al.,* 2015; Rorheim *et al.,* 2016). Nevertheless, even though large-scale production and market penetration results in a significant price reduction, extremely high unaffordable cost of cultured meat, increased requirement of technology and public acceptance of an unnatural meat are considered as the potential barriers for in-vitro meat production (Verbeke *et al.*, 2015).

The current study aimed at unveiling the perception of Sri Lankans on cultured meat and their desire to try and buy if it becomes available in Sri Lankan context with the use of a questionnaire-based survey. The concept of lab-grown meat is totally a novel concept to Sri Lankans. Hence, a brief introduction including the pros and cons of production of in-vitro meat was delivered prior to presenting the pre-tested questionnaire. The major objective of this study was to analyze the perception of Sri Lankans about cultured meat, which is a very novel concept to Sri Lanka, their desire to accept in-vitro meat if it becomes available and the potential to introduce cultured meat to Sri Lanka. Accordingly, the survey focused on studying the meat consumption pattern among Sri Lankans, the extent of vegetarianism, whether there is a potential to introduce lab-grown meat to Sri Lanka, the important factors to be considered when introducing cultured meat to Sri Lankan society and the relationship of education level of people and the acceptance of this novel food technology.

METHODOLOGY

This survey was conducted using a sample of 14200 people covering 11 districts of Sri Lanka. A structural questionnaire was used for this survey.

Sampling Procedure

Probability sampling techniques were adopted to select sample for this survey. Eleven districts representing rural and urban communities in Sri Lanka were used for this survey and districts were used as clusters. Stratified random sampling and simple random sampling approaches were practiced to choose a sample of 14200 people for this survey. Based on the population 85 Divisional Secretariat divisions and 440 Gama Niladhari divisions were selected from these 11 districts using stratified random sampling technique and participants to the survey were selected by simple random sampling techniques from the selected Gama Niladhari divisions. The selected sample included individuals from various professional backgrounds such as medical, agricultural, engineering, banking, business, academic and administrative fields representing both government and private sector employees while 5% of the sample were non-employed.

Conducting the Questionnaire Based Survey

The structured questionnaire was prepared. Questionnaire was designed with most closed-ended questions and few open-ended questions. Few open-ended questions were designed to obtain information about participant background information and to collect their opinion regarding the consumption of cultured-meat if it becomes available in Sri Lanka (i.e., the most considerable factor regarding the lab-grown meat). Close ended questions were in a double-choice or multiple-choice format and some questions demanded multiple answers while some questions allowed selecting more than one answer. Those questions mostly focused on quantitative data collection from the tested sample. Participants were not informed in advance to avoid biasness and modifications. The questionnaire was designed in the Sinhala,

Tamil and English language. A brief outline, including the requirement of introducing in-vitro meat to modern societies and its pros and cons, was conducted prior to presenting the questionnaire. This survey was mainly conducted as an online survey mode using Google online survey platform Open-ended questions

The design of the questionnaire was composed of three sections: (1) socio-demographic information (gender, religion, residence; whether living in urban/ semi-urban/rural area, educational status, occupation and income level), (2) meat consumption pattern (i.e., whether participants are vegetarians or not, reasons for being vegetarians or meat consumers, preference on different meat types, the frequency of meat and meat-based product purchases and consumption at households) and (3) the perception of respondents on cultured meat (intention to reduce or avoid harvested meat, intention to purchase or consume lab-grown meat if it becomes available, factors consider when purchasing cultured meat, whether vegetarians are prone to consume cultured meat, whether meat consumers are prone to substitute harvested meat with cultured meat and whether the participants agree with six important facts; the first three statements were regarding the positive impacts of cultured meat production process (i.e., the involvement in environmental sustainability, food security and animal welfare), the remaining three statements were about beliefs regarding the intrinsic characteristics (i.e., cultured meat would be similar or better in safety aspects, sensory attributes, and nutritional aspects). To evaluate the level of agreement on the above facts, the participants were provided with a five-point Likert scale, ranging from “strongly disagree” (1) to “strongly agree” (5). The relationship between the educational levels of people with the possibility for acceptance of lab-grown meat concept by consumers was tested using regression analysis. The education level of participants was taken as 1.0: Primary education; 2.0: Secondary Education and 3.0: University Education. Their desire to purchase lab-grown meat was ranked using Likert scale ranging from 1-3; 1: Never, 2: May be and 3: Yes, will try. Minitab14 software program was employed for the statistical analysis of collected data (non-parametric) while some data was descriptively analyzed using Microsoft Excel 2010.

RESULTS AND DISCUSSION

Socio-demographic information of the tested sample

The questioned sample was comprised of 67.5% men and 32.5% women. Other socio-demographic information of the survey is shown in Table 1.

Table 1: Socio-demographic information

Age (years)	
<25	8.75%
25-45	62.5%
46-65	15.00%
>65	13.75%
Religion	
Buddhist	85.00%
Catholic	3.75%
Muslim	6.25%
Hindu	3.75%
Other	1.25%
Place of residence	
Urban	30.00%
Semi urban	46.25%
Rural	23.75%

Generally, education level and income of the community are very important parameters when studying a perception (Wilks and Phillips, 2017) and following Figures (Figure 1 and 2) depict the education level and income level of the survey group.

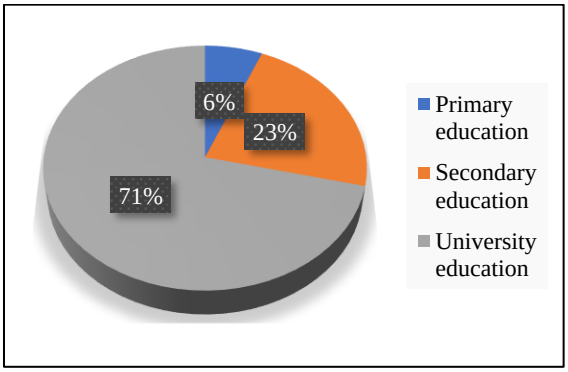

Figure 1: Education levels of the survey group

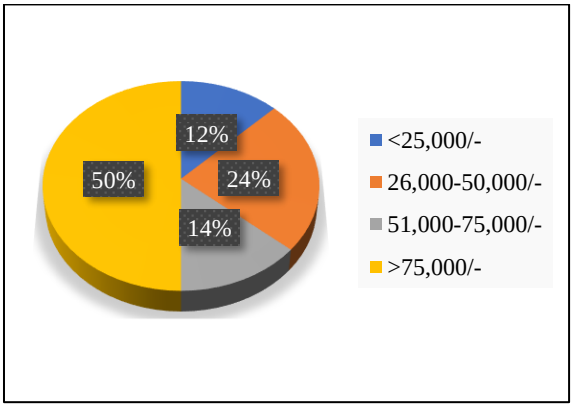

Figure 2: Income levels (LKR) of the survey group

Consumption pattern

Only 2% of the sample was recorded to be vegetarians who avoid meat products. The reasons for being vegetarians, was the unwillingness towards animal slaughtering, health concerns and religious concerns and 71% out of them expressed willingness to consume cultured meat. Literature revealed that the production of in-vitro meat is acceptable and worth promoting concerning the vegetarian concepts (Wilks and Phillips, 2017; Stephans *et al.,* 2018). Those who consume meat, 38.4% stated their intention to reduce conventional meat consumption and all those were females. As a whole, this fact proves that consumers are hesitant to cut their meat consumption in a substantial way although some evidence declared ongoing interest among Sri Lankans in reducing meat consumption by considering the negative health impacts related with conventional meat consumption.

When considering the meat consumption pattern of the tested group of people, chicken meat was noted as the most preferred meat item which was followed by the pork, mutton, and beef respectively. Desire on different meat types were recorded as; chicken 86.25%, pork 50%, mutton 45% and beef 30%. Only 10.61% of the interviewees consume meat products in all main meals and 69.7% of the group consume meat frequently but not in all main meals. Among the tested participants, 13.64% consume meat only in special meals while 6.06% consume meat rarely. Further, 24.25% of the sample purchases raw meat twice or more per week, 48.5% purchase around once a week and the rest purchase once a month. And, 56.06% mentioned that they purchase 1-5 kg in each time whereas 43.94% said that it is less than 1 kg. Regarding the processed meat products consumption, 38.46% of the tested sample commented that they purchase processed meat products such as sausages, meat balls once a week whereas 23.08% stated that they purchase once a month. .

Perception on cultured meat

In current study, the statistical evaluation of factors considered by the respondents when they are purchasing cultured meat (when it is available) revealed that the impact on health is the highest considered factor followed by nutritional properties, sensory properties, and price (Kruskal-Wallis test, average rank 160.5). The 75% of the sample had displayed an interest towards the novel product. Thus, it is possible to predict that there will be a substantial market in Sri Lanka for cultured meat especially after making consumers more educated regarding this concept. But it will remain indefinite how the consumers would react to this novel food produced utilizing a different technology compared to prevailing livestock methods as well as under which circumstances, they would accept this innovative food (Verbeke *et al.,* 2015; Stephans *et al.,* 2018). Hence, it can be recommended that there is a requirement to conduct some more research surveys in Sri Lankan context regarding this novel concept.

The statistical analysis (Wilcoxon Signed Rank Test) confirmed that the tested sample agrees with the first three statements which state cultured meat supports to preserve natural resources ($p<0.05$), supports better animal welfare ($p<0.05$) and contributes to alleviate starvation ($p<0.05$). The results revealed that the consumers understand the negative impacts of intensive animal farming (for meat) on sustainable environmental aspects and animal welfare. In addition, production of cultured meat can contribute to ensure food security of the country.

Results suggested that there was no evidence to accept that the tested sample agrees on statements which state cultured meat is similar or better in sensory ($p>0.05$) and nutritional properties ($p>0.05$) to that of harvested meat and cultured meat is safe ($p>0.05$) to consume. To test the consumer acceptability of cultured meat, sensory attributes of meat, for instance, flavor, tenderness and juiciness, must be evaluated with a sound analytical procedure. Especially when considering meat substitutes, consumers are not ready to accept a new substitute rapidly as they search for the meaty flavor and other specific sensory attributes of natural meat to reduce the food neophobia (Mancini and Antonioli, 2020). People with food neophobia are prone to reject consumption of cultured meat (Ruzgys and Pickering, 2020). Concerning the nutritional aspects, it is of crucial importance to provide detailed nutritional facts on the developed novel product to consumers as it is the second most considered intrinsic attribute. Regarding the safety aspect of cultured meat, people need to know in which way the product is not making any harm to human health majorly due to the fact that consumers view cultured meat as an unnatural product which is one of the strongest obstacles for the public acceptance of this product *(*Welin, 2013*).*

Previous studies disclosed that lack of trust, uncertainty, and concerns over potential adverse long-term consequences are resulted by the unfamiliarity with novel technologies (Frewer *et al.,* 2013; Marcu *et al.,* 2015; Siegrist and Sütterlin, 2017). Even though, there is great uncertainty regarding the acceptance of cultured meat by consumers, provision of information and educating consumers is an effective way to inspire the public to express their opinions and be more accepting (Palmieri *et al.,* 2021).

A regression analysis was conducted to test the relationship between education level and the desire on purchasing laboratory grown meat confirmed that the acceptance level of the lab-grown meat increases with the education level of consumers (Figure 3). Accordingly, it was revealed that people with better education would be the potential group of consumers of cultured meat when it will be available in Sri Lankan context. However, the acceptance of cultured meat can be further raised by awareness and education programs among the consumers in an organized manner, (Palmieri *et al.*, 2021) even among the consumers with lower educational levels.

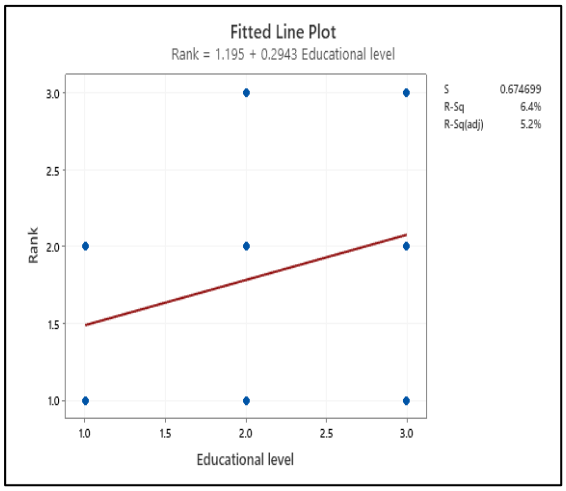

Figure 3: Relationship between education level of consumers and acceptance of cultured meat. Education level; 1.0: Primary education; 2.0: Secondary Education; 3.0: University Education, Rank; Likert scale to depict the desire to purchase cultured meat; 1: Never, 2: May be and 3: Yes, will try.

Answer of most respondents for the question "most considered factor when purchasing lab-grown meat" showed, that genetically modified food is the most considered factor. Hence, cultured meat with genetic modifications is probable to face more resistance from the public when compared with non-genetically modified cultured meat.

CONCLUSIONS

This study basically assessed the meat consumption pattern of Sri Lankans in addition to the evaluation of their perception on cultured meat. It was revealed that Sri Lankan meat consumers are reluctant to cut their meat consumption in a substantial amount even though people are more informed about the negative health impacts of continuous consumption of conventional meat. Further the study recognized that a satisfactory count of consumers including both vegetarians and non-vegetarians were interested in experiencing cultured meat product. There was a good acceptance level for the lab-grown meat in Sri Lanka if meat is not genetically modified. In addition to that, the level of acceptance of this novel product has linear correlation with the education level of the consumers. These results confirmed that Sri Lankans have a good understanding about the positive impacts of cultured meat on animal welfare, environmental sustainability and food security. The survey recommended the requirement of further investigations on this concept which is a novel concept to Sri Lanka..

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GROWTH AND YIELD PERFORMANCES OF TURMERIC (*Curcuma longa*) GROWN IN DRY ZONE OF SRI LANKA AS AFFECTED BY PLANTING SPACE, GROWING MEDIA AND SHADE

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ABSTRACT

Turmeric is mainly grown as monocrop or intercrop in wet and intermediate zones of Sri Lanka. However, promoting the dry zone turmeric cultivation under intensive irrigation and proper shade conditions could address the increased demand for locally produced Turmeric and create an extra potential for exportation. Therefore, it is essential and urgent need to find out the feasibility of growing Turmeric in dry and semi-arid areas. Thus, this study focus evaluate the effect of different plant spacing, growing media, and shade on growth and yield performances of Turmeric in Hambantota district,belong to semi-arid zones. The split-plot design was used. The main plot consisted of two shade levels (30% shade and without shade), and subplots were assigned three spacing (30 x 20 cm, 30 x 30 cm, 30 x 40 cm) and two different potting media (Cow dung: Topsoil - 1:1, Cow dung: Topsoil: Sand – 1: 1: 0.5 replicated by three times. Results revealed no significant interaction of shade, planting spacing and planting media on plant height, leaf length and yield. However, the interaction effects were found between shade and planting media on plant height and shade and planting spacing on rhizome yield. The significant improvement of yield and plant height in plants established in cow dung: topsoil; 1:1 media under shade and plant grown in 30 x 30 cm plant spacing. The significantly highest leaf length was recorded from the plant established under 30% shade compared to without shade and the highest number of sprouts was recorded from the plants in cow dung: topsoil; 1:1 media. The significantly highest yield were recorded from the plants established in both 30 x 30 cm and 30 x 40 cm spacing under shade. Thus, the results could be concluded that plants are grown in cow dung: topsoil: 1:1 media with 30 x 40 cm spacing under 30% shade condition are suitable for turmeric cultivation under dry/semi-arid areas of Sri Lanka.

Keywords: Curcuma longa, Media, Shade, Spacing, Turmeric

INTRODUCTION

Turmeric (*Curcuma longa*) is an herbaceous perennial plant belonging to the family Zingiberaceae native to tropical South Asia, mainly cultivated in India, China, Bangladesh, and Indonesia. *C. longa* is a valued spice and aromatic medicinal plant. The rhizomes of Turmeric are commonly used as a flavoring, coloring agent, and preservative. Mainly it is used as a condiment and coloring agent in the food industry. Additionally, it has a great demand in many industries such as the cosmetic, pharmaceutical industry, and ayurvedic medicines (Abeynayaka *et al.,* 2020). Further, it is used to prepare curry mixtures, color in textiles, and prepare specific paints. The principal constituent of Turmeric is Curcumin, which is diferuloylmethane. Other constituents are curcuminoids and an essential oil called zingiberene. The yellow coloring substances are known as curcuminoids (Gayathiri and Narendhiran, 2020).

Turmeric is an essential component of traditional Indian and Chinese medicine. The main active compound curcumin possesses a vast array of pharmacological effects, including antioxidant, anticancer, anti-inflammatory, antimicrobial (antibacterial, antifungal, and antiviral), antidiabetic, antirheumatic, angiogenic, antifertility, wound healing properties and is used in gastrointestinal and respiratory disorders (Chaudhary *et al.,* 2010, Dasgupta and Klein, 2014).

Turmeric is grown in wet and intermediate zones of Sri Lanka, mainly in Kurunegala, Gampaha, Kalutara, Kandy Matale, and Ampara districts, and generally cultivated as a mono-crop and an intercrop under coconut (DEA, 2021). Furthermore, several locally grown varieties are available, not specially identified. Also, there are imported varieties, namely Gunter, Puna, and Madurasi Majal, and they have been mixed with

local varieties. Currently, turmeric production in Sri Lanka is not self-sufficient. To keep pace with the increased demand, a significant proportion of the local demand is being imported, putting a heavy burden on national income (Abeynayaka *et al.,* 2020).

Moreover, due to the import restrictions imposed by the Government on export agricultural crop products such as ginger, pepper, and Turmeric, farmers showed a significant interest in cultivating such crops. Accordingly, raw turmeric production at 25,506 metric tons in 2020 recorded a remarkable growth of 170.9 percent (Central Bank, 2021). However, to meet increased demand, it is important and urgent to study the feasibility of growing Turmeric in non-conventional areas such as dry and semi-arid areas. Moreover, plenty of lands are available in the dry zone for cultivations, but it is still hardly found that any research has been done on growing Turmeric in dry and semi-arid areas of Sri Lanka. However, DEA (2021) stated that successfully growing Turmeric required medium-level shade and 1500 mm or above annual rainfall.

Further, they stated that Turmeric could be grown in the dry zone under irrigation. Moreover, recent research indicates the effectiveness of planting spacing, growing media, and shade level to the yield and quality performance of Turmeric (Aly *et al.,* 2019; Bhadouria *et al.,* 2014). Therefore, the present research was designed to study the growth and yield performances of Turmeric as affected by different planting spacings, growing media, and shade under dry zone conditions in Sri Lanka.

METHODOLOGY

Experimental Location

The experiment was carried out at the research farm of the University of Colombo Institute for Agro-Technology, and Rural Sciences (UCIARS) in Weligatta, Hambanthota, at an altitude of 17 meters above mean sea level and DL5 Agro-ecological region in Sri Lanka, which is one of the areas where least amount of annual rainfall received.

Experiment design

The experiment was designed according to the Split plot design with 12 treatment combinations with three replicates, and each replicate contains 40 plants. The main plot consisted of two shade levels as 30% shade (S1) and without shade (S2), and subplots were assigned three spacing 30cm x 20cm, 30cm x 30cm, 30cm x 40cm respectively for P1, P2, and P3, and two different potting media Cow dung: Topsoil - 1:1 (M1), Cow dung: Topsoil: Sand – 1: 1: 0.5 (M2).

Plant establishment

Thirty-six beds with 3 m length and 1m width were prepared, and topsoil, sand, cow dung were added to the beds according to the treatments during the bed preparation. Healthy matured finger rhizomes were collected from the UCIARS farm and planted 50 g per planting hole.

Fertilization was practiced according to the DEA recommendations (Urea Kg/ha and MOP Kg/ha as a basal and Urea Kg/ha and MOP Kg/ha as a top dressing, 90 days after planting). Watering was practiced once every two days up to 7 months of planting if there were no rains. Watering frequency was reduced seven months after planting. Weeding was done when necessary.

Data collection

Plant height, leaf length, and the number of sprouts per plant were taken as growth parameters biweekly, and fresh rhizome yield was taken at harvesting as yield parameters.

Data analysis

Analysis of data was carried out using ANOVA procedure, and mean comparison was performed using Turkey pair-wise analysis using the MINITAB version 17 to evaluate statistical significance (P= 0.05)

RESULTS AND DISCUSSION

Weather

The average temperature of the field was 28.33 oC during the growing period. The light intensity of the field was around 38860 lux with 30% shade and 86160 lux without shade during the growing period of Turmeric.

Growth parameters

Plant height

There was no significant interaction of shade, planting spacing, and planting media on plant height. However, there was a significant interaction between shade and media on plant height after 23 weeks of planting up to 31 weeks after planting (Table 1). The height of plants established in cow dung: topsoil; 1:1 media and cow dung: topsoil: sand; 1:1: 0.5 media under shade were significantly higher than the plants established without shade. This might be due to the low light intensity and high relative humidity under the shade net situation (Babu *et al.,* 2019).

Leaf Length

There was no significant interaction effect of shade, planting spacing, and growing media on the leaf length of turmeric plants. However, there was

Table 1: Height of plants in different treatment combinations of shade and planting media

Treatment	21WAP	23 WAP	25 WAP	27 WAP	29 WAP	31 WAP
S1: M1	97.48±8.49^{a}	114.40±8.05^{a}	120.79±8.85^{a}	127.36±11.17^{a}	127.67±10.99^{a}	127.86±11.31^{a}
S1: M2	96.27±11.89^{a}	110.78±12.21^{ab}	120.34±12.21^{a}	126.86±16.47^{a}	127.02±15.95^{a}	127.50±16.34^{a}
S2: M1	83.11±12.44^{b}	88.49±11.88^{c}	93.27±11.88^{c}	97.42±13.01^{c}	97.82±13.32^{c}	97.83±13.64^{c}
S2: M2	91.48±12.77^{ab}	99.57±11.66^{bc}	104.95±11.66^{b}	109.59±11.64^{b}	110.86±12.17^{b}	111.18±12.58^{b}
P value	0.123	0.018	0.050	0.001	0.000	0.000

WAP – weeks after planting. Mean ± SE. Values in each column followed by the same letter are not significantly different at 0.05 probability level according to ANOVA

Table 3: Fresh yield of different treatment combination

Interaction Effect	Treatment Combination	Fresh weight of Turmeric (g)	P-value
Shade level and the potting media	S1:M1	428.000±33.81^{a}	0.039
	S1:M2	386.222±18.66^{ab}	
	S2:M1	267.444±25.16^{c}	
	S2:M2	326.556±25.66^{bc}	
Shade level and the growing spacing	S1:P1	338.33±29.17^{bc}	0.017
	S1:P2	413.67±26.49^{ab}	
	S1:P3	469.33±23.64^{a}	
	S2:P1	329.83±34.65^{bc}	
	S2:P2	244.00±17.67^{c}	
	S2:P3	317.17±33.52^{bc}	

Mean ± SE. Values in each column followed by the same letter are not significantly different at 0.05 probability level according to ANOVA

Table 2: Leaf length and number of sprout in different treatments

Treatment	9WAP	11WAP	13WAP	15WAP	17WAP	19WAP	21WAP	23WAP	25WAP	29WAP	31WAP
Leaf Length											
Shade 30%	14.10±0.45^{a}	17.90±0.75^{a}	22.99±1.58^{a}	28.33±2.19^{a}	33.62±2.66^{a}	40.02±2.49^{a}	43.60±2.49^{a}	47.78±2.29^{a}	52.70±2.06^{a}	58.85±1.74^{a}	56.85±1.74^{a}
Without shade	12.30±0.42^{b}	15.96±0.89^{a}	19.32±1.37^{b}	23.58±2.06^{b}	27.64±2.40^{b}	32.03±2.59^{b}	36.67±2.44^{b}	41.15±2.24^{b}	47.09±1.99^{b}	49.44±1.71^{b}	49.44±1.77^{b}
P Value	0.006	0.066	0.022	0.014	0.012	0.005	0.010	0.012	0.036	0.006	0.006
Number of Sprout per plant											
M1	7.98±0.084^{a}	2.56±0.15^{a}	3.13±0.18^{a}	3.68±0.23^{a}	4.20±0.26^{a}	4.75±0.27^{a}	5.23±0.28^{a}	5.70±0.29^{a}	6.11±0.27^{a}	6.51±0.27^{a}	6.73±0.27^{a}
M2	1.75±0.52^{a}	2.13±0.15^{b}	2.53±0.17^{b}	2.95±0.16^{b}	3.53±0.18^{b}	4.00±0.19^{b}	4.40±0.20^{b}	4.80±0.21^{b}	5.19±0.24^{b}	5.62±0.24^{b}	5.81±0.23^{b}
P value	0.299	0.37	0.010	0.008	0.038	0.029	0.018	0.013	0.015	0.014	0.013

WAP - weeks after planting. Mean ± SE. Values in each column followed by the same letter are not significantly different at 0.05 probability level according to ANOVA

a significant effect of shade on the leaf length of turmeric plants (Table 2). The significantly highest leaf length was recorded from the plants established under 30% shade from 13 weeks to 31 weeks after planting.

Number of sprouts per plant

There was no significant interaction effect of shade, planting spacing, and media on the number of turmeric plants sprout. There was a significant effect of growing media on the number of sprouts per plant (Table 2). The significantly highest number of sprouts per plant was recorded from the plants established in cow dung: topsoil; 1:1 media.

Yield Parameters

Fresh weight of Turmeric

There was no significant interaction effect of shade, planting spacing, and planting media on the yield of Turmeric. There was a significant interaction effect of shade and growing media on the fresh yield of Turmeric (Table 3). However, there was a significant interaction of shade and planting spacing and shade and growing media on rhizome yield. The significantly highest fresh yield was recorded from the plants established in cow dung: topsoil; 1:1 media under shade. The significantly higher yield was recorded from plants established in 30 x 40 cm spacing and 30 x30 cm spacing under shade.

Kiran and colleagues in 2013 studied the effect of plant spacing on vegetative characters and the yield of Turmeric. The study revealed that the spacing 30 x 50 cm had significantly least days taken to sprouting, maximum plant height, number of leaves per plant, leaf length, leaf diameter, stem per plant, number of fingers per plant, finger length, finger weight, the diameter of the finger and turmeric yield. Further, Bhadouria and colleagues in 2014 and Kumar and Gill in 2009 were observed a significantly high yield with wide spacing 60 x 20 cm and 83,333 plants per ha, respectively.

The present study reveals a significant interaction between shade and media on plant height, a significant effect of shade on the leaf length, and growing media's effect on the number of sprouts on the turmeric plant. Further, it was shown that there was a significant interaction effect of shade and growing media on the fresh yield of Turmeric.

Recent research conducted by Shannon and colleagues in 2019 stated that Turmeric plants established under shade showed a significant increment of plant height, leaf size, and fresh weight of rhizomes. According to Srikrishnah and Sutharsan (2015), the biomass and the yield of turmeric plants cultivated under 50% shade level were significantly higher than those cultivated in zero shade. The increment of shade level of more than 50% reduced the amount of solar radiation and caused decreased photosynthesis. Aly and colleagues in 2019 identified that the plant height, number of leaves per plant, leaf area, and dry matter content was higher in the ginger plants established in shade level compared to the plants without any shade. Further, the shade significantly improved the number of tillers per plant and the rhizome weight of ginger, while plants established without any shade showed a reduction in ginger's growth and yield (Aly et al., 2019).

CONCLUSIONS

Significant yield performance for the growing media was shown by cow dung: topsoil; 1:1from the tested media combination. Suitable plant spacing and shade level for the turmeric cultivation in dry zone area is 30 cm x 40 cm and 30% shade condition. Turmeric can be cultivated successfully in the country's driest areas in Hambantota with intensive irrigation and proper shade condition.

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