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Editorial Policies

The Journal of Dry Zone Agriculture (JDZA) publishes two issues in a volume annually with original research articles covering all aspects of dry zone agriculture. Authors preparing manuscripts should follow the instructions appearing at the end of this volume. All opinions reflect the views of the authors and are not necessarily the views of Faculty of Agriculture, University of Jaffna. Final decision of the acceptance or rejection of the papers is made by the editorial board. The JDZA is devoted to sustain the standard through a rigorous blind review along with strict ethical policies. The JDZA publishes original research works that have not been published in any form except abstract or not currently under consideration for publication elsewhere. Any violations of professional ethical codes such as plagiarism, fraudulent use of data and bogus claims of authorship are taken seriously by the editors. Authors are expected to acknowledge the funding sources. Copyright materials must be reproduced only with the permission and acknowledgement. Authors should ensure that text, equations or figures from published sources have been cited.

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Editor's Note

It is with great pleasure and privilege to publish the Volume 5 of the Journal of Dry Zone Agriculture (JDZA) of Faculty of Agriculture, University of Jaffna, Sri Lanka. The objective of the JDZA is to publish up-to-date and high quality research findings, focusing all aspects of agriculture in the dry zone of Sri Lanka. Since 2/3 of Sri Lanka is under dry zone and agriculture in these areas witnessed severe losses due to climate change at recent times especially abnormal floods and prolonged severe drought that are given prime importance in the Sustainable Development Goals to be achieved in 2030. Mitigating climate change is the prioritized area to be considered in the next decade since water will be an expensive commodity in near future. Solutions through research to support the activities identified against SDGs will contribute immensely to the regional, national and by global contexts.

Agriculture needs further advancement in technological applications into diversifying the habitat, resource management, marketing, value addition and storage. Integration of all the sectors in agriculture with the livestock and fisher sectors is the real-time development expected in Northern Province to increase the employment opportunities as well as to uplift its GDP contribution. Researches should also need to focus on agro based industrial development, automation, use of renewable energy and labour consuming technologies to uplift the agricultural development to the next level. This volume consists of twelve full research articles are selected from the abstracts presented at 4th International Conference on Dry Zone Agriculture (ICDA 2018) and submitted research papers in 2019. The Research papers submitted to JDZA are not published previously in the same, or any other form or being considered for publication elsewhere. To ensure the quality of the research papers, all the papers are peer reviewed and finalized by the team of experts.

I would like to thank the contributions made by the authors, and voluntary support given by the reviewers, editors and the editorial board for their tireless efforts to finalize the articles and messages to this volume. Further I also would like to acknowledge the financial support provided by the University of Jaffna to publish the journal. The Editorial Board encourages publications relating to research and development especially on dry zone agriculture containing new methodological approaches to disseminate the knowledge to the community. At last I thank all who witnesses the release of this journal on the inaugural day of the 5th International Conference on Dry Zone Agriculture in December, 2019.

Prof. Thushyanthy Mikunthan
Editor-in-Chief

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Effect of Different Potting Medium on Growth and Yield Performances of Capsicum under Organic and Inorganic Management

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Abstract: A pot experiment was conducted to evaluate the effect of different potting medium on growth and yield performances of capsicum (*Capsicum annum* var. Hungarian Yellow Wax) under organic and inorganic management conditions. The experiment was carried out in Completely Randomized Design (CRD) with six replicates. Four potting medium combinations; cattle manure: topsoil 2:1, compost: topsoil 2:1, leaf mould: topsoil 2:1, topsoil only were used under organic and inorganic managements as treatments. For inorganic management, all management practices were uniformly performed based on the recommendations of Department of Agriculture, while for the organic management, farmers adopted practices were followed. Growth parameters such as leaf number, number of branches and plant height were measured in biweekly interval and yield parameters such as weight of fruit, length, circumference and average yield per pot were measured after harvesting. ANOVA and Duncan Multiple Range test were used for data analysis. There were significant differences observed in growth parameters; plant height and leaf number among the treatments, but there was no significant difference in number of branches. There were significant differences in yield parameters among the treatments. The highest fruit length, circumference and individual fruit weight were observed in compost: topsoil combination under organic management. The highest average fruit yield per pot was observed in compost: topsoil combination under inorganic management due to the production of higher number of fruits in inorganic management. It can be concluded that under organic management, rooting medium combination of compost: topsoil at the ratio of 2:1 can be recommended for small scale pot cultivation due to eco-friendly cultivation, whereas, under inorganic management, incorporation of compost with soil can be recommended for profitable commercial level cultivation in the field.

Keywords: Capsicum, Inorganic fertilizer, Organic fertilizer, Potting media, Yield

Introduction

Consuming vegetables provides many health benefits. People who eat more vegetables and fruits as part of an overall healthy diet are likely to have a reduced risk of some chronic diseases. Vegetables provide nutrients vital for health and maintenance of human body. Most vegetables are naturally low in fat and calories. None have cholesterol.

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Vegetables are important sources of many nutrients, including carbohydrate, protein, fats, potassium, dietary fiber, folic acid, vitamin A and vitamin C (Yawalker, 1985).

Capsicum is an important Solanaceae family crop of sup-tropics and tropics possessing 10 species. In Sri Lanka, this vegetable crop is cultivated in large extent due to its good market demand (Sarkar *et al.,* 2007). It has a unique place in Asian diet as spice and vegetable. Capsicum is consumed as fresh pod throughout the world. It is rich in proteins, lipids, carbohydrates, fibers, mineral salts; Ca, P, Fe and in vitamins A, D_3, E, C, K, B_2 and B_{12}. The fruits are a good source of health-related phytochemical compounds that are very important in preventing chronic diseases such as cancer, asthma, coughs, sore throats, toothache, diabetes, and cardiovascular diseases (Orobiyi *et al.,* 2013).The production of capsicum was 73,679 Metric tons and 62,666 Metric tons in 2014 and 2015, respectively in Sri Lanka. The reason for 14.6% of yield reduction from 2015 to 2016 might be adverse climatic condition and leaf curl complex.

It is easy to think of soil as a good medium, but most soils when used alone are very poor growing medium. The structure of the growing medium must be soft and porous enough, so that roots can easily penetrate widely into the material and it must also provide anchorage and support for the plants (Utobo *et al*., 2015). The physical, chemical and biological properties of a growing medium can be used as a basis of classifying the suitability of a growing medium in relation to the needs of the roots (Egunjobi and Ekundare, 1981). The materials used in a potting mix can be manipulated or processed to produce a growing medium with superior physical properties to the soil (George and Kelvin, 2004).

Organic farming is defined as the production system in which avoids or largely excludes the use of synthetically compounded fertilizers, pesticide, growth regulator and livestock feed additives. To the maximum extent feasible organic farming system rely upon crop rotations, crop residues, animal manures, legumes, green manure, off-farm organic wastes and aspects of biological pest control insets, pest weeds etc.

Although the vegetable production at present is mostly depending on the inorganic fertilizers, the organic production of vegetable is timely needed due to the problems associated with inorganic fertilizers. There were several studies carried out regarding effect of potting medium on growth and yield of capsicum, but only few studies have been carried out in Sri Lanka, especially in Kilinochchi. By considering this gap, this study was conducted to evaluate the effect of organic and inorganic management of capsicum among different potting media and its influence on growth and yield performances of capsicum by finding the suitable potting medium to optimize the yield and evaluating the impact of organic and inorganic managements on growth and yield performance of capsicum.

Materials and Methods

An experiment was carried out in the Faculty of Agriculture, Ariviyal Nagar, Kilinochchi during the period of March to July 2018 to study the effect of different potting media on growth and yield performances of capsicum under organic and inorganic managements. The experiment was carried out in Completely Randomized Design (CRD) with six replications. Four growing media combinations (cattle manure: topsoil 2:1, compost: topsoil 2:1, leaf mould: topsoil 2:1, topsoil only) were used as treatments in organic and inorganic management for capsicum Hungarian Yellow Wax variety.

Capsicum Hungarian yellow wax variety was selected due to conical shape fruits, thick flesh, smooth and shiny surface and it has good market demand in Northern region of Sri Lanka. Seeds were treated with captan (3.75 g/kg) and sowed in a nursery tray (22.5 cm width and 52.5 cm length) with cells dimensions of 6.25 × 6.25× 6.25 cm each. Rooting media for nursery trays was prepared by using the sterilized coir dust and topsoil at the ratio of 1:1 and treated with captan (6 g/m^2). Regular watering was done by using a hand sprayer at morning and evening until the seeds are germinated.

One month after germination, uniform size capsicum seedlings were transplanted in plastic pots filled with rooting media as in the treatments and two seedlings were assigned in each pot. All pots were kept in a shade for one week to prevent the stress conditions. Thereafter, the pots were transferred to the field. After the successful establishment of the seedlings, one vigorous healthy seedling was allowed per pot. Capsicum pots were arranged according to recommended spacing of 30 cm ×15 cm.

Watering was done by using a watering can and the surface soil in each pot was kept in wet condition, but excess watering was avoided. All management practices were done as recommendation made by Department of Agriculture in inorganic management. In organic management, bio fertilizer (*Aspergillus spp.*) was used as a basal fertilizer at the rate of 125 g per pot, then, water was applied, next day seedlings were transplanted in the pot. Vermiwash liquid was used as foliar spray at the rate of 1: l mixed with 500 mL water and organic solution.

Five leaf solution (made-up with castor (*Ricinus communis*), gliricidia (*Gliricidia sepium*), Parvettai (*Pavetta indica*), Vandukolli (*Cassia alata*) and Ardathodai (*Justicia adhatoda*) was sprayed to control pest and disease incidences whenever observed. Harvesting was done 75 days after planting when the fruit reached yellowish green colour. Growth parameters such as leaf number, number of branches and plant height were measured biweekly interval commenced from 2 weeks after transplanting and yield parameters such as fruit weight, fruit length, fruit circumference and total yield of treatments were measured after harvesting. Data were analyzed by using the SAS 9.1 and mean separation was done using Duncan's Multiple Range Test.

Results and discussion

Growth parameters

Number of leaves

There was significant difference among the treatments in the number of leaves per plant during their vegetative growth (Table 1). The highest leaf number was observed in compost: topsoil medium under inorganic cultivation (T_6) and the lowest leaf number in leaf mould: topsoil medium under organic management (T_3). There was significant difference between organic and inorganic management in the number of leaves per plant during their vegetative growth. Number of leaves was higher in inorganic management compared to organic management of each potting medium. The difference among the treatments would be due to the different composition of potting medium. Bilderback *et al*. (2005) stated that organic components decompose during crop production and may change both the physical and chemical composition of the medium. This may affect crop growth and development.

Plant Height

Plant height is an important growth parameter which is influenced by the genetic and the environmental factors. The results revealed that there were significant difference among the different treatments and management practices (Figure 1). Highest plant height was observed in compost: topsoil medium under inorganic management and the lowest plant height was recorded in leaf mould: topsoil under organic management. The reason may be the variation in nutrient contents in different types of rooting media. Akanbi *et al*. (2002) stated that in container or poly bags crop production, use of organic potting media substrate offers a great advantage over the conventional topsoil. George (2004) stated that compost is perhaps the most common potting mix

Table 1: Number of leaves of capsicum in different potting media in organic and inorganic management

Treatment		2 weeks	4 weeks	6 weeks	8 weeks	10 weeks
Organic	Cattle manure+ topsoil	7.16 ^{d}	18.33 ^{d}	30.83 ^{c}	41.16 ^{ab}	45.66 ^{bc}
	Compost + topsoil	8.83 ^{c}	18.66 ^{d}	33.66 ^{a}	45.16 ^{a}	50.00 ^{ab}
	Leaf mould+ topsoil	6.33 ^{d}	17.16 ^{d}	26.33 ^{d}	34.33 ^{c}	37.66 ^{d}
	Topsoil	6.83 ^{d}	17.33 ^{d}	28.33 ^{cd}	34.83 ^{c}	39.5 ^{d}
Inorganic	Cattle manure+ topsoil	14.66 ^{b}	25.66 ^{a}	36.83 ^{a}	45.16 ^{a}	51.16 ^{a}
	Compost + topsoil	16.66 ^{a}	27.33 ^{a}	36.83 ^{a}	45.16 ^{a}	52.16 ^{a}
	Leaf mould+ topsoil	13.5 ^{b}	23.00 ^{c}	30.83 ^{bc}	37.00 ^{bc}	41.5 ^{cd}
	Topsoil	13.33 ^{d}	22.00 ^{c}	28.83 ^{cd}	35.33^{c}	41.00 ^{cd}

Each Colum values followed by the same letter are not significantly different by DMRT at p=0.05

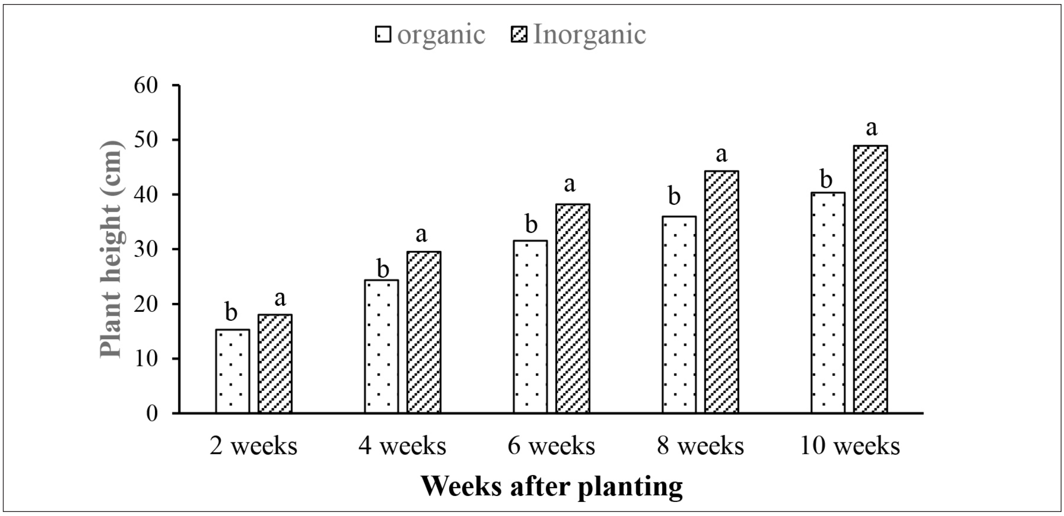

Figure 1: Plant height under organic and inorganic management

ingredient among organic products. Compost holds water well. This result was agreed with Edwards and Hailu (2011) reported that the application of compost at reasonable rates improved plant growth and soil physical properties and increased the available soil nutrient levels.

Number of Branches

Number of branches is important growth parameter which influenced by genetic and environmental factors and affects the flower and fruit number. Although the differences in number of branches were not significant among treatments, the result showed that the branch production under inorganic management was higher than in the organic management.

Yield Parameters

Fruit Length

Fruit length was insignificant among treatments except leaf mould: topsoil in organic management. Maximum fruit length was observed in the compost: topsoil media in organic management and the lowest fruit length was observed in the leaf mould: topsoil in organic management.

Fruit Circumference

There was a significant difference in fruit circumference among different potting medium in organic and inorganic management. The highest fruit circumference was observed in compost: topsoil medium in organic management and the lowest fruit circumference was observed in leaf mould: topsoil medium in organic management. There was no significant difference in cattle manure: topsoil medium and topsoil medium in organic management and cattle manure: topsoil in inorganic management. Utobo *et al.* (2015) stated that the potting media mixture significantly affected all the vegetative growth parameters and yield parameters in plants.

Individual Fruit Weight

There was a significant difference in fruit weight among different potting medium in organic and inorganic management (Figure 2). Highest average fruit weight of 26.5 g was observed in compost: topsoil medium in organic management and the lowest fruit weight (15.8 g) was observed in leaf mould: topsoil medium in organic management.

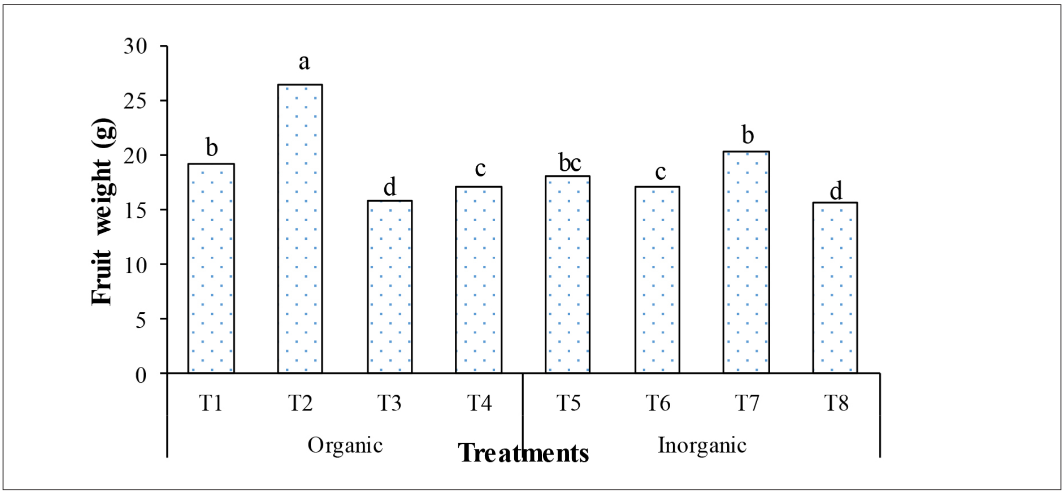

Figure 2: Average fruit weight of capsicum in different potting medium under organic and inorganic management

T_1, T_5 - cattle manure + topsoil
T_3, T_7- leaf mould + topsoil
T_2, T_6 – compost + topsoil
T_4, T_8 - topsoil

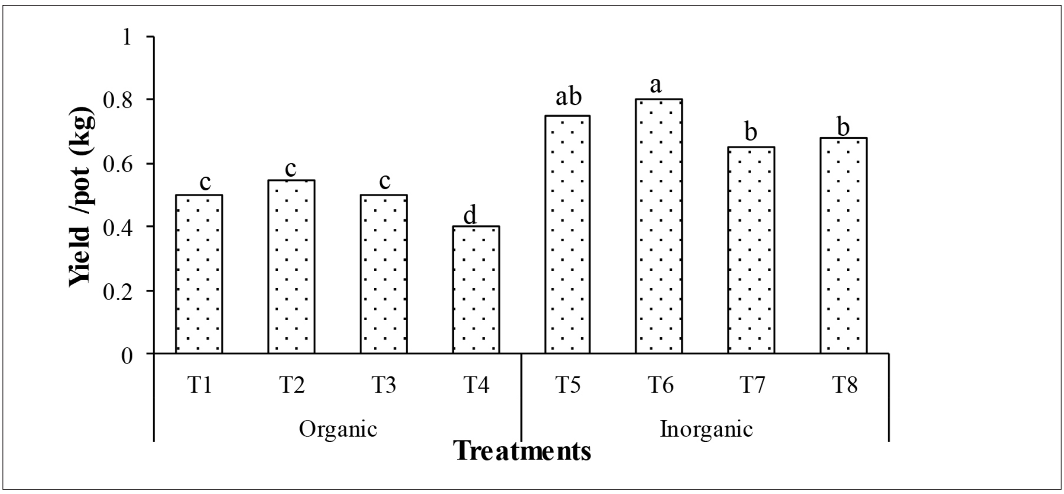

Figure 3: Average yield/Pot of capsicum in different potting medium in organic and inorganic management.

T1 , T5 - cattle manure + topsoil
T3 , T7- leaf mould + topsoil
T2 , T6 – compost + topsoil
T4 , T8 - topsoil

Average Yield / Pot

The yield was significant among treatments and the highest yield of 0.805 kg/pot was recorded in compost: topsoil medium under the inorganic management and the lowest yield was obtained in topsoil medium under the organic management (Figure 3). There was no significant variation between leaf mould and topsoil medium and cattle manure and topsoil medium and compost and topsoil under the organic management. The highest yield in compost: topsoil medium could be coupled to the production of higher number of fruits than the other treatments

Griffin and Porter (2004) and Elisabetta and Nicola (2009) stated that compost application to the soil has several beneficial effects on crop yield and soil fertility by improving and increasing soil organic matter, water holding capacity, nutrient contents, soil aggregation and microbial activity. Bilderback *et al.* (2005) stated growing media have three main functions as; provide aeration and water, allow for maximum root growth and physically support the plant.

Growing media should have large particles with adequate pore spaces between the particles. Appropriate particle size selection or combination is critical for a light and fluffy (well-aerated) medium that promotes fast seed germination, strong root growth and adequate water drainage. Due to its multiple positive effects on the physical, chemical and biological soil properties, compost contributes to the stabilization and increase of crop productivity and crop quality (Amlinger *et al*., 2007; Tayebeh *et al*., 2010). Long-term field trials proved that compost has an equalizing effect of annual/seasonal fluctuations regarding water, air and heat balance of soils, the availability of plant nutrients and thus the final crop yields (Amlinger *et al*., 2007). An integrated approach, combing application of compost with an application of artificial fertilizer is a good strategy for sustainable crop production (Gete *et al.,* 2010)

Conclusions

All growth parameters such as number of leaves and plant height were significantly differed among treatments and the highest was obtained in compost: topsoil media under inorganic management and the lowest was in leaf mould: topsoil media under organic management. There was insignificant difference in number of branches among the treatments. There was a significant difference in all yield parameter among treatments.

The fruit length, fruit circumference and fruit weight were highest in compost: topsoil media under organic treatment, but the highest average yield was recorded in the compost: topsoil media under inorganic management due to higher number of fruits. It can be concluded that compost: topsoil in 2:1 ratio under organic management can be recommended for home garden container cultivation with eco-friendly manner and incorporation of compost with soil under inorganic management can be recommended for profitable commercial level cultivation in the farmers' field.

Suggestions

This experiment should be carried out by using other locally available materials; wood shavings, partially burnt paddy husk as rooting media and the experiment can be repeated in both *Maha* and *Yala* seasons with same and other varieties of capsicum to get consistency. Further, the same experiment should be repeated with chemical analysis of media at different growth stages of capsicum.

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Promising lines of Eggplant (*Solanum melongena*) Developed through Population improvement of locally popular cultivar –Plastic

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Abstract: Recurrent selection is an important breeding method employed to improve the populations of crop plants particularly those of cross-pollinated species. Brinjal (*Solanum melongenum* L.) is one major cross-pollinated crop which most important vegetables of the world and a huge prospect in Sri Lanka. Several brinjal landraces are being cultivated in Sri Lanka even though few brinjal varieties have been released by Department of Agriculture. A local brinjal cultivar, so-called 'Plastic', is also one of the popular cultivars being cultivated by farmers in the northern region, especially in Vanni area of Sri Lanka. This cultivar does not have a pure population in the farmer's field and the farmers received the seed materials from unreliable sources. Regional Agriculture Research and Development Centre (RARDC), Kilinochchi has initiated a purification program of the plastic cultivar since the year of 2016. Randomized complete block design (RCBD) was used with five replicates. Recurrent selection and restricted open-pollination methods have been continued for five consecutive seasons with five lines to get a purified high-yielding brinjal cultivar. Originally developed five lines were advanced for three seasons and one line (number 5) was dropped out from the third season owing to its low yielding performance. While improving the population, yield evaluation was also made. Yield evaluation conducted in the fourth and the fifth seasons with the selected lines that indicated significant difference in their yield performances among these lines. Finally, two high performing uniform lines (Line number 02 and 03) with the yield more than 22 t/ha were generated. These two lines could be promoted as promising variety/s after conducting multi-locations trials.

Keywords**:** Landraces, Population improvement, Recurrent selection

Introduction

Eggplant (*Solanum melongena*) is a widely grown species among the *Solanaceous* crops in both greenhouses and at the open fields, consumed throughout the year, in Asia, Africa, and the subtropics, including the southern USA and the Mediterranean region (Daunay, 2008). They show a wide variation according to their

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morphological structure (Cericola *et al*., 2013). It has large diversity of fruit color, shape and size and a large number of cultivars have been cultivated throughout the world according to market needs and consumer demands (Sidhu *et al*., 2005). Genetic improvement of any crop mainly depends on the amount of genetic variability present in the population and the germplasm serves as a valuable source of base population and provide scope for wide variability (Gavade and Ghadage, 2015). An improvement in yield and quality of brinjal is normally achieved by selecting the genotypes with desirable character combination existing in nature or from recombinant population developed through by hybridization.

Varieties of eggplants varying in size, shape, and color are put in the market for sale. Healthy looking, shiny, bright-colored fruits that feel heavy and firm with stout and green stalks are considered as fresh. Several brinjal landraces are being cultivated in Sri Lanka even though few brinjal varieties have been released by Department of Agriculture for general cultivation (Arasakesary *et al*., 2013). A local brinjal cultivar so-called "Plastic" also one of the popular cultivar is being cultivated by farmers in the northern region, especially in Vanni area of Sri Lanka. The average yield of this local cultivar is varying from 15-20 t/ha. However, this cultivar does not have a pure-population in the farmer's field and the farmers received their seed materials from unreliable sources. The growers are often not producing their own seeds. So, availability of the pure plastic cultivar is important for brinjal production. To meet required seed supply, self-seed production is promoted by various agencies. RARDC, Kilinochchi has initiated a purification program of the plastic cultivar with the support of Food and Agriculture (FAO), Kilinochchi since the year of 2016. This paper stems out from the series of the experiments conducted on purification of plastic brinjal cultivar.

Methodology

The seeds used in this experiment were received from the Deputy Director (Extension), Department of Agriculture, Vavuniya. The seeds were graded as Very good (14.9 g), Good (4.6 g) and Bad (1.1 g) respectively to get good vigorous seedlings for selection process. Good seeds were sown in the nursery beds on 11th of January 2016. Base population was established with 550 plants in 2015/16 *Maha* season. Twenty-five day old seedlings were planted with a spacing of 90 x 60 cm as a single plant per hill in 3.6 x 3 m plots. Primarily selection was based on the characters; plant height, number of branches per plant and number of leaves per plant. At fruits maturity, a second and more vigorous selection was practiced and compared with the primarily selected plants based on the fruit's characteristics; number of fruits per plant, fruits weight, fruit length and the diameter. Selected plants were then covered by insect proofing net to assure open fruit setting by open-pollination within the flowers of the same plants. Thus 60 plants were selected from the whole population based on the plants and fruit characters. The second generation was raised from the selected superior individuals; the same selection procedure was continued for another three seasons thereby four superior lines were identified and established at fourth and fifth seasons. Each line was selected with 80 plants. In the later season the populations were near homozygocity. Thus the off types were only removed and the seeds of selected lines were bulk to have uniform population. Agronomic traits were characterized using the descriptors of Plant Generic Resource Center, Gannoruwa. Fifteen traits were used to separate the line generated at fourth season. At flowering stage; the following traits were measured from five plants from each line; plant height (cm), Leaf blade length (cm), and Leaf blade Maximum Width (cm). Other morphological characterization also was done to identify the variation among these selected lines. Samples of five randomly selected fruits, at the maturity stage of each plant were used to determine the fruit traits; length (cm), diameter (cm) and weight (g). While, number of fruits per plant and total fruit yield per plant (g) were also estimated on the basis of average value of five plants. Superior lines were identified from overall performance of line generated at final season.

Results and discussion

Morphological characters observed in the segregating population of the plastic cultivar observed are given in table 1.

Growth habit comprising fifteen characters were not considerably different among these lines except notable difference of the plant high which ranged from 71.2 to 81 cm. The prominent difference in the plant height and the fruit length were observed although seeds were generated for the fourth season.

Average values of the yield attributing traits observed in the fourth season

Table 1: Details of morphological characters observed in plastic cultivar

Character	Line 01	Line 02	Line 03	Line 04
Growth habit	Intermediate	Intermediate	Intermediate	Intermediate
Petiole color	Green	Green	Green	Green
Leaf blade color	Violet	Violet	Violet	Violet
Leaf blade length(cm)	33.3	34	35	34.4
Leaf blade maximum width (cm)	15.7	15.5	17.3	15.8
Leaf blade lobbing	Weak	Weak	Weak	Weak
Leaf blade tip angle	Intermediate	Intermediate	Intermediate	Intermediate
No of leaf prickles on upper surface of the leaf	None	None	None	None
Plant height at flowering stage (cm)	75.1	81	75.9	71.2
Days to flowering	36	36	36	36
Corolla color	Light Violet	Light Violet	Light Violet	Light Violet
Fruit curvature	Slightly Curved	Slightly Curved	Slightly Curved	Slightly Curved
Fruit apex shape	Rounded	Rounded	Rounded	Rounded
Primary fruit color at table use maturity	Purple	Purple	Purple	Purple
Fruits color at physiological ripeness	Deep-yellow	Deep-yellow	Deep-yellow	Deep-yellow

Table 2: Details of some yield related characters observed in four lines of plastic cultivar

Characters	Line 01	Line 02	Line 03	Line 04
Number of flowers per inflorescence	3	4	4	3
Length of mature fruit (cm)	20.2	23.5	22.92	19.6
Fruits diameter at broadest part (cm)	4.47	5.12	4.97	4.26
No of fruits per inflorescence	1	1	1	1
Average number of fruits per plant at one shot harvest	4	6	5	3
Weight of fruit at table use maturity (g)	88	96	92	87

were depicted in the table 2. The observed value indicated that the line number 01 and 04 had three flowers per inflorescence while this value was four in line number 2 and 3. Correspondingly the length of the mature fruit also had around 3 cm longer than that in fruits of line number 1 and 4. Number of fruits per plant at one shot harvesting was highest in line number 2 (6) while low in line number 4 (3). Weight of the fruit at table use maturity also had the highest value in line number 2 (96 g) flowed by the line number 3 (92 g).

Originally developed five lines were advanced for three seasons and line number 5 was dropped out from the third season owing toit's low yielding performance. Yield evaluation was conducted in the fourth and fifth seasons with remaining four selected lines and it indicated that there were significant improvement and differences in their yield performance among these lines on the selection in continues season (Table 3). Selection is the most important tool in plant breeding and it's effective in changing gene and genotype frequencies.

Table 3: Diversified yield performances of selected plastic cultivar lines

	2016/17 *Maha*		2017*Yala*		2017/18 *Maha*	
Line	Marketable Yield t/ha	None Marketable Yield t/ha	Marketable Yield t/ha	None Marketable Yield t/ha	Marketable Yield t/ha	None Marketable Yield t/ha
Line-01	$12.83^{b}\pm0.30$	5.72^{a}	$10.75^{b}\pm0.32$	4.66^{a}	$17.17^{c}\pm0.27$	6.38^{b}
Line-02	$16.28^{a}\pm0.65$	4.17^{d}	$17.11^{a}\pm0.27$	3.69^{d}	$22.88^{a}\pm0.27$	4.75^{d}
Line-03	$16.88^{a}\pm0.50$	4.88^{c}	$17.08^{a}\pm0.75$	3.94^{c}	$22.25^{b}\pm0.36$	5.48^{c}
Line-04	$12.84^{b}\pm0.38$	5.29^{b}	$10.26^{b}\pm0.50$	4.28^{b}	$16.05^{d}\pm0.27$	7.45^{a}
Line-05	8.72^{c}	5.37^{ab}	-	-	-	-
LSD	1.65	0.40	1.53	0.23	0.28	0.46
CV	6.65	4.32	5.57	2.85	0.73	3.88

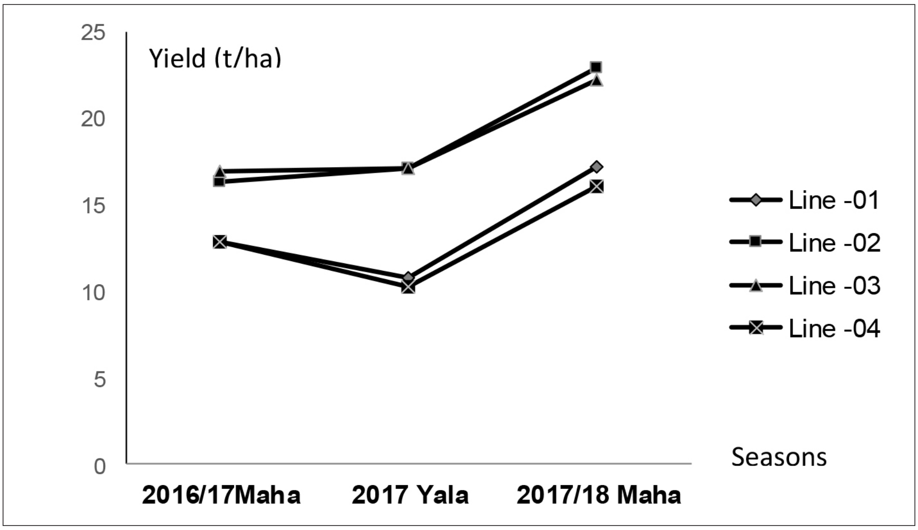

Figure 1: Comparison of the yield variation among the lines with the season

As a result, it alters the mean in the direction of selection and new genotype appear due to new gene combinations (Singh, 1993).

Notably, the selection procedure has led to an increased yield nearly five ton/ha all four seasons. This may be attributed due to the recurrent selection of high performing individuals and by the open pollination within the flowers of the same plant which mitigated inbreeding depression.

A recurrent selection through the season on high performing individuals yielded with two superior lines out of four subjected for population improvement. Line number 01 and 04 relatively had the same yield in *Maha* and *Yala* season. However, other two lines one and four had relatively notable yield reduction in *Yala* season, wherein generally brinjal yields are lower than that of *Maha*. However, final season yield was increased in all four lines this might also be attributed due to the recurrent selection and open-pollination. Therefore, this study has yielded two superior breeding lines with the uniform population having high yield more than 22 t/ha and attractive fruits for marketing also had preferred canopy and transportable fruits. Thus these two lines could be promoted as improved lines of plastic cultivar.

Conclusion

Purification programme of plastic cultivar has been completed and four generated lines were characterized. While improving the population yield evaluation was made. Thus two high performing uniform lines 2 and 3 were generated through population improvement. The seeds are available to be distributed among the Vanni farmers. These two lines as could be promoted as promising variety after conducting multi location trials.

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Effect of Different Time of Earthing up on Growth and Yield Performances of Groundnut (*Arachis hypogea* L.) Varieties

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Abstract: An experiment was conducted to assess the effect of different time of earthing up on growth and yield performances of groundnut (*Arachis hypogea* L.) varieties at the Faculty of Agriculture, Kilinochchi during the period of February to July 2018. Two factor factorial experiment was conducted in Randomized Complete Block Design (RCBD) with four replicates. Different dates of earthing up such as 23 days after (T_1), 30 days after (T_2) and 37 days after (T_3) planting and five groundnut varieties; Lanka jumbo (V_1), Tissa (V_2), Tikiri (V_3), Indi (V_4), and ANK G1 (V_5) were used as factors. The groundnut varieties were planted at the spacing of 45 cm × 15 cm and all other agronomic practices were done according to the recommendation of Department of Agriculture. The growth and yield parameters were recorded and shelling percentage was calculated. ANOVA and Duncan's Multiple Range Test (DMRT) were performed to find out the significant differences among the treatment combinations. Growth parameters of groundnut varieties such as plant height, number of leaves and branches were not significantly differed among the varieties with duration of earthing up. The yield parameters such as fresh and dry pods weight per plant, 100 pods and seed weight and mature pods per plant were significantly differed among the duration of earthing up and also among the varieties and the highest records in T_3 treatment in all varieties. There was no interaction effect among earthing up period and varieties. The highest shelling percentage of 84 % was observed in groundnut variety Lanka jumbo under the T_3. The highest yield was obtained from T_3 treatment in each variety and among the varieties; Lanka jumbo gave the highest yield. It can be concluded that 37 days after earthing up and Lanka jumbo can be selected as suitable treatment combination to obtain the highest yield from groundnut in Kilinochchi District.

***Keywords*:** Earthing up, Groundnut, Shelling percentage, Yield.

Introduction

Groundnut (*Arachis hypogaea* L.) belongs to the family Fabaceae. It is also called as Peanut, *earthnut*, *monkey nut*, *pinda*, *goober* and *manila nut* (Beghin *et al.,* 2003). It contains 48 - 50 % oil, 26 - 28 % protein and 11 - 27 % carbohydrates, minerals and vitamins (Mukhtar, 2009). The groundnut can be used for extraction of edible oil, eaten as roasted nut and used to prepare peanut milk, butter, snacks and confectioneries.

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The oil of the groundnut is used in the industries to produce soap, cosmetic cream, plasters and oil (Reddy and Kaul, 1986).

Groundnut is grown in nearly 23.95 million ha in worldwide with the total production of 36.45 million Mt and an average yield of 1520 kg/ha (FAOSTAT, 2011). In dry and intermediate zones of Sri Lanka, it can be grown as rain fed crop in highland during *Maha* season and irrigated crop in paddy lands during *Yala* season. In Sri Lanka, it is grown mainly in Moneragala, Kurunegala, Ampara, Badulla, Puttalam and Ratnapura districts. It was cultivated in an extent of 11609 ha with a total production of 21953 tons and an average yield of 1890 kg/ha in Sri Lanka (Department of Agriculture, 2012a). In Northern Province of Sri Lanka, groundnut is cultivated in 3914 hectares of lands and its production was 6305 tons (Vavuniya 807 hectares, Mullaitivu 2648 hectares, Kilinochchi 154 hectares, Mannar 170 hectares and Jaffna 135 hectares) (Department of Agriculture, 2012c).

Earthing up is the raising of the soil around the base of the plant in order to cover the pegs (Mhungu and Chitaka, 2010). The aerial pod formation of groundnut was first reported by Prasad (1985). Swanevelder (1998) reported that earthing up has a positive influence on the groundnut yield. Major constraints in groundnut leading to low yield are low soil fertility and use of improper agronomic practices as a result of lack of knowledge of the appropriate timing of earthing up (Madamba, 1997). Department of Agriculture released eight varieties such as Red Spanish, Number 45, Tissa, Walawe, Indi, Tikiri, ANK G1 and Lanka jumbo (Department of Agriculture, 2012b).

Several researches have been conducted to study the growth and yield of groundnut by modifying cultural practices worldwide including in Sri Lanka. However, only few of the researches were reported to study the time of earthing on growth and yield performance of groundnut, especially in Kilinochchi. Studying the impact of different time of earthing up on groundnut yield would facilitate the farmers to get additional groundnut production and income. With this view, the experiment was carried out with the main objective of studying impact of different time of earthing up on growth and yield performances of different varieties of groundnut and to evaluate the yield parameters and shelling percentage under different time of earthing up with different varieties.

Materials and Methods

A field experiment was carried out at the Faculty of Agriculture, Ariviyal Nagar, Kilinochchi, which belongs to the agro-ecological region of DL_3, during February to July 2018 to study the effect of different time of earthing up on growth and yield performance of groundnut varieties. Two factor factorial experiment was carried out in Randomized Complete Block Design (RCBD) with four replicates. Different time of earthing up such as 23 days after planting (T_1), 30 days after planting (T_2)

and 37 days after planting (T_3) were used as first factor and five groundnut varieties; Lanka jumbo (V_1), Tissa (V_2), Tikiri (V_3), Indi (V_4), and ANK G1 (V_5) were used as second factor. Certified seeds were collected from District Agriculture Research and Training Centre, Kilinochchi. Unshelled seeds were mixed with captan (fungicide) and kept for 2-3 hours. Planting was done in recommended spacing of 45 cm × 15 cm with the rate of one seed per hill. In each plot 24 seeds were planted. Gap filling was done by replanting the groundnut plants which were produced in the small cups simultaneously during field planting and same plant population was maintained in the field for each treatment. All other management practices were carried out according to the recommendations of Department of Agriculture.

The earthing up height was maintained as 5 cm from the collar region based on the previous study of Ragulan *et al*. (2016). Groundnut varieties were harvested at different periods when those varieties reached the maturity by vein yellowing and leaves start to shed. Tissa and ANK G1 varieties were harvested at 95 days after planting and Lanka jumbo, Indi and Tikiri Varieties were harvested at the 110 days after planting. After harvesting the pods were separated from the plants and allowed 5 days for sun drying until the pods were dried.

Growth parameters such as plant height (cm), number of leaves and number of branches were measured at weekly interval after planting of seed and yield parameters such as fresh weight of pods per plant (g), dry weight of pods per plant (g), number of mature pods per plant, number of immature pods per plant,100 pods weight (g),100 seed weight (g) were recorded and shelling percentage (%) was calculated by five randomly selected plants from each plot and estimated as ratio between dry kernel weight to dry pod weight. ANOVA was performed by using statistical package SAS (9.1) and mean separation was done by using Duncan's Multiple Range Test at p value of 0.05.

Results and Discussion

Growth Parameters

Plant Height of Groundnut

Plant height is important growth parameter which is influenced by the genetic and the environmental factors. There was no interaction effect on plant height among time of earthing up and varieties. There was no significant difference among the different time of earthing up (Table 1). But there was a significant difference among varieties after the 8th week of planting. The maximum height of 32.4 cm was observed in ANK G1 variety and the minimum height of 24.6 cm was observed in variety Tissa after 10th weeks of planting.

Number of Leaves

Number of leaves is important for photosynthesis. There was no interaction effect between time of earthing up and varieties. Numbers of leaves were non-significant among different time of earthing up. It may be depending on the genetic characters of the plant. Number

Table1: Plant height of the groundnut varieties under different time of earthing up.

Varieties	Treatments	Weeks after planting				
		2nd	4th	6th	8th	10th
Lanka jumbo	T_1	5.8[a]	10[a]	17.3[a]	26.4[a]	34.1[a]
	T_2	5.3[a]	9.6[a]	17[a]	25.9[a]	32.1[a]
	T_3	5.7[a]	10[a]	16.5[a]	25.4[a]	30.8[a]
Tissa	T_1	3.5[a]	7.9[a]	13.6[a]	22.3[a]	24.4[a]
	T_2	3.5[a]	7.9[a]	13.8[a]	23.5[a]	24.9[a]
	T_3	3.4[a]	8.3[a]	14.8[a]	22.3[a]	23.3[a]
Tikiri	T_1	3.7[a]	8.0[a]	15.6[a]	23.1[a]	28.1[a]
	T_2	3.6[a]	7.9[a]	15.2[a]	24.1[a]	27.4[a]
	T_3	3.5[a]	7.5[a]	14.7[a]	23.9[a]	26.3[a]
Indi	T_1	3.1[a]	8.4[a]	14.4[a]	20.2[a]	25.2[a]
	T_2	3.2[a]	9.1[a]	13.2[a]	21.6[a]	26.9[a]
	T_3	3.1[a]	9.1[a]	13.2[a]	20.9[a]	24.4[a]
ANK G1	T_1	6.5[a]	13.8[a]	21[a]	30.9[a]	28.8[a]
	T_2	6.5[a]	12.5[a]	20.1[a]	29.2[a]	29.7[a]
	T_3	6.6[a]	12.6[a]	22.7[a]	30.5[a]	30.2[a]

Mean with the same letter indicate not significantly different at p=0.05 in each variety within the treatments

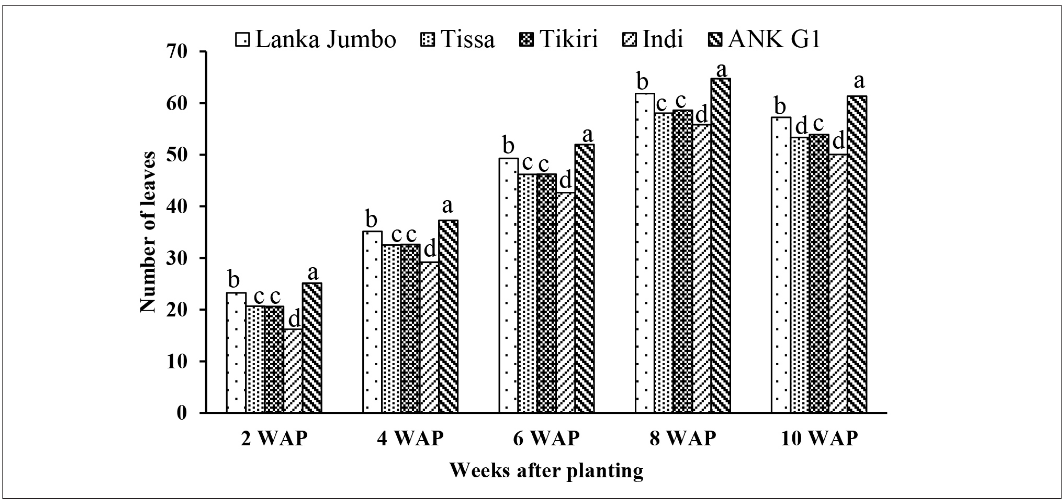

Figure 1: Number of leaves of groundnut varieties at two weeks interval from 2 weeks after planting.
Means with same letters are not significant at p=0.05

of leaves was significantly differed among the varieties except Tissa and Tikiri (Figure 1). Maximum numbers of leaves were observed in ANK G1 variety and minimum number of leaves observed in Indi variety

Number of Branches

There was no interaction effect between time of earthing up and varieties. Number of branches was non-significant among the treatments and significantly differed among the varieties. The maximum number of branches was observed in Lanka jumbo variety and minimum was recorded in Indi variety.

Yield Parameters

Fresh Weight of Pods per Plant

There was a significant difference with the time of earthing up and varieties except in Tissa and Indi (Figure 2). There was no interaction effect between varieties and time of earthing up. Lanka jumbo had the highest fresh weight of pods/plant (136.75 g), under the T_3 than other varieties. Eathing up at 37 days after sowing (T_3) increased the pod weight in each variety and average lowest pod weight was produced by earthing up at 23 days after sowing (T_1). Ouedraogo *et al.* (2012) reported similar results by doing earthing up at 7 weeks after sowing in Bambara groundnut.

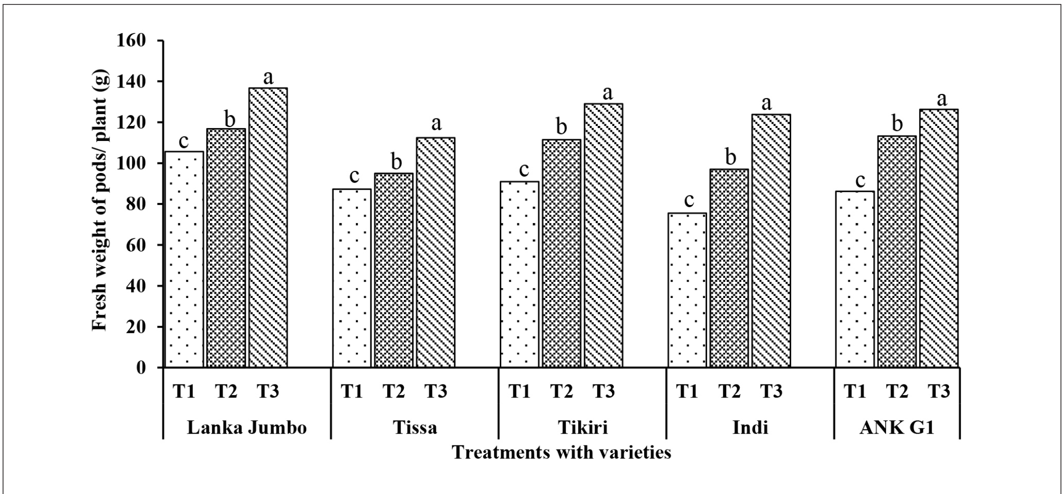

Figure 2: Fresh weight pods / plant with different treatments with varieties.
Means with same letters are not significant at p=0.05

Dry Pods Weight per Plant (g)

Dry pods weight per plant showed the same trend of fresh pods weight per plant. Among the varieties, the highest (107.62 g) and lowest (73.9 g) pod weight was observed in Lanka jumbo and Tissa varieties, respectively.

Hundred Pod Weight

The highest hundred pod weight was observed in time of earthing up of 37 days after planting (T_3). The highest hundred pod weight was observed in Lanka jumbo (189.6 g) under the T_3 (Figure 3).

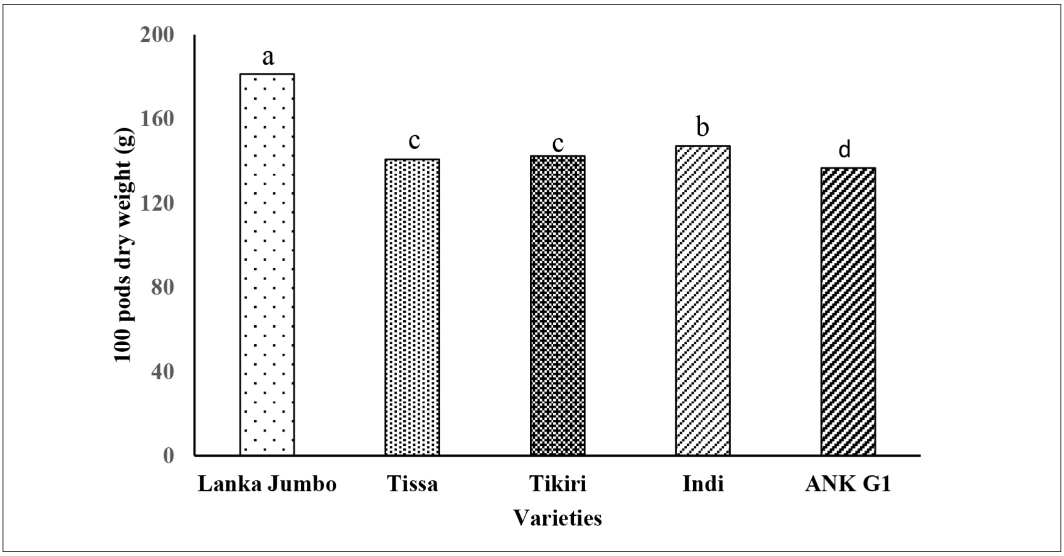

Figure 3: 100 Pods weight in different varieties.
Means with same letters are not significant at p=0.05.

Hundred Seed weight

Hundred seed weight also showed the same results as 100 pod weight (Figure 4). The highest 100 seed weight of 91.71 g observed in Lanka Jumbo under the T_3 treatment. The weight of the seed depends on the genetic characters as well as the timing of the earthing up. The results are in agreement with Prasad and Muralidharudu (1991), Mkandawire and Sibuga (2002) and Ouedraogo *et al.* (2012).

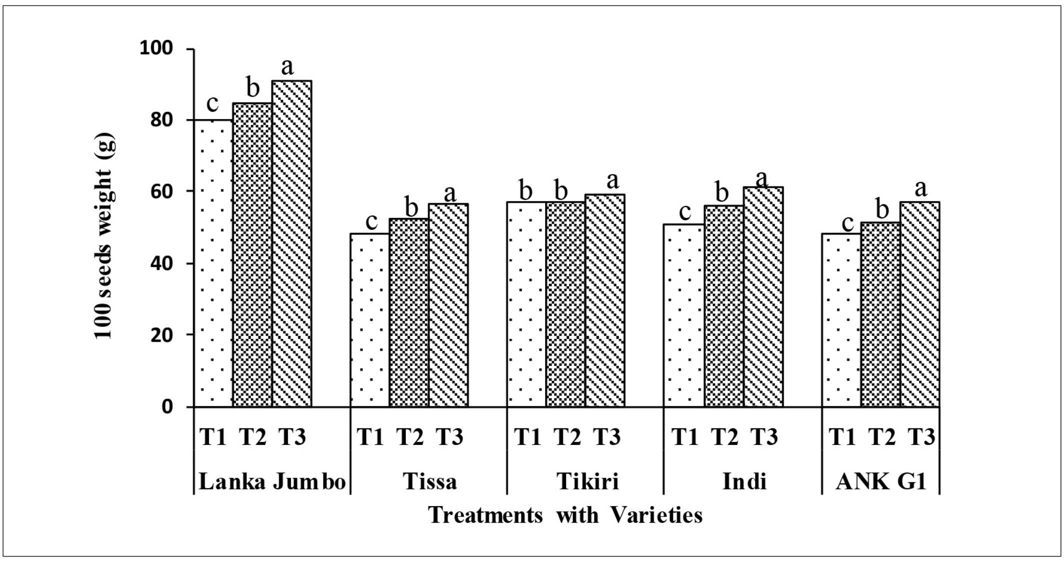

Figure 4: 100 seeds weight in different treatments with varieties.
Means with same letters are not significant at p=0.05.

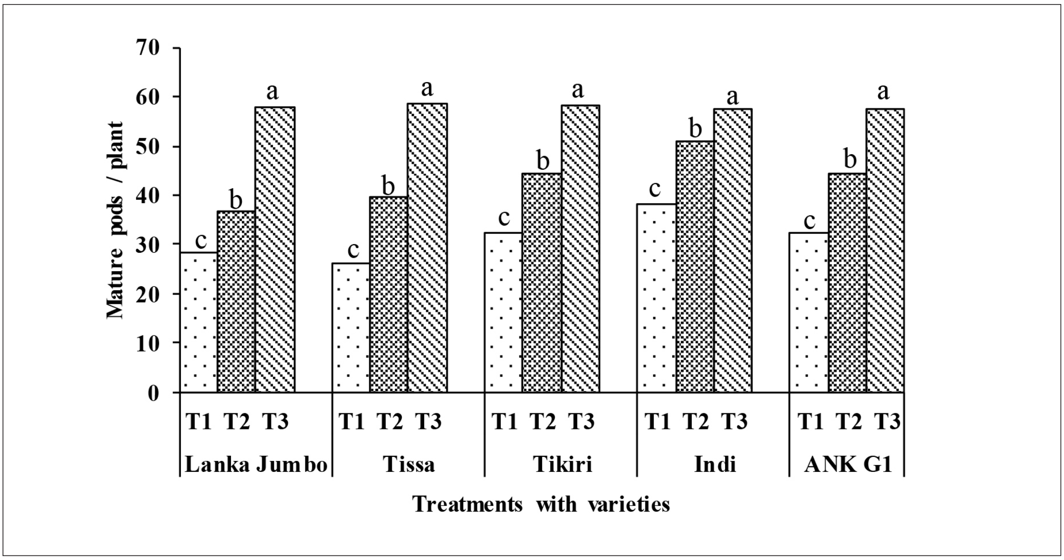

Figure 5: Mature pods per plant in different treatments with varieties.
Means with same letters are not significant at p=0.05

Mature Pods per Plant

Number of mature pods per plant was significantly differed with time of earthing up and varieties (Figure 5). Matured pod number was significantly highest in T_3 and the lowest in T_1.The highest mature number of pods of 48 was observed in Indi variety and the lowest number of 40 was observed in Lanka jumbo variety. This variation may also be due to genetic characteristics of these varieties (Naeem *et al*., 2015).

Shelling Percentage

The highest shelling percentage was observed in time of earthing up of 37 days after sowing in each variety (T_3). The highest and lowest shelling percentages were observed in varieties such as Lanka Jumbo and ANK G1, respectively, in all treatments. This result agreed with Balole *et al.* (2003), who stated that the positive effect of mounding on shelling percentage in Bambara groundnut in 10 different landraces. Ouedraogo *et al*. (2012) indicated that the sandy soil structure, temperature and rainfall allowed the expression of the genetic potential of the landraces that had a high rate of pod filling irrespective of the timing of mounding.

Yield

According to the results, the average total groundnut yield (t /ha) was significantly different among the treatments (Figure 6). The highest groundnut yield (6.8 t/ha) was observed in the Lanka Jumbo variety under the time of earthing up of 37 days after planting (T_3) when compared with the other treatments. The lowest yield of 2.9 t/ha was observed in the Tikiri and Indi varieties under the time of earthing up of 23 days after planting (T_1). Yield was significantly higher in the Lanka Jumbo variety than other varieties (Figure 7).

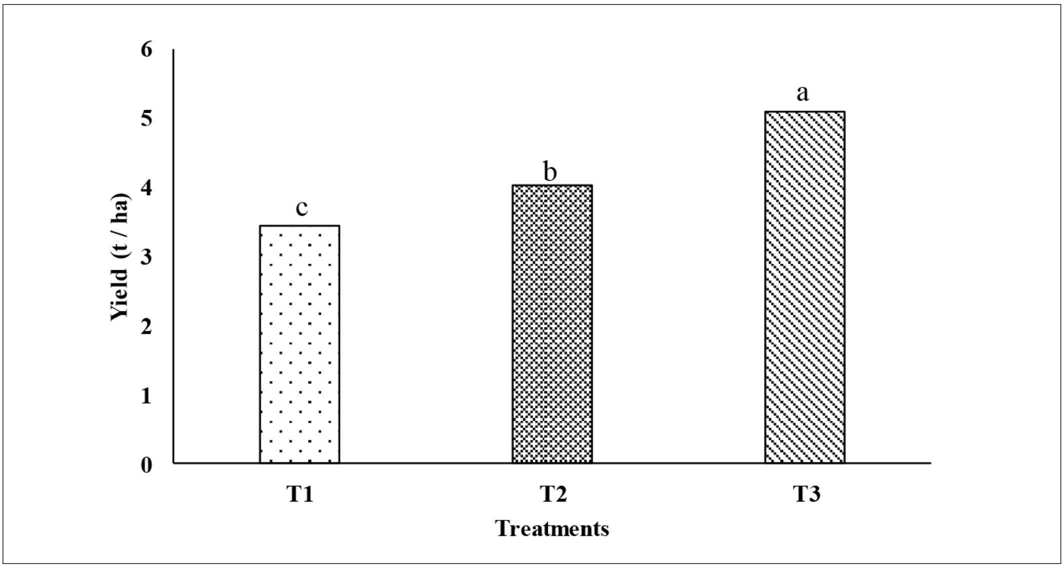

Figure 6: Yield (t /ha) in different treatments.
Means with same letters are not significant at p=0.05

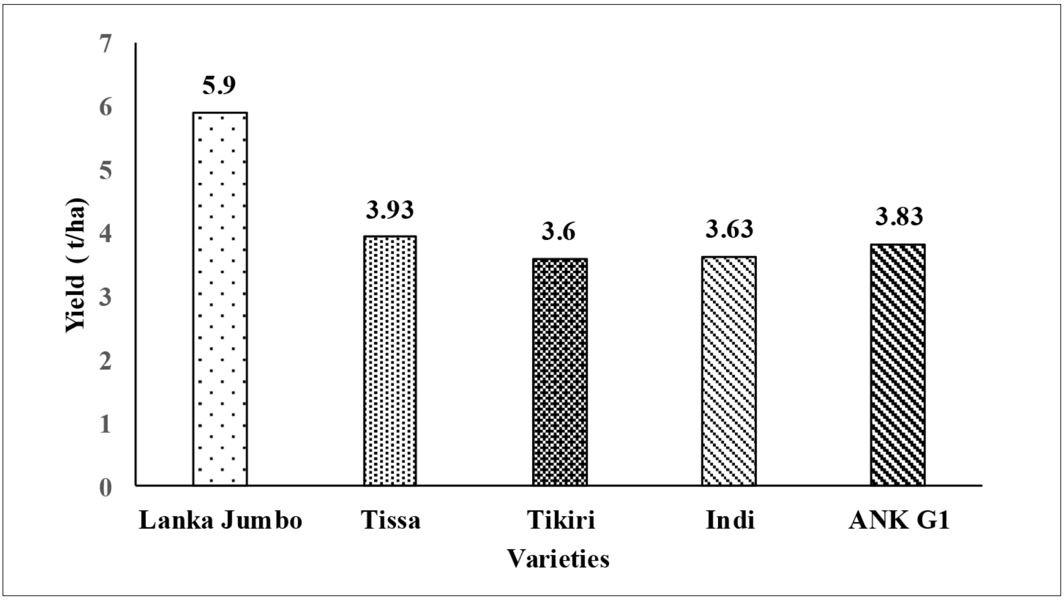

Figure 7: Yield (t /ha) of different varieties.

The potential yield of groundnut is above 4.5 t/ha (Department of Agriculture, 2012 for example, potential yield for ANK G1 variety is 4.5 t/ha). In this study, yield obtained from each variety was higher than the average yield, but less than the potential yield. This research was carried out in intensive management practices, therefore, there was a possibility to achieve the yield near to potential yield.

Conclusion

Time of earthing up practice did not show significant influence on the growth parameters of each variety of groundnut, but significantly influenced the yield parameters. Among the time of earthing up, 37 days after planting earthing up showed the highest yield than the other times of earthing up. Among the varieties, Lanka jumbo variety gave the highest yield. Therefore, Lanka jumbo variety and 37 days after planting of earthing up combination can be recommended to Kilinochchi farmers to obtain high yield in Groundnut.

Suggestions

This experiment should be repeated during *Maha* season for evaluating the performance of groundnut varieties under different climatic conditions. Research should be carried out to study the height of earthing up on growth and yield performance of different varieties of groundnut.

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Effect of *Azolla filiculoides* Application on Weed Population in Paddy Fields

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Abstract: The integrated use of organic and inorganic fertilizers is desirable to sustain paddy cultivation. Study was conducted at Rice Research Station, Paranthan, Sri Lanka to develop effective weed control method to gain economic return from irrigated paddy fields in the Dry Zone. The experiment was carried out during the period of November-February, 2017 (*Maha*), using randomized complete design with six treatments with three replicates; *Azolla* only, *Azolla* with three nitrogen levels (25%, 50%, 100% kg N/ha) of the recommended level of nitrogen, only recommended level of nitrogen (100 kg N/ha) and plot with absence of chemical fertilizer and *Azolla* (control). The nutrients potassium and phosphorus were applied to respective plots based on the recommended level. Results showed partial suppression of weed growth by *Azolla filiculoides* even under full plot area coverage. The range of weed suppression at rice 30 days after planting was 64.21 - 88.31%. However, *Azolla* failed to suppress the growth of some weeds such as *Aeschynomene indica, Ipomoea aquatic* and *Cyperus iria*. Plots with combined application of *Azolla* and different levels of nitrogen fertilizer revealed greater value for weed control efficiency the range of 76.81 – 80.93%. There was no significant difference in the yield in plots treated with *Azolla* + recommended level of N fertilizer, *Azolla* + 50 kg/ha recommended level of N fertilizer (6066 and 5966 kg/ha respectively) and only recommended level of N fertilizer without *Azolla* (5533 kg/ha). Therefore the use of *Azolla* in the rice cultivation has greater influence on suppressing the weeds and also reduces the nitrogen fertilizer and herbicides application requirements.

Keywords**:** *Azolla*, Fertilizer, Nitrogen, Suppress, Weeds.

Introduction

Azolla has not been used traditionally as a green manure in Sri Lanka and has remained a mere botanically curiosity until recently. Research on *Azolla* in relation to rice cultivation began in the mid 1970 and a primary investigation revealed that, it could increase the rice yield. Using *Azolla* biomass as a bio fertilizer to replace artificial nitrogen fertilizer reduces pollution by nitrogen losses of rice cultivation and provides added value to farmers (Mishra and Dash, 2014).

With increasing cost of fertilizer, the cost of this input in rice cultivation is becoming problematic, as fertilizers

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alone are reported to cost 40 to 50% of the total input. In order to decrease the cost towards fertilizer, organic fertilizers like *Azolla* can be substituted for chemical fertilizers. Use of organic fertilizer mobilizes cheap resources for productive purpose replacing high cost chemical fertilizers. One crop of *Azolla* provided 20 - 40 kg N/ha to the rice crop in about 20-25 days as reported by Watanabe *et al*. (1977). Singh *et al.* (1984) also reported that, the expenditure involved in production of inoculum + *Azolla* dual cropping, supplying almost 30 kg N/ha in rice field was lower price than the cost of 30 kg N/ha as urea.

Two incorporations of *Azolla* (grown in dual culture with rice) during a single crop cycle, resulted in grain yields equivalent to fields that received 55 to 84 kg N/ha of chemical nitrogen fertilizer (Kulasooriya *et al*., 1984). *Azolla* in dual culture with rice also brought about a 50 % reduction in weed growth. It increased rice yields 14 % and reduced weed growth 34 % in broadcast seeded rice, increased yield 22 % and reduced weed growth 52 % in transplanted rice, and increased yield 47 % and reduced weed growth 43 % in row-planted rice (Kulasooriya *et al*., 1984).

The most widely used system is to raise *Azolla* in rice paddies, by floating *Azolla* in the paddy prior to rice planting, the water is drained after 6–8 weeks and *Azolla* is subsequently ploughed into the soil. This improves the soil quality by increasing organic-nitrogen levels, improving water-holding and cation-exchange capacities of the soil (Hill and McConnachie, 2009). Therefore, the aim of this study is to find out the effect of application of *Azolla* on weed growth and nitrogen use efficiency of irrigated rice in the Dry zone.

Materials and methods

Plot size of the experiment was 6 m × 3 m. Rice variety Bg300 was used. Experiment comprises 06 treatments with thee replicates as

T1: Absence of *Azolla* and chemical fertilizer as control

T2: *Azolla* only

T3: *Azolla* with application of 25 % recommended N fertilizer

T4: *Azolla* with application of 50% recommended N fertilizer

T5: Only recommended N fertilizer (100 kg N/ha)

T6: *Azolla* with recommended level of N fertilizer (100 kg N/ha).

The department of Agriculture recommended doses of K_2O: P_2O_5 at 35: 25 kg/ha were applied in the form of muriate of potash (MOP) and triple super phosphate (TSP) to all the treatments. Raised nursery bed was established, and fifteen days old seedlings were manually transplanted with the row spacing of 15 x 15 cm. At 3 days after planting, *Azolla filiculoides* was inoculated at a rate of 200 g fresh weight/m^2. Well grown *Azolla* mat in the plots was incorporated into the soil by Cono weeder at 20 and 40 days after planting (DAP) except treatment T1.

Data and statistical analyses

Five quadrate (30 × 30 cm) were sampled in each plot at vegetative (30 DAP) stage. Collected weed species by using a quadrant from each plot were identified, listed, grouped (grass, broadleaf and sedges) and counted. Collected weeds were washed, sorted by species, stages and expressed as number/m^2. Also the dry weight of the weed was recorded at 30 DAP. Data on weed density and weed dry weight were transformed using square root transformation. Paddy yield (kg/ha) of each plot was also recorded. Data were subjected to analysis of variance (ANOVA) using the SAS statistical software 9.2. Significant differences among means were separated using Least Significant Difference (LSD) test at 5% level of probability.

Weed indices

Weed indices were computed using the standard procedure according to Misra and Misra (1997) and Devasenapathy (2008) as follows:

Weed persistence index (WPI)

This index indicates the resistance in weeds against the tested treatments and confirms the effectiveness of the Azolla on weed control, using the given formula by Misra and Misra (1997)

$$WPI = \frac{Weed\ biomass\ of\ treated\ plot}{Weed\ biomass\ of\ control\ plot} \times \frac{Weed\ density\ of\ control\ plot}{Weed\ density\ of\ treatedplot}$$

Weed control efficiency (WCE)

Weed control efficiency measures the efficiency of any weed control treatment in comparison to weedy treatment (Mani *et al*., 1973: Das, 2008) as follows;

$$WCE = \frac{weed\ population\ control\ plot\ - weed\ population\ in\ treated\ plot}{weed\ population\ in\ control\ plot} \times 100$$

Weed management index (WMI)

This index is the ratio of yield increase over the control because of weed management and percent control of weeds by the respective treatment (Misra and Misra, 1997).

$$WMI = \frac{Precent\ yield\ increase\ over\ control}{Percent\ control\ of\ weeds}$$

Weed control index (WCI)

To compare the different treatments of weed control on the basis of dry weight, weed control index (WCI) was calculated (Mani *et al*., 1973: Das, 2008) as follows;

$$WCI = \frac{Dry\ weight\ of\ weeds\ in\ control\ plots - Dry\ weight\ of\ weeds\ in\ treated\ plots}{Dry\ weight\ of\ weeds\ in\ control\ plots} \times 100$$

Results and Discussion

Weed occurrence

All three major weed groups; grasses, broadleaves and sedges were recorded. *Echinochloa colonum*, *Echinochloa glabrescens* and *Leptochloa chinensis* as grasses; *Ipomoea aquatica*, *Monochoria viginalis* and *Aeschynomene indica* as broad leaves; and *Cyperus iria* and *Cyperus difformis* as sedges. Altogether, broad leaf weeds *Aeschynomene indica* and *Ipomoea aquatica* were predominant, followed by sedges, especially, *Cyperus iria* in the experimental field. Sivakumar *et al*. (1999) reported that, the addition of *Azolla* in rice fields suppressed the weeds such as *Echinochloa crusgalli* and *Cyperus difformis* and the degree of suppression increased with the increase in percentage of *Azolla* cover and water depth.

Weed Density

Emergences of grasses, broad leaves and sedges were shown significant (p<0.05) decrease in the *Azolla* treated plots compared with, only recommended level of nitrogen fertilizer (T5) and without *Azolla* and chemical fertilizer plots (T1) at 30 DAP (Table 1). Without *Azolla* and chemical fertilizer plot (T1) recorded maximum number of weeds per plot followed by only recommended level of nitrogen fertilizer (T5). As well, the lower weed density was recorded in *Azolla* with recommended level of nitrogen (T6). It is evident from this experiment that *Azolla* treated plots were significantly reduced the weed population that ranged from 64.21 % - 88.31 % at vegetative stage compared with the without *Azolla* and chemical fertilizer treatment. This reduction may be due to the dense mat of *Azolla* which developed a few days after inoculation and effectively reduced the light available for weed growth (Gnanavel and Kathiresan, 2002). However, among the *Azolla* treated plots, weed emergence were observed, due to the needle like leaves that easily pierce the thick *Azolla* mat (Singh *et al*., 1984; Satapathy and Singh, 1985).

Weed Control Efficiency

The values of weed indices are presented in table 2. Application of *Azolla* gave higher weed control efficiency (WCE), weed management index (WMI), weed control index (WCI) and lower weed persistency index (WPI), than the other treatments. However, higher weed density was in without *Azolla* and chemical fertilizer resulted in highest WPI, and lower WCE, WMI and WCI.

Yield (kg/ ha)

Paddy yield was maximum (6066 kg/ha) in *Azolla* with recommended level of nitrogen (Figure 1). However, it was pared with only recommended level of nitrogen and *Azolla* with application of 50 kg N/ha (5533 and 5966 kg/ha, respectively). Similarly, there was no significant difference between the *Azolla* only and *Azolla* with application of 25 kg N/ha (4783 and 5283 kg/ha). It revealed that, there are possible to improve the paddy yield by using *Azolla* which providing of 50 % required nitrogen for rice crop without using of fertilizer, if the environmental condition favours for growth of *Azolla* (Watanabe *et al*., 1977).

Table 1: Effect of different treatments on weed density and weed dry weight at 30 DAP.

Treatments	Weed density (number/ m^2)				Weed dry weight (g/ m^2)			
	Grass	Broad leaf	Sedge	Total	Grass	Broad leaf	Sedge	Total
T1	72.44 **(8.47)**	57.33 **(7.57)**	113.33 **(10.65)**	247.11 **(15.72)**	322.8 **(17.97)**	65.45 **(8.09)**	61.06 **(7.81)**	449.31 **(21.20)**
T2	8.0 **(2.83)**	20.0 **(4.47)**	31.56 **(5.62)**	59.56 **(7.72)**	54.63 **(7.39)**	20.46 **(4.52)**	29.93 **(5.47)**	105.02 **(10.25)**
T3	8.89 **(2.98)**	35.11 **(5.93)**	41.78 **(6.46)**	85.78 **(9.26)**	37.53 **(6.13)**	27.45 **(5.24)**	16.59 **(4.07)**	81.57 **(9.03)**
T4	4.44 **(2.11)**	32.44 **(5.7)**	51.56 **(7.18)**	88.44 **(9.4)**	44.46 **(6.67)**	25.01 **(5.0)**	23.08 **(4.8)**	92.55 **(9.62)**
T5	23.56 **(4.85)**	56.44 **(7.51)**	45.33 **(6.73)**	125.33 **(11.20)**	45.33 **(6.73)**	27.63 **(5.26)**	39.55 **(6.29)**	112.51 **(10.61)**
T6	2.22 **(1.49)**	11.11 **(3.33)**	15.56 **(3.94)**	28.89 **(5.37)**	23.8 **(4.88)**	23.06 **(4.80)**	19.29 **(4.39)**	66.15 **(8.13)**
SE ± m	**1.04**	**0.68**	**0.91**	**1.43**	**1.97**	**0.53**	**0.57**	**1.98**
LSD (0.05)	**0.24**	**0.10**	**0.33**	**0.27**	**0.28**	**0.29**	**0.22**	**0.45**

DAP; Days after planting, SE ± m; Standard error of means, LSD; Least significance difference at $p<0.05$

Table 2: Effects of *Azolla* on various weed indices in paddy

Treatments	**WPI**	**WCE**	**WMI**	**WCI**
Without *Azolla* and chemical fertilizer	1.00	0.00	0.00	0.00
Azolla only	0.68	80.93	0.25	81.31
Azolla + 25 kg N. ha^{-1}	0.75	79.82	0.39	84.83
Azolla + 50 kg N. ha^{-1}	0.56	70.54	0.60	83.40
only recommended level of nitrogen (100 kg N. ha^{-1})	0.84	31.56	0.52	76.41
Azolla + recommended level of nitrogen (100 kg N. ha^{-1})	0.52	76.81	0.59	87.85

WPI = weed persistence index, WCE= weed control efficiency, WMI = weed management index, WCI = weed control index,

Further, it may be due to timely and effective control of weeds by competing for light, space and nutrient. This favoured the crop to produce more leaf area and biomass production. The results were in conformity to those of Castro *et al*. (2003) and Satapathy (1993) who reported that it was due to soil that was supplemented with availability of organic nitrogen and organic matter supported larger and diverse population of micro organisms and more nitrogen

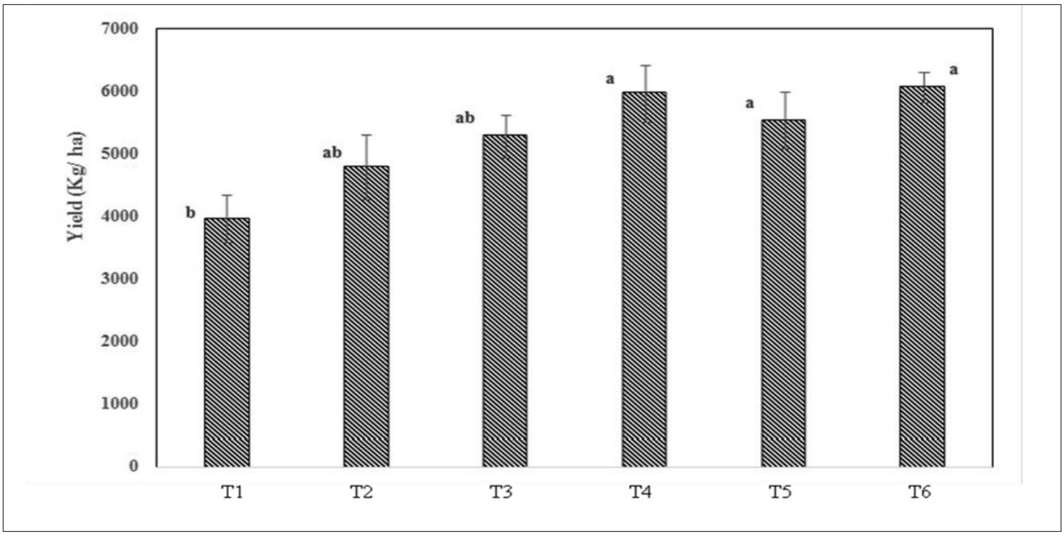

Figure 1: Effect of paddy yield under different conditions of nitrogen fertilizer and Azolla.

Vertical bars represent the SD. Different letters indicate a significant difference at p<0.05.

uptake was observed in *Azolla* inoculated treatments than the control, which was due to the mineralization of *Azolla* nitrogen and its simultaneous uptake by rice plants.

Conclusion

Azolla in rice field does not only use as a source of organic nitrogen fertilizer, it also effectively supress the 64.21 - 88.31 % of weed population for a certain extent under the suitable growing conditions of *Azolla*. Further, replacing of *Azolla* reduce the cost incurred for the nitrogen fertilizer and increase the profit of paddy cultivation.

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Impact of Different Depths of Transplanting by Machine Transplanter on Growth and Yield Performance of Rice Variety (Bw 361)

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Abstract: Depth of transplanting is an important factor which influences the grain yield in rice production systems by determining the number of tillers. Field trial was conducted to evaluate the growth and yield response of different planting depths of seedlings of mechanical transplanted rice. Four rows of behind-walk type paddy KUBOTA (SPW 48c) transplanter was used with 30 cm row spacing and five different planting depth (0.7, 1.4, 2.1, 2.8 and 3.7 cm), and replicated four times. The growth parameters of plant height, number of tillers, root length and yield parameters of panicle per hill, panicle length, and grain yield were recorded. Plant height (cm) during vegetative period, was significantly ($p<0.05$) higher at shallow planting depth of 0.7 cm. Root length and panicle length were not significantly influenced by depth of planting. The number of tillers per hill was significantly ($p<0.05$) differed among depth of planting. A positive correlation was observed between depth and tillers per hill up to 2.1 cm depth. The maximum number of tillers per hill and panicle numbers per hill were recorded at the depth of 2.1 cm. Results revealed that the planting depth of 2.1 cm produces significantly higher tillers, panicles per hill and grain yield. Therefore, 2.1 cm planting depth is more appropriate for cultivation of Bw361 variety in machine transplanting system in low country dry zone of Sri Lanka.

***Keywords*:** Mechanical transplanting, Planting Depth, Rice, Yield

Introduction

Rice (*Oryza sativa* L.) is the most important cereal food crop of the developing world and the staple food of more than 3.5 billion people or more than half of the world's population (Tripathi *et al.,* 2004). There is a need to increase the productivity of rice using reduced inputs and resources to feed the burgeoning population (Das *et al.,* 2010). Rice production in Sri Lanka is an important part of the National economy. Yield of transplanted rice is generally believed to be higher than that of dry-seeded rice (Balasubramanian *et al*., 2007). In manual transplanting, 20-30 people are required to transplant one ha/day. It consumes time and labour for planting and makes drudgery to farmers. To overcome this problem, Machine Transplanting (MT) was introduced in 'Yaya 11 program' to farmers by the Department of Agriculture in 2016.

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MT of rice is the process of transplanting young seedlings, which have been grown in a mat nursery, using a rice transplanter (Joseph *et al.,* 2015). Major advantages of this method are labour saving and timely crop establishment (Tripathi *et al.,* 2004). Three people can transplant approximately 2 ha/day using a rice transplanter. The other advantages of MT include uniform spacing, optimum plant density, less transplanting shock and better employment opportunities for rural youth through the development of custom service business (Illangakoon *et al*., 2017). It is also capable of adjusting desired within row space, seedlings number per hill and planting depth.

MT has useful to work mechanical weeder for weed control and working of rotary weeder churns the soil and provides greater aeration which helps in buildup of enormous microbial growth, thereby enhancement of nutrient supply to root which ultimately result in healthy plant growth and higher yields at lower costs (Archana *et al*., *2016).*

Among the different agronomic practices, planting geometry and depth of planting play a vital role in achieving higher yield levels of improved varieties of rice (Archana *et al*., 2016). It is because the proper distributions of rice plants per unit area and efficient utilization of available nutrient and other resources. Therefore, the research was conducted to study the impact of different depths of transplanting by machine transplanter on growth and yield of rice.

Materials and Methods

Field trail was conducted at Rice Research Station, Paranthan, Kilinochchi; situated in Low Country Dry Zone (DL_3) during *Maha* 2016/2017. The experimental site receives an average rainfall of 750 mm and average temperatures of 34.5ºC (max.) and 19.7ºC (min.). Five planting depth levels; 0.7 cm (T_1), 1.4 cm (T_2), 2.1 cm (T_3), 2.8 cm (T_4) and 3.7 cm (T_5) were tested as treatments. Planting depth of 0.7 cm and 1.4 cm were considered as shallow depth of planting and 3.7 cm planting depth was considered as deep depth of planting. Other two depths; 2.1 cm and 2.8 cm were taken as medium depth of planting.

The field trial was laid in a Randomized Complete Block Design (RCBD) with four replicates in each depth level. The plot size was 6 m x 4.5 m. Red pericarp high yielding rice variety Bw 361 was selected. Seedlings were raised in a dapog nursery to use in MT. Seedlings of 2-3 leaf stage (15 days) were fed to transplanter. The man-propelled paddy KUBOTA walk-behind type (Model SPW 48c) transplanter with four rows was used for planting at 3-4 seedlings per hill throughout the treatments. The seedlings were transplanted at 30 cm row spacing and 16 cm within the row spacing.

Fields were ploughed twice and puddling and leveling were done before transplanting. Fertilizer application was done according to the recommendation of irrigated rice in Dry zone (Srisena, 2013). Pretilachlor (300 g/L EC) was applied for weed control at the rate of 1.6 L/ha on 3rd day after establishment. Plots were maintained under irrigated condition and all other management practices were done based on the recommendation made by the Department of Agriculture.

Data collection

The growth and yield parameters were recorded on plant height (cm) at different growth stages of 30 (vegetative), 75 (reproductive) and 110 (maturity) days after planting, number of tillers per hill, root length (cm), panicle length (cm), number of panicles per hill (productive tillers per hill) and grain yield (t/ha).

Ten hills were randomly selected from each plot and averages were taken for evaluation of growth and yield parameters. Plant height was measured from the base to the tip of the highest leaf. Tillers and productive tillers were individually counted. Panicle length was measured from the base of collar to tip of panicle. Root length was measured from the crown of the root to the tip of the root. Grain yield was measured by taking grain dry weight of treatment plots by using electronic balance at the level of 13 % moisture and converted to t/ha.

Data analysis

ANOVA was performed by using software SAS (version 9.1) and mean separation was done in Duncan's Multiple Range Test (DMRT) at $\alpha \leq 0.05$ (Schlotzhauer and Littell, 1997).

Results and Discussion

Plant height

There was significant difference in plant height with different depths of planting in vegetative stage. Deep transplanting (3.7 cm) showed less plant height compared to shallow depth of transplanting (0.7 cm) in vegetative stage. Archana *et al*. (2016) and Saburo (1962) had shown the similar findings. But

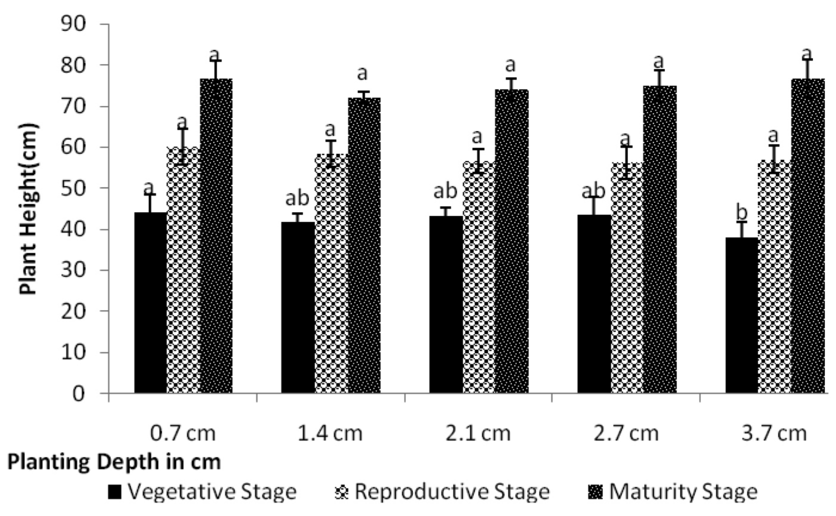

Figure 1: Plant Height variation in different growth stages

there were no significant difference in reproductive and maturity stage in different depths of planting.

Number of tillers per hill and panicle number per hill

Number of tillers produced per hill under the different depth of planting was presented in Table 1. The number of tillers per hill was significantly ($p<0.05$) differed among different depth of planting. A positive correlation was observed between depth of planting and tillers per hill up to 2.1 cm depth. The total number of tillers per hill and number of panicle per hill were significantly higher in medium depth of 2.1 cm planting. The maximum numbers of panicle per hill were recorded in the plots planted at the depth of 2.1 cm. Lowest number of tillers per hill and panicle numbers per hill were observed in the planting depth of 3.7 cm. Deep transplanting caused decreased in number of tillers and panicles. Similar results were shown by Archana *et al*. (2016).

Panicle Length (cm)

The data (Table 1) revealed that there was no significant difference in the panicle length among different depth of transplanting, means panicle length has not influenced by different depth of planting.

Root Length (cm)

There was no significant difference in the root length (Table 1) among the different depth of transplanting. Higher root length was observed in 2.1 cm depth of planting and lowest in 3.7 cm depth of planting.

Grain yield (tons/ha)

The effect of different depth of planting on grain yield is presented in Table 1. Grain yield was significantly ($p<0.05$) influenced by the planting depth. Grain yield was higher (5.625 t/ha) in 2.1 cm depth of planting and the lower yield (3.906 t/ha) was recorded in deep transplantation of 3.7 cm It may be, the primary ill-effect of deep transplantation seemed to be the retardation of rooting caused elongation of tiller node which induced the decreasing of number of tillers and consequently panicle numbers, that may be the reason for reduction in the yield. But yield was significantly greater under medium (2.1 cm) depth compared to deep planting (3.7 cm) by machine transplanter.

Table 1: Variation of Growth and Yield Parameters at Different Planting Depths

Depth Category	Treatment	Number of tillers /Hill	number of panicle /Hill	Root Length (cm)	Panicle Length(cm)	Yield (t/ha)
Shallow	0.7 cm	10.96±0.4 ^{b}	10.70±0.3 ^{b}	22.00±2.8 ^{a}	20.83±1.2 ^{a}	4.218±1.2 ^{ab}
	1.4 cm	11.33±1.1 ^{b}	11.13±1.3 ^{b}	21.50±0.5 ^{a}	20.50±0.4 ^{a}	4.270±0.9 ^{ab}
Medium	2.1 cm	14.29±1.4 ^{a}	14.23±1.2 ^{a}	22.75±1.6 ^{a}	20.17±0.2 ^{a}	5.625±1.0 ^{a}
	2.7 cm	12.04±3.1 ^{ab}	11.38±2.0 ^{b}	22.50±2.2 ^{a}	20.63±1.4 ^{a}	4.635±0.6 ^{ab}
Deep	3.7 cm	9.92±0.9 ^{b}	9.73±1.0 ^{b}	20.25±1.1 ^{a}	20.96±0.7 ^{a}	3.906±1.0 ^{b}

Results were supported by Archana *et al*. (2016) and Saburo (1962).

Conclusion

Planting depth can play a vital role in rice yield under mechanical transplanting system. The growth parameters and yield attributes significantly greater under moderate depth (2.1 cm) of planting than shallow depth of planting and deeper planting depth. Depth of planting at 2.1 cm produced 33.2% higher yield than 0.7 cm shallow depth of planting. The results revealed that the optimum depth of transplantation to be 2.1 cm for Bw 361 rice variety by machine transplanter.

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Implications of Seasonal Rainfall Trends for Agriculture in the Dry Zone of Sri Lanka

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Abstract: Sri Lanka is vulnerable to the changing climate because of the departures from the usual rainfall. This paper analyses the consistency in trends of rainfall in the dry zone of Sri Lanka with particular emphasis on the influence of four monsoon seasons on the regional agriculture. The data analyzed consists of the daily rainfall records (1996-2015) at 10 stations distributed throughout the dry zone of Sri Lanka. The non-parametric Mann-Kendall and Sen-Theil statistical methods were used for the investigation which is appropriate for the non-normal data with missing or censored records. To analyse the data with seasons, modified seasonal Mann-Kendall trend test was used. The pre-whitening method was applied to remove autocorrelation from the time series. Though the results show an increasing annual rainfall, a consistent reduction has been revealed in monthly rainfall during June and July. Nearly 30% of the stations demonstrated a statistically significant ($p<0.05$) increase in rainfall during the northeast monsoon season. However, statistically significant decline in monthly rainfall during June and July led the dry zone drier, which may have reduced the availability of the irrigable surface water during *Yala* (minor rainy) season. Findings of rainfall variation in dry zone help speculate water availability for crop requirement in the dry zone in Sri Lanka.

Keywords: Daily rainfall, Monsoon season, Non-parametric, Trend analysis

Introduction

Being an island and influenced by regional climate, the rainfall has changed in recent decades especially in the dry zone of Sri Lanka. Although it is highly influenced by the Indian Ocean and Indian Mainland which are responsible for the regional climate, there is a high chance for climatic drivers which makes vulnerable to the variable rainfall trends in Sri Lanka (Burt and Weerasinghe, 2014). Consisting two-thirds of the total land area of Sri Lanka, dry zone water availability is critical for the agriculture in Sri Lanka (Senaratne and Rodrigo, 2014).

The frequent rainfall events have intensified in recent years at least true in the countries of South Asian including

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Sri Lanka. The IPCC (Intergovernmental Panel for Climate Change) indicates that climate change takes place mainly by increasing intensity and frequency of the weather events although averages are not significant (IPCC, 2007). Such a gradual change in rainfall worsens the existing situation causing tremendous impacts; therefore, it is now essential to understand the country's vulnerability to the rainfall changes.

Most climate change investigations always proceeded with understanding historical trends (Irizarry-Ortiz *et al*., 2012). This paper uses linear climate metrics to study the trends of rainfall in the dry zone of Sri Lanka for the period of 1996-2015 using the 10 synoptic meteorological stations scattered throughout the dry zone.

Further, seasonal impacts of rainfall were also studied in the dry zone. Primarily, two monsoon winds highly influence the climate in Sri Lanka. The southwest monsoon (SWM) and northeast monsoon (NEM) reach Sri Lanka from May to September and December to February, respectively. During the SWM and NEM seasons, winds come from the northeast and southwest (Wickramagamage, 2010), respectively (Figure 1). The periods between these primary monsoons are referred to as inter-monsoonal seasons, which usually last for two months. They are called the first inter-monsoon (FIM) and second inter-monsoon (SIM) and occur during the periods of March-April and October-November, respectively. This portioning of seasons is widely used by many works of literature relevant to the climate in Sri Lanka (Malmgren *et al*., 2003; De Silva, 2006; Zubair *et al*., 2008; Nishadi and Smakhtin, 2009). The *Maha* season, which is the primary crop growing season in the dry zone of Sri Lanka, composed of SIM and NEM rainfall. The regional climatic patterns in Sri Lanka are primarily influenced by the El Nino-Southern Oscillation (ENSO) (Zubair *et al*., 2008). Due to its island geography, seasonal monsoons moderate the climate of Sri Lanka (National Atlas of Sri Lanka, 2007). Although non-parametric statistical techniques were previously used by Karunathilaka *et al*. (2017); Herath and Rathnayake (2005); Jayawardene *et al*. (2005), but seasonality components were not addressed appropriately for the detection of long-term trends. The primary objective of this paper is to assess the implications of rainfall trends in the dry zone of Sri Lanka using the daily rainfall records.

Methodology

Data

The data used for this study are precisely two decade or 20-year records of raw (or unadjusted) rainfall (mm) for the period of 1996-2015. Prior to 1996 at least five-year data are missing in the stations such as Jaffna, Pottuvil and Vavuniya. Daily rainfall records at 10 main meteorological stations scattered throughout the dry zone of Sri Lanka were selected for the analysis (Figure 1). These station records were gathered from the Meteorological Department of Sri Lanka. The rainfall data investigated is subject to consistency checks such as for station relocations,

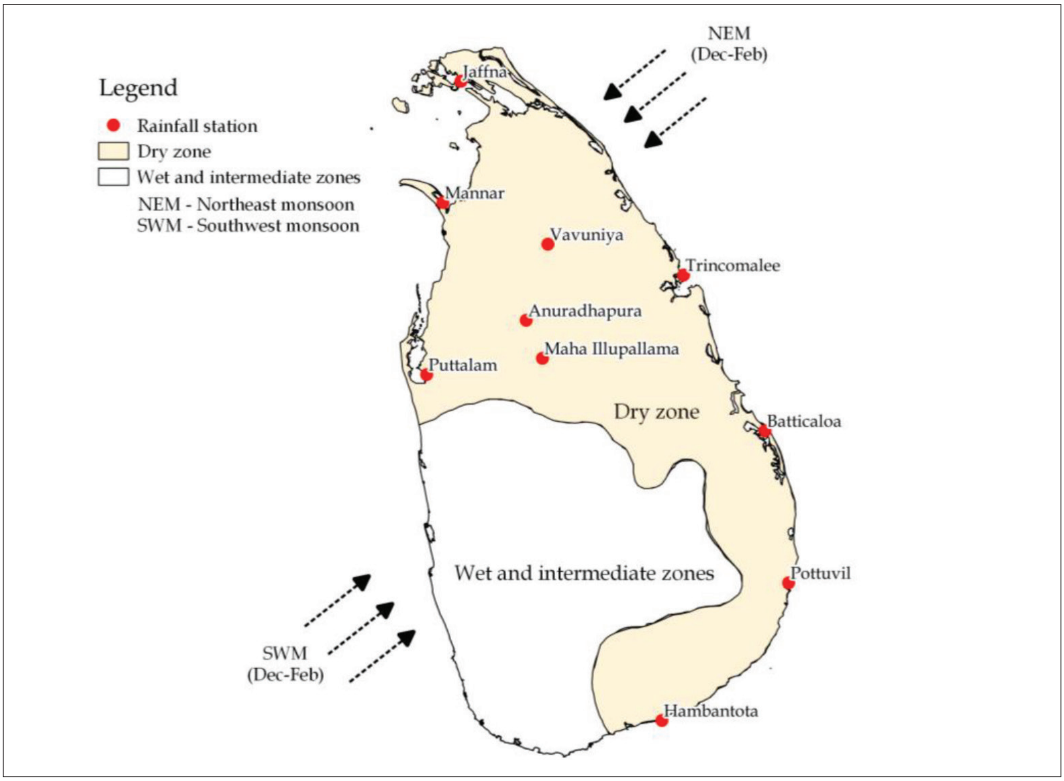


Figure 1: Rainfall stations in the dry zone of Sri Lanka.

instrumentation upgrade and changes in the surrounding ecosystem, which may introduce inhomogeneity, affecting the actual trend. Also, such inhomogeneity corrections may introduce false trends in the data (Pielke *et al*., 2007). Therefore, raw rainfall data was used to reveal the actual trends.

Analysis

Monthly, seasonal and annual trends were investigated for the statistically consistent trends. Although there is a possibility for a non-linear trend, this study seeks to reveal the presence or absence of a linear trend with a year as the explanatory variable. The standard methods are used to test the statistical significance of the slope parameter. For the majority of the trends in this study, the non-parametric Mann-Kendall trend test and Sen-Theil regression were utilized.

The Sen-Theil estimator was used to compute the trend slopes (Theil, 1950; Sen, 1968). The fitted regression line called a Sen-Theil trend line is a non-parametric, alternative to ordinary least square, can be used in conjunction with the Mann-Kendall test. The *p*- value of the estimated Theil-Sen slope is obtained using the Mann-Kendall test.

If there is a significant positive autocorrelation, the test tends to overestimate the significance, which leads to the rejection of the null hypothesis according to the selected level of significance. The opposite is also true where the test tends to underestimate the significance possibly when negative autocorrelation exists (Yue *et al*., 2002). Since the rainfall data of Sri Lanka showed significant autocorrelation, pre-whitening is applied to remove the positive autocorrelation.

In this investigation, the iterative pre-whitening method was performed as executed in the "*zyp*" package in R-programming environment (Zhang *et al*., 2000). Finally, the slopes of the Mann-Kendall test and Sen-Theil were computed for the pre-whitened data set. A modified Mann-Kendall trend test and Sen-Theil have been used to correct mild autocorrelation in between seasons, developed by Hirsch and Slack (1984).

The seasonal Sen-Theil slope estimator is computed by calculating pairwise slopes within each season and obtaining slopes from all seasons to compute a median slope for the entire period of record. In this approach, if there are opposing trends, then the power of the test is reduced because such trends may cancel each other out. Therefore, homogeneity between seasons was initially verified using the van Belle and Hughes trend test (van Belle and Hughes, 1984) prior to the application of seasonal Mann-Kendall and Sen-Theil tests. If the data were heterogeneous between seasons, then the original trend test was performed with pre-whitening.

The analysis was performed in the R-programming environment (R). R is an integrated, interactive environment for data manipulation and serves as a platform for high-level statistical data analysis (R-Core Team, 2016). Numerous statistical libraries available in R was used for the trend detection investigation. A default level of significance of 0.05 was used for all the statistical tests.

Results and discussion

Annual rainfall

Rainfall variability in the dry zone of Sri Lanka was observed to be high. However, average annual rainfall demonstrated linear increasing trend (Figure 2) of +15 mm/year, which agree with the recent rainfall trends reported for the dry zone (Abeysekera *et al*., 2015; Karunathilaka *et al*., 2017) and for Sri Lanka reported by various studies (Jayawardena *et al*., 2018; Naveendrakumar *et al*., 2018).

Notably, these annual average rainfall trends contradict with a decade old prediction by De Silva (2006), may be due to the usage of different baseline data (1961-1990).In general, annual average rainfall in the dry zone was scattered in between the range of 1100-1800 mm for the period of 1996-2015 with higher rainfall during the recent decade. The excess moisture condition (due to increased rainfall) in agriculture fields has severe implications on the crop management that may lead to a reduction in productivity (Herath and Thirumarpan, 2017; Senaratne and Rodrigo, 2014).

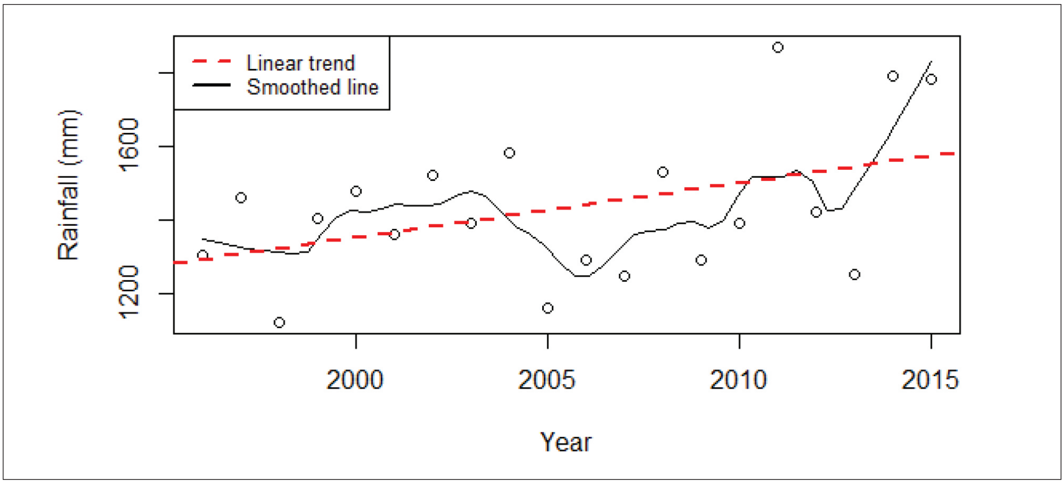


Figure 2: Average annual rainfall trend in the dry zone of Sri Lanka for the period of 1996-2015.

Monthly rainfall

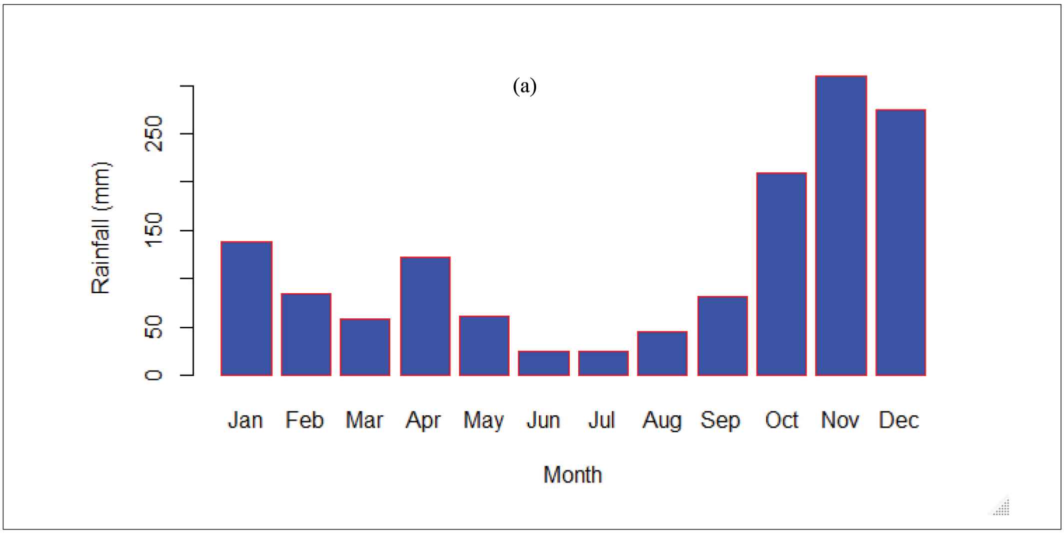
Table 1 presents the number of stations (out of 10) showed statistical trends (either positive or negative) in terms of monthly rainfall. It has been observed at least one station showed a statistically significant decrease in monthly total rainfall during June and July. Especially during June, 100% of the stations showed decreases only indicate a reduction in rainfall of dry zone of Sri Lanka during the middle phase of SWM. It also evidently indicates that dry months in dry zone underwent even drier due to consistently decreasing rainfall, although annual rainfall was

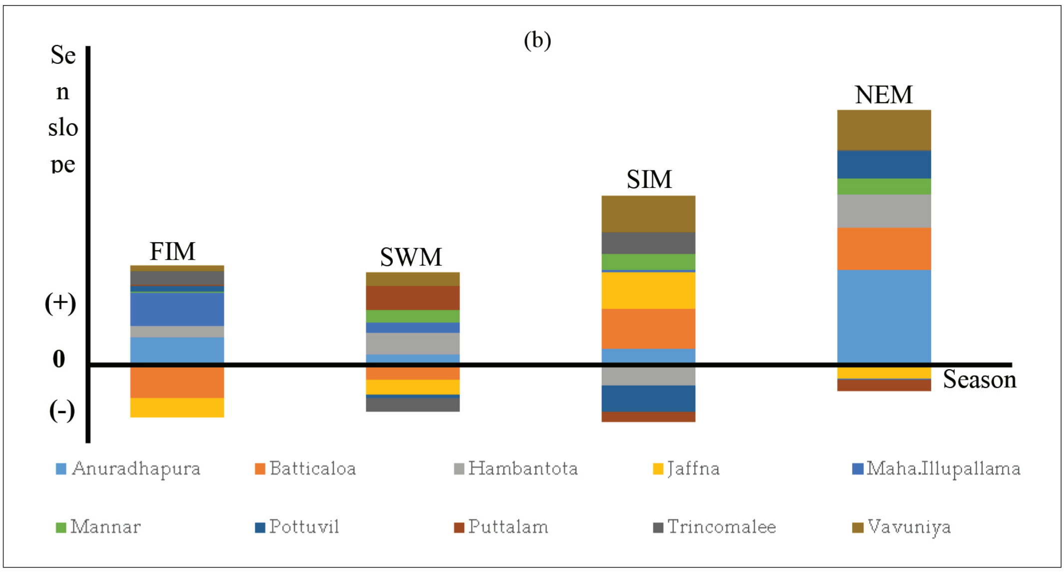
Table 1: Number of stations observed for decreases (-) and increases (+) in monthly total rainfall in stations of dry zone in Sri Lanka for the period of 1996-2015.

Month	Trend* -	Trend* +	Stations (statistically significant)
Jan	9 (0)	1 (0)	
Feb	5 (0)	5 (0)	
Mar	1 (0)	9 (3)	Hambantota, Pottuvil and Trincomalee
Apr	6 (0)	4 (0)	
May	6 (0)	4 (0)	
Jun	10 (1)	0 (0)	Maha Ilupallama
Jul	9 (2)	1 (0)	Jaffna and Mannar
Aug	1 (0)	9 (1)	Mannar
Sep	4 (0)	6 (0)	
Oct	1 (0)	9 (1)	Anuradhapura
Nov	3 (0)	7 (0)	
Dec	1 (0)	9 (0)	

**Stations showed a statistically significant trend (at the 5% level of alpha) are given in parenthesis* revealed an increase. The highest number of stations (30%) was observed during March (Hambantota, Pottuvil, and Trincomalee) followed by August (Mannar) and October (Anuradhapura) during the latter phase of the SWM and SIM. The surplus rainfall obtained during these months critical for the agricultural seed sowing in the dry zone of Sri Lanka.

The monthly rainfall ranged in between 30-300 mm in the dry zone of Sri Lanka. The highest rainfall has been obtained during November followed by December which is the latter phase of SIM and initial phase of NEM, respectively (Figure 3 (a)). It is clear that the dry zone is more influenced by the NEM comparing with the SWM in Sri Lanka. At least 70% of the rainfall stations with positive Sen slopes were observed mostly during the NEM and SIM when comparing with other rainfall seasons in dry zone (Figure 3 (b)).





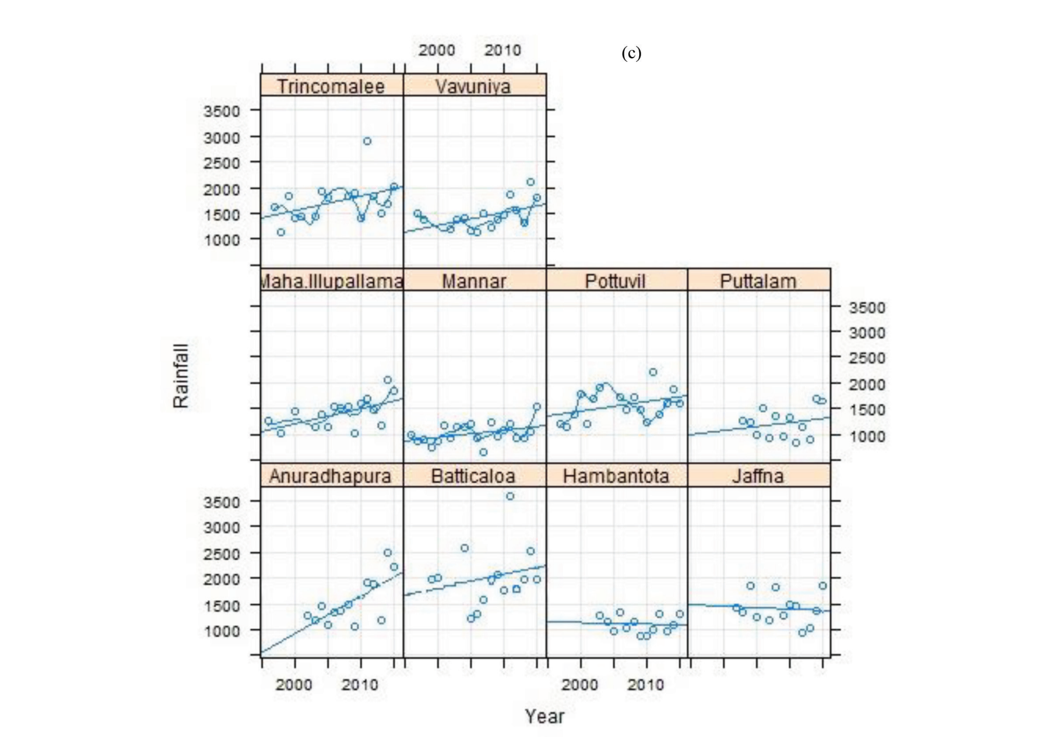


Figure 3: (a) Monthly rainfall, (b) Sen slopes of rainfall stations, and (c) Annual rainfall in the dry zone of Sri Lanka for the period of 1996-2015.

However, Jaffna, Maha Illupallama and Puttalam showed declining rainfall trend during the months of NEM season which agrees with the prediction by De Silva (2006). Figure 3(c) shows the annual average rainfall in the stations of dry zone of Sri Lanka for the period of 1996 to 2015.

Seasonal rainfall

Majority of the stations showed increases in rainfall during all four seasons. Almost 100% of the stations demonstrated a positive trend in which at least 10% of the stations showed a statistically significant increase in seasonal rainfall during the FIM, SWM and NEM seasons (Table 2). Especially during NEM season, 30% of the stations (Anuradhapura, Jaffna and Puttalam) showed a statistically significant increasing trend in seasonal rainfall over dry zone of Sri Lanka. Being an interior station, Anuradhapura demonstrated a statistically significant increase in seasonal rainfall during SWM, SIM and NEM seasons. The stations in coastal peripherals such as Hambantota and Jaffna showed statistically significant increase in rainfall during NEM and SIM seasons, respectively. Though statistically not significant, Jaffna was the only station revealed for the decrease in rainfall during SIM season. However, consistent surplus rainfall obtained in the proceeding NEM season may balance the deficit during SIM season, is an important source of water for agriculture in the dry zone (Senaratne and Rodrigo, 2014).

The increased rainfall during NEM season with high intensity may be the reason for the flood events reported in the past (Burt and Weerasinghe, 2014). Further, an increased rainfall during the *Maha* season and the prolonged dry spells during *Yala* season, may lead to the dry zone more vulnerable to groundwater exploitation due to unregulated water extraction for agricultural practices (Senaratne and Rodrigo, 2014).

Conclusion

Though annual rainfall in the dry zone has increased in the recent decade, consistent reduction during June and July makes the region drier in terms of water availability is evident. This increased rainfall during the *Maha* season and the prolonged dry spells during *Yala* season may lead to groundwater exploitation due to unregulated water extraction. Although it is difficult to reason out for such rainfall variation, the regional climatic driver may be the reason for such increasing rainfall trends in Sri Lanka. Findings of rainfall variation in dry zone are helpful in speculating water availability for crop cultivation especially during deciding on alternating tank-fed and rain-fed agricultural practices in the dry zone of Sri Lanka.

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Page 3 onwards

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This result was later contradicted by Becker and Seligman (1996).

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