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Effect of Plant Spacing on Yield and Fruit Characteristics of Okra (*Abelmoschus esculentus*)

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ABSTRACT. *A field experiment was conducted to investigate the effect of different plant spacings on yield and fruit characteristics of okra (variety: Haritha). Treatments consisted of four plant spacings (90 x 60 cm, 60 x 45 cm, 45 x 45 cm and 45 x 30 cm) among which the spacing recommended (90 x 60 cm) by the Department of Agriculture served as the control. Treatments were arranged in a Randomized Complete Block Design with three replicates. Fertilizer was applied per plant basis as per the Department of Agriculture recommendation. Green fruits were harvested every two days and data on total yield (kg/ha), length of fruit (cm), weight of fruit (g) and number of fruits per plant were collected at each harvest. Total fruit yield, fruit length, fruit weight and number of fruits per plant were significantly affected by plant spacing. When compared to the control, total fruit yield increased by 35% and 160% at 45 x 45 cm spacing during the yala season and at 45x30 cm during the maha season. In contrast, the fruit length decreased by 11.6% at 45 x 45 cm during yala and by 11.3% at 45 x 30 cm during maha when compared to the control. During yala, single fruit weight decreased by 16% at 45 x 45 cm and by 16.5% at 45 x 30 cm spacing during maha when compared to the control. Number of fruits per plant decreased while total yields increased when compared to the control as plant population increased during both seasons. The study indicated that, a 45 x 45 cm spacing could be selected for the yala season while, a 45 x 30 cm spacing is appropriate for maha season for higher yields and quality fruits of okra.*

INTRODUCTION

Okra (*Abelmoschus esculentus* L.**),** which originated in Asia and Africa, is one of the most important warm season fruit vegetables grown throughout the tropical countries. It is also recognized as one of the world's oldest cultivated crops. It is a popular vegetable in Sri Lanka which ranks fourth in cultivated extent among the low country vegetables (Anon, 2007). It shows a wide adaptability and is cultivated in various regions of the country either as a home garden crop or on a commercial scale. It also shows vast potential for earning foreign exchange.

The green, tender fruits of okra are rich sources of vitamins, calcium, potassium, and other minerals. If the crop is managed properly, okra produces green fruits continuously for several months. Factors which influence the crop yield include genetic and nutritional factors and space available to plants. Appropriate plant spacing can lead to optimum fruit

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yield whereas too high or low plant spacing could result in relatively low yields and quality. With increasing plant population, yield per unit area increases upto a certain limit, beyond which it decreases as resources for plant growth become limited. Appropriate spacing differs from one situation to another and according to AVRDC (1990), plant population for okra varies from 30,000 to 120,000 plants per hectare depending primarily on the variety and other management practices. Further, it was reported that optimum plant population is the key element for higher yields, as plant growth and yield are affected by intra and inter row spacing (Amjad *et al*., 2002).

Okra is a popular vegetable among the farmers of the dry zone of Sri Lanka due to favorable climatic and soil conditions prevailing in the area and the ease in growing. The farmers of the dry zone extensively cultivate okra as a monocrop in irrigated uplands as well as in rice based cropping systems during the *yala* season and to a lesser extent in well drained highlands during the *maha* season.

The spacing recommended by the Department of Agriculture (DOA) is not practiced by a majority of farmers in the dry zone of Sri Lanka. This is mainly due to low marketable fruit characteristics and low yields associated with wide spacing recommended by the DOA (unpublished survey data and personal communication). Therefore, farmers tend to use closer spacings on the basis of their own experience in order to harvest a higher yield and medium size green fruits (18-20 cm in length and 28-30 g in weight) which have higher consumer preference (unpublished survey data and personal communication). Due to these ad hoc practices, growers are not procuring the optimum return from the okra crop. Hence, a field experiment was conducted in both *yala* and *maha* seasons to investigate the effect of different plant spacings on the yield and fruit characteristics using a recommended okra variety *Haritha,* to determine the optimum spacing for higher fruit yields and fruits with high consumer preference.

MATERIALS AND METHODS

The okra variety "*Haritha*", which is reputed to be tolerant to yellow mosaic virus disease was selected for the study. The study was conducted at the Field Crops Research and Development Institute, Mahailluppallama (agro-ecological region DL1b) during 2007 *yala* and 2007/2008 *maha* seasons. Variations of rainfall and temperature during both seasons are given in Tables 1 and 2.

Table 1. Variation of rainfall and ambient temperature during the 2007 *yala* season

March	66.4	3	26.3
April	177.3	16	27.1
May	2.1	1	27.8
June	11.6	4	27.0
July	26.4	2	26.5
August	9.4	3	26.6
Total	293.2	29	

Table 2. Variation of rainfall and ambient temperature during the 2007/2008 *maha* season

Month	Monthly rainfall total (mm)	Number of rainy days	Mean monthly temperature (^{0}C)
September	129.1	4	26.6
October	338.2	20	25.7
November	283.1	12	25.2
December	257.4	15	24.5
January	60	12	24.6
February	70.1	10	25.4
Total	1137.9	73	

Treatments consisted of four plant spacings (90 × 60, 60 × 45, 45 × 45 and 45 × 30 cm) including spacing recommended (90 × 60 cm) by the DOA, as the control. Treatments were arranged in a Randomized Complete Block Design (RCBD) with three replicates. The unit plot size was 3 × 3.6 m. In each planting hole, 3 - 4 seeds were sown and after about 7 days, seedlings were thinned out leaving only 2 plants per hole. Plant densities under different treatments are given in Table 3.

Table 3. Plant densities at different spacing

Plant spacing (cm^2)	Plant density (plants / ha)
90 × 60 (T1)	37037
60 × 45 (T2)	74074
45 × 45 (T3)	98765
45 × 30 (T4)	148148

Fertilizer was applied per plant basis as per the recommendation of the DOA (Anon. 2007) and other management practices were followed as stated in the "Techno-guide" of DOA (Anon, 2002).

Tender, green fruits were harvested at two day intervals as practiced by the farmers in the area and the fruit length (cm), and fruit weight (g) were measured at each harvest. The number of green fruits per plant and the total yield (kg/ha) were recorded. The data were statistically analyzed using the SAS system and means were separated using Duncan's multiple range test (DMRT) at 0.05 level of probability.

RESULTS AND DISCUSSION

Statistical analysis of the data generated during two seasons revealed that the interaction between two seasons was significant. Therefore, the data of two seasons were considered separately for interpretation.

Table 4. Effect of different plant spacing on yield and fruit characteristics of okra in the *yala* 2007

Character	T1 (90 x 60 cm)	T2 (60 x 45 cm)	T3 (45 x 45 cm)	T4 (45 x 30 cm)	Pr > F	C. V. (%)
Total yield (kg/ha)	26875 b*	35519 a	36252 a	37358 a	0.0001	5.762
Fruit weight (g)	36.68 a	33.4 b	30.8 c	26.9 d	0.0001	3.817
Fruit length (cm)	24.9 a	22.7 b	22 b	20.57 c	0.0001	2.789
No. of fruits/plant	17.75 a	11.72 b	9.09 c	7.61 d	0.0001	6.610

* DMRT results: Means in each row having the same letter(s) are not significantly different at P≥0.05

Table 5. Effect of different plant spacing on yield and fruit characteristics of okra in the *maha* 2007/2008

Character	T1 (90 x 60 cm)	T2 (60 x 45 cm)	T3 (45 x 45 cm)	T4 (45 x 30 cm)	Pr > F	C. V (%)
Total yield (kg/ha)	14810 d*	24025 c	28658 b	38542 a	0.0001	0.988
Fruit weight (g)	34.37 a	33.03 b	30.24 c	28.7 d	0.0001	1.924
Fruit length (cm)	22.16 a	20.85 b	20.16 b	19.65 c	0.0011	2.851
No. of fruits/plant	15.22 a	12.43 b	11.6 b	9.36 c	0.0001	6.319

* DMRT results: Means in each row having the same letter(s) are not significantly different at P≥0.05

Total yield

Total yield (kg/ha) was significantly affected by the plant spacing both in *yala* and *maha* seasons (Tables 4 and 5). The highest total yield was recorded at the closest spacing (45 × 30 cm) while the lowest yield was obtained from the widest spacing (90 × 60 cm). Total fruit yield at 45x45cm during *yala* season was increased by 35% and total fruit yield at 45 x 30cm spacing in *maha* season increased by 160% when compared to the control (60 x 90 cm). Higher yields which were found at narrower spacing could be attributed to the increased number of plants per unit area.

The total yield primarily depends upon the yield per plant and plant population. Therefore, closer spacing up to a certain limit produces higher yields due to more number of plants per hectare. Wider spacings lead to a lower number of plants per hectare and ultimately lower yields. The possibility of producing higher green fruit yield per hectare with a closer spacing has been reported by Singh (1990). However, as a rule, all crops tend to increase yield per unit area as plant population increased, but only up to a certain limit (AVRDC, 1990).

In the *yala* season, though yields were remarkably high when compared to the control, no significant differences were observed between the treatments 2, 3 and 4. It is well known that, being a tropical plant, okra prefers warm growing conditions with sufficient moisture levels for optimum growth. As these conditions prevail in the dry zone during the *yala* season, they would have favoured the better growth of the okra plant irrespective of the space provided. However, as okra grows well giving higher yields in the *yala* season, which is warmer when compared to the *maha* season (Tables 1 and 2), fruit characteristics should be considered in deciding an appropriate spacing for the *yala* season.

Fruit weight

As shown in Tables 4 and 5, weight of the green fruit was significantly affected ($p<0.05$) by the plant spacing. The heaviest green fruits were produced by the plants at the wider spacings (90 × 60 cm), while minimum green fruit weight was recorded at the closest spacing. This trend could be seen in both seasons, which indicates that, fruit weight was not affected by the season but the spacing. Weight per fruit at 45 x 45 cm spacing in *yala* season decreased by 16% and weight per fruit at 45 x 30 cm spacing in *maha* season decreased by 16.5% when compared to the control (60 x 90 cm). Unpublished survey data obtained prior to the study revealed that market demand and consumer preference is higher for the fruits with 28-30 g in weight. Hence, 45 x 45 cm spacing in *yala* season and 45 x 30 cm spacing in the *maha* season are appropriate to harvest green fruits with a desirable fruit weight.

Fruit length

The plant spacing had a significant effect on fruit length and was longest at the widest spacing. The results of the present study are in accordance with Singh (1990) who reported that maximum fruit length was obtained at wider spacings due to the abundance of growth factors such as space and moisture which have been favored towards the low plant populations. Unpublished survey data obtained prior to the study revealed that, fruits with 18-20 cm length have the highest market demand and consumer preference while postharvest losses are minimal when compared to large sized fruits. Hence, considering fruits with desirable length, 45 x 45 cm spacing level is appropriate for the *yala* season while both 45 x 45 cm and 45 x 30 cm spacings could be considered for the *maha* season.

Number of fruits per plant

Yield of green fruits per plant significantly decreased with the decrease in inter and intra row plant spacing in *yala* and *maha* seasons. With the wider spacings, fruit yield per plant was high and maximum per plant fruit yield was obtained with the widest spacing (60 x 90 cm). Number of fruits per plant at 45 x 45 cm spacing in the *yala* season, though the yield was highest, decreased by 48.8% when compared to the control (60 x 90 cm). Similarly, number of fruits per plant at 45 x 30 cm spacing in the *maha* season also decreased by 38.5%. Although every plant received almost similar amount of nutrients in this experiment, it can be assumed that plants given a wider spacing had less competition for moisture and light as compared to plants given closer spacing. Therefore, the lateral growth of the plant has been favored and tends to produces plants with many lateral branches at wider spacing. As a result, number of fruits per plant increased. A decrease in branch number as plant population density increased was reported by Wu *et al.*, (2003). Further, Bisen *et al*., (1994), Birbal *et al*., (1995) and Olasantan (2001) have reported higher number of green fruits per plant at wider spacing.

The results of the present study revealed that, with the increasing plant density of okra, the total fruit yield increased. The length of green fruits, weight per green fruit and number of green fruits per plant decreased in favor of preferred fruit characteristics. This is attributed to competition between plants for available resources at higher populations which in turn affects the growth and the yield components. The two spacings (90 x 60 cm) and (60 x 45

cm) during both seasons have given comparatively low total yields and the harvested green fruits also did not match the preferred marketable characteristics.

Data from the *yala* season revealed that, although length of fruits harvested at the 45 x 30 cm spacing was within the range of higher consumer preference, single fruit weight and per plant productivity (Table 5) were very low compared to 45 x 45 cm spacing. Further, there was no significant difference among total yields obtained from 45 x 45 cm and 45 x 30 cm spacings. Hence, the 45 x 45 cm spacing level could be considered appropriate for the *yala* season to obtain higher yields with marketable fruit characteristics as moisture stress could limit productivity during the *yala* season at higher population densities.

In contrast, during the *maha*, though it is not the major growing season, spacing of 45 x 30 cm produced considerable high yield while producing fruits with desirable length and single fruit weight compared to 45 x 45 cm spacing. Higher yields obtained at 45 x 30 cm spacing (Table 5) could be attributed to the high moisture availability, a characteristic feature of the *maha* season in the dry zone, which has favored the higher plant population.

Economic benefits

As plant density increases, cost of production increased due to increased application of fertilizers and other agronomic practices. On the other hand, high planting densities produced shorter fruits with higher consumer preference, which in turn fetch higher market prices as compared to the longer fruits of wider densities. Therefore, the extra cost of fertilizer and labor to produce okra under high densities is compensated by the additional income due to yield advantage, high price (Table 6) and presumably lower post harvest losses.

Table 6. Economic analysis for the major cropping season (*Yala*)

Parameter	Spacing			% increase
	90 x 60 cm	45 x 45 cm	Difference	
Fertilizer cost (Rs./ha)	72915.00*	194439.00*	121524.00	166.7
Labor cost (Rs./ha)	70000.00	75000.00	5000.00	7.1
Total cost (Rs./ha)	142915.00	269439.00	126524.00	88.5
Yield kg/ha	26875	36252	9377	34.9
Income (Rs./ha)	403125.00**	652536.00***	249411.00	55.7
Profit (Rs./ha)	273935.00	383097.00	109162.00	38.6

* Fertilizer cost Rs. 1.97/plant
** Income calculated at average price of Rs. 15/kg marketable fruits
*** Income calculated at average price of Rs. 18/kg marketable fruits

CONCLUSIONS

Considering all parameters tested and the crop management practices involved, 45 × 45 cm spacing is suitable in the *yala* season while 45 x 30 cm spacing is appropriate in the *maha* season to obtain high yields and desirable fruit characteristics. However, in facilitating crop management practices like fertilizing, weeding and harvesting, 45 × 45 cm spacing would be ideal for both seasons, since yield given at this spacing is still higher than the yield recorded by using the present DOA recommendation. Further, increasing plant density by narrowing plant spacing, increases the productivity (34.9%) and profitability (38.6%) of Okra.

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