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Fertilizer Requirement for Densely Planted Okra (*Abelmoschus esculentus* L.)

A.M.K.C.K. Abeykoon, R.M. Fonseka[1], S. Paththinige[2] and K.W.L.K. Weerasinghe[2]

Postgraduate Institute of Agriculture
University of Peradeniya
Sri Lanka

ABSTRACT. *A study was conducted at Mahailluppallama, in the Low country Dry zone (DL1b) of Sri Lanka, during Maha (2008/2009) to determine the fertilizer requirement of Okra when planted at closer spacings. Three (03) fertilizer levels (T1- DOA recommendation/ plant, 2 - DOA recommendation/ unit area and T3- 1 ½ times DOA recommendation/ unit area) were tested using Okra varieties Haritha and Green Tender (F1 Hybrid). Concurrently, another set of treatments were employed to find out the effect of removal of leaf immediate belowe the fruit at the time of harvesting on yield. Treatments were arranged according to the Split plot design (Variety as the main plot factor and fertilizer as the subplot factor) with three replicates. Yield per plant, yield per hectare, plant height, number of fruits per plant, fruit length, fruit diameter and the average fruit weight were measured.*

Yield per plant was significantly higher in T1 (188.3±19.4g) than T2 (154.2±13.1g) while T3 (176.6±19.9 g) was not significantly different from other treatments. Yield per hectare was significantly higher in T1 (8.5±0.60 t/ha) while variety Haritha produced significantly higher yield/ha (8.7±0.38 t/ha) compared to the Hybrid (6.0±0.33 t/ha). There were no significant differences found between plant height, fruit length and fruit diameter with the fertilizer treatments. However, a significant difference was observed in plant height between varieties since the Hybrid was taller, but fruit characteristics such as length and diameter were not significantly different between the two varieties. These results revealed that, fertilizer application on a per plant basis leads to higher yield per hectare at closer spacing. However, it appears that, the same per plant yield together with preferable fruit characteristics could be obtained by providing 1 ½ times the fertilizer recommendation, which is cost effective, compared to fertilizer application as per plant basis. Removal of the immediate lower leaf to the harvested fruit could not produce significant differences in relation to any growth or yield parameters measured.

INTRODUCTION

Okra (*Abelmoschus esculentus* L.), which originated in Asia and Africa, is one of the most important warm season fruit vegetables grown throughout the tropics and recognized as one of the world's oldest cultivated crops. It is a popular vegetable in Sri Lanka, ranked fourth in cultivated extent among the low country vegetables (Anon., 2007). It shows a wide adaptability and is cultivated either as a homegarden crop or on a commercial scale in the

[1] Department of Crop Science, Faculty of Agriculture, University of Peradeniya

[2] Field Crops Research and Development Institute, Mahailluppallama, Sri Lanka

Wet, Intermediate and Dry zones of Sri Lanka. It also shows vast potential for earning foreign exchange. Presently, okra is successfully cultivated in the districts of Hambantota, Kurunagala, Ratnapura and Matale and expanding in potential districts such as Anuradhapura, Puttalam, Matara, Badulla and Moneragala (Anon., 2009). Okra is a very popular vegetable among the dry zone farmers due to favorable climatic and soil conditions and the simplicity of crop management. It is cultivated in the dry zone as a monocrop in irrigated uplands as well as in rice-based cropping systems during the *Yala* season and also in well drained highlands during the *Maha* season.

The green fruits of okra, being rich sources of vitamins, calcium, potassium, and other minerals (Great-workout.com 2009), are produced continuously for several months if the crop is managed properly. In most vegetable crops, appropriate plant spacing could lead to optimized plant growth and fruit yields whereas too high or low plant densities could result in relatively lower yields and poor fruit quality (Paththinige *et al.*, 2008). With increasing plant population, yield per unit area increases until a certain limit, beyond which yield decreases due to limitation of environmental resources required for plant growth. Further, it has been reported that optimum plant population is the key element for higher yields of okra, as plant growth and yield are affected by intra and inter row spacing (Amjad *et al*., 2002).

The spacing recommended by the Department of Agriculture (DOA) for okra is not followed by the majority of farmers in the dry zone but denser planting is practiced. This is mainly due to low marketable fruit characteristics and low gross and marketable yields under wider spacing recommended by the DOA (Unpublished data). Therefore, experienced farmers tend to use closer spacing and obtain higher yields and medium size green fruits (18-20 cm in length and 28-30g in weight) which have higher consumer preference (Paththinige *et al*., 2008).

However, without proper recommendations for the agronomy of the crop under dense planting growers do not receive the potential return from the Okra crop. Hence, DOA investigated the effect of different plant spacing on the yield and fruit characteristics using a recommended okra variety *Haritha* and established the optimum spacing for higher yields and fruits with high consumer preference. According to this study, it was found that 45 cm × 45 cm spacing reaches the yield quality targets in both *Yala* and *Maha* seasons (Paththinige *et al*., 2008). However, it can be presumed that densely planted okra, (*i.e*. at 45 cm x 45 cm spacing), may demand large quantities of fertilizers when calculated on the per plant basis. Therefore, this study was conducted to find out the fertilizer requirement for okra, when planted at closer spacing while maintaining the fruit yields and fruit characteristics which were obtained by the previous study.

Further, okra fruits are usually harvested frequently (*i.e*. every other day). It may create difficulties during harvesting in a closely spaced crop. As a remedy, farmers tend to remove the immediate lower leaf to the harvested fruit at the time of harvesting. Therefore, this aspect was also investigated in terms of yield and fruit characteristics of okra when planted at closer spacing.

MATERIALS AND METHODS

The okra variety "*Haritha*", which is reported to be tolerant to yellow mosaic virus disease and an exotic F1 hybrid variety "*Green Tender*", which is used by majority of dry zone farmers were selected for the study. The study was conducted at Mahailluppallama in the Dry zone (DL1b) during *Maha* (2008/2009). The weather conditions that prevailed in the area during the experiment are given in Table 1, while Table 2 shows the soil chemical properties of the experimental site.

In this study, three (03) fertilizer levels (T_1- DOA recommendation / plant, T_2-DOA recommendation / unit area and T_3-1 ½ times DOA recommendation / unit area) were tested for two okra varieties, *Haritha* and *Green Tender*. The DOA fertilizer recommendation for okra and respective fertilizer dosages given under each treatment are given in Tables 3 and 4 respectively. Concurrently, another set of treatments were established to examine the effect of removal of immediate lower leaf at the time of harvesting.

Treatments were arranged according to Split plot design (variety as the main plot and fertilizer as sub plot factors) with three replicates. The unit plot size was 2.5 m × 4.5 m. All the other management practices were followed as stated in the "Techno-guide" of DOA throughout the growing period (Anon, 2002).

Table 1. Variation of rainfall and ambient temperature during the 2008/2009 *Maha* season (Mahailluppallama)

Month	Monthly rainfall total (mm)	Number of rainy days	Mean monthly temperature (^oC)
October	207.3	20	27.4
November	207.5	19	26.3
December	276.2	15	25.1
January	63.7	07	24.7
February	2.0	02	25.7
March	92.1	10	27.9

Tender green fruits were harvested every two days as practiced by the farmers. The number of fruits per plant, fruit length (cm), fruit diameter (cm) and fruit weight (g) were determined at each harvest. The yield was recorded per plant and per plot and used to calculate the total yield (kg/ha). The plant height and the chlorophyll content of leaves were measured at two week intervals. The data were statistically analyzed using the SAS system and means were separated based on the Least Significant Differences (LSD) at 0.05 level of probability.

Table 2. Chemical properties of soils of the experimental site

Chemical	Value
pH	6.86
Total C %	0.83
Total N %	0.07
Total P %	0.04
NO_3^- (mg/kg soil)	4.82
NH_4^- (mg/kg soil)	0.13
PO_4^- (mg/kg soil)	19.91
K (mg/kg soil)	175

Table 3. Department of Agriculture fertilizer recommendation for okra

	Urea(kg/ha)	TSP(kg/ha)	MOP(kg/ha)
Basal dressing	100	200	100
Top dressing 1	100	-	50
Top dressing 2	100	-	50

Table 4. Dosages of fertilizers given in different treatments

	B/D (kg/ha)			T/D1 (kg/ha)			T/D2 (kg/ha)		
	Urea	TSP	MOP	Urea	TSP	MOP	Urea	TSP	MOP
T1	240	480	240	240	-	120	240	-	120
T2	100	200	100	100	-	50	100	-	50
T3	150	300	150	150	-	75	150	-	75

T1 – DOA recommendation / plant T2 - DOA recommendation / unit area
T3 - 1 ½ DOA. recommendation / unit area

RESULTS AND DISCUSSION

Statistical analysis on the data revealed that the interactions between treatment combinations *i.e*. three fertilizer treatments, two varieties and removal of lower leaf at the time of harvesting were not significant. Therefore, the data were considered separately for each treatment for interpretation.

Total yield

Total yield (kg/ha) was significantly affected by the fertilizer treatments (Table 5). The highest total yield per hectare was recorded from the per plant basis treatment (T1) while the lowest yield per hectare was obtained from the per area basis treatment (T2). In the per plant basis treatment, fertilizer requirement of plants was fulfilled based on the individual plant requirement, while in the per area basis treatment individual plants received relatively low amount of fertilizer than that of the normal fertilizer recommendation, due to the increased number of plants per unit area. However, the 1 ½ area basis treatment (T3) recorded significantly higher yield compared to that of per area basis treatment. The total yield primarily depends upon the yield per plant and the plant population. 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 report, 1990). Therefore, at closer spacing, it produces higher yields due to higher number of plants per hectare, only if fertilizer was supplied as per plant basis recommended by DOA.

The data revealed that variety *Haritha* gives significantly higher yield per hectare than the variety "*Green Tender*" (Table 6). Usually F1 hybrids are better yielders compared to open pollinated varieties if given the right conditions. However, the exotic F1 variety "Green Tender" may not be well adapted to prevailing climatic and soil conditions in the dry zone. Therefore, it produces lower yield compared to *Haritha*.

Table 5. Effect of different fertilizer treatments on the yield of okra

Fertilizer Treatment	Total Yield (t/ha)	Yield per plant (g)
DOA recommendation / plant	8.5 a*	188.3 a*
DOA recommendation / unit area	6.0 b	154.2 b
1 ½ DOA recommendation / unit area	7.5 c	176.6 ab
Pr > F	0.0001	0.0973
CV %	12.272	21.432

* Means in each column having the same letter(s) are not significantly different at P≥0.05

Table 6. Effect of different varieties on the yield of okra

Variety	Total Yield (t/ha)	Yield per plant (g)
Haritha	8.7* a	217.7* a
Green Tender (F1 Hybrid)	6.0 b	128.3 b
Pr > F	0.0001	0.0001
CV %	12.272	21.432

* Means in each column having the same letter(s) are not significantly different at P≥0.05.

It is well known that, being a tropical plant, okra prefers warm growing conditions with sufficient moisture levels for optimum growth. Hence, the *Maha* season in the dry zone is considered as the major okra growing season. This would have favored the better performance of the variety *Haritha* which is well adapted to the dry zone conditions and tolerant to yellow mosaic virus, which is considered a major problem for okra cultivation in the dry zone.

The removal of the immediate lower leaf at the time of fruit harvesting which is a common farmer practice in the area has no significant influence in terms of total yield per hectare (Table 7).

Table 7. Effect of removal of immediately lower leaf at the time of harvesting on the yield of okra

Treatment	Total Yield (t/ha)	Yield per plant (g)
Removal of the lower leaf	7.2 a*	169.0 a*
Non removal of the lower leaf	7.5 a	177.0 a
Pr > F	0.3632	0.5241
CV %	12.272	21.432

* Means in each column having the same letter(s) are not significantly different at P≥0.05

Average yield per plant

The average yield per plant was significantly higher in the T1 treatment compared to that of T2 treatment though the yield of T3 was not significantly different from T1 (Table 5). This could be attributed to the higher amounts of fertilizer received by each plant in T1 and T3 treatments as compared to plants in T2 which received less amount of fertilizes at the rate of area basis of DOA recommendation under the high plant density.

As shown in Table 6, the variety *Haritha* produces significantly higher yield per plant compared to the F1 Hybrid. There was no significant effect of removing immediately lower leaf at the time of harvesting on per plant yield (Table 7).

Plant height

The data revealed that plant height did not vary significantly by the fertilizer treatments throughout the crop duration (Table 8). This may be attributed to the use of phosphorus and potassium in larger quantities in combination with nitrogen denying the dominating effect of nitrogen (Amjad *et al*., 2002). Furthermore, application of additional fertilizer beyond a specific dose may not be effective (Amjad *et al*., 2002).

Table 8. Effect of different fertilizer treatments on plant height

Fertilizer Treatment	Plant Height (cm)				
	2 WAP	4WAP	6WAP	8WAP	10WAP
DOA recommendation / plant	4.5 a*	14.6 a	35.1 a	55.3 a	68.6 a
DOA recommendation / unit area	4.5 a	14.8 a	34.6 a	55.6 a	69.2 a
1 ½ DOA recommendation / area	4.9 a	14.9 a	37.9 a	56.3 a	75.7 a

* Means in each column having the same letter(s) are not significantly different at P≥0.05

Table 9 shows that there was a significant difference in plant height related to the variety, where hybrid variety gives significantly taller plants than variety *Haritha*, due to its superior growth rate.

Table 9. Effect of different varieties on plant height

Fertilizer Treatment	Plant Height (cm)				
	2 WAP	4WAP	6WAP	8WAP	10WAP
Haritha	5.8 b*	13.4 b	27.9 b	51.6 b	64.8 b
Green Tender	3.4 a	17.3 a	43.9 a	60.5 a	77.5 a

***** Means in each column having the same letter(s) are not significantly different at P≥0.05

Fruit characteristics

Fruit length

Fruits having 15-20 cm length are reported to have the highest market demand and consumer preference while post harvest losses are minimal when compared to larger size fruits (Paththinige *et al*., 2008). The data revealed that mean fruit length did not show any significant difference in relation to the different fertilizer treatments throughout the growing period. The mean fruit length in per plant basis treatment (T1) was 12.539±0.509 cm, while the mean fruit length of per area basis treatment (T2) was 12.38±0.705 cm. The mean fruit length of 1½ dose of fertilizer treatment (T3) was 13.15±0.516 cm. The data also revealed that mean fruit length did not show any significant difference in relation to the variety, where

the mean fruit length of *Haritha* was 13.97±0.23 cm while for *Green Tender* the mean fruit length was 13.42±0.18 cm. It indicates that the desired fruit characteristics obtained during the previous study had not changed due to the fertilizer treatments in the present study. The fruit diameter also showed similar trends, where neither fertilizer treatment nor variety had any significant influence on fruit diameter.

Total number of fruits per plant

Unlike fruit length and fruit diameter, number of fruits per plant was significantly affected by fertilizer treatments, where T1 produced the highest total number of fruits per plant (15.62±1.08). The minimum total number of fruits per plant was recorded by T2 (11.83±1.15) while T3 (15.20±0.95) produced almost similar total number of fruits per plant as observed for T1. This is an indication of lack of sufficient amounts of plant nutrients at dense planting with current fertilizer recommendation, where dense planting must be supported with intensified crop management such as supplementing of plant nutrition and other soil and climatic factors in order to maintain higher yields.

Further, the data revealed that variety *Haritha* gave significantly higher number of fruits per plant than the exotic variety "*Green Tender*". This indicates that, the exotic F1 variety may not be well adapted to prevailing climatic and soil conditions in the dry zone. Therefore, it produced lower number of fruits per plant compared to *Haritha*.

Leaf chlorophyll content

The chlorophyll content of leaves was measured using SPAD meter throughout the crop duration. However, results did not show any statistically significant relationship between chlorophyll content of the leaves and the treatments (α =0.05) at different heights of the plant at closer spacing.

The data obtained from this study revealed that removal of immediate lower leaf at the time of harvesting had no significant effect on any measured parameters.

Even though recent studies conducted by the DOA revealed that 45 cm × 45 cm spacing gives higher yield per hectare during both *Yala* and *Maha* seasons with fruit characteristics that are preferred by consumers and low post harvest losses, the closer spacing demands large amounts of fertilizers with increased plant density. It increases the fertilizer requirement per hectare by 150% when considered on a per plant basis of fertilizer application as per the DOA recommendation. Also, the results of the previous study revealed that, with the increasing plant density of okra, the demand for fertilizer increased (Paththinige *et al*., 2008). This is attributed to the competition between plants for available resources at higher populations. But the present study revealed that, 1½ dose of fertilizer treatment produced almost same yield per plant with desired fruit characteristics than those obtained during the previous study, even though this treatment has resulted in lower yield per hectare compared to that of the per plant basis fertilizer treatment.

Economic benefits

Treatment 3 (1 ½ dose of area basis fertilizer treatment) produced almost the same yield per plant compared to per plant basis of fertilizer treatment (T1). Even though application of fertilizer at 1 ½ dose of area basis resulted in somewhat lower yield per hectare it was more cost effective in high density okra cultivations.

Table 10: Cost benefit analysis

	T1	T3	Difference	% Decrease
Cost for Urea (Rs/ha)	57600	36000	21600	37.5
Cost for MOP (Rs/ha)	43200	27000	16200	37.5
Cost for TSP (Rs/ha)	43200	27000	16200	37.5
Cost for Fertilizer (Rs/ha)	144000	90000	54000	37.5
Av. Yield (mt/ha)	8.5327	7.4899	1.0428	12.2
Income (Rs)	153426.6	134818.2	18608.4	12.1
Net Profit (Rs)	9426.6	44818.2	35391.6	-375.44
Farm gate price (Rs/kg)=18.00				

As the desired fruit characteristics have not been changed during the present experiment, it is safe to presume that the market price of okra too may not be affected. Therefore, the extra fertilizer cost incurred with per plant basis fertilizer treatment (T1) can be compensated by the low fertilizer cost involved with 1½ area basis fertilizer treatment (T3) together with its slightly lower yields.

CONCLUSION

Considering all the parameters evaluated, fertilizer application should be done according to per plant basis for okra in order to obtain higher yield per hectare at closer spacings. However, the same per plant yield with preferable fruit characteristics could be attained by adding 1 ½ times the dose of DOA fertilizer recommendation, which is more cost effective and more environmentally friendly than applying fertilizer on per plant basis of DOA recommendation. Further, applying fertilizer as per 1½ times the dose of DOA recommendation increased profitability by about 375.4 % compared to per plant basis fertilizer application even though it resulted in a yield reduction of 12.2 %.

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