

Impact of plant spacing and picking interval on the growth, fruit quality and yield of okra (*Abelmoschus esculentus* (L.) Moench)

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To cite this article:

Rajendra Prasad Maurya, Jamar A. Bailey, Jeff St. A. Chandler. Impact of Plant Spacing and Picking Interval on the Growth, Fruit Quality and Yield of Okra (*Abelmoschus esculentus* (L.) Moench). *American Journal of Agriculture and Forestry*.

Vol. 1, No. 4, 2013, pp. 48-54. doi: 10.11648/j.ajaf.20130104.11

Abstract: A field experiment was conducted on okra to determine the optimum plant spacing (30 cm x 45 cm, 60 cm x 30 cm and 60 cm x 45 cm) and picking interval (1 and 2 days) regime which would promote the maximum yield with quality fruits of okra cv. 'Clemson Spineless'. The study was carried out in the Department of Biological and Chemical Sciences during April – July 2012. The six treatments were laid out in a randomized complete blocked design (RCBD), using three replications. The thickest (2.50 cm) stem diameter, greatest (41.86 cm) leaf diameter and maximum (1.72) number of branches per plant and the highest (415.60 g) yield per plant was recorded at the widest (60 cm x 45 cm) spacing. However, the yield per hectare was decreased with the increasing plant spacing. The highest (147.20 cm) plant height and (18.96 tons) yield per hectare was obtained in the closest spacing (45 cm x 30 cm). The longest (15.96 cm) length, widest (2.22 cm) diameter, fresh (27.23 g) and dry (5.38 g) weight per fruit per plant were recorded at 2 days fruit picking interval and all fruits were tender and very marketable. The highest (23.99 tons) yield per hectare was recorded at the closest spacing of 45 cm x 30 cm at 2 days picking interval which was significantly higher than any other combination of plant spacing and picking interval.

Keywords: Okra, *Abelmoschus esculentus*, Plant Spacing, Picking Interval

1. Introduction

Okra (*Abelmoschus esculentus* (L.) Moench) also known as Lady's finger is an economically important summer vegetable crop that belongs to the family Malvaceae [10]. The crop originated from tropical Africa and was first cultivated by the Egyptians in the 12th century AD [29]. Okra is now widely cultivated throughout the tropics, subtropics, and warmer parts of the temperate regions [10]. Globally, okra is cultivated in 0.78 m ha area with 4.99 m tons production and average productivity is 6.39 t ha⁻¹ [15, 28]. India is the largest okra producer; producing 3.5 million tonnes annually (70% of the total world production) from 0.35 m ha area [11]. The crop is quite popular due to its easy cultivation, dependable yield and adaptability to varying moisture conditions (resistant to drought and waterlogging) and soil types. Successful production has

also been recorded in China, Thailand, Egypt, South Africa, Cyprus, Brazil and the Caribbean [20].

The economic importance of okra cannot be overemphasized; all plant parts are useful [10]. Okra plants are mainly cultivated throughout the world for its tender pods. Its tender fruits are very popular as a vegetable among all classes of people around the world [27]. Okra plays an important role in meeting the demand of nutrition when other vegetables are scarce in the market [3]. It is a nutritious rich vegetable which provides an important source of carbohydrates, protein, vitamins A, B₁ and C, calcium, potassium, dietary fibre, and mineral matters; hence it plays a vital role in the human diet [23]. Young immature pods are important fresh fruit vegetables that can be consumed in many different forms; raw, steamed, boiled or fried [10].

Okra's medicinal value has also been reported in curing ulcers and relief of hemorrhoids [2]. [19] Asserted okra is

useful against spermatorrhoea, chronic dysentery and genito-urinary disorders. Leaves are sometimes used as a basis for poultices, as an emollient, sudorific or antiscorbutic and treat dysuria [2]. The hibiscus like flowers and erect stature gives the okra plant its ornamental value [20]. Okra flowers can be very attractive and sometimes are used in decorating the living room [25]. Additionally, dry okra pods can be used as naturals for crafting [5]. In India, mucilage from the roots, pods and stems of okra are used for cleaning the cane juice from which jaggery or brown sugar is prepared [7].

Suitable plant spacing can lead to optimum yield but incorrect plant spacing could result in relatively low yield and poor quality fruits [1, 18]. A significant decrease of pod yield per plant with increasing plant density was observed by [8]. Dense plant populations may result in rigorous growth, poor quality fruits and low yield due to intra specific competition [27].

Picking interval can also influence the yield of okra since it is a quick growing crop [27]. Earlier picking depresses yields because of low fruit weight, but delayed picking depresses marketable yields because over-aged fruits become fibrous [6]. [27] observed that the okra yield was gradually decreased with increasing picking interval and the highest pod yield was obtained at 2 days picking interval (21.74 t ha⁻¹) This variation arises because short picking interval encouraged the plant to produce higher number of fruits per plant and long picking interval increase the fruit size and weight, which in turn produced highest fruit yield per plant as well as per hectare [27].

Barbados is a small country with an ever increasing population hence there is a great food demand. Okra is one of the main food crops and local farmers cultivate to meet this increasing food demand. Farmers strive for maximum crop yields which would alleviate some of the pressure caused by this great food demand. However many farmers, are currently cultivating okras at plant spacings which are inappropriate for obtaining maximum yields. These inappropriate plant spacings often lead to poor plant growth, fruit quality, and low yields which are insufficient to offset production costs which results in a failed crop (substantial losses). The farmer's low yield problem is further compounded by the utilization of inappropriate picking intervals. Additionally local farmers are further limited since the information regarding the effect of spacing and picking interval on growth and yield of okra in the Caribbean is very limited. In recognition of the economic importance of okra, the present investigation was carried out to find the most suitable plant spacing regime and picking interval which would produce maximum okra yield in the Barbados.

2. Materials and Methods

The present investigation was conducted in the Department of Biological and Chemical Sciences at the University of the West Indies, Cave Hill Campus, Barbados

from April – July 2012. Three levels of plant spacing viz. S₁ (30 cm x 45 cm), S₂ (60 cm x 30 cm) and S₃ (60 cm x 45 cm) and two levels of fruit picking intervals viz. D₁ (one day) on alternate days and D₂ (two days) two days gap in fruit picking were the treatments of the experiments. The okra seeds of cultivar 'Clemson Spineless' from Steensen International Inc, U.S.A were used for this study. Six raised beds were prepared and each bed was divided in to three plots (3.24 m² in size). Okra seeds were sown in seedling trays containing Shamrock Seed and Potting Compost and one week old seedlings were transplanted. The six treatments with three replications were laid out in randomized complete block design (factorial) (RCBD). Twelve plants per plot were transplanted during the evening using the appropriate plant-to-plant and row-to-row spacing. These plants were fertilized with 170 g per m² of complex fertilizers (12 N: 12 P: 17K: 2 Mg). The fertilizer was applied as broadcasting in three equal splits at 30, 45 and 60 days after transplanting and plants were irrigated after fertilization. Plants were irrigated by the sprinkler system for 15 minutes daily in evening. Earthing and propping was done at early stage of seedling growth to support the plants. Manual weeding was done weekly in beds and Roundup herbicide was sprayed between the beds to control the weeds. Hoeing and other intercultural operations were done as and when necessary. Data on different parameters were recorded from 10 plants in each plot. The mean values of all parameters were statistically analyzed using GenStat (4th edition, VSN International, UK). The separation of means for significant effect was by the use of Least Significant Difference (LSD) at 5% level of significance.

3. Results and Discussion

3.1. Effect of Plant Spacing

Plant spacing had a significant effect on vegetative growth, fruit quality characteristics and yield parameters of okra cv. 'Clemson Spineless'. The highest (147.20 cm) plant height was found in the closest (30 cm x 45 cm) plant spacing while lowest (111.70 cm) plant height was recorded in the widest (60 cm x 45 cm) spacing (Table 1). This might be attributed to the competition for light and other growth resources among the plants that were crowded at the closer plant spacing. These results are in close conformity with the findings of [13, 26]. The thickest (2.50 cm) stem diameter and greatest (41.86 cm) leaf diameter were recorded in the widest (60 cm x 45 cm) plant spacing. The closest (30 cm x 45 cm) spaced plants had the thinnest (1.74 cm) stem diameter and smallest (28.72 cm) leaf diameter meanwhile plants cultivated in intermediate (60 cm x 30 cm) spacing had intermediate effect on size (2.09 cm) and (35.59 cm) of stem diameter and leaf diameter, respectively (Table 1). Plant spacing also had a significant influence on the number of branches and leaves per plant. The maximum (1.72) branches and (15.25) leaves per plant was recorded in the widest (60 cm x 45 cm) plant spacing

and minimum (1.24) branches and (10.57) leaves per plant in the closest (30 cm x 45 cm) plant spacing (Table 1). The reduced competition for light and other resources as well as reduced overlapping from adjacent okra plants within the population could have enabled the plants to utilize its energy for maximum branching and subsequently the production of larger leaf area [24]. Similar results also reported by [14]

The vegetative growth characteristics results obtained may be attributed to the varying levels of intraspecific competition caused by the 3 plant spacings utilized in the experiment. In nature the competition effect may be completely absent until population density reaches some threshold at which resources become limited [17]. Additionally [17] also stated that individuals of the same species will have the same ecological requirements, if these requirements are limited intraspecific competition will

result. One can infer that at the widest (60 cm x 45 cm) plant spacing there were more nutrients, light and moisture available per plant since plant density was at its lowest. The availability of more nutrients, moisture and light at the widest (60 cm x 45 cm) plant spacing possibly resulted in better growth characteristics. Contrastingly one can assume that at the closest (30 cm x 45 cm) plant spacing the availability of nutrients, light and moisture per plant was low since plant density was at its highest. One can infer that intraspecific competition was at its greatest at the closest (30 cm x 45 cm) spacing resulting in plants having the worst growth characteristics. It could be attributed to competition for photosynthetically active radiation and resources in closer plant spacing [16]. The effect of plant spacing on vegetative characteristics is in close conformity with the findings of [27]. Wider plant spacing produced healthier plants than closer plant spacing [24].

Table 1: Interaction effect of plant spacing and picking intervals on vegetative growth characteristics of okra.

Treatments	Plant height (cm)	Stem diameter (cm)	Number of branches	Number of leaves	Leaf diameter (cm)
Plant spacing					
S ₁ (30 cm x 45 cm)	147.2	1.74	1.24	10.57	28.72
S ₂ (60 cm x 30 cm)	128.4	2.09	1.45	11.98	35.59
S ₃ (60 cm x 45 cm)	111.7	2.50	1.72	15.25	41.86
LSD (5%)	6.69	0.24	0.22	3.09	1.69
Picking interval					
D ₁ (One day interval)	128.2	2.15	1.49	13.43	35.63
D ₂ (Two days interval)	130.0	2.06	1.44	11.77	35.15
LSD (5%)	8.19	0.29	0.28	3.79	2.07
Interaction (Plant spacing and picking interval)					
S ₁ D ₁	111.6	1.79	1.28	11.13	28.48
S ₂ D ₁	124.4	2.12	1.43	13.00	36.24
S ₃ D ₁	148.8	2.55	1.76	16.17	42.16
S ₁ D ₂	111.9	1.68	1.20	10.00	28.95
S ₂ D ₂	132.4	2.05	1.46	10.97	34.94
S ₃ D ₂	145.6	2.46	1.67	14.33	41.55
LSD (5%)	11.58	0.41	0.39	5.35	2.92

Significant differences according to least significant difference ($P \leq 0.05$)

Table 2: Interaction effect of plant spacing and picking intervals on fruit quality characteristics and yield of okra.

Treatments	Fruit length (cm)	Fruit diameter (cm)	Fresh weight/fruit (g)	Dry weight/fruit (g)	Number of fruits per plant	Yield per plant (g)	Yield (ton/ha)
Plant spacing							
S ₁ (30 cm x 45 cm)	10.95	1.59	16.60	3.00	16.04	256.00	18.96
S ₂ (60 cm x 30 cm)	13.06	1.80	19.34	3.84	18.60	331.50	18.42
S ₃ (60 cm x 45 cm)	14.63	2.05	23.17	4.99	21.49	415.60	15.39
LSD (5%)	0.74	0.13	1.12	0.43	1.82	27.09	1.71
Picking interval							
D ₁ (One day interval)	9.80	1.40	12.17	2.29	22.21	266.20	13.80
D ₂ (Two days interval)	15.96	2.22	27.23	5.38	15.21	402.50	21.39
LSD (5%)	0.61	0.11	0.92	0.35	1.48	22.12	1.40
Interaction (Plant spacing and picking interval)							
S ₁ D ₁	7.89	1.20	9.97	1.59	19.30	188.20	13.94
S ₂ D ₁	10.07	1.34	12.20	2.42	22.05	261.40	14.52
S ₃ D ₁	11.43	1.67	14.35	2.85	25.29	349.00	12.93
S ₁ D ₂	14.01	1.97	23.23	4.41	12.78	323.80	23.99
S ₂ D ₂	16.05	2.26	26.48	5.26	15.15	401.50	22.31
S ₃ D ₂	17.83	2.42	31.98	6.45	17.70	482.30	17.86
LSD (5%)	1.05	0.18	1.59	0.61	2.57	38.31	2.42

Significant differences according to least significant difference ($P \leq 0.05$)

The plant spacing had significantly influenced the fruit quality and yield of okra (Table 2). The longest (14.63 cm) fruit length, widest (2.05 cm) fruit diameter and heavier (23.17 g and 4.99 g) fresh and dry weight per fruit was obtained in the widest (60 cm x 45 cm) plant spacing while the smallest (10.95 cm), lowest (1.59 cm) fruit diameter and lighter (16.60 g and 3.00 g) fresh and dry weight per fruit was recorded in the closest (30 cm x 45 cm) plant spacing (Table 2). Significant differences were observed in fruit quality characteristics among all three plant spacing. The maximum (21.49) number of fruits that produced 415.60 g yield per plant was recorded in the widest (60 cm x 45 cm) plant spacing followed by 18.60 fruits with 331.50 g per plant and 16.04 fruits with 256.00 g per plant in intermediate (60 cm x 30 cm) and the closest (30 cm x 45 cm) plant spacing, respectively. The widest spaced plants produced fruits which exhibited better fruit quality characteristics possibly because there were availability of sufficient nutrients, moisture and sunlight per plant due to the low plant density. The 'striving' wider spaced plants are possibly translocating more of their photo assimilates into their fruits making them larger and heavier than those

produced by the plants in the closest and intermediate spacing. Similar results were observed by [18] where the maximum number of mature fruits per plant, maximum fruit length and diameter was recorded at the widest plant spacing. These results are also in close conformity with the findings of [27]. However, the highest (18.96 ton) yield per hectare was recorded in the closest (30 cm x 45 cm) plant spacing followed by 18.42 and 15.39 ton yield per hectare in intermediate (60 cm x 30 cm) and the widest (60 cm x 45 cm) plant spacing, respectively. This highest yield per hectare in the closest plant spacing is due to accommodation of double plant population instead of wider plant spacing. However, yield per plant was low but total accumulation of yield per hectare was high. The highest yield per hectare was found in the closer plant spacing due to accommodation of maximum number of plants reported by [12, 21].

3.2. Effect of Picking Interval

There were no significant differences between picking intervals observed when plant height, stem diameter, branches and leaves numbers and leaf diameter were

considered (Table 1) but picking interval between two successive harvesting significantly influenced the fruit quality characteristics and yield parameters of okra (Table 2).

The longest (15.96 cm) fruit length, widest (2.22 cm) fruit diameter and heaviest (27.23 g and 5.38 g) fresh and dry weight per fruit were obtained in two days picking interval while the smallest (9.80 cm), lowest (1.40 cm) fruit diameter and lighter fruits (12.17 g and 2.29 g) fresh and dry weight per fruit were recorded in one day picking interval (Table 2). There was a significant difference observed between both picking intervals on fruit quality characteristics. Two days picking interval fruits exhibited better quality characteristics over one day picking interval fruits. It is important to note that there is a relationship between fruit length, fruit diameter, and fresh and dry fruit weight. Fruits which are longer in length generally are larger and heavier fruits. Similarly, fruits which are shorter in length generally are smaller and lighter fruits. This may be due to frequent harvesting of green pods which allow the plant to produce further fruits. Longer picking interval allowed the pods to have more growth and development by utilizing of more photosynthate before harvesting, [22, 27] also reported the similar results that length of the fruit increased at long picking interval. The pod length and diameter significantly reduced at closer intra-row spacing [18]. These results are also in close conformity with the findings of [9].

The maximum (22.21) number of fruits per plant was produced when the green pods harvested at one day picking interval which was significantly higher than the minimum (15.21) number of fruits per plant harvested at two days picking interval. This occurred mainly because there was more number of picking days at the one day picking interval compared to the two days picking interval. The plants harvested at one day picking interval yielded more fruits per plant because increased picking encourages faster fruiting rates in okra. Frequent harvesting of green pods might be increasing the plant to produce further fruits [27], [3, 4] also reported the similar findings at the lowest planting density. Picking interval significantly influenced the fruit yield per plant as well as per hectare. The highest (402.50 g) fruit yield per plant and (21.39 ton) yield per hectare were recorded when harvested at two days picking interval and the lowest (266.20 g) yield per plant and (13.80 ton) yield per hectare when harvested at one day picking intervals. This variation arises because two days picking interval encourages the plants to produce heavier fruits per plant with regards to the increase in fruit size (length, diameter and weight), one can infer that the plants were using more of their assimilates for fruit growth and development and diverting less to plant growth during fruiting. The fruit quality of two days picking interval resulted in heavy weight per fruit, which ultimately in turn produced higher fruit yield per hectare. Similar findings were reported by [24, 27].

3.3. Interaction Effects of Plant Spacing and Picking Interval

The data revealed that the thickest (2.55 cm) stem and widest (42.16 cm) leaf diameter and maximum (1.76) branches and (16.17) leaves per plant were observed in the widest (60 cm x 45 cm) plant spacing and one day picking interval followed by (2.46 cm) stem diameter and (41.55 cm) leaf diameter and (1.67) branches and (14.33) leaves per plant were observed in the widest (60 cm x 45 cm) plant spacing and two days picking interval. However, the maximum (148.80 cm) plant height was found in the closest (30 cm x 45 cm) plant spacing and one day picking interval followed by (145.60 cm) plant height in closer spacing and two days picking interval (Table 1). The availability of more nutrients, moisture and light at the wider plant spacing possibly resulted in better photosynthesis that increase the stem and leaf diameter and also number of branches and leaves per plant. Contrastingly one can assume that at the closest plant spacing there were lack of nutrients, light and moisture per plant due to high plant density. Plants were grown taller to receive maximum sun light from upper region. Other possible reasons of better results on the widest plant spacing (60 cm x 45 cm) and one day picking interval the photosynthates are utilized for growth and development of plants while at two days picking interval on same spacing the photosynthates are utilized to increase the fruit size. Similar results were obtained by [24, 27].

The longest (17.83 cm) fruit length, thickest (2.42 cm) fruit diameter and heaviest (31.98) fresh and (6.45) dry weight per fruit were recorded at the widest (60 cm x 45 cm) plant spacing and two day picking interval while maximum (25.29) number of fruits per plant was recorded at the widest spacing and one day picking interval. This might be due to more picking days throughout the picking duration of okra fruits. The possible reasons for better fruit quality characteristics at the widest spacing (60 cm x 45 cm) and two days picking intervals are availability of sufficient nutrients, moisture and sunlight for photosynthesis as well as in two days picking interval fruits had one additional day for utilization of photosynthates in increasing fruit size and weight. These results are in close conformity with the findings of [13, 27]. The highest (482.30 g) yield per plant also obtained from the widest spacing (60 cm x 45 cm) plant spacing with two days picking interval followed by 401.50 g yield per plant from intermediate (60 cm x 30 cm) spacing with two days picking interval and the lowest 188.20 g yield per plant from closer (30 cm x 45 cm) plant spacing with one day picking interval. However, highest yield (23.99 t/ha) were recorded from (30 cm x 45 cm) plant spacing with two days picking interval followed by 22.31 t/ha and 17.86 t/ha yield from intermediate and wider spacing, respectively. This highest yield per hectare in the closest plant spacing with two days picking interval is due to accommodation of superior plant population per hectare. Contrastingly the lowest crop yield was obtained from the widest plant spacing, due to its

low plant density. Similar results were obtained by [27]. The highest yield per hectare in the closest plant spacing was obtained due to accommodation of maximum number of plants. These results are in close conformity with the findings of [12, 13, 21].

4. Conclusion

The study showed that in Barbados agro-climatic conditions the okra cv. 'Clemenson Spineless' produced the maximum plant height and highest yield per hectare was in the closest (45 cm x 30 cm) plant spacing. The better fruit quality characteristics were exhibited at 2 days fruit picking interval and all fruits were tender and very marketable. However, the highest yield per hectare was recorded at the closest spacing of 45 cm x 30 cm at 2 days picking interval. The plant spacing and picking interval had significant effect on fruit quality and yield parameters on okra but no significant interaction effect was observed. These results indicate that further experimentation is needed to maximize the benefits of plant spacing and picking interval.

Acknowledgements

The authors would like to thank to Dean, Faculty of Science and Technology and Head, Department of Biological and Chemical Sciences for providing facilities to conduct this research. We would also like to thank Dr. Francis B. Lopez for his help in statistical analysis and data interpretation. We would also like to thank Devon Slator, Andrew Harewood, Romel Forde, Julicia Payne and Justin Springer for their assistance in planting and data collection.

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