

—Original Research Article

Effects of Row Spacing on the Growth, Yield and Yield Components of Okra (*Abelmoschus esculentus* L.) in Botswana

ABSTRACT

The effects of various row spacing on the growth, yield and yield components of okra (Clemson spineless) was evaluated from January to April 2010 at Botswana College of Agriculture in Sebele. The treatments consisted of five intra-row spacing of 30, 45, 60, 75 and 90 cm for treatments 1-5 respectively, thus R₃₀, R₄₅, R₆₀, R₇₅ and R₉₀ with a constant row spacing of 50 cm, each of the treatment was replicated three times in a randomized complete block design (RCBD). Developmental, yield and yield components as follows; plant height, stem diameter, fresh weight, fruit length and diameter, number of branches, leaves, flowers, fruits and seeds were measured out on five pre-determined plants from each plot and the raw data was subjected to analysis of variance (ANOVA). Generally a significant treatment effect was revealed for plant height with narrower plant spacing (R₃₀) significantly increasing the plant height and a similar trend was observed for number of seeds. Wider plant spacing (R₉₀) significantly increased the plant weight, number of branches and leaves. A non-significant treatment effect was observed for stem diameter, fruit length and diameter, number of flowers and fruits. Based on the results wider plant spacing and narrower spacing are recommended for more vegetative development and seed production respectively. Moreover, wider plant spacing is recommended for the non-significant parameters observed from the present study because of the superior absolute numbers.

Keywords: Plant spacing, Clemson spineless, vegetative development and *Abelmoschus esculentus*

1. INTRODUCTION

Okra is a member of the mallow family Malveceae and genus *Abelmoschus* [1,2,3,4,5]. It is a vigorous, half-woody, herbaceous, semi-fibrous, warm season annual and dicotyledonous plant [6]. Okra thrives well in most soil types from sandy loam, loam and or clay soils with a pH range of 5.8-8.0 [7]. It is native to an area extending from Ethiopia to the Sudan and was introduced to Egypt in the seventh century [1,2]. It was then carried through North Africa and areas bordering the Mediterranean and eastward [1,2]. Okra is also known elsewhere as okro, gumbo, ochro, bhindee, lady's finger and guimbabo [3]. There are numerous types which differ in fruiting time and shape, colour of leaves and stem length [8,3,4]. The mostly cultivated varieties are *Abelmoschus caillei* (A. Chev) and *Abelmoschus esculentus* (L.) Moench. *A. caillei* is an unconventional okra type, which grows naturally in many parts of West Africa whereas *A. esculentus* is a conventional type, which is a native of Asia [4]. The successful exotic cultivar to Botswana is *A. esculentus* commonly referred to as Clemson spineless which is a uniformly spineless, medium dark green, angular pods 12-15 cm long. It

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grows up to 1.2-1.5 m in height and takes about 55-58 days to fruit [8]. The immature fruits are ready for fresh harvest between three and seven days after flowering [9].

Total world production of okra was estimated at 4.1 million metric tons out of which West African countries (Nigeria, Ghana, Togo and Benin) together produced 3.1 million metric tons [2,5]. Production of okra is all year round but more abundant during the rainy season. However, specific local cultivars are grown in specific areas depending upon their photoperiodic requirements. During dry season okra is grown under irrigation or in valley bottoms or riverbanks using residual moisture [10]. According to Majanbu et al [11] fresh pod is highly valuable and can be found in almost every African market. Moreover, fresh pods are usually marketed in open streets markets or supermarkets without any kind of temperature or humidity control [12]. Okra is of great economic importance because of its nutritional value. The green pods contain essential vitamins for example, vitamin C and mineral salts such as calcium, phosphorus, magnesium and iron [13,6]. It is also valuable with regards to anti-carcinogenicity, human immunity promotion, ageing prevention and health-care [14,1,10]. Okra leaves are eaten fresh either boiled or raw in salads. The leaves can be dried and used during a period when okra is out of season [6,15]. According to Ijoyah et al [13] immature pods are used as boiled vegetable while its dried form is used as soup thickener. Schippers [16] noted that okra plants and flowers are used for ornamental purposes because of their attractiveness and colours.

One of the major aspects of crop ecology, production and management which limit crop production is improper crop spacing in the field [17,18,1,19,20] and to some extent fluctuating environmental factors [4]. A spacing of 60-90 cm × 20-90 cm is used depending mostly on the growth habit of the cultivar [17,20]. In addition, wider row spacing is said to be more productive since management practices like weeding and other practices can be easily carried out [1]. Fatokun and Chheda [21] investigated the response of two high yielding okra cultivars to different population densities in Ibadan (Nigeria). The authors- It is reported that the number and weight of fruits-per plant¹ as well as the vegetative branches-per plant¹ decreased significantly with increase in population density from 61 × 30.5 cm to 61 × 91.5 cm. However, with late planting in the season two plants per stand were found to increase yield for the two cultivars over the single plant stand. Norman [22] reported in studies of four plant population density in Makurdi (Nigeria) that a spacing of 40 × 40 cm produced not only highest number of productive branches and fruits-per plant¹, but also the highest fruit weight-per plant¹, and together with spacing of 40 × 30 cm they produced the highest fruit yield per hectare. Fruit size for spacing 40 × 30 cm, 40 × 35 cm and 40 cm × 40 cm which was essentially similar was larger than that of 40 × 25 cm spacing which produced the lowest number of productive branches and fruits per plant, and the lowest fruit weight per plant and fruit yield per hectare. Similar results were obtained by [13,6]. Many local farmers practice broadcasting system in Botswana. This wastes seeds planted per hectare and promotes over-crowding, thus increasing competition among plants and making weeding and other farm operations difficult. There has not been substantial research done on okra by the Department of Agriculture Research (DAR) in Botswana, as such information on the effects of row spacing on the growth and yield of okra is not sufficient. This study was undertaken so as to provide necessary and very useful information about the growth aspects and production of okra. The aim of this study was to evaluate effects of spacing on the commonly grown okra variety in Botswana.

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2. MATERIAL AND METHODS

2.1 Location and climate

The field experiment was conducted using variety Clemson Spineless at Botswana College of Agriculture (BCA) garden in Sebele from January to April 2010. The garden is located 24°33' S and longitude 25°54' E at elevation of 994 m above sea level, 10 km from Gaborone City, along Gaborone-Francistown highway. The climate of the study area is semi-arid with an average annual rainfall (30 year mean) of 538 mm [23,24]. Most of rainfall is received in the summer months, starting in late October, continuing to March/April. Soils are predominantly sandy loams (76% sand, 10% silt and 14% clay) with low water holding capacity, low cation exchange capacity (1.2 meq/100 g) and pH of 6.3.

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2.2 Experimental design and establishment

The experiment was laid out in a randomized complete block design (RCBD) consisting of five treatments each replicated three times giving a total of fifteen (15) plots of 2.5 m × 5.0 m. The five treatments were row-spacing as follows; 30 × 50 cm, 45 × 50 cm, 60 × 50 cm, 75 × 50 cm and 90 × 50 cm for treatment 1-5 respectively, thus R₃₀, R₄₅, R₆₀, R₇₅ and R₉₀ respectively. Two Clemson Spineless seeds were sown per hole and thinning out to one seedling per stand at three to four leaf-stage was done. Clemson is uniformly spineless and medium to dark green in colour. Land preparations involved soil cultivation and making a fine tilth.

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2.3 Cultural practices

Watering was done once or twice per week depending on the weather conditions to keep the soil moist. Compound fertilizer NPK 2:3:2 (22) was applied once at a rate of 80 kg/ha before planting. Weeds were removed whenever they appeared in the experimental site; the most common and problematic weeds species were; *Argemone mexicana*, *Chenopodium carinatum*, *Datura ferox* and *Tribullus terrestris*.

2.4 Data collection

Developmental measurements were carried out on five pre-determined plants from each plot. Plants were tagged and the following data was recorded every fortnight from 6 weeks after emergence (WAE); plant height measured using a meter ruler from base to the terminal bud, stem diameter measured using a digital calibrated vernier caliper at about 10 cm above the soil surface, number of leaves and plant braches both determined quantitatively by counting. Number of flowers and fruits produced were both determined quantitatively by counting and were recorded every seven days from 8 and 9 WAE, respectively. A sample of five fruits from each plot was selected at random and their fresh weight measured using an electric balance (PGW 4502e), length measured using a 30 cm ruler, fruit diameter measured using a digital calibrated vernier caliper and seed number determined quantitatively by counting were recorded at termination of the study.

Comment [S35]: Okra give you pods after every 3 or 4 days so how you collected the data after 7-8 days as the okra would have get matured which will not be acceptable for people consumption.

2.5 Data analysis

The data collected was subjected to analysis of variance (ANOVA) using the STATISTIX-8 program. Treatment means were separated using Tukey's Studentized Range (HSD) Test at $P = .05$.

3. RESULTS AND DISCUSSION

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137 **3.1 Branch-lets and leaves**
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139 Treatments had no effect on okra branching for the first two weeks (week 6 and 8) and
140 number of leaves for week twelve. However, wider spacing treatments (R_{90} , R_{75} , R_{60} and
141 R_{45}) significantly increased branching (weeks 10 and 12) and leaf production (weeks 6, 8
142 and 10) as compared to (R_{30}) narrower spacing (Table 1). It is suspected that wider spacing
143 helped the okra plant to utilize its energy properly in the production of leaves and branching
144 because there was less competition for light, nutrients nor was overlapping from adjacent
145 okra plants within the row [25]. It was also observed that the taller okra plants had fewer
146 branches and hence fewer number of leaves (Table 1 and 2). Leaf numbers also decreased
147 over time (Table 1). Similar result was obtained by [13,6] where taller okra plants and fewer
148 leaves were observed at closer spacing. Ibeawuchi et al [1] observed that okra height
149 decreased over time as row spacing increased. The study also showed that okra spaced at
150 30 cm within the row was significantly taller than other okra plants spaced otherwise from 2-
151 8 weeks after planting. Ijoyah et al [13] also reported that tallest okra plants were produced
152 from the intra-row spacing of 25 cm which was significantly ($P < .05$) greater than that
153 produced from the wider intra-row spacing. The number of branches ~~per plant~~^{per plant⁻²} and leaf area
154 also decreased as intra-row spacing reduced. This may be attributed to competition for light
155 because plants at closer spacing get less amount of sunlight and other growth resources
156 hence their tendency to grow upright instead of lateral and producing branches. Wider
157 spacing helped the plants to utilize its energy properly in branching because there was not
158 much competition for light nor was overlapping from adjacent okra plants within the row.
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160 **3.2 Number of flowers and fruits**
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162 Spacing treatments had no significant ($P > .05$) effect on the number of flowers and fruits
163 (Table 1). The flower production across the treatments was affected by rainfall that rained
164 every day of the week with an average rainfall amount of 113.9 mm recorded in April (Fig. 1).
165 It was expected that treatment R_{90} , R_{75} and R_{60} respectively would have high flower
166 production but most of the flowers were destroyed and dropped by the rains. Fruit production
167 was also indirectly affected by the loss of flowers. Table 2 shows that treatments R_{90} , R_{75}
168 and R_{60} had notably higher fruit production. This ~~could be attributed~~^{could be attributed} to the increase in
169 productive node of okra that increased with row spacing; R_{90} had -77%, while R_{75} and R_{60}
170 had 69% and 66% respectively which affected yield as reported by [1]. However, the
171 differences in means of the fruits produced were not significantly different for all row spacing.
172 Ijoyah et al [13] reported that the number of okra pods per plant decreased as intra-row
173 spacing reduced.

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Comment [S37]: As the data was taken in weekly interval but if you look to okra the It give fruits in 3 days and in week interval time the okra may matured which would not be of edible use. So how you recorded the data???

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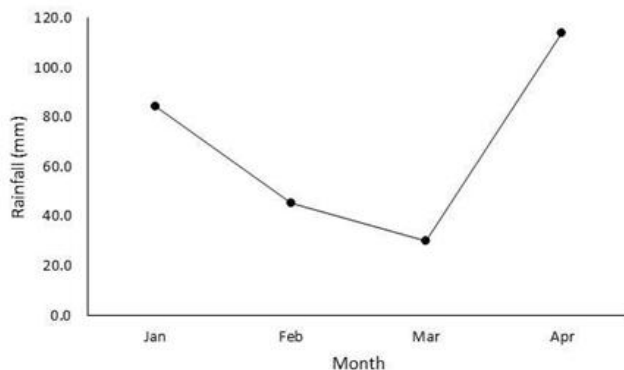


Fig. 1. Mean monthly rainfall recorded during the study

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3.3 Seeds

Treatment R₆₀ significantly ($P < .01$) produced the highest number of seeds per fruit (84.3) though similar to R₄₅ (Table 1). This could be attributed to the fact that at lower plant spacing there was intense competition among the plants while at wider spacing vegetative production was stimulated in the expense of seed production. Moniruzzaman et al [26] found out that at the spacing of 60 × 30 cm the plants grew relatively taller and increase seed yield per hectare but reduced number of mature fruits per plant, length and diameter of mature fruit and number of seeds per fruit. The highest number of seeds per fruit¹⁴ (62.2) was recorded in the widest spacing of (60 × 60 cm) identically followed by 60 × 50 cm spacing. Similarly, the highest seed yield per plant was obtained from the widest spacing (60 × 60 cm) followed by 60 × 50 cm. However, the widest spacing of (60 × 60 cm) gave the lowest seed yield per hectare (1.96 tons).

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3.4 Plant height

Generally, effect of spacing seemed to be negatively correlated on okra plant height with plants spaced at 30 cm revealing superior absolute numbers compared to the rest. However, the effect was non-significant for the first week (week 6), a highly significant and significant ($P < .05$) effects were observed for week 8 and 10 respectively (Table 2). Moreover, a non-significant effect was observed for week twelve (Table 2). This may be attributed to the close spacing of 30 cm along the row which resulted in tall plants, possibly because of intra competition for light and other growth resources. Similar results were reported by [27,20] in green pepper where closer spacing produced the tallest plants and shortest plants were obtained from the widest spacing. Plants spaced at 45, 60, 75 and 90 cm respectively are of approximately the same height possibly because there was less competition for light. Maya et al [27] and Islam et al [20] also reported maximum average number of branches per plant was recorded from plants of the widest spacing and the lowest number of branches from closest spacing. This might be due to the fact that the plants of wider spacing receive more light, nutrients and other resources than of close spacing.

Comment [S41]: If it is the reason so number of branches and leaves are positively correlate d with height increases increased height would increase the number of braches and leaves but it is not the case so kindly explain?

210 **3.5 Stem diameter**

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212 Spacing treatments had no significant ($P > .05$) effect on okra stem diameter for the entire
213 period of the study (Table 2). However, wide row spacing with lesser plant population
214 revealed superior stem diameter. On contrary, study by Islam et al [20] on green pepper
215 found out that stem girth was statistically significant due to different plant spacing. The
216 widest spacing produced the maximum stem girth and it gradually decreased with
217 decreasing spacing. The plants planted at widest spacing produced profuse branching
218 without lodging [13]. From the present study, wider row spacing tended to produce stronger
219 plants that did not require any support unlike at closer spacing where the plants were thinner
220 and weaker.

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222 **3.6 Fresh fruit weight**

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224 Treatments effect seemed to be positively correlated on okra fresh fruit weight with 90 cm
225 spacing significantly ($P < .01$) increasing fruit fresh weight for week 8 and a significant ($P <$
226 $.05$) effect was observed for weeks 9, 10 and 11 respectively (Table 2). Plant spacing
227 influenced the individual fruit weight. The maximum fruit weight was obtained in the widest
228 spacing (90 cm). The widely spaced plants produced heavier fruits as they had stronger
229 plants than at closer spacing. The result are in agreement with Ijoyah et al [13], Islam et al
230 [20] and Maurya [6] who reported maximum yield at wide spacing because wider spacing
231 facilitated the plants to develop properly with less inter and intra plant competition for utilizing
232 the available resources resulting in higher yield per plant.

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234 **3.7 Fruit size (length and diameter)**

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236 Mean fruit length and diameter were not significantly different at $P > .05$ across the five
237 treatments evaluated (Table 2). However, treatment R_{45} and R_{60} had the largest fruit
238 compared to the rest. In a study by Norman [22], narrower plant spacing of 40×30 cm and
239 40×40 cm produced the largest fruit as compared to wider plant spacing, this finding partly
240 agrees with the current study for the wider spacing which had smaller fruits. Ijoyah et al [13]
241 and Maurya [6] obtained significantly higher fruit weight and fruit diameter of okra at spacing
242 of 60×40 cm higher than at wider spacing. It can be deduced from the results that the
243 widest spacing does not necessarily result in a proportional increase in fruit weight and
244 diameter.

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Table 1. Mean branch, leaf, flower, fruit and seed number of okra as influenced by plant spacing

Treatments	Branch				Leaves				Flowers				Fruits			Seeds
	Week 6	Week 8	Week 10	Week 12	Week 6	Week 8	Week 10	Week 12	Week 8	Week 9	Week 10	Week 11	Week 9	Week 10	Week 11	
	6	8	10	12	6	8	10	12	8	9	10	11	9	10	11	
R ₃₀	1.0	1.0	1.0b	1.0b	12.3b	21.7b	22.7b	15.7	1.3	3.0	3.0	2.3	1.0	1.7	1.7	65.3bc
R ₄₅	1.0	1.0	1.0b	1.3b	21.7ab	31.3ab	27.7ab	18.7	1.0	2.7	2.7	2.3	1.0	2.0	2.0	79.3ab
R ₆₀	1.0	1.3	1.3ab	2.7a	21.7ab	31.0ab	29.7ab	18.7	1.0	2.7	3.0	3.0	0.3	1.7	2.7	84.3a
R ₇₅	1.3	1.3	1.7ab	2.7a	22.7ab	35.0a	32.7a	18.7	1.0	3.0	3.0	3.0	0.6	2.7	2.7	59.7c
R ₉₀	1.3	1.3	2.0a	3.0a	28.3a	34.7a	32.7a	19.7	1.0	2.7	2.7	2.7	1.0	2.7	2.7	63.7c
Significance	ns	ns	*	**	*	*	*	ns	ns	ns	ns	ns	ns	ns	ns	**
HSD	ns	ns	0.96	1.03	10.85	12.12	8.77	ns	ns	ns	ns	ns	ns	ns	ns	14.39
CV (%)	27.90	26.35	24.40	17.12	18.06	14.01	10.71	20.99	24.21	15.97	13.51	16.06	42.70	24.21	22.13	7.25

** Highly significant at $P < .01$, * significant at $P < .05$, ^{ns} non-significant at $P > .05$. Means separated using Tukey's studentized range (HSD) test at $P \leq .05$, means within columns followed by the same letters are not significantly different. Where R₃₀-R₉₀ are intra-row spacing of 30, 45, 60, 75 and 90 cm.

Table 2. Mean plant height, stem diameter, fresh fruit weight, fruit length and fruit diameter of okra as influenced by plant spacing

Treatments	Plant height (mm)				Stem diameter (cm)				Weight (g)				Fruit	
	Week 6	Week 8	Week 10	Week 12	Week 6	Week 8	Week 10	Week 12	Week 8	Week 9	Week 10	Week 11	length (cm)	diameter (cm)
	6	8	10	12	6	8	10	12	8	9	10	11	length (cm)	diameter (cm)
R ₃₀	256.7	569.7a	759.7a	861.5	1.4	2.0	2.3	2.6	60.8b	55.6b	58.7b	54.5b	13.4	2.7
R ₄₅	236.9	527.8b	683.6ab	800.8	1.5	2.7	2.5	2.7	64.1b	62.3ab	59.3b	62.6ab	15.0	3.0
R ₆₀	232.7	516.3b	683.7ab	790.7	1.6	2.5	2.6	2.8	65.7b	66.3ab	62.1ab	61.9ab	15.3	2.9
R ₇₅	243.5	516.7b	660.7ab	774.3	1.6	2.5	2.5	2.7	69.7ab	72.5ab	76.2a	72.8ab	13.7	2.8
R ₉₀	230.5	511.5b	611.2b	722.4	1.7	2.5	2.9	3.1	78.2a	80.6a	71.1ab	80.2a	13.9	2.8
Significance	ns	**	*	ns	ns	ns	ns	ns	**	*	*	*	ns	ns
HSD	ns	38.73	129.12	ns	ns	ns	ns	ns	10.06	23.50	15.00	24.60	ns	ns
CV (%)	13.88	2.60	6.75	12.07	18.61	13.44	27.08	17.86	5.28	12.37	8.13	13.16	16.76	9.33

** Highly significant at $P < .01$, * significant at $P < .05$, ^{ns} non-significant at $P > .05$. Means separated using Tukey's studentized range (HSD) test at $P \leq .05$, means within columns followed by the same letters are not significantly different. Where R₃₀-R₉₀ are intra-row spacing of 30, 45, 60, 75 and 90 cm.

Comment [S43]: Why in week 12 there is a significant variation in the branches as when time passes so there is a decline in plant which led to senescence so kindly explain why this happen???

Comment [S44]: Why there is a non significant effect on flowers regarding row spacing as more space more leaves and which will produce more number of flowers and fruits so any good reason for that???????

Comment [S45]: Why you have not taken the data for the 12th week for flowers, flower and weight etc.

Comment [S46]: As the fruit length and diameter is non significantly influenced by row spacing but the data for seed are significant why it is so??? As all the fruits are of same size and shape so how the seed number get increased or decreased by row spacing? Kindly do explain

Comment [S47]: Why the number of leaves get increased gradually and then decreased and then increased why these dynamics occur??? Kindly explain.

Comment [S48]: As the branches and leaves are correlated with plant height? But in week 12 branches and leaves are significantly influenced by row spacing but the plant height remain the same for all the treatment? Any good reason for such a trend?

Comment [S49]: As the fruit length and diameter remain the same for all treatment but the weight is significantly get changed for treatments so kindly explain why it is so?????

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4. CONCLUSION

Wider plant spacing and narrower spacing significantly influenced vegetative development and seed production respectively, therefore both wider and narrower plant spacing are recommended for more vegetative development and seed production respectively. Moreover, wider plant spacing is recommended for the non-significant parameters observed because of the superior absolute numbers.

COMPETING INTERESTS EXIST

No competing interests exist

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Comment [S50]: Only conclusions are given??? You have given both the conclusion and recommendations.

Comment [S51]: If you are recommending both the wider and narrower spacing then why have conducted the experiment and why was the purpose and need of the experiment. Your conclusions and recommendations are different from your results. Kindly revisit and make some useful conclusion and recommendation.

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