Research Article

Plant Spacing Affects the Growth and Seed Production of Okra Varieties

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Abstract | The influence of plant spacing on the growth and seed production of okra varieties was studied at the Horticulture Farm of the University of Agriculture, Peshawar during spring seasons of the years 2012-13. The research experiment was conducted using RCB Design with 2 factors and 3 replications. Five okra varieties viz. Sabz Pari, Arka Anamika, Pusa Sawani, Punjab Selection and Green Star were grown at three plants spacing i.e. 20, 30 and 40 cm and were evaluated for growth and seed production. Variety Arka Anamika had the maximum plant height (136.8 cm), number of branches per plant (1.42), number of pods per plant (26.33), number of seeds per pod (60.67), seed weight per pod (3.87 g) and seed yield (4.54 t ha^{-1}). The plant spacing of 20 cm resulted in the maximum plant height (136.92 cm) but minimum values for all other attributes. 40 cm plant spacing resulted in the maximum seeds per pod (67.28), seed weight per pod (4.61 g), hundred seed weight (6.87 g) and seed yield (4.42 t ha^{-1}). The okra varieties and plant spacing interaction was significant for seed weight per pod only. In conclusion, 40 cm plant spacing can be recommended for optimum seed production in okra.

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Introduction

Okra (*Abelmoschus esculentus* L. Moench) belongs to the family Malvaceae and is a valuable summer vegetable crop in Pakistan. In addition to the exquisite beauty of eye-catching blooms in the vegetable garden, okra also possesses high nutritional as well as medicinal values. The fresh fruit of okra contains 9.6% carbohydrates, 2.25% protein, 1.1% fiber, 0.2% fat in addition to several vitamins and minerals such as iron, potassium, magnesium, sodium, calcium, zinc, nickel and manganese (Cook et al., 2000; Moyin-Jesu, 2007). The fiber of okra is of two types i.e. soluble and insoluble. The soluble fiber aids in reducing cholesterol level and chance of heart diseases, while insoluble fiber helps in healthy digestive system especially intestine. The fiber of okra slows down sugar absorption, hence is a useful anti-diabetic food (Fajinmi and Fajinmi, 2010; Arapitsas, 2008; Gopalan et al., 2007). In Pakistan, there has been a progressive increase in the area under cultivation of okra. At present the okra crop is grown over 15500 hectares with 117900 tons total production and 7.52 t average yield per hectare (Anonymous, 2016). However, the average yield of okra in Pakistan is lower than several countries around the globe (Chattopadhyay et al., 2011). The lower yield in Pakistan could be attributed to poor cultural practices, insects, pests and diseases and the non-availability of good quality seed (Amjad et al., 2002; Rahman et al., 2013).

Okra requires proper nutrition, moisture and sunlight for optimum growth and productivity (Ezeakunne, 2004). Due to small land holdings and high prizes of fertilizers, the farmers try to increase the plant population per unit area to get maximum yield (Weiner, 1990). The proper plant population density is essential for optimum okra plant growth and seed yield (Yadav et al., 2001). The plant spacing affect the availability of water, nutrients and light and an optimum population density may promote the yield and seed quality (Absar and Siddique, 1982; Ezeakunne, 2004). Thus, it is essential to optimize the plant spacing in relation to local climatic conditions and varieties to promote seed yield of okra (Absar and Siddique, 1982). Due to the importance of plant spacing on growth of okra crop and seed production, the current experiment was performed to evaluate the performance of different okra varieties at different plant spacing for quality seed production under agro climatic conditions of Peshawar.

Materials and Methods

To investigate the plant spacing influence on growth and seed production in okra varieties, the experimental research was carried out at the Horticulture Farm, The University of Agriculture, Peshawar, Pakistan amid spring season of the years 2012-2013. The site of experiment is situated at 34° North, 71.3° East with an altitude of 460 meters over sea level. The soil texture of the research field appeared to be silty clay loam, with limited nitrogen (0.02-0.035%), less organic matter (0.6-1%) and high in pH (8.2-8.3). Five okra varieties viz. Sabz Pari, Arka Anamika, Pusa Sawani, Punjab Selection and Green Star were grown at three plants spacing i.e. 20, 30 and 40 cm. Row to row distance was kept constant at 60 cm. The recommended fertilizer dose for okra crop (120-150-120) was applied in shape of Urea, SSP and SOP. The recommended dosage of FYM was applied before soil preparation. All routine cultural practices like weeding, hoeing and pesticides application were kept uniform and constant.

Attributes studied

Plant height (cm): In each replication eight to ten plants were randomly selected and their heights were measured and averaged to be expressed in centimeters.

Number of branches plant^{-1}: The branches emerging from central stem were noted in ten random plants random and averaged to represent the number of branches in a plant.

Number of leaves plant^{-1}: The numbers of leaves in ten plants at random were noted and the average number of leaves per plant was determined for each treatment as well as replication.

Number of pods plant^{-1}: The pods produced per plant were noted in ten plants selected at random per treatment and replication and the average number of pods per plant was determined.

Number of seeds pod^{-1}: The number of seed from ten selected pods excised from randomly selected plants was counted and averaged as number of seeds per pod.

Seed weight pod^{-1} (g): The seeds obtained from ten randomly selected pods were weighed separately and the average of seed weight per pod was noted in grams.

Hundred seed weight: The pods from each replication were harvested and threshed separately. Hundred seeds were taken from randomly selected pods in each treatment and replication and the average weight was recorded and expressed in grams.

Seed yield (tons ha^{-1}): The average seed yield of ten tagged plants selected for counting the values were added to the seed yield of net experimental area of plot to estimate the seed yield per hectare (noted as tons ha^{-1}) according to the following formula.

$$Seed\ Yield(tons\ ha^{-1}) = \frac{\text{Yield per plot (kg)}}{\text{Area of plot (m}^2\text{)}} \times 10000$$

Statistical analysis

The data were analyzed using software *Statistix 8.1* appropriate for RCBD with split plot preparation applying LSD test at 0.05 probability level, while the F-values were significant and the means were separated as described by Steel and Torrie (1984).

Results and Discussion

Plant height (cm)

The plant height of okra varieties differed significantly under study (Table 1). Arka Anamika had the maximum plant height (136.8 cm) followed by Green Star (132.5 cm) and lowest plant height (121.3 cm) was noted in Sabz Pari. Plant height of Punjab

Selection (126.83 cm) and Pusa Sawani (126.73 cm) varieties were at par with each other. Plant spacing also significantly affected the plant height. Closer spacing (20 cm) resulted in greater plant height (136.92 cm) as compared to 129.34 cm and 120.26 cm recorded in plants separated at 30 and 40 cm. Non-significant interaction of varieties × plant spacing was observed for plant height.

Table 1: *Plant height (cm), number of branches plant^{-1}, number of leaves plant^{-1} and number of pods plant^{-1} in various okra varieties as affected by plant spacing.*

Okra Varieties	Plant height (cm)	Branches plant^{-1}	Leaves plant^{-1}	Pods plant^{-1}
Sabz Pari	121.3 d	1.2	32.4 bc	18.8 c
Arka Anamika	136.8 a	1.42	33.33 b	26.33 a
Pusa Sawani	126.73 c	1.2	29.33 d	19.13 bc
Punjab Selection	126.83 c	1.42	34.84 a	18.8 c
Green Star	132.53 b	1.18	31.8 c	20.07 b
LSD (P≤ 0.05)	3.4050	ns	1.1236	1.2511
Plant spacing (cm)				
20	136.92 a	0.88 c	28.68 c	19.24 c
30	129.34 b	1.29 b	31.99 b	20.6 b
40	120.26 c	1.68 a	36.36 a	22.04 a
LSD (P≤ 0.05)	2.6375	0.2296	0.8704	0.9691
Interactions				
Varieties × Method	ns	ns	ns	ns

Means followed by different letters in column differ significantly at p ≤ 0.05.

Number of branches plant^{-1}: The number of branches per plant were not significantly different among the okra varieties but were significantly affected by plant spacing (Table 1). The least number of branches per plant (0.88) were noted in 20 cm plant spacing and increased to 1.29 and 1.68 with wider spacing. The varieties and plant spacing interaction was non-significant for number of branches per plant.

Number of leaves plant^{-1}: It is obvious from Table 1 that number of leaves per plant were highest in variety Punjab Selection (34.84) followed by Arka Anamika (33.33) and the minimum number of leaves per plant in Pusa Swani (29.33). The Sabz Pari and Green Star varieties had 32.40 and 31.80 leaves plant^{-1}, respectively. The number of leaves per plant varied with variations in plant spacing. The counting of leaves per plant increased from the minimum of 28.68 with 20 cm plant spacing, which increased to 31.99 and 36.36 with increasing plant spacing to 30 and 40 cm respectively. The varieties and plant spacing interaction was non-significant for leaves per plant.

Number of pods plant^{-1}: Variety Arka Anamika exhibited highest number of pods (26.33) per plant, followed by Green Star (20.07) and Pusa Sawani (19.13). The lowest numbers of pods per plant (18.80) were recorded in Sabz Pari and Punjab Selection. The numbers of pods plant^{-1} were also influenced significantly by various plant spacing. The minimum number of pods per plant (19.24) increased significantly to 20.6 and 22.04 pods per plant by increasing plant spacing to 30 and 40 cm respectively.

Number of seeds pod^{-1}: Though counting of seeds per pod were highest in variety Green Star (61.67) but statistically at par with Arka Anamika (60.67) and Sabz Pari (60). By contrast, the least integer of seeds per pod (56.53) was noted in Pusa Sawani that was non-significant with 56.73 seeds per pod in Punjab Selection (Table 2).

Table 2: *Number of seeds pod^{-1}, seed weight pod^{-1} (g), 100 seed weight (g) seed yield (t ha^{-1}) of various okra varieties as affected by plant spacings.*

Okra Varieties	Seeds pod^{-1}	Seed weight pod^{-1} (g)	100 seed weight (g)	Seed yield (t ha^{-1})
Sabz Pari	60 a	3.57 bc	5.89 c	3.01 c
Arka Anamika	60.67 a	3.87 a	6.3a	4.54 a
Pusa Sawani	56.53 b	3.61 b	6.34 a	3.09 c
Punjab Selection	56.73 b	3.46 c	6.05 b	2.92 c
Green Star	61.67 a	3.84 a	6.19 ab	3.46 b
LSD (P≤ 0.05)	2.8910	0.1281	0.1564	0.2394
Plant spacing (cm)				
20	51.88 c	2.82 c	5.448 c	3.29 c
30	58.28 b	3.58 b	6.15 b	3.51 b
40	67.2 a	4.61 a	6.87 a	4.42 a
LSD (P≤ 0.05)	2.2394	0.0992	0.1211	0.1283
Interactions				
Varieties × Methods	ns	** (Figure 1)	ns	ns

Means followed by different letters in column differ significantly at p ≤ 0.05.

The influence of plant spacing on the statistic of seeds pod^{-1} was also significant. The least number of seeds per pod (50.88) was reported with 20 cm plant spacing, which increased to 58.28 and 67.2 seeds per pod when plant spacing was increased to 30 and 40 cm respectively. The varieties and plant spacing

interaction was non-significant for integer of seeds per pod (Table 2).

Seed weight pod^{-1}: The seed weight per pod was 3.87 and 3.84 g in okra varieties Arka Anamika and Green Star respectively, with the difference being non-significant and followed by Pusa Sawani with 3.61 g seeds per pod. The seed weight per pod in okra varieties Sabz Pari and Punjab Selection were 3.57 and 3.46 g, respectively (Table 2). Seed weight per pod was significantly affected by plant spacing, so that least plant spacing (20 cm) resulted in the minimum seed weight per pod (2.82 g), which was 3.58 and 4.61 g with increasing in plant spacing to 30 and 40 cm respectively (Table 2). Significant effect was noted for the interaction of varieties and plant on the seed weight per pod. Seed weight per pod increased with expanding the plant spacing from 20 to 40 cm. Minimum seed weight per pod (2.72 g) was recorded in Punjab Selection followed by 2.73 g and 2.79 g in Sabz Pari and Pusa Sawani respectively grown at 20 cm plant spacing. The seed weight per pod was highest in variety Arka Anamika (5.01 g) at 40 cm plant spacing followed by Green Star (4.76 g) at same plant spacing (**Figure 1**).

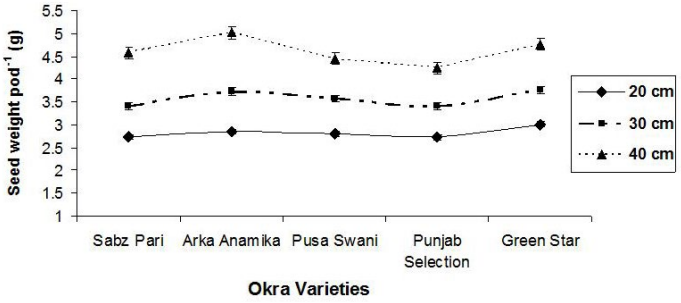

Figure 1: *Interaction effect of varieties and plant spacing on the okra seed weight pod^{-1}.*

Hundred seed weight

There were significant variations in hundred seed weight of different okra varieties. The maximum 100 seed weight (6.34 g) of Pusa Sawani was non-significantly different from 6.30 g, 6.19 g and 6.05 g of Arka Anamika, Green Star and Punjab Selection accordingly. The least 100 seed weight (5.89 g) was recorded for okra variety Sabz Pari (Table 2).

Significant influence of plant spacing on hundred seed weight was observed. The 100 seed weight was the least (5.45 g) with the least plant spacing (20 cm), which increased to 6.15 and 6.87 g with increasing plant spacing to 30 and 40 cm respectively. The interaction of varieties and plant spacing had non-significant effect on hundred seed weight of different okra varieties (Table 2).

Seed yield (t ha^{-1})

The seed yield of okra varieties varied significantly. Highest yield of 4.53 t ha^{-1} was observed in Arka Anamika, which was followed by Green Star with 3.46 t ha^{-1}. The seed yield of Pusa Sawani, Sabz Pari and Punjab Selection were 3.09, 3.01 and 2.92 t ha^{-1}, respectively (Table 2).

The seed yield of okra varieties was significantly affected by plant spacing. The seed yield was the least (3.29 t ha^{-1}) with 20 cm plant spacing, which increased significantly to 3.51 and 4.42 tons per hectare with increasing plant spacing to 30 and 40 cm respectively. The varieties and plant spacing interaction was non-significant for seed yield per hectare in okra varieties (Table 2)

Among the five okra varieties studied, Arka Anamika had the maximum vegetative and reproductive growth as evident from the maximum height of plant, branches produced in each plant, pods produced in each plant, seed count in each pod, seed weight for each pod and yield of seed. By contrast, the okra variety Pusa Sawani, with the minimum height of plant, branches and leaves produced in each plant showed inferior vegetative growth. Punjab Selection was poor in yield attributes such as pods produced in each plant, seed weight in each pod, hundred seed weight and seed yield. Since the okra varieties differ significantly in genetic makeup and hence vegetative and reproductive growth attributes, it is likely to observe significant variation in growth and yield (Mohammed et al., 2013). In an earlier study of okra varieties, Solangi et al. (2015) reported greater nutrient uptake by Sabz Pari as compared to other varieties, thus it is likely that Arka Anamika might have higher nutrients uptake potentials than the variety Sabz Pari. In a similar study, okra variety Arka Anamika was found superior for both vegetative as well as reproductive growth along with yield (Rahman et al., 2012). The Arka Anamika variety of okra is also known to for its resistance to various pests, and that could have contributed to its higher reproductive growth and yield (Hussain et al., 2012). In a previous study Saif-Ullah et al. (2012) evaluated different okra varieties including Arka Anamika and Sabz Pari and reported significantly higher leaf area,

shoot dry weight per plant and yield of in variety Arka Anamika. Similar reports of superior performance of the okra variety Arka Anamika has also been stated by Maurya et al. (2013).

The plant height was less with wider spacing. Since, at 20 cm spacing the plant compete for light and hence tends to grow taller (Maurya et al., 2013), it is reasonable to observe relatively short statured plant at 40 cm plant spacing. By contrast, planting at 40 cm spacing resulted in more branches produced by each plant (Birbal et al., 1995).

The plant spacing also significantly affected the seed yield characteristics of okra. It has been observed that closer spacing increase the population of plants per unit area. Despite, the increased number of plants per unit area, the 20 cm plant spacing resulted in the least yield of seed, which may be due to poor nutrients availability and greater allocation of food and nutrients for vegetative growth (Zanin and Kimoto, 1988). The 40 cm spacing in this experiment may be a modest plant spacing, which resulted in higher seed yield due to increase in number of pods and seed weight per pod despite less number of plants in a unit area. In a similar study, Ghanti et al. (1991) stated that the yield of okra begins to decline, when the row spacing is decreased from 30 cm. The greater seed yield at 40 cm spacing can be associated to increased number of leaves per plant that increased the synthesis of carbohydrates required for reproductive growth (Ram et al., 2013). Thus, more availability of nutrients and moisture and photo assimilates synthesis and partitioning to the developing pods may have contributed to the superior reproductive growth (pods per plant, seeds per pod, hundred seed weight, seed weight per pod, and seed yield) with 40 cm plant spacing (Gupta et al., 1981; Ezeakunne, 2004; Ram et al., 2013). Since, narrow plant spacing (20 cm) had lower number of leaves per plant, it resulted in lower seed yield (Gupta et al., 1981). These results confirm the findings that the count of pods in a plant, seed weight for each pod, seed yield for each plant, hundred seed weight and seed yield for each hectare are enhanced by planting at wider spacing (Birbal et al., 1995; Amjad et al., 2002). Since, the seed size has significant effect on subsequent crop production (Aryannia et al., 2011; Thapa et al., 2012), it seems desirable to use appropriate wider plant spacing for increased seed yield and superior quality.

Conclusions and Recommendations

It can be concluded from the experiment that Arka Anamika is superior to the other varieties in vegetative growth attributes (plant height, number of branches and number of leaves per plant) as well as in the seed production as evident from the maximum pods per plant, seeds per pod, seed weight per pod and seed yield. Among the different plant spacing, plant to plant spacing of 40 cm resulted in the maximum seed yield contributing factors and final seed yield.

Novelty Statement

The current research work evaluated the plant spacing influence on okra seed development and quality, which will pave the way towards developing quality seed in the local conditions

Author's Contribution

This research is part of Ph. D experimentation of the Principal Author and the Co-author is the Major Supervisor, who guided me in the whole Ph. D work.

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