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Effect of plant nutrition and fruit position on seed quality of okra cv. Arka Anamika

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Abstract
The field and laboratory experiments were conducted to study the effect of nutrition and position of fruit on plant growth, seed yield and quality of okra at NSP, UAS, Bangalore. The experiment was laid out in FRCBD design with 12 treatment combinations replicated thrice which four levels of nutrients N_0 (100% RDF), N_1 (125% RDF), N_2 (150% RDF) and N_3 (200% RDF) (RDF: 156.25: 93.75: 78.75 kg NPK ha^{-1} And thrice consisting of three fruit position top (P_1), middle (P_2) and bottom (P3). It was found that bottom fruits (P_3) produced highest quality seeds with maximum germination (88.61%), mean seedling length (32.77 cm), mean seedling dry weight (50.32 g), seedling vigour index-I (2927) and II (4474), 100-seed weight (7.53 g) and total dehydrogenase activity (2.80), while electrical conductivity (674 µS cm^{-1}) of seed leachates recorded minimum in seeds from bottom fruits of okra.

Keywords: Planting geometry, Plant nutrition, Seed quality, Okra

Introduction
Okra (*Abelmoschus esculentus* (L.) Moench) known in many English-speaking countries as ladies finger, bhindi, bamila, ochro or gumbo, is a flowering plant in the *Malvaceae* family and it is valued for its edible green pods. It is widely cultivated in tropics, sub-tropics and warm temperate regions around the world. Okra originated near the equator in Africa. It is an important pan-tropical vegetable, particularly in West Africa, India, Brazil and Southern USA (Gruben, 1989) [5]. It is widely cultivated in Uttar Pradesh, Assam, Bihar, Orissa, Maharashtra, West Bengal and Karnataka states of India. India is second largest producer of okra after China. In India, okra is grown during pre-*kharif* (March to June) and *kharif* season (July to October). In India okra is cultivated in an area of 511 thousand ha with an annual production of 5849 thousand tonnes and productivity of 11.5 t ha^{-1}. In Karnataka, okra occupies an area of 9.66 thousand hectares with an annual production of 79.61 thousand tonnes and productivity of 8.24 tha^{-1}. (Horti. Statistics at glance, 2015).

Okra plays a significant role in human nutrition by providing carbohydrates, protein, fat, minerals and vitamins that are generally deficient in basic foods. Okra is a vegetable valued for many of its properties. The fruits are used in making soup, salad and for flavoring when dried and powdered. Sometime, the seeds are roasted and used as a substitute for coffee. Its ripe fruit and stems contain crude fiber, which is used in the paper industry. The tender fruits contain minerals especially calcium, magnesium, iron, phosphorus, protein, vitamin A and C including riboflavin as well as high mucilage (Ndaeyo *et al*., 2005) [13]. Its every 100 g green pod contains among others, protein 1.8g, carbohydrate 6.4g, fiber 1.2g, vitamin C 18 mg and Ca 90 mg (Rashid, 1999) [15]. Mature okra seeds are good source of protein and oil and it has been known to be very important in nutritional quality. Okra accounts for 60 per cent of export of fresh vegetables excluding potato, onion and garlic (Sharma and Arora, 1993) [17].

Due to this high prominence, okra has been a beneficiary of worldwide research over many years resulting in many varieties currently been planted in different parts of the world. Seed is very important input on which the ultimate yield of the crop depends. To obtain maximum seed yield with superior quality, the proper growth of the plant and its fruits are desired. Most of the studies are concerned with the development of varieties adopted to specific other needs while seed quality has been neglected. Hence, there is need to give utmost attention to both monetary (Fertilizers) and non-monetary (Spacing and fruit position) inputs for improvement of seed yield and quality. Optimum plant population provides conditions for maximum light interception right from early period of crop growth and it ensures the plants to grow uniformly and properly through efficient utilization of moisture, nutrients and lack of it thus eases to produce maximum yield in okra. The yield and quality of commercial vegetables are directly related to plant population (Samlind and Sam Ruban, 2007) [16]. By changing planting geometry, it is possible to achieve better plant growth which in turn contributes to a higher yield. Further, it has been reported that optimum plant population is the key element for better yields of okra, as plant growth and yield are affected by intra and inter row spacing (Amjad *et al.*, 2002) [1].

Present nutritional rates are insufficient to sustain higher yields and to replenish nutrient removal by the crop due to continuous cropping and use of high yielding varieties, there is depletion of nutrients from soil. Hence, to meet the crop demand in long run, there is a need to apply NPK nutrients based on soil fertility status. So, present investigation will helpful to standardize the nutrition level which influence on seed yield and quality in okra. (Naveen Kumar *et al*., 2017) [12]. Various factors influence the seed quality in okra among which position of fruit is of great significance. Ability of seeds to produce a greater number of normal and vigorous seedlings depends on fruit position which affects proper seed filling and maturation due to the competition for assimilates between fruits and within fruit distresses seed set and development (Bertin, 1998) [3]. Fruits produced at the base; middle and apex positions of the stem would have a variation in seed quality due to the varied flow of nutrients (source-sink relationship) and micro-environment experienced by the seed due to its position on the parent plant. (Kortse P. Alohoand Oketa Anita, 2016) [11].

Material and Methods

Seeds of okra variety Arka Anamika was obtained from Indian Institute of Horticultural Research (IIHR), Hessaraghatta, Bengaluru. The field and laboratory experiments were conducted to study the nutrition and position of fruit on plant growth, seed yield and quality of okra at NSP, UAS, Bangalore. The experiment was laid out in FRCBD design with 12 treatment combinations replicated thrice which includes three different planting geometry S_0 (60 × 45 cm), S_1 (60 × 30 cm) and S_2 (60 × 60 cm), four levels of nutrients N_0 (100% RDF), N_1 (125% RDF), N_2 (150% RDF) and N_3 (200% RDF) (RDF: 156.25: 93.75: 78.75 kg NPK ha^{-1}) and Individual plant was divided into three parts (top, middle and bottom) harvested fruits separately and will be evaluated for following seed quality parameters.

Result and discussion

Fruit length (cm)

The data on fruit length as influenced by fruit position, planting geometry, nutrition and their interactions are presented in the Table 1. Fruit length was significantly influenced by fruit position. Maximum fruit length was recorded in P_3 (23.52 cm), whereas minimum was in P_1 (12.58 cm). Fruit length differed significantly among the plant spacings. S_2 (19.91 cm) noted fruit length, while lowest in S_1 (18.48 cm). Among the different nutrient levels, the fruit length differed significantly. The highest fruit length (22.19 cm) was recorded in N_1, while, the lowest fruit length was noticed in control (N_0) (16.35 cm). The interaction of planting geometry and nutrition for fruit length was found to be significant. The maximum fruit length was noticed in S_2N_1 (25.11 cm), and the minimum was recorded in S_1N_0 (15.98 cm). The results revealed that significant effect on fruit length due to interaction between fruit position and planting geometry. Highest fruit length was measured in S_2P_3 (24.43 cm). However, least was in S_1P_1 (12.23 cm).

There were significant differences due to interaction of nutrition and fruit position with respect to fruit length. Maximum fruit length was recorded in N_1P_3 (26.37 cm), however the minimum was in N_0P_1 (9.44 cm). Fruits from bottom position produced lengthy and larger fruits compared to top position might be due to a greater number of cells and high capacity to compete for photo assimilates. Decrease in length in top fruits could be due to presence of developing fruits at the bottom and middle inhibit the subsequent fruit development. Similar results reported by Ozlem Alan and Benian Eser (2007) [14] in hot pepper.

Fruit diameter (cm)

The values of fruit diameter(cm) as influenced by fruit position, planting geometry, nutrition and their interaction was presented in Table 1. Statistically significant differences were observed with respect to fruit diameter due to influence of fruit position. More fruit diameter was measured in P_3 (2.27 cm) and minimum was in P_1 (1.49 cm). Maximum fruit diameter was recorded in N_1 (2.43 cm) and minimum was in N_0 (1.66 cm). There were significant differences due to interaction of nutrition and fruit position with respect to fruit diameter. Maximum fruit diameter was proclaimed in N_1P_3 (2.63 cm) however the minimum was in N_0P_1 (0.98 cm). The results revealed there was significant difference for fruit diameter due to interaction effect of fruit position. Fruits located on bottom position had larger diameter and heavier fruits due to their high capacity to compete for photo-assimilates in mother plant. The present results are in line with studies conducted by Zubairu *et al.* (2017) [19] in okra.

Seed germination (%)

The results pertaining seed germination as influenced by fruit position, planting geometry, nutrition and their interaction are presented in Table 2. Seed germination percent was significantly influenced by fruit position. Maximum seed germination was recorded in P_3 (88.61%), whereas minimum was in P_1 (77.50%). There was significant difference among the planting geometry with respect to seed germination. Highest seed germination was observed in S_2 (84.97%) followed by S_0 (83.18%) and least was in S_1 (81.94%). Seed germination percent was markedly influenced by nutrient levels. Maximum seed germination was recorded in N_1 (88.78%), while minimum was in N_0 (77.67%). Seed germination percent showed significant differences due to interaction effects of planting geometry and nutrition. Highest germination was found in S_2P_3 (89.58%) and least was noticed in S_1P_1 (76.08%). There were significant differences due to interaction of nutrition and fruit position with respect to seed germination%. Maximum seed germination was recorded in N_1P_3 (92.22%) however the Minimum was in N_0P_1 (71.44%). The results revealed there was significant difference due to interaction effect of fruit position and nutrition. Higher seed germination from bottom fruit seeds might be due to appropriate conversion, deposition and partitioning of assimilates in the fruits located at bottom nodes. Therefore, seeds from bottom fruits were bold, vigourous and contained more assimilates food reserve for better germination. The results are in same line with studies made by Mohammud Amjad *et al.* (2005), Hedau *et al*. (2010) [7] in okra and Kazem *et al*. (2012) [10] in pinto bean.

Mean seedling length (cm)
The values on mean seedling length (cm) fruit position, planting geometry, nutrition and their interaction was presented in Table 2. Statistically significant differences were observed with respect to mean seedling length due to influence of fruit position. More seedling length was measured in P_3 (32.77 cm) and minimum was in P_1 (23.48 cm) Maximum mean seedling length was taped in N_1 (35.80 cm) and minimum was in N_0 (21.78 cm). The results revealed significant differences on mean seedling length due to interaction effect of planting geometry and nutrition. Highest mean seedling length was measured in S_2N_1 (37.76 cm) followed by S_0N_1 (35.76 cm). Whereas, least was in S_1N_0 (20.11 cm). There were significant differences due to interaction of nutrition and fruit position with respect to mean seedling length. Maximum mean seedling length was proclaimed in N_1P_3 (40.72 cm) however the minimum was in N_0P_1 (20.12 cm). Large and best quality seeds were obtained from the lower fruits of the main stem of okra so that heavier seeds can produce larger seedlings. The advantage of large seeds in enhancing the seedling size lies in their higher reserve content and the ability to provide energy to the growing seedling at a faster rate. Similar trend indicated by Kazem *et al*. (2012) [10] in soy bean bean and Gangaraju *et al*., (2023) [4] in Maize.

Mean seedling dry weight (mg)
The data on seedling dry weight as influenced by fruit position, nutrition and their interactions are presented in the Table 2. Mean seedling dry weight was significantly influenced by fruit position. Maximum mean seedling dry weight was observed in P_3 (50.32 mg), whereas minimum was in P_1 (44.30 mg). Among the different nutrient levels, the mean seedling dry weight differed significantly. The highest mean seedling dry weight (53.04 mg) was found in N_1, while, the lowest mean seedling dry weight was noticed in control (N_0) (42.36 mg). The results revealed that significant effect on mean seedling dry weight due to interaction between fruit position and planting geometry. Highest mean seedling dry weight was measured in S_2P_3 (52.22 mg). However, least was in S_1P_1 (41.85 mg). There were significant differences due to interaction of nutrition and fruit position with respect to mean seedling dry weight. Maximum mean seedling dry weight was noted in N_1P_3 (56.38 mg) however the minimum was in N_0P_1 (40.79 mg). The fruit position, planting geometry, nutrition and their interactions for mean seedling dry weight was found to be significant. The maximum mean seedling dry weight was observed in $S_2N_1P_3$ (59.49 mg) and the minimum mean seedling dry weight was observed in $S_1N_0P_1$ (35.32 mg). Individual comparison of fruit position showed that bottom fruit seeds had more dry weight compared to top fruit seeds might be due to seeds and seedlings from bottom fruits had significantly highest fresh weight due to accumulation of more photosynthates in bottom fruits compared to top fruit seeds. The present results are in line with studies conducted by Amjad *et al*. (2002) [1] in okra.

Seedling vigour index-I (SVI-I)
Seedling vigour index-I differed markedly among the fruit position. Higher seedling vigour index-I was found in P_3 (2927). Whereas, lower was in P_1 (1836). The influence of planting geometry on seedling vigour index-I was differed significantly. Seedling vigour index-I showed significant differences due to influence of different nutrient levels. Maximum seedling vigour index-I was measured in N_1 (3198) and minimum was in N_0 (1700). The interaction of nutrition and fruit position for seedling vigour index-I was found to be significant. The maximum seedling vigour index-I was recorded in N_1P_3 (3757), and the minimum was recorded in N_0P_1 (1437). The fruit position. Early formed embryos in the lower fruits might be at a temporal and spatial advantage in garnering resources so that higher seed germination and more seedlings formed resulted in higher viguor index in seeds obtained from bottom fruits. These findings were in agreement with the findings of Hai Chun Jing *et al*. (2000) [6] in cucumber and Mahamad shafi Korabu (2013) [18] in oriental melon.

Seedling vigour index-II (SVI-II)
Seedling vigour index-II differed markedly among the fruit position. Highest seedling vigour index-II was recorded in P_3 (4474). Whereas, lowest was in P_1 (3451). Seedling vigour index-II showed statistically significant differences due to influence of nutrient levels. Maximum seed yield per ha was found in N_1 (4721) while, minimum was in N_0 (3300). The fruit position and planting geometry interactions for seedling vigour index-II was found to be significant. The highest seedling vigour index-II was noticed in S_2P_3 (4689) and the lowest was recorded in S_1P_1 (3200). The interaction of nutrition and fruit position for seedling vigour index-II was found to be significant. The maximum seedling vigour index-II was observed in N_1P_3 (5201), and the minimum was found in N_0P_1 (2920). The fruit position, planting geometry, nutrition and their interactions for seedling vigour index-II was found to be significant. This increase in seedling vigour index-II was attributed to increase in germination percentage and mean seedling dry weight. These findings were in agreement with the findings of Mahamad shafi Korabu (2013) in oriental melon.

Hundred seed weight (g)
Statistically significant differences were observed with respect to hundred seed weight due to influence of fruit position. More hundred seed weight was measured in P_3 (7.53 g) and minimum was in P_1 (6.19 g). Significant results were obtained for 100-seed weight due to influence of 100-seed weight. Hundred seed weight was significantly influenced by nutrition levels. Maximum hundred seed weight was found in N_1 (7.63 g) and minimum was in N_0 (6.14 g). There were significant differences due to interaction of nutrition and fruit position with respect to 100-seed weight. Maximum hundred seed weight was recorded in N_1P_3 (8.28 g) however the minimum was in N_0P_1 (5.51 g). The competition for partitioning of assimilates between developing fruits and seeds at several nodes. Since, fruits at lower nodes get maximum share of assimilate and water during seed development and maturation. This could be attributed to early formation and

longer duration of pod filling at lower fruits which resulted in the production of larger seeds resulted in higher hundred seed weight. Incidentally, fruits at higher nodes lag behind in the competition for assimilate as the time available for assimilation of storage reserves is quite shorter. The present results are in line with studies conducted by Kazem *et al*. (2012) [10] in soybean and Hedau *et al*. (2010) [7] in okra.

Seed moisture content (%)

Moisture content of resultant seeds as influenced by fruit position, planting geometry, nutrition and their interaction are presented in Table 4. There was no significant difference among treatments for seed moisture content. This might be due to seed moisture content depends upon the physiological maturity of the seed (time of harvesting) and weather conditions at the time of harvesting. Therefore, the fruit position did not have any significant effect on moisture contents of the seeds. These findings are in agreement with the results of Muhammad Amjad *et al*. (2002) [1] in okra.

Electrical conductivity of seed leachates (µScm^{-1})

Statically non-significant difference found for the electrical conductivity of seed leachate among the treatments and their interactions except fruit position. Electrical conductivity of seed leachate differed markedly among the fruit position. Minimum electrical conductivity was recorded in P_3 (674). Whereas, maximum was in P_1 (885). It is well established fact that the electrical conductivity (EC) values indicate the membrane integrity and quality of seeds. EC and seed quality are inversely proportional. EC had significant differences due to fruit positions. Highest EC recorded in top fruit seeds might be due to less membrane integrity of seeds. Similar results were obtained by Ashok Sajjan *et al*. (2002) [1] in okra, Mahamad shafi Korabu in oriental melon and Siddarudh *et al*., (2013) [18] in maize.

Total dehydrogenase activity (OD value at A_{480nm})

The data regarding to total dehydrogenase activity as influenced by planting geometry, nutrition and their interaction are furnished in Table 4. There was no significant difference for TDH activity of seeds among treatments and their interactions except fruit position. Statistically significant differences were observed with respect to total dehydrogenase activity due to influence of fruit position. More TDH activity (OD value) was observed in P_3 (2.80) and minimum was in P_1 (1.64). TDH activity was highest in the seeds of lower position fruits might be due to lower position fruits had bold sized seeds which developed fully contained matured embryo whereas top fruit seeds could not get sufficient duration for complete development of embryo and maturation in crop growth period. These findings were in agreement with the findings of Jay Gopal Kushwaha (2002) [9] in okra.

Table 1: Effect of planting geometry, nutrition and fruit position on fruit length and fruit diameter of okra cv. Arka Anamika

Treatments	Fruit length (cm)	Fruit diameter (cm)
Nutrition Levels (N)		
N_0: 100% RDF	16.35	1.66
N_1: 125% RDF	22.19	2.43
N_2: 150% RDF	19.38	2.04
N_3: 200% RDF	18.23	1.76
S.Em±	0.27	0.02
C.D (P= 0.05)	0.77	0.07
Fruit position (P)		
P_1: Top	12.58	1.49
P_2: Middle	21.01	2.16
P_3: Bottom	23.52	2.27
S.Em±	0.24	0.02
C.D (P= 0.05)	0.66	0.06
Interaction (N × P)		
N_0P_1	9.44	0.98
N_0P_2	18.89	1.96
N_0P_3	20.71	2.03
N_1P_1	17.13	2.17
N_1P_2	23.06	2.49
N_1P_3	26.37	2.63
N_2P_1	13.01	1.69
N_2P_2	20.88	2.14
N_2P_3	24.24	2.30
N_3P_1	10.72	1.11
N_3P_2	21.20	2.04
N_3P_3	22.77	2.13
S.Em±	0.47	0.04
C.D (P= 0.05)	1.33	0.12

(RDF: Recommended Dose of Fertilizer- 125: 75: 63 kg of N: P_2O_5: K_2O ha^{-1}

Table 2: Effect of planting geometry, nutrition and fruit position on seed germination per cent, mean seedling length and mean seedling dry weight of okra cv. Arka Anamika

Treatments	Seed germination (%)	Mean seedling length (cm)	Mean seedling dry weight (mg)
Nutrition Levels (N)			
N_0: 100% RDF	77.67	21.78	42.36
N_1: 125% RDF	88.78	35.80	53.04
N_2: 150% RDF	84.37	28.79	47.07
N_3: 200% RDF	82.65	26.70	44.87
S.Em±	0.34	0.21	0.27
C.D (P= 0.05)	0.95	0.59	0.77
Fruit position (P)			
P_1: Top	77.50	23.48	44.30
P_2: Middle	83.99	28.55	45.90
P_3: Bottom	88.61	32.77	50.32
S.Em±	0.29	0.18	0.24
Interaction (N × P)			
N_0P_1	71.44	20.12	40.79
N_0P_2	78.67	21.89	41.69
N_0P_3	82.89	23.32	44.61
N_1P_1	84.33	29.12	49.66
N_1P_2	89.78	37.57	53.09
N_1P_3	92.22	40.72	56.38
N_2P_1	78.56	22.54	44.34
N_2P_2	84.56	29.81	45.29
N_2P_3	90.00	34.00	51.58
N_3P_1	75.67	22.12	42.41
N_3P_2	82.96	24.93	43.52
N_3P_3	89.33	33.03	48.70
S.Em±	0.59	0.36	0.47
C.D (P= 0.05)	1.65	1.02	1.33

(RDF: Recommended Dose of Fertilizer- 125: 75: 63 kg of N: P_2O_5: K_2O ha^{-1})

Table 3: Effect of planting geometry, nutrition and fruit position on seedling vigour index I and II of okra cv. Arka Anamika

Treatments	Seedling Vigour Index I	Seedling Vigour Index II
Nutrition Levels (N)		
N_0: 100% RDF	1700	3300
N_1: 125% RDF	3198	4721
N_2: 150% RDF	2452	3985
N_3: 200% RDF	2232	3723
S.Em±	20.18	26.01
C.D (P= 0.05)	56.89	73.33
Fruit position (P)		
P_1: Top	1836	3451
P_2: Middle	2423	3872
P_3: Bottom	2927	4474
S.Em±	17.48	22.53
C.D (P= 0.05)	49.27	63.51
Interaction (N × P)		
N_0P_1	1437	2920
N_0P_2	1724	3280
N_0P_3	1940	3701
N_1P_1	2461	4194
N_1P_2	3375	4769
N_1P_3	3757	5201
N_2P_1	1772	3484
N_2P_2	2524	3830
N_2P_3	3059	4641
N_3P_1	1674	3208
N_3P_2	2070	3610
N_3P_3	2951	4351
S.Em±	34.95	45.05
C.D (P= 0.05)	98.54	127.01

(RDF: Recommended Dose of Fertilizer- 125: 75: 63 kg of N: P_2O_5: K_2O ha^{-1})

Table 4: Effect of planting geometry, nutrition and fruit position on seed moisture percent, hundred seed weight, electrical conductivity of seed leachate and total dehydrogenase activity of okra cv. Arka Anamika

Treatments	Seed moisture (%)	Hundred seed weight (g)	Electrical conductivity (μScm^{-1})	Total dehydrogenase activity (A_{480}nm)
Nutrition Levels (N)				
N_0: 100% RDF	8.53	6.14	776	2.22
N_1: 125% RDF	8.59	7.63	780	2.24
N_2: 150% RDF	8.46	7.00	782	2.24
N_3: 200% RDF	8.37	6.59	775	2.30
S.Em±	0.07	0.03	4.71	0.02
C.D (P= 0.05)	NS	0.07	NS	NS
Fruit position (P)				
P_1: Top	8.50	6.19	885	1.64
P_2: Middle	8.49	6.81	776	2.32
P_3: Bottom	8.47	7.53	674	2.80
S.Em±	0.06	0.02	4.08	0.02
C.D (P= 0.05)	NS	0.06	11.51	0.05
Interaction (N × P)				
N_0P_1	8.66	5.51	888	1.68
N_0P_2	8.51	6.16	766	2.26
N_0P_3	8.42	6.75	675	2.71
N_1P_1	8.56	7.07	894	1.61
N_1P_2	8.72	7.54	783	2.30
N_1P_3	8.47	8.28	664	2.81
N_2P_1	8.32	6.26	880	1.60
N_2P_2	8.34	6.94	790	2.31
N_2P_3	8.71	7.80	676	2.82
N_3P_1	8.46	5.90	878	1.66
N_3P_2	8.40	6.59	767	2.38
N_3P_3	8.26	7.28	681	2.86
S.Em±	0.13	0.05	8.16	0.04
C.D (P= 0.05)	NS	0.13	NS	NS

(RDF: Recommended Dose of Fertilizer- 125: 75: 63 kg of N: P_2O_5: K_2O ha^{-1})

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