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Growth and Yield Performance of Okra (*Abelmoschus esculentus* (L.) Moench.) in Relation to Fertigation Using Different Rates and Sources of Fertilizers

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A B S T R A C T

A field experiment was conducted at Bangalore during 2013 and 2014 to study the effect of fertigation on the performance of okra. The trial included total of ten treatments comprising of varying rates and different sources of fertilizers were tested. Application of recommended dose of fertilizer (180:120:120 kg NPK/ha) through fertigation using water soluble fertilizers on weekly interval resulted in higher values for plant height (153.6 cm), pods per plant (15.79), pod length (16.33 cm), pod girth (6.48 cm) and pod weight (21.28 g), which remained on par with same amount of fertilizer applied bi-weekly. In general treatments which received the fertilizers through fertigation have taken less number of days for flowering over the conventional soil application of fertilizers. All fertigation treatments recorded higher marketable okra pod yield over the conventional soil application of fertilizers to the tune of 12.5 to 46.0 per cent. Among fertigation treatments, application of recommended dose using water soluble fertilizers through 100 per cent weekly fertigation resulted in highest marketable yields (21.65 t/ha). The highest net income (Rs.187852/ha) and B: C ratio (1.53) was obtained with the treatment where in 50 per cent of recommended dose of N: K using water soluble fertilizers supplied through fertigation.

Introduction

Okra **[***Abelmoschus esculentus* (L.) Moench] is an important vegetable of tropics and sub tropics, which is widely grown in India for its mature, tender and green fruits for the culinary purpose. Other than its nutritional values, it has high acceptability in Indian market and fetches good price (Haris *et al.*, 2014). In India, okra is grown in 5.33 lakh hectares with a production of 63.4 lakh tonnes and a productivity of 11.9 tonnes per hectare (NHB, 2014). Though it is grown predominantly during *kharif* season, change in climatic conditions coupled with erratic monsoon necessitates providing irrigation during dry spell period. As such even during this season, it is nowadays grown with a provision for irrigation and more so using drip irrigation system. In present era of acute water shortage caused by over utilization and depletion of both surface and sub terrain water resources, micro irrigation lend a helping hand to sustain vegetable production. Therefore, adoption of modern irrigation technique is needed to be emphasized to

increase water use efficiency and bring more vegetable area under cultivation. Drip irrigation is the most effective way to supply water and nutrients to the plant which not only saves water but also increases yield of fruits and vegetable (Spehia *et al.,* 2010). Studies carried on elsewhere have indicated that the fertilizer should be applied regularly and timely in small amount for better plant growth and yield in onion (Neeraja *et al.*, 1999). Okra has responded with increased production with nitrogen, phosphorus and potash injected into the irrigation water as compared to soil application of recommended dose of fertilizers (Venkadeswaran *et al.*, 2014a). Scientific information on fertigation especially on *kharif* grown okra is very less, hence the present study was undertaken to determine the effect of fertigation of recommended dose of fertilizers and sources through drip irrigation for commercial production of okra.

Materials and Methods

The experiment was conducted during *kharif* seasons of 2013 and 2014 at ICAR-Indian Institute of Horticultural Research, Hessarghatta, Bangalore, Karnataka, India. The mean weather parameters during crop growth period are presented in table 1. The soil was well drained sandy loam having initial organic carbon (0.61%), pH (6.65), available N (167 kg/ha), available P (80 kg/ha), available K (267 kg/ha) and electrical conductivity (0.25 dSm^{-1}) with available water holding capacity of 135 mm in one meter soil depth. Okra seeds of cultivar Arka Anamika were sown at 60-40 x 20 cm plant-to-plant spacing under paired row system during the first week of July. The experiment was laid out in Randomized Block Design with ten treatments and three replications. A uniform basal application of Farm yard manure @ 25 tonnes $hectare^{-1}$ was applied prior to sowing. The treatment details and amount of different fertilizers applied are given in tables 2 and 3, respectively. In case of soil application treatment, entire P and half of N and K were given as basal and remaining half of N and K was side dressed 30 and 60 days after sowing in equal splits. Urea, Polyfeed (19-19-19), potassium nitrate (13-0-45) and muriate of potash were used as water soluble fertilizers for treatments T_3 to T_{10}, while urea, single super phosphate and muriate of potash were used as conventional fertilizers for treatments T_1 and T_2. Drip system installed consisted 16 mm inline drip lateral with 2 lph output dripper spaced at 40 cm. Drip irrigations were given depending on the rate of evaporation and amount of effective rainfall received. It worked out to be 70 mm and 90 mm of supplemental irrigation water for first and second year of cropping season after making necessary adjustment for the effective rainfall received.

After three weeks of sowing, fertilizers were applied through drip system as per the treatments at weekly and bi-weekly interval. The desired amounts of fertilizers were dissolved in 20 liters of water and applied via ventury system through drip irrigation in the fertigation treatments by maintaining the fertigation schedule in 12 cycles at weekly and 24 cycles at bi-weekly interval and continued up to 20 days before completion of crop growth period.

The drip application time was determined based on daily evaporative values collected from IIHR meteorological observatory and an Epan coefficient of 0.7. Various yield parameters (pods per plant, pod length, pod girth, pod weight) were recorded from five plants selected randomly replication wise in all the treatments. All the agronomic and plant protection measures were adopted as per the recommended package of practices (Prabhakar *et al.*, 2010). The experimental data were statistically analysed (Gomez and Gomez, 1983) and compared using critical difference at five per cent probability level.

Results and Discussion

All the fertigation treatments resulted in better okra growth (Table 4) as seen by higher plant height at harvest and number of days taken to first flowering compared to conventional soil application of fertilizers. The pooled data analysis revealed that T_3 recorded maximum plant height (153.6 cm) and number of leaves per plant (13.60), which was significantly higher than most of the treatments but remained on par with T_4, T_5 and T_7 for plant height and with T_7 for number of leaves. The higher plant height and leaves in fertigation treatments may be attributed to continuous supply and consequent availability of plant nutrients in the root zone. This is in conformity with the findings of Venkadeswaran *et al.,* (2014b).

It was also observed that in general the treatments that received the fertigation have taken less number of days for flowering over the conventional soil application of fertilizers (T_1). The NPK fertigation treatments (T_3, T_5 and T_7) recorded the least number of days for first flowering (33.0), which is significantly less than T_1, T_2 and T_{10}. This indicated that 100 per cent N: P: K fertigation of the recommended dose (180:120:120 kg NPK/ha) at weekly or bi-weekly and 100 per cent N: P: K fertigation of the 75 per cent of the recommended dose (135:90:90 kg NPK/ha) at weekly interval resulted in longer period of flowering during the reproductive stages of growth than other treatments. Similar results of better plant height and significantly reduced number of days taken for first flowering were reported by Mahendran *et al.*, (2011). Treatment receiving 100 per cent NPK fertigation at recommended dose (T_3) also recorded significantly higher number of pods per plant (15.79) and pod length (16.33 cm) than T_1, T_2, T_6, T_9 and T_{10}. Application of 100 % NPK fertigation through water soluble fertilizers resulted in significantly higher pod weight (21.28 g) than treatments receiving fertilizers through soil (T_1 and T_2). The same treatment also recorded highest pod girth (6.48 cm) and remained on par with most of the treatments except T_1, T_2 and T_{10}. Mahendran *et al.,* (2011) also observed higher number of pods per plant, pod length, pod girth and pod weight with application of 100 % NPK fertigation through water soluble fertilizers in okra. All the fertigation treatments recorded higher marketable okra pod yield over the conventional soil application of fertilizers (T_1) to the tune of 12.5 to 46.0 per cent. Most of the fertigation treatments with water soluble fertilizers remained on par except T_{10}, and among those T_3 recorded the highest (21.65 t/ha) and T_{10} lowest (17.35 t/ha) pod yield. Patel and Rajput (2003) and Varughese *et al.,* (2014) also observed highest yield in okra with 100 per cent fertigation of the recommended dose. These higher yields were due to better growth and yield parameters like days to flowering, plant height, number of fruits per plant and fruit length. Goswami *et al.,* (2015) also reported significant positive correlation of okra fruit yield with above mentioned parameters. There were very marginal differences between the yields of 100 or 75 per cent recommended dose of NPK fertigation given weekly or bi-weekly.

Similarly, application of 50% NK through fertigation of 100 per cent recommended dose shows no difference when applied weekly or bi-weekly, however with reduced dose of fertilizers the same treatment produced marginally higher yield when applied weekly than bi-weekly. It showed that application of water soluble fertilizers through fertigation at recommended or reduced rate will not affect the yield by weekly or bi-weekly fertigation interval. Difference between 100 or 75 per cent of NPK or NK fertigation was less when applied weekly interval as compared to bi-weekly application with same treatment.

Table.1 Meteorological parameters during the crop growth period

Month	Temperature (°C)		Relative humidity (%)		Total rainfall (mm)	Evaporation (mm)	Wind Speed (km/h)
	Max.	Min.	Morning	Evening			
July 2013	26.9	19.4	76.9	51.3	51.0	4.5	6.05
August 2013	28.8	18.4	82.8	53.3	55.5	3.8	4.24
September 2013	30.6	20.3	83.7	51.2	290.5	3.1	4.47
October 2013	29.4	20.8	84.8	54.7	85.2	3.6	4.20
July 2014	26.2	19.5	64.8	42.4	166.8	3.3	8.52
August 2014	28.6	20.2	67.1	53.9	149.0	3.1	6.81
September 2014	28.9	20.9	69.7	47.2	185.0	3.2	5.48
October 2014	28.7	21.0	70.3	45.7	395.0	3.5	3.44

Table.2 Fertigation treatment details

Symbol	Treatment	Fertilizer	Application dose	Basal dose (kg/ha)	Top dressing (kg/ha)	Fertigaton (kg/ha)	Frequency
T_1	100 % recommended dose (180:120:120 Kg/ha)	Commercial	100 % soil application	90:120:60	90:0:60		
T_2		Commercial	50 % NK fertigation	90:120:60		90:0:60	Weekly
T_3		WSF	100 % NPK fertigation			180:120:120	Weekly
T_4		WSF	50 % NK fertigation	90:120:60		90:0:60	Weekly
T_5	75 % recommended dose (135:90:90 kg/ha)	WSF	100 % NPK fertigation			135:90:90	Weekly
T_6		WSF	50 % NK fertigation	67.5:90:45		67.5:90:45	Weekly
T_7	100 % recommended dose (180:120:120 Kg/ha)	WSF	100 % NPK fertigation			180:120:120	Bi-weekly
T_8		WSF	50 % NK fertiogation	90:120:60		90:0:60	Bi-weekly
T_9	75 % recommended dose (135:90:90 kg/ha)	WSF	100 % NPK fertigation			135:90:90	Bi-weekly
T_{10}		WSF	50 % NK fertigation	67.5:90:45		67.5:90:45	Bi-weekly

WSF: Water soluble fertilizers

Table.3 Treatment wise fertilizers applied (Kg/ha) under fertigation

Treatments	Basal Dose			Top dressing		Fertigation			
	Urea	Single super phosphate	Muriate of Potash	Urea	Muriate of Potash	Urea	Muriate of Potash	Potassium Nitrate	19 All
T_1	195.0	750.0	100.0	195.0	100.0				
T_2	195.0	750.0	100.0			195.0	100.0		
T_3	0.0	0.0	0.0			130.0			632.0
T_4	195.0	750.0	100.0			158.0		130.0	
T_5	0.0	0.0	0.0			98.0			474
T_6	67.5	90.0	45.0			120.0		98.0	
T_7	0.0	0.0	0.0			130.0	632.0		276.3
T_8	195.0	750.0	100.0			158.0		130.0	
T_9	0.0	0.0	0.0			98.0	474.0		
T_{10}	67.5	90.0	45.0			120.0		98.0	

Table.4 Growth and yield parameters of okra as influenced by fertigation treatments (Pooled data)

Treatment	Plant height at harvest (cm)	No. of leaves per plant	Days to first flowering	Pods per plant	Pod length (cm)	Pod girth (cm)	Pod weight (g)	Yield (tonnes/ha)	Water use efficiency (kg/ha-mm)
T_1	127.4	9.37	41.0	9.76	11.38	5.23	15.07	14.83	48.9
T_2	133.2	9.75	38.0	11.89	12.57	5.53	16.76	16.68	55.0
T_3	153.6	13.60	33.0	15.79	16.33	6.48	21.28	21.65	71.5
T_4	148.3	10.96	34.0	14.25	15.79	6.41	20.04	20.69	68.3
T_5	149.0	11.31	33.0	13.98	14.93	6.00	19.74	20.66	68.1
T_6	140.0	10.21	35.0	12.10	13.76	5.91	18.66	19.52	64.6
T_7	152.2	13.10	33.0	14.70	15.94	6.25	21.10	20.35	67.2
T_8	146.0	10.57	35.0	13.83	14.39	6.16	18.96	19.38	64.0
T_9	146.4	10.60	35.0	13.30	14.19	5.95	19.34	19.96	65.8
T_{10}	137.5	9.89	37.0	11.00	12.87	5.53	18.71	17.35	57.2
CD (*P*=0.05)	5.84	1.67	2.58	2.16	2.02	0.65	2.98	3.10	

Table.5 Economics of okra crop in relation to fertigation treatments

Treatment	Average yield (t/ha)	Gross investment (Rs/ha)	Gross income (Rs/ha)	Net income (Rs/ha)	Benefit: cost ratio
T_1	14.83	113246	222450	109204	0.96
T_2	16.68	113246	250200	136954	1.21
T_3	21.65	164480	324750	160270	0.97
T_4	20.69	122498	310350	187852	1.53
T_5	20.66	148488	309900	161412	1.08
T_6	19.52	117249	292800	175551	1.49
T_7	20.35	164480	305250	140770	0.86
T_8	19.38	122498	290700	168202	1.37
T_9	19.96	148488	299400	150912	1.01
T_{10}	17.35	117249	260250	143001	1.22

Sale Price = Rs.15.00/kg

Data on water use efficiency in okra is presented in table 4. The results clearly indicated that irrespective of the dosages, higher water use efficiency was observed with fertigation treatments using water soluble fertilizers as compared to conventional method of fertilizer application (T_1) as well as fertigation using conventional fertilizers (T_2). Among fertigation treatments the highest water use efficiency of 71.5 kg per hectare-mm was observed with 100 per cent NPK fertigation using water soluble fertilizers (T_3). This was mainly due to maximum okra pod yield recorded with same amount of irrigation water used. This is in confirmation with the findings of Soumya *et al.,* (2008) and Mahendran *et al.,* (2011). Cutting across the level and frequency of fertigation, NPK fertigation in general resulted in marginally superior water use efficiency (65.8-71.50 kg/ha-mm) over NK fertigation treatments (57.2-68.2 kg/ha-mm).

Details on economics and benefit: cost ratio of okra cultivar Arka Anamika in relation to various treatments are given in table 5. The values revealed that all the fertigation treatments with water soluble fertilizers resulted in higher gross income than soil application (T_1) and fertigation with common fertilizers (T_2). Among fertigation treatments, where the water soluble fertilizers were used, application of 100 recommended dose through fertigation on weekly basis has resulted in highest gross income (Rs.324750/ha). Regarding net income, NK fertigation of 50 per cent of 100 or 75 per cent of the recommended dose on weekly basis recorded higher values (Rs.187852 and Rs.175551/ha).

This is mainly due to less gross investment coupled with moderately higher levels of yield compared to other treatments. Because of this, wherever 50 per cent amount of N and K applied through fertigation and reaming 50 per cent through soil application resulted in higher B: C ratio, which ranged from 1.22 to 1.53, irrespective of weekly or bi-weekly applications.

From this study it can be concluded that for good pod yield in *kharif* grown okra weekly fertigation of nitrogen and potash at recommended dose (180:120:120 kg NPK/ha) through water soluble fertilizers was found good. This also resulted in highest net income of Rs.1,87,852 per hectare.

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