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Nutrient uptake of hybrid okra [*Abelmoschus esculentus* (L.) Moench] under drip fertigation

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ABSTRACT

An experiment was conducted to compare the effect of conventional fertilisers and water soluble fertilisers at varying frequency interval of application on nutrient uptake of hybrid okra [*Abelmoschus esculentus* (L.) Moench]. The experiment was laid out in a Randomised block design with two control involving ten treatments in a factorial way and was replicated thrice. The plot receiving daily fertigation of water soluble fertilisers (S_1F_1) had recorded the highest fruit N, P and K uptake (53.66, 9.19 and 30.14 kg ha^{-1} of N, P and K respectively) followed by daily fertigation of conventional fertilisers (51.45, 8.85 and 29.40 kg ha^{-1} of N, P and K respectively). However they were found to be at par. The plant uptake of N, P and K was also found to be higher in the treatment receiving water soluble fertilisers on daily basis (21.94, 5.29 and 15.21 kg ha^{-1} of N, P and K respectively). Daily fertigation of conventional fertilisers (20.82, 5.04 and 14.66 kg ha^{-1} of N, P and K respectively) was the next best treatment and it was not found to differ significantly from S_1F_1. The lowest post harvest available N, P and K recorded in plots receiving daily fertigation using water soluble fertilisers (47.27, 30.18 and 340.67 kg ha^{-1} of N, P and K respectively) was found comparable to daily fertigation of conventional fertilisers (48.08, 30.75 and 341.67 kg ha^{-1} of N, P and K respectively). The maximum post harvest available soil N, P and K was recorded in control wherein the entire recommended fertilisers were applied in soil.

Key words: Conventional fertilisers, Fertigation, Fertigation frequency, Nutrient uptake, Water soluble fertilisers.

INTRODUCTION

Vegetables play an important role in providing a balanced diet by supplying nutrients, vitamins, minerals and antioxidants. India is the second largest producer of vegetables in the world accounting for 14 per cent of the global vegetable production. However, the area and production of vegetables have almost plateued since 2005 and the vegetable consumption of an average Indian is (183 g) far less than the recommended dietary allowance of 300 g (Singh *et al.*, 2011a) and this demand supply gap is likely to widen further with the growing population and shrinking resources.

Water and nutrients are the two most critical inputs needed to be managed efficiently for increasing the yield as well as to sustain the environmental quality. Drip fertigation has been well recognised as an efficient and precise method of fertiliser application directly to the root zone for maximising productivity and net returns in horticultural crops (Meenakshi, 2002).

With this background the present investigation on fertigation in okra was taken up to study the effect of solid water soluble fertilisers and conventional fertilisers on growth and yield of hybrid okra under fertigation and to optimise the frequency of fertiliser application through drip for achieving enhanced nutrient uptake.

MATERIALS AND METHODS

The experiment was conducted in the horticulture farm of Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal, U.T. of Puducherry during summer 2012. 'Shakti' a hybrid okra was used for the study. The experiment was laid out in randomized block design (RBD) with two controls involving ten treatments as detailed below in a factorial way and was replicated thrice.

Treatments	Details
S_1F_1	Daily fertigation with water soluble fertilisers
S_1F_2	Fertigation at 3 days interval with water soluble fertilisers
S_1F_3	Fertigation at 5 days interval with water soluble fertilisers
S_1F_4	Fertigation at 7 days interval with water soluble fertilisers
S_2F_1	Daily fertigation with conventional fertilisers
S_2F_2	Fertigation at 3 days interval with conventional fertilisers
S_2F_3	Fertigation at 5 days interval with conventional fertilisers
S_2F_4	Fertigation at 7 days interval with conventional fertilisers
RDF	Soil application of recommended dose of fertilisers
Control	No fertiliser

A plot size of 22.50 m^2 was maintained for each treatment. The crop was irrigated daily considering the E_{pan} value and the crop co-efficient value (Kc). The entire

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quantity of water lost through evapo transpiration was replenished every day through drip system (Rekha *et al.*, 2006). The ET value was worked out as suggested by Kisekka *et al*. (2010). A fertiliser dose of 200:100:100 kg NPK ha^{-1} along with 15 t ha^{-1} of FYM was uniformly applied to all the treatment plots (Crop production techniques of horticultural crops, 2004) except in absolute control. The FYM and full dose of NPK were applied through soil in RDF while FYM along with 75 per cent of recommended P_2O_5 as super phosphate were applied as basal in all the fertigation treatments. Full 'N' and K_2O along with the remaining 25 per cent of P_2O_5 were applied through fertigation. The treatments that were not fertigated on a particular day were given drip irrigation alone for a similar duration. Urea, Polyfeed (19-19-19), potassium nitrate (13-0-45) and mono ammonium phosphate (12-61-0) were used as water soluble fertilisers (S_1), while urea, diammonium phosphate and muriate of potash were used as conventional fertilisers (S_2). The solution of Diammonium Phosphate and Muriate of Potash were filtered before injecting into the system to avoid clogging of emitters. Fertigation scheduling was done by dividing the entire crop period into 4 different growth stages as recommended by Vadivel (2006). The total quantity of fertilisers recommended during each stage was split according to the frequency interval and was supplied through the fertigation system. The seeds were raised on beds in a paired row system with a spacing of 90 x 60 x 30 cm. Other cultural practices as recommended (Crop production techniques of horticultural crops, 2004) were followed uniformly for all the plots. Various yield parameters were recorded from five plants selected at random in each treatment under each replication (Mahajan *et al.*, 2000). The experimental data were statistically analysed (Rangaswamy, 1995) and compared using critical difference at 5 per cent probability level.

Analysis	Methodology	Authors
Available nitrogen	Alkaline permanganate method	Subbiah and Asija (1956)
Available phosphorous	Using 0.5 M $NaHCO_3$ of pH 8.5	Olsen *et al.* (1954)
Available potassium	Flame photometric method	Stanford and English (1949)
Total nitrogen	Kjeldahl's method	Bremner (1965)
Total phosphorous	Vanadomolybdate yellow colour method using diacid extract	Jackson (1973)
Total potassium	Flame photometric method using the neutralised diacid extract	Jackson (1973)

RESULTS AND DISCUSSION

Fruit yield $plant^{-1}$ (g): The influence of two sources of fertilisers and four frequency interval of fertigation on plant yield was well recognised in the present study. Of the two sources of fertilisers used the highest yield of 755.46 g $plant^{-1}$ was recorded with water soluble fertilisers and it was found significantly superior to the conventional fertilisers.

The comparison of plant yield obtained from plots fertigated at varying frequencies revealed that daily fertigation (794.55 g) was significantly superior to rest of the frequencies (Table 1). Such an increased yield with more frequent fertigation had been reported earlier by Patel and Rajput (2005), Badr and El-Yazied (2007), Singh *et al.* (2011b) and Badr *et al.* (2011). More frequent fertigation results in the maintenance of constant, optimal moisture in the root zone which reduces the variation in nutrient concentration, thereby enhancing their availability to plants and reducing the leaching of nutrients beneath the root zone. The highest yield $plant^{-1}$ recorded in S_1F_1 (808.82 g) was significantly superior to the rest of the treatments. S_2F_1 was found to be the second best treatment (780.27 g $plant^{-1}$) and it was on par with S_1F_2 (774.45 g $plant^{-1}$). All the fertigated plots were found to produce significantly higher yield over soil application of recommended fertilisers as reported earlier by Prabhakar *et al.* (2001), Gupta *et al.* (2010), Brahma *et al.* (2010) and Savitha *et al.* (2010).

Nutrient uptake by okra fruit: The N uptake by okra fruits under water soluble fertilisers and conventional fertilisers did not differ significantly (Table 2). Among the four frequency levels of fertigation, the N uptake of okra fruit observed in daily fertigation was the maximum (52.55 kg ha^{-1}) and was found comparable to fertigation at 3 days interval (47.02 kg ha^{-1}), which was again found to be on par with the other two frequency levels of fertigation *viz.*, 5 days and 7 days interval. The effects due to interaction of fertiliser source and fertigation frequencies were however found insignificant. Though the highest nitrogen uptake of 53.66 kg ha^{-1} by okra fruits was observed with daily fertigation of

Table 1: Effect of fertigation on fruit yield $plant^{-1}$ (g) in okra

Source → / Frequency ↓	Fruit yield $plant^{-1}$ (g)		
	S_1	S_2	Mean
F_1	808.82	780.27	794.55
F_2	774.45	736.35	755.40
F_3	725.84	677.08	701.46
F_4	712.74	657.94	685.34
Mean	755.46	712.91	-
RDF			495.86
Control			218.99
Factor		SEd	CD (p=0.05)
Fertiliser source		16.356	34.36
Fertigation frequency		13.684	28.75
Source x Frequency		10.200	NS
Control Vs RDF Vs Rest		7.650	16.07

Source : S_1 – Fertigation with water soluble fertilisers; S_2 – Fertigation with conventional fertilisers

Frequency: F_1 – Daily; F_2 – Three days interval; F_3 – Five days interval; F_4 – Weekly interval

RDF : Soil application of recommended dose of fertilisers

Control : No fertilizer

Table 2: Effect of fertigation on N, P and K uptake (kg ha^{-1}) of okra

Source → / Frequency ↓	Fruit N uptake (kg ha^{-1})			Fruit P uptake (kg ha^{-1})			Fruit K uptake (kg ha^{-1})		
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
F_1	53.66	51.45	52.55	9.19	8.85	9.02	30.14	29.40	29.77
F_2	48.85	45.19	47.02	8.68	8.30	8.49	28.48	27.45	27.97
F_3	44.76	40.64	42.70	8.23	7.45	7.84	27.12	25.35	26.24
F_4	42.40	38.97	40.68	7.68	7.29	7.48	25.81	24.73	25.27
Mean	47.42	44.06	-	8.45	7.97	-	27.89	26.73	-
RDF			36.76			6.69			22.95
Control			18.14			3.26			13.07
Factor		SEd	CD (p = 0.05)		SEd	CD (p = 0.05)		SEd	CD (p = 0.05)
Fertiliser source		4.243	NS		0.807	NS		3.045	NS
Fertigation frequency		3.550	7.46		0.676	1.42		2.548	NS
Source x Frequency		2.646	NS		0.504	NS		1.899	NS
Control Vs RDF Vs Rest		1.984	4.17		0.378	0.79		1.424	2.99

Source : S_1 – Fertigation with water soluble fertilisers; S_2 – Fertigation with conventional fertilisers
Frequency: F_1 – Daily; F_2 – Three days interval; F_3 – Five days interval; F_4 – Weekly interval
RDF : Soil application of recommended dose of fertilisers
Control : No fertiliser

water soluble fertilisers (S_1F_1) it was on par with N uptake by fruits registered with daily fertigation of conventional fertiliser (51.45 kg ha^{-1}). Fertigation of water soluble fertilisers at all frequency levels and conventional fertilisers either daily or at 3 days interval were found superior to RDF, while all the treatments including RDF differed significantly from control for uptake of N by okra fruits.

Though the sources of fertilisers used for fertigation did not show any significant impact for uptake of P, there were significant differences among the various frequency levels of fertigation tried. The maximum P uptake of 9.02 kg ha^{-1} was observed in daily fertigation and was on par with fertigation at 3 days interval (8.49 kg ha^{-1}) and this was comparable with other two frequencies. Though the superiority of all fertigation treatments over control was well endorsed in the present study, the fertigation of water soluble fertilisers at all frequency levels tried and fertigation of conventional fertilisers either daily or at 3 days interval were found significantly superior to RDF for P uptake by okra fruit.

The data on potassium uptake by okra fruit shows that the influence of two different sources of fertilisers, four frequency intervals of fertigation as well as their interaction were non significant. The plots fertigated daily and at 3 days interval using either water soluble fertilisers or conventional fertilisers were found superior to RDF. The highest K uptake by okra fruits was recorded in S_1F_1 (30.14 kg ha^{-1}), which was on par with S_2F_1 (29.40 kg ha^{-1}), S_1F_2 (28.48 kg ha^{-1}) and S_2F_2 (27.45 kg ha^{-1}). All the fertiliser treatments were found superior to control.

The uptake of N and P was found to have been significantly influenced by the varying fertigation frequencies while it did not exert any influence on uptake of K. This is quite expected since the available K status of soil is high. All the fertilized plots were found superior to control for this trait, while the maximum nutrient uptake by fruits were recorded under daily fertigation of water soluble fertilisers, which was found comparable to daily fertigation of conventional fertiliser and such a significance of fertigation over RDF has been reported earlier by Sharma *et al.* (2011). This might be due to the increased availability of nutrients in soil and a well proliferated root system, which enhanced the nutrient absorption capacity of roots.

Plant nutrient uptake: The uptake of N by okra plants ranged from 9.03 kg ha^{-1} (control) to 21.94 kg ha^{1} (S_1F_1). The effect of two different sources of fertilisers *viz.*, water soluble fertilisers and conventional fertilisers as well as their interaction with different fertigation frequencies were found insignificant for N uptake of plant (Table 3). Among the frequency intervals tried, daily fertigation was found to record the highest N uptake by plants (21.38 kg ha^{1}) and it was found to be on par with the N uptake under fertigation at 3 days interval (19.63 kg ha^{-1}). The lowest uptake was found with F_4 which did not differ significantly from F_2 and F_3. The study also revealed the superiority of all the fertigated plots except S_2F_4 (16.76 kg ha^{-1}) over RDF (16.15 kg ha^{-1}) and control (9.03 kg ha^{-1}). The highest N uptake was recorded in S_1F_1 (21.94 kg ha^{-1}) and was found comparable to S_2F_1 (20.82 kg ha^{1}).

The difference observed in plant P uptake with two different sources of fertiliser was not found to be statistically significant. Among the frequency intervals tried, the phosphorus uptake of plant was the maximum in daily fertigation (5.16 kg ha^{-1}) and was found to be on par with the P uptake under fertigation at 3 days interval (4.88 kg ha^{-1}) which was again found comparable to F_3 and F_4. The

Table 3: Effect of fertigation on N, P and K uptake (kg ha^{-1}) of okra plant

Source →	Plant N uptake (kg ha^{-1})			Plant P uptake (kg ha^{-1})			Plant K uptake (kg ha^{-1})		
Frequency ↓	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
F_1	21.94	20.82	21.38	5.29	5.04	5.16	15.21	14.66	14.97
F_2	19.95	19.31	19.63	4.91	4.85	4.88	14.18	14.08	14.13
F_3	19.13	18.32	18.72	4.81	4.56	4.68	13.94	13.50	13.72
F_4	18.71	16.76	17.74	4.77	4.22	4.50	14.02	12.47	13.25
Mean	19.93	18.80	-	4.95	4.67	-	14.35	13.68	-
RDF			16.15			3.97			11.88
Control			9.03			2.19			7.22
Factor		SEd	CD (p = 0.05)		SEd	CD (p = 0.05)		SEd	CD (p = 0.05)
Fertiliser source		1.486	NS		0.296	NS		1.017	NS
Fertigation frequency		1.243	2.61		0.248	0.52		0.851	NS
Source x Frequency		0.927	NS		0.185	NS		0.634	NS
Control Vs RDF Vs Rest		0.695	1.46		0.139	0.29		0.476	1.00

Source : S_1 – Fertigation with water soluble fertilisers; S_2 – Fertigation with conventional fertilisers
Frequency: F_1 – Daily; F_2 – Three days interval; F_3 – Five days interval; F_4 – Weekly interval
RDF : Soil application of recommended dose of fertilisers
Control : No fertiliser

interaction effect of source with fertigation frequencies was found to be non significant. Significance of all the fertigation treatments except S_2F_4 was observed in the present study for P uptake of plants over RDF (3.97 kg ha^{-1}) and control (2.19 kg ha^{-1}). The highest P uptake of plants recorded in S_1F_1 (5.29 kg ha^{-1}) was comparable to S_2F_1 (5.04 kg ha^{-1}).

The differences observed in the K uptake of plants due to varying fertiliser source, different fertigation frequencies as well as their interaction were all found insignificant. However the fertigated plants under all the treatments except S_2F_4 were found to show better K uptake over RDF (11.88 kg ha^{-1}). The plant K uptake was the highest (15.21 kg ha^{-1}) in S_1F_1, which was on par with S_2F_1 (14.66 kg ha^{-1}).

The variations observed in uptake of nutrients by plant with the use of two different sources of fertilisers used were found to be statistically insignificant for all the three major nutrients in the present study. The uptake of N and P by plant was significantly influenced by the varying frequency levels of fertigation, while it was not having any significant influence on plant K uptake and is ascribed to the higher available K status of soil. All the fertigated plots except application of conventional fertilisers at weekly interval (S_2F_4) had proved superior to RDF and similar findings had been reported earlier by Shedeed *et al.* (2009) and Imamsaheb *et al.* (2011), Tumbare and Bhoite (2002) and Tumbare and Nikam (2004). The increased uptake of nutrients observed under fertigation might be due to cyclic regulation and continuous wetting of soil through drip irrigation resulting in optimum soil moisture as reported by Rajput and Patil (2006).

Post harvest available NPK status of okra field: The variation observed in the post harvest N status of soil fertigated using water soluble fertiliser and conventional fertiliser was found insignificant (Table 4). Of the varying frequency interval of fertigation tried, the lowest available N was observed in F_1 (47.68 kg ha^{-1}) and was found comparable to F_2 (49.09 kg ha^{-1}). The available N status was the highest in F_4 (53.08 kg ha^{-1}) which was however on par with F_3 (52.45 kg ha^{-1}). The soil application of recommended fertiliser had recorded higher post harvest available N (54.28 kg ha^{-1}) and was comparable with fertigation of conventional fertilisers at 5 days (S_2F_3) and 7 days interval (S_2F_4). Among the fertigated plots the lowest available soil N was recorded in S_1F_1 (47.27 kg ha^{-1}) andwas on par with S_2F_1 (48.08 kg ha^{-1}). This was followed by S_1F_2 (48.60 kg ha^{-1}) which is comparable to S_2F_2 (49.58 kg ha^{-1}). The lowest $KMnO_4$-N was found in control (39.23 kg ha^{-1}).

The P content of post harvest soil of okra was high under weekly fertigation (33.61 kg ha^{-1}) and it was on par with fertigation at 5 days interval (33.13 kg ha^{-1}). The lowest Olsen-P was found in F_1 (30.47 kg ha^{-1}) which was found comparable to F_2 (31.44 kg ha^{-1}). Soil application of recommended fertiliser (RDF) had recorded higher Olsen-P (35.36 kg ha^{-1}) and was found to be on par with S_2F_4 (34.77 kg ha^{-1}). The treatments S_1F_1 (30.18 kg ha^{-1}) and S_2F_1 (30.75 kg ha^{-1}) had also recorded lower post harvest Olsen-P and were comparable.

The analysis of soil for post harvest status of available K revealed significant difference in post harvest K status over control (319.33 kg ha^{-1}). Daily fertigation of both water soluble fertiliser (340.67 kg ha^{-1}) and conventional fertiliser (341.67 kg ha^{-1}) as well as fertigating water soluble fertiliser at 3 days interval (345.00 kg ha^{-1}) were found comparable and recorded lower available K in the post harvest soil of okra field. They were also found to record lower available K than RDF (355.33 kg ha^{-1}).

Table 4: Effect of fertigation on post harvest available NPK status of okra field

Source → / Frequency ↓	Available N status (kg ha^{-1})			Available P status (kg ha^{-1})			Available K status (kg ha^{-1})		
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
F_1	47.27	48.08	47.68	30.18	30.75	30.47	340.67	341.67	341.17
F_2	48.60	49.58	49.09	31.23	31.65	31.44	345.00	348.33	346.67
F_3	51.45	53.45	52.45	32.12	34.13	33.13	350.33	351.67	351.00
F_4	52.48	53.68	53.08	32.45	34.77	33.61	351.33	354.33	352.83
Mean	49.95	51.20	-	31.50	32.83	-	346.83	349.00	-
RDF			54.28			35.36			355.33
Control			39.23			25.59			319.33
Factor		SEd	CD (p = 0.05)		SEd	CD (p = 0.05)		SEd	CD (p = 0.05)
Fertiliser source		1.068	NS		0.989	NS		7.519	NS
Fertigation frequency		0.894	1.88		0.828	1.74		6.291	NS
Source x Frequency		0.666	NS		0.617	NS		4.689	NS
Control Vs RDF Vs Rest		0.500	1.05		0.463	0.97		3.517	7.39

Source : S_1 – Fertigation with water soluble fertilisers; S_2 – Fertigation with conventional fertilisers
Frequency: F_1 – Daily; F_2 – Three days interval; F_3 – Five days interval; F_4 – Weekly interval
RDF : Soil application of recommended dose of fertilisers
Control : No fertiliser

Daily fertigation of water soluble fertilisers and conventional fertilisers as well as fertigation of water soluble fertiliser at 3 days interval were found to be significant over RDF for all the three major nutrients in the present study and this low NPK status might be due to increased plant uptake under frequent fertigation and similar findings had been reported earlier by Imamsaheb *et al.* (2011) and Singh *et al.* (2011b) in tomato.

Hence, from the present study on fertigation in okra it could be concluded that the application of fertilisers in small doses at high frequency (*i.e.* on daily basis) through drip fertigation could ensure a continuous and stable supply of nutrients to meet the growth demands of hybrid okra and hence could be recommended for improving nutrient uptake responsible for ultimate increase in productivity.

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