E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; SP-7(8): 577-584
Received: 04-07-2024
Accepted: 11-08-2024

C Lokesh
Water Technology Centre, Professor Jayashankar Telangana State Agricultural University, Hyderabad, Telangana, India

B Balaji Naik
Regional Sugarcane and Rice Research Station, Rudrur, Nizamabad, Telangana, India

M Uma Devi
Agriculture College, Professor Jayashankar Telangana State Agricultural University, Jagtial, Telangana, India

M Venkateshwara Reddy
Department of Horticulture, Professor Jayashankar Telangana State Agricultural University, Hyderabad, Telangana, India

Corresponding Author:
C Lokesh
Water Technology Centre, Professor Jayashankar Telangana State Agricultural University, Hyderabad, Telangana, India

Influence of drip irrigation scheduling and nitrogen levels on yield and nutrient uptakes of okra (*Abelmoschus esculentus* L.)

C Lokesh, B Balaji Naik, M Uma Devi and M Venkateshwara Reddy

DOI: https://doi.org/10.33545/2618060X.2024.v7.i8Sh.1331

Abstract
A field experiment was conducted at Water Technology Centre, College of Agriculture, PJTSAU, Rajendranagar, Hyderabad during *summer* 2020-21 on "Optimization of irrigation and nitrogen levels under drip fertigation in okra (*Abelmoschus esculentus* l.) during *summer*" 2020-21. The experiment was laid out in a split-plot design with Radhika hybrid (40 cm x 45 cm) and replicated thrice. The treatments comprise of three irrigation levels through drip scheduled at 0.75 Epan, 1.0 Epan and 1.25 Epan as main-plots and four nitrogen levels *viz.*, 75% RDN (112.5 kg N ha^{-1}), 100% RDN (150 kg N ha^{-1}), 125% RDN (187.5 kg N ha^{-1}) and 150% RDN (225 kg N ha^{-1}) as sub-plots. Experimental soil was sandy clay in texture, alkaline in reaction, medium in organic carbon content, low in available nitrogen, high in available phosphorous and available potassium, respectively. The results indicated that, the highest yield and accumulation of nutrient (kg ha^{-1}) was highest under drip irrigation scheduled at 1.0 Epan treatment. Among the nitrogen level the highest nutrient accumulation (kg ha^{-1}) was recorded at 100% RDN (N_2) treatment. The crop irrigation scheduled at 1.0 Epan in conjunction with 100% RDN (I_2N_2) recorded maximum N uptake in okra.

Keywords: Drip irrigation, nitrogen levels, nutrient uptakes, fertigation, okra

Introduction
Okra (*Abelmoschus esculentus* L.) is an important vegetable of India occupies 5.90 lakh hectare area with total production of 69.49 lakh tons and productivity of 12.0 t ha^{-1} (Horticultural Statistics at a glance, 2018). It is grown throughout the country for its tender green fruits during spring-summer and rainy seasons. It is a good source of vitamins A, B, C and also rich in protein, carbohydrates and fats (Adiroubane and Letachoumanane, 1992) [1]. It is one of the popular vegetable crops grown in Telangana with total 13,006-hectare area while in summer it occupies an area of 810 hectares (Horticulture Department, Telangana State, 2019) [15] with overall production of 2.60 lakh tons and 20.49 t ha^{-1} productivity. Okra is a warm-season vegetable crop requires warm and humid conditions for good growth. Bhendi can be grown in a wide range of soils. However, it grows best in loose, friable, well-drained sandy loam soils rich in organic matter. It also gives good yield in heavy soils with good drainage. A pH range of 6.0-6.8 is considered as optimum. Alkaline, saline soils and soils with poor drainage are not good for this crop, it also requires high amount of organic fertilization (Akanbi *et al.*, 2010 and Akande *et al.*, 2010) [2, 3]. It is susceptible to low temperature. Seeds of okra fail to germinate below 20 ˚C temperature. For optimal growth, flowering and fruit initiation, okra requires an average temperature ranging between 25– 30 ˚C. The okra plants grow taller in the rainy season than in the warm summer. Okra requires a well distributed moderate rainfall (80-100 cm) for production of its young edible fruits. Increased vigour and high productivity were observed when the crop was grown in rainy season than summer season. Increasing differences between day and night temperatures can reduces seed yield considerably especially during summer season (Dhankhar *et al.*, 2012) [10]. Therefore, appropriate agronomic management need to be envisaged to improve yield during summer season.
For yield enhancement of okra, suitable water supply to maintain sufficient moisture condition

in soil throughout the crop growth period is essential especially during summer season. The influence of water deficit on yield in this span is more under surroundings of high temperature and low humidity (Vadar *et al.*, 2019) [50] which is more common during summer season. To meet these optimal conditions, drip irrigation was proved to be most effective agronomic management option for enhancement of yield and quality of okra. It was reported that, the drip irrigation alone enhances the crop yield up 40% over conventional irrigation (Sivanappan *et al*., 1994) [41].

Use of proper doses of fertilizer is one of the most important ways of quality green pod yield production of okra. Nitrogen is an essential macro nutrient which has great significance in growth, development and metabolism of plants. Nitrogen application significantly increases pod weight, diameter, number of fruits per plant and number of seeds per pod in okra (Moniruzzaman and Quamruzzaman, 2009) [23]. Fertilizers applied under traditional methods are generally not utilized efficiently by the crop. In fertigation, nutrients are applied through emitters directly into the zone of maximum root activity and consequently fertilizer-use efficiency can be improved over conventional method of fertilizer application. The drip fertigation in okra offers increased pod yield, pod weight, pod length, maximum root penetration depth and better pod quality (Hari and Ramesh, 2017) [14] and also reduces cost of weeding and irrigation management thereby enhances economic returns (Sreeja and Satasiya, 2015) [39].

It should be noted that surface irrigation of agricultural crops has been practiced for more than four thousand years and sprinkler irrigation for most of the 20th century. Whereas, drip irrigation is the "new kid on the block" having only been commercially adopted only in the last quarter of the 20th century. This means that drip irrigation design systems, products and management practices have been rapidly evolving to cater the new areas and crops there exists a range of opportunities and challenges which are yet to be fully explored for field application in years to come to tackle the likelihood of water scarcity and population explosion issues in India and in Telangana.

The area under drip irrigation in the world has increased from just 40 ha in 1960 to about 54,600 ha in 1975 and further to about 1.78 mha in 1991 (INCID, 1994). As per the recent estimate, the global area under drip method of irrigation is over 8 million hectare and the leading countries are USA, India and Spain etc. Surprisingly, in countries like Israel, Austria and Germany, all the irrigated areas are brought under micro-irrigation due to its comparative advantages over flood irrigation.

The micro irrigation in Telangana state rapidly picking up and reached to 7.42 lakh hectares by 2018-19 due to active role is being played by Telangana Micro Irrigation Project (Irrigation department website). There is a bright scope to increase area under micro irrigation as Telangana state has 20.48 lakh ha under borewells and 37.04 lakh ha under major, medium and minor irrigation projects (Telangana water resource information system bhuvan-app1.nrsc.gov.in). Keeping in view of the opportunity and research gap in okra crop, the investigation on optimization of irrigation levels, quantification of water requirement under drip system and N levels for fertigation of summer season okra crop was prioritized.

Materials and Methods

A field experiment was conducted at Water Technology Centre, College of Agriculture, PJTSAU, Rajendranagar, Hyderabad (17°19’24.7” N, 78°24’34.0” E at an altitude of 542.4 m amsl). The experimental site received 12.6 mm of precipitation overall during the summer growing season for okra. Soil texture is sandy clay soil which is low in nitrogen, high in phosphorus and potassium that is readily available, medium in organic carbon content, alkaline in reactivity, and non-saline. Irrigation water was neutral (7.20 pH) and classified as C3 class, suggesting that it is suitable for irrigation when following good management practices. Radhika was the variety of okra utilised. With an inline dripper spacing of 40 cm and a 2 L/h discharge rate, the drip irrigation lateral was of the inline kind. Split-plot design was used to set up the experiment, with 12 treatments that were replicated three times. These treatments included drip irrigation scheduled at three different times: 0.75 Epan as I_1, 1.0 Epan as I_2, and 1.25 Epan as I_3 and four different nitrogen concentrations: 75% RDN (N_1), 100% RDN (N_2), 125% RDN (N_3), and 150% RDN (N_4). Full dose of P2O5 and K2O were applied in their whole as basal in the forms of DAP and MOP. Nitrogen was applied as fertigation in 18 splits, with a 4-day gap between each split, starting 15 days after sowing and ending with the final picking.

Green pod yield (kg ha^{-1})

Green pod yield was recorded by weighing the harvested pods from first picking to final picking. The total yield of pods per hectare was computed and expressed in kg ha^{-1}.

Plant Nutrient Studies

The N, P and K content (%) in okra shoots was estimated from sowing to fruit initiation and shoot and fruit from first picking to last picking at every 15 days interval. The N, P and K uptakes (kg ha^{-1}) was computed.

Nitrogen Content (%)

Estimation of nitrogen content in plant sample was done by Micro Kjeldahl distillation method using Kelplus N analyzer (A.O.A.C., 1965) [4].

Phosphorus Content (%)

Estimation of phosphorus content in plant samples was done by Vanado – molybdo phosphoric acid method (Jackson, 1967) by di-acid digestion of plant samples by knowing the intensity of the color produced was measured by using a spectrophotometer at a wavelength of 420 nm.

Potassium Content (%)

For estimating the potassium content of plant sample, di-acid was determined by using a flame photometer (A.O.A.C., 1965) [4].

Uptake of Nutrients

The uptakes of N, P and K nutrients was calculated using the following formula and expressed in kg ha^{-1}.

$$\text{Uptake of nutrients (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%) x dry matter production (kg ha}^{-1}\text{)}}{100}$$

Results and Discussion

Total green pod yield (kg ha^{-1})

The influence of drip irrigation scheduling, nitrogen levels and their interactions on total green pod yield (kg ha^{-1}) is analyzed statistically. It is the sum of twelve pickings.

Irrigation scheduling

The green pod yield (kg ha^{-1}) of okra differed significantly with irrigation scheduling. The maximum green pod yield (24829 kg ha^{-1}) was recorded with 1.0 Epan was significantly more over 1.25 Epan (21013 kg ha^{-1}) and 0.75 Epan (16631 kg ha^{-1}). However, the crop irrigation scheduled at 0.75 Epan (I_1) remained significantly inferior to 1.0 Epan (I_2) and 1.25 Epan (I_3) treatments.

Green pod yield is a function of different growth parameters and their interaction with growing environment. The crop yield is mainly limited by factors such as low nutrient and water availability, because they compromise physiological processes related to plant growth Sharma *et al.* (2016). The reason for higher grain yield in I_2 (1.0 Epan) might be attributed to favorable soil moisture conditions maintained throughout the crop growth. Krittika and Misal, (2018) [20] reported that irrigation practices carried out at 0.8 Epan recorded considerably higher pod yield. Okra pod yield decreased when irrigation practices were performed with higher irrigation treatment at 1.25 Epan. Therefore, irrigation of okra should be performed at 1.0 Epan irrigation scheduling so that to provide optimal soil moisture to produce higher yield. Similar results were also reported by several researchers (Haris *et al.*, 2014, Babu *et al.*, 2015, Bahadur *et al.*, 2020, Naik, 2017, Khedkar, 2018, Rani and Mariappan, 2019) [6, 7, 19, 25, 32, 40]

Nitrogen levels

The green pod yield of okra is influenced by nitrogen levels. The crop nurtured with 100% RDN (N_2) recorded maximum green pod yield (23077 kg ha^{-1}) as compared to its preceding lower 75% RDN (18867 kg ha^{-1}) as well as succeeding higher 125% RDN (21069 kg ha^{-1}) and 150% RDN (20285 kg ha^{-1}) treatments. With increasing the nitrogen dose from 100% RDN to 125% RDN and further to 150% RDN, the green pod yield was decreased significantly. Whereas, the lowest green pod yield (18867 kg ha^{-1}) was recorded with crop nurtured with 75% RDN (N_1) significantly remained inferior to N_2, N_3 and N_4 treatments, respectively. Chovatia (2005) [9] stated that application of 150 kg N ha^{-1} recorded maximum yield of okra which was at par with 112.5 kg N ha^{-1}. This was due to favorable nutrition to the plants. Over and above, the yield attributing characters like number of fruits per plant seems favorably influenced the greater photosynthetic activity and thereby producing more photosynthate, which is responsible for increase in growth attributes. The higher number of metabolites might have helped in increasing these characters. Feroz (2009) [12] reported that positive response of N availability on yield production could also be due to its role in delaying plant maturity and resultant more assimilate synthesis that played significant role in more pods production. Uddin *et al.* (2014) [45] stated that growth attributes significantly increased with increasing nitrogen supply. In addition, higher optimal levels of nitrogen of the rooting medium proved to be inhibitory to okra. Possibly, reduction in growth under high nitrogen supply results from its general adaptation to low nitrogen. Symptoms of toxicity due to an excess of nitrogen or symptoms of nitrogen deficiency were not observed on plants. These results were in accordance with the findings of Sharma *et al.* 2016, Fatima *et al.*, 2019, Kanal *et al.*, 2020, Nair *et al.*, 2017, Padmanabha *et al.*, 2018, Raval *et al.*, 2013, Naik, 2017) [11,40. 18, 26, 27, 33, 25]

Interaction effect

The interaction effect of irrigation scheduling and nitrogen levels on green pod yield (kg ha^{-1}) of okra was found significant. The crop irrigation scheduled at I_1 (0.75Epan) with increasing nitrogen dose from 75% RDN to 100% RDN, the green pod yield was increased significantly from 15810 to 18629 kg ha^{-1} and further increasing nitrogen dose from 100 to 125% and 125% RDN to 150% RDN, the green pod yield was decreased significantly from 16188 to 15897 kg ha^{-1}, respectively. Similar trend was also reflected at 1.0 Epan (I_2).

At I_3 irrigation scheduling the significantly higher green pod yield (23745 kg ha^{-1}) was recorded with 100% RDN which is followed by 125% RDN (21160 kg ha^{-1}). The lowest green pod yield was recorded with N_1 which was comparable with N_4 and significantly inferior to N_2 and N_3 levels.

Among the combination of treatment, the crop irrigation scheduled at I_2 (1.0 Epan) in conjunction with 100% RDN (I_2N_2) recorded maximum green pod yield of 26857 kg ha^{-1}. However, it is comparable with 1.0 Epan (I_2) in conjunction with 125% RDN (I_2N_3) with green pod yield of 25859 kg ha^{-1} which remained significantly more over rest of the treatment combinations. The interaction effects between irrigation scheduling and nitrogen levels clearly indicated that, for okra crop 100% RDN is optimum for maximum green pod yield irrespective of irrigation scheduling. Krittika and Misal, 2018 [20] stated that maximum green pod yield was recorded with application of 0.8 Epan in conjunction with 80% RDN which was followed by 1.0 Epan in conjunction with 80% RDN. Bhatti *et al.* (2011) [8] also stated that under high nitrogen supply nitrogen is translocated to shoot in the form of nitrate where it is reduced. Reduction and assimilation of nitrate have a high-energy requirement, i.e., 15 mol ATP for reduction of 1 mol of NO_3. Possibly diversion of energy may cause the reduced growth. The results are in line with finding of several researchers, Puneet and Arun (2016) [31], krittika and Misal, (2018) [20], Thokal *et al.* (2020) [44], Rekha *et al.* (2006) [34], Job *et al.* (2018) [17], Sukruth, (2006) [41].

Nutrient Uptake (kg ha^{-1})

Nitrogen accumulation (kg ha^{-1}) in okra

The influence of irrigation scheduling and nitrogen levels on accumulation of nitrogen in shoot and fruit (kg ha^{-1}) recorded at 15 days intervals are presented in Table 1 and 2, respectively.

Table 1: Effect of drip irrigation scheduling and nitrogen levels on green pod yield (kg ha-1) of okra.

	Green pod yield (kg ha^{-1})				
Treatments	**N_1**	**N_2**	**N_3**	**N_4**	**Mean**
I_1	15810	18629	16188	15897	16631
I_2	21651	26857	25859	24951	24829
I_3	19141	23745	21160	20008	21013
Mean	18867	23077	21069	20285	
Factors		S.Em+		CD (p=0.05)	
Main (I)		216		871	
Sub (N)		156		469	
Sub (N) at same main (I)		432		941	
Main (I) at same or different sub (N)		319		1107	

Note: I_1, I_2 and I_3 are different irrigation levels replenished at 0.75, 1.0, 1.25 Epan and N_1, N_2, N_3 and N_4 are 75% (112.5 kg N ha^{-1}), 100% (150 kg N ha^{-1}), 125% (187.5 kg N ha^{-1}) and 150% (225 kg N ha^{-1}) recommended dose of nitrogen, respectively; NS – non significant.

Irrigation scheduling

The accumulation of nitrogen (kg ha^{-1}) in shoot (Table 2) recorded from 30 to 90 DAS and in fruit recorded from 60 to 90 DAS was maximum in crop irrigation scheduled at 1.0 Epan (I_2). However, it was comparable with 1.25 Epan (I_3) at 90 DAS and significantly more over 0.75 Epan and 1.25 Epan at all other stages of observation. The lowest amount of nitrogen was accumulated in 0.75 Epan (I_1) treatment across the stages of observation.

A careful perusal of data indicated that the application of optimum level of irrigation (1.0 Epan) resulted in increased N uptake. As expected, the lowest uptake of N was under deficit irrigation i.e., 0.75 Epan. Hence, optimum irrigation level under any soil condition results in higher uptake and finally greater yield levels (Montazer and Behzad, 2012) [24]. The increased nitrogen uptake can also be traced back from the continuous and optimum availability of soil moisture content at higher level of drip irrigation. Which helped to solubilize the plant nutrients near the root zone and preferential easy absorption of plant nutrients by the crop under higher irrigation regimes. Similar observations were also reported by Tumbare and Nikam (2004) [48] in chilli. These results are in consonance with the finding of shaymaa *et al.* (2009) [36] who opined that more nutrient content and uptake due to more dry matter production in optimum irrigation level (1.0 Epan) then compared to 1.25 Epan and 0.75 Epan irrigation scheduling through drip.

Nitrogen levels

The accumulation of nitrogen (kg ha^{-1}) in shoot (Table 2) recorded from 45 to 90 DAS and in fruit recorded from 60 to 90 DAS was maximum in crop nurtured with 100% RDN (N_2). However, it was comparable with 125% RDN (N_3) at 45 DAS, 60 DAS in shoot, 75 and 90 DAS in fruit and significantly more over 150% RDN (N_4) and 75% RDN (N_1) at all other stages of observation. The lowest amount of nitrogen was accumulated in 75% RDN (N_1) treatment across the stages of observation.

The optimal nitrogen applied in split with fertigation found to be beneficial since hydrolysis of urea have made nutrients easily available to the plant roots and this phenomenon coupled with higher dry matter accumulation attributed to higher N uptake (Shanmugasundaram and Savithri, 2000) [35]. These results are in conformation with Kumar *et al.* (2017) [21] who opined that nutrient by drip fertigation at 100 per cent RDN then compared to succeeding higher (120 per cent RDN) and preceding lower dose (80 per cent RDN) of nitrogen may have resulted in reduced nutrient wastage and hence, leading to better crop growth. In contrast to this Rani and Mariappan (2019) [32] stated that maximum nitrogen uptake (104.1 kg N ha^{-1}) was recorded with application of 150 per cent recommended dose of fertilizers which was followed by 125 per cent recommended dose of fertilizers.

Interaction effect

The interaction effect of drip irrigation scheduling and nitrogen levels on N uptake (Table 3) was found significant at 90 DAS in okra shoot. At I_1 (0.75 Epan) irrigation scheduling, the maximum N uptake (106.83 kg ha^{-1}) was recorded with 100% RDN (N_2) which was significantly more over its preceding lower dose and succeeding higher doses of nitrogen. While, the crop nurtured with 125% RDN and 150% RDN were found on par with each other. However, these three nitrogen levels (N_1, N_3 and N_4) did not differ significantly. Similar trend was reflected at I_2 and I_3 irrigation scheduling. Among the different treatment combinations, irrigation schedule at 1.0 Epan in conjunction with 100% RDN (I_2N_2) recorded significantly more N uptake (167.87 kg ha^{-1}) over rest of the treatment combinations.

Table 2: Effect of drip irrigation scheduling and nitrogen levels on nitrogen uptake (kg ha^{-1}) at 15, 30, 45, 60, 75, 90 DAS of okra (Shoot and fruit)

Treatments	**15 DAS**	**30 DAS**	**45 DAS**	**60 DAS**			**75 DAS**			**90 DAS**		
Main plot – (Irrigation regimes):	**Shoot**	**Shoot**	**Shoot**	**Shoot**	**Fruit**	**Shoot +Fruit**	**Shoot**	**Fruit**	**Shoot +Fruit**	**Shoot**	**Shoot**	**Shoot + Fruit**
I_1: Surface drip irrigation at 0.75 Epan	0.202	7.70	19.58	58.43	5.74	68.18	83.04	7.89	90.93	99.28	8.70	108.00
I_2: Surface drip irrigation at 1.0 Epan	0.204	8.54	32.36	79.85	6.22	86.08	117.28	8.40	125.69	150.12	8.93	159.05
I_3: Surface drip irrigation at 1.25 Epan	0.198	8.07	24.40	65.26	5.87	71.13	100.63	8.11	108.75	124.40	8.89	133.29
SEm ±	0.002	0.09	0.28	2.10	0.06	2.98	1.10	0.03	1.59	1.27	0.04	3.77
C.D (P=0.05)	NS	0.38	1.16	8.49	0.25	8.52	4.45	0.12	4.55	5.15	0.18	10.77

Sub plot – (Fertigation levels):												
N_1 – 75% RD N (112.5 kg ha^{-1})	0.199	7.86	23.88	65.32	5.88	71.20	93.08	8.00	101.08	116.56	8.59	125.18
N_2 – 100% RD N (150 kg N ha^{-1})	0.207	8.33	26.92	73.89	5.97	79.86	110.22	8.22	118.45	136.41	9.02	145.43
N_3 – 125% RD N (187.5 kg N ha^{-1})	0.202	8.29	26.05	70.01	5.99	76.01	99.86	8.21	108.08	123.00	8.89	131.89
N_4 – 150% RD N (225 kg N ha^{-1})	0.198	7.94	24.93	62.16	5.94	68.11	98.11	8.10	106.21	122.42	8.87	131.30
SEm ±	0.003	0.17	0.32	2.44	0.04	3.44	1.01	0.03	1.45	0.92	0.10	2.77
C.D (P=0.05)	NS	NS	0.97	7.31	NS	7.28	3.03	0.11	3.07	2.77	0.30	5.86
Interaction:												
Fertigation levels at same level of irrigation regimes:												
SEm ±	0.003	0.18	0.57	4.21	0.12	5.96	2.20	0.06	2.51	2.55	0.09	4.79
C.D (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	5.57	NS	NS
Irrigation regimes at same or different levels of fertigation:												
SEm ±	0.004	0.27	0.56	4.22	0.09	5.96	1.87	0.06	2.70	1.89	0.15	5.61
C.D (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	6.55	NS	NS

Table 3: Interaction effect of irrigation scheduling and nitrogen levels on total nitrogen uptake (kg ha^{-1}) at 90 DAS of okra shoot.

Treatments	N_1	N_2	N_3	N_4	Mean
I_1	92.9	106.8	98.1	99.2	99.2
I_2	139.1	167.8	147.2	146.2	150.1
I_3	117.6	134.5	123.6	121.8	124.4
Mean	116.5	136.4	123.0	122.4	
Factors	SEm±		C.D (p=0.05)		
Factor(A)	1.27		5.15		
Factor(B)	0.92		2.77		
Factor(B)at same level of A	2.55		5.57		
Factor(A)at same level of B	1.89		6.55		

Phosphorus accumulation (kg ha^{-1}) in okra

The influence of irrigation scheduling and nitrogen levels on accumulation of phosphorus in shoot and fruit (kg ha^{-1}) recorded at 15 days intervals are presented in Table 4, respectively.

Irrigation scheduling

The accumulation of phosphorus (kg ha^{-1}) in shoot (Table 4) recorded from 45 to 90 DAS and in fruit recorded from 60 to 90 DAS was maximum in 1.0 Epan (I_2) followed by 1.25 Epan (I_3) at 45 to 90 DAS and significantly more over 0.75 Epan (I_1) at all the other stages of observation. While, the amount of phosphorus was accumulated in 0.75 Epan (I_1) treatment remained inferior across the stages of observation.

In the present study, the drip irrigation scheduled at 0.75 Epan reduced the phosphorus uptake in shoot and fruit. It is, therefore, obvious that reduced water supply not only reduced the absorption of phosphorus but also did not permit normal distribution of phosphorus from vegetative parts to the fruit. It could be concluded that phosphorus content in fruit was decreased under reduced water supply probably because of reduced upward movement of phosphorus by mass flow and restricted development of stem and inflorescences of okra. Availability of adequate soil moisture enhanced mineralization of P from native and applied sources of P, thereby more acquisition through dry matter and availability of other nutrients through dissolution and transport. These results are in accordance with Prasad and Prasad (1988) [30], Sridhar *et al*. (1991) [40] and Singh *et al*. (1997) [37].

Nitrogen levels

The accumulation of phosphorus (kg ha^{-1}) in shoot (Table 4) recorded from 45 to 90 DAS was maximum in crop fertilized with 100% RDN (N_2). However, it was comparable with 125% RDN (N_3) at 60 DAS, 75 DAS and 90 DAS in shoot and 60 and 90 DAS in fruit and was significantly more over 150% RDN (N_4) and 75% RDN (N_1) at all other stages of observations. The lowest amount of nitrogen was accumulated in 75% RDN (N_1) treatment across all the stages of observations.

Among the nitrogen levels the crop nurtured with 100% RDN recorded maximum phosphorus uptake then compared to crop nurtured with 125% RDN, 150% RDN and 75% RDN. The lowest uptake was recorded with 75% RDN treatment at all crop growth stages. Each higher level of nitrogen significantly increased phosphorus uptake up to 100% RDN (150 kg N ha^{-1}). Application of 125% RDN and 150% RDN did not prove advantageous over 100% RDN in improving phosphorus uptake. These results are in tune with the findings of Parihar and Tiwari (2003) who reported that the P uptake in grain as well as straw showed progressive increase with increase in N level up to 120 kg N ha^{-1}. Significantly the lowest phosphorous uptake was found with deficit nitrogen treatment (N_0). These results are in consonance with the findings of Gunes (1998) [13] who stated that application of 5.88 mM of nitrogen has increased the phosphorus content up to 1.03% and further increment in N levels to 5.88 mM to 8.81 mM and 8.81 mM to 11.75 mM reduced the phosphorus content to 0.88%. Similar results were also reported by Malve *et al.* (2020) [22] who stated that phosphorus uptake was found to be higher with 160 kg N ha^{-1} which was followed by 120 kg N ha^{-1} in 2012-13. However, significant response was found up to 120 kg N ha^{-1}. Application of 160 kg N ha^{-1} did not prove advantageous over 120 kg N ha^{-1} in improving the nitrogen uptake.

Potassium accumulation (kg ha^{-1} in okra

The accumulation of potassium (kg ha^{-1}) in shoot and fruit (kg ha^{-1}) recorded at 15 days intervals are presented in Table 5, respectively

Irrigation scheduling

The accumulation of potassium (kg ha^{-1}) in shoot (Table 5) recorded from 30 to 90 DAS and in fruit at 60 and 75 DAS was highest with 1.0 Epan (I_2). However, it was comparable with 1.25 Epan at 30 DAS in shoot and in fruit recorded at 60, 75 and 90 DAS and significantly more over 0.75 Epan and 1.25 Epan at all other stages of observations. The lowest amount of potassium was accumulated in 0.75 Epan (I_1) treatments across all the other stages of observations.

The results clearly suggests that movement of exchangeable potassium was more under adequate soil moisture and nitrogen availability which led to higher uptake of potash, but increased water stress definitely restricted the movement of potassium and ultimately resulted in poor uptake (Patel and Rajput, 2008).

Nitrogen levels

The accumulation of potassium (kg ha^{-1}) in shoot recorded from 30 to 90 DAS and fruit from 60 to 90 DAS was maximum in crop nurtured with 100% RDN (N_2). However, it was comparable with 125% RDN (N_3) at 60 and 75 DAS in shoot and at 60, 75 and 90 DAS in fruit and significantly more over 150% RDN (N_4) and 75% RDN (N_1) at all stages of observations. The lowest amount of potassium accumulation in fruit and shoot with 75% RDN (N_1) was recorded at all the stages of the observations. These results are in consonance with the findings of Gunes (1998) [13] who stated that application of 5.88 mM of nitrogen has increase the phosphorus content up to 11.34% and further increment in N levels from 5.8 mM to 8.81 mM and 8.81 mM to 11.75 mM reduced the potassium content from 9.64% to 7.34%. Similar results were also reported by Malve *et al.* (2020) [24] who stated that each higher level of nitrogen significantly increased potassium uptake up to 120 kg N ha^{-1} (N_{120}). Application of 160 kg N ha^{-1} (N_{160}) did not prove advantageous over N_{120} in improving the phosphorous uptake.

Table 4: Effect of drip irrigation scheduling and nitrogen levels on phosphorus uptake (kg ha^{-1}) at 15, 30, 45, 60, 75, 90 DAS of okra (Shoot and fruit)

Treatments	15 DAS	30 DAS	45 DAS	60 DAS			75 DAS			90 DAS		
Main plot – (Irrigation regimes):	**Shoot**	**Shoot**	**Shoot**	**Shoot**	**Fruit**	**Shoot +Fruit**	**Shoot**	**Fruit**	**Shoot +Fruit**	**Shoot**	**Shoot**	**Shoot + fruit**
I_1: Surface drip irrigation at 0.75 Epan	0.35	1.19	3.19	9.01	1.27	10.28	10.02	1.42	11.44	13.26	1.43	14.70
I_2: Surface drip irrigation at 1.0 Epan	0.35	1.47	5.40	12.56	1.38	13.95	13.33	1.52	14.86	19.28	1.50	20.79
I_3: Surface drip irrigation at 1.25 Epan	0.35	1.24	4.08	10.10	1.31	12.03	11.59	1.40	13.00	17.02	1.45	18.48
SEm ±	0.01	0.01	0.04	0.47	0.01	0.12	0.47	0.01	0.40	0.25	0.01	0.26
C.D (P=0.05)	NS	0.06	0.18	1.92	0.05	0.49	1.91	0.05	1.62	1.03	0.04	1.06
Sub plot – (Fertigation levels):												
N_1 – 75% RD N (112.5 kg ha^{-1})	0.35	1.29	3.82	9.87	1.27	11.14	10.36	1.39	11.76	16.19	1.39	17.58
N_2 – 100% RD N (150 kg N ha^{-1})	0.35	1.31	4.54	11.77	1.36	13.13	12.42	1.51	13.93	17.41	1.54	18.95
N_3 – 125% RD N (187.5 kg N ha^{-1})	0.35	1.29	4.50	10.91	1.35	12.26	12.21	1.47	13.69	16.87	1.48	18.36
N_4 – 150% RD N (225 kg N ha^{-1})	0.34	1.31	4.07	9.68	1.31	11.81	11.60	1.42	13.02	15.62	1.44	17.07
SEm ±	0.01	0.01	0.03	0.46	0.01	0.08	0.43	0.01	0.46	0.38	0.01	0.39
C.D (P=0.05)	NS	NS	0.09	1.37	0.03	0.24	1.29	0.03	1.38	1.14	0.05	1.18
Interaction:												
Fertigation levels at same level of irrigation regimes:												
SEm ±	0.03	0.033	0.09	0.95	0.02	0.24	0.94	0.03	0.80	0.51	0.02	0.53
C.D (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Irrigation regimes at same or different levels of fertigation:												
SEm ±	0.02	0.02	0.06	0.84	0.02	0.17	0.80	0.02	0.80	0.62	0.02	0.65
C.D (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 5: Effect of drip irrigation scheduling and nitrogen levels on potassium uptake (kg ha^{-1}) at 15, 30, 45, 60, 75, 90 DAS of okra (Shoot and fruit)

Treatments	15 DAS	30 DAS	45 DAS	60 DAS			75 DAS			90 DAS		
Main plot – (Irrigation regimes):	**Shoot**	**Shoot**	**Shoot**	**Shoot**	**Fruit**	**Shoot +Fruit**	**Shoot**	**Fruit**	**Shoot +Fruit**	**Shoot**	**Shoot**	**Shoot + fruit**
I_1: Surface drip irrigation at 0.75 Epan	2.50	6.84	12.60	30.78	2.46	33.24	35.23	2.69	37.92	35.47	2.55	38.03
I_2: Surface drip irrigation at 1.0 Epan	2.52	7.79	20.04	39.44	2.72	42.17	49.42	2.89	52.31	55.35	2.68	58.04
I_3: Surface drip irrigation at 1.25 Epan	2.51	7.49	15.39	33.04	2.67	35.72	41.69	2.85	44.54	45.59	2.59	48.18
SEm ±	0.02	0.10	0.25	1.11	0.02	1.14	0.63	0.01	0.58	0.79	0.02	0.82
C.D (P=0.05)	NS	0.42	1.02	4.50	0.11	4.61	2.57	0.05	2.35	3.21	0.10	3.31
Sub plot – (Fertigation levels):												
N_1 – 75% RD N (112.5 kg ha^{-1})	2.50	7.20	15.08	33.74	2.55	36.30	39.41	2.74	42.15	43.02	2.54	45.56
N_2 – 100% RD N (150 kg N ha^{-1})	2.54	7.44	17.03	37.00	2.68	39.68	46.25	2.89	49.15	49.26	2.67	51.93
N_3 – 125% RD N (187.5 kg N ha^{-1})	2.52	7.42	16.30	36.15	2.66	38.81	41.28	2.84	44.13	44.95	2.63	47.58
N_4 – 150% RD N (225 kg N ha^{-1})	2.49	7.44	15.64	30.80	2.58	33.38	41.51	2.76	44.28	44.66	2.58	47.25
SEm ±	0.01	0.14	0.16	0.94	0.01	0.96	0.43	0.03	0.35	0.56	0.02	0.56
C.D (P=0.05)	NS	NS	0.49	2.83	0.05	2.88	1.29	0.11	1.05	1.69	0.06	1.70
Interaction:												
Fertigation levels at same level of irrigation regimes:												
SEm ±	0.05	0.21	0.50	2.23	0.05	2.29	1.27	0.02	1.16	1.59	0.05	1.64
C.D (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Irrigation regimes at same or different levels of fertigation:												
SEm ±	0.03	0.24	0.35	1.80	0.04	1.84	0.90	0.05	0.78	1.16	0.04	1.18
C.D (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Conclusion

Yield and nutrient uptake by okra was significantly influenced by drip irrigation scheduling and nitrogen levels. N, P and K uptakes and yield of okra was highest under drip irrigation scheduled at 1.0 Epan treatment. Among the nitrogen level the highest nutrient accumulation (kg ha^{-1}) was recorded with 100% RDN. While, the lowest yield and N, P and K uptake of okra was recorded with 0.75 Epan (I_1) treatment and among nitrogen levels 75% RDN (N_1) recorded lowest yield and N, P and K uptake respectively.

Acknowledgements

The authors acknowledge all the staff of the Water Technology Centre for their help during the study period.

Reference

1. Adiroubane D, Letachoumanane S. Growth and yield performance of okra (*Abelmoschus esculentus* L.) cultivars. Indian J Agric Sci. 1992;68:168-70.
2. Akanbi WB, Togun AO, Adediran JA, Ilupeju EAO. Growth, dry matter and fruit yield components of okra under organic and inorganic sources of nutrients. Am-Eurasian J Sustain Agric. 2010;4(1):1-13.
3. Akande MO, Oluwatoyinbo FI, Makinde EA, Adepoju AS, Adepoju IS. Response of okra to organic and inorganic fertilization. Nat Sci. 2010;28(1):1545-0740.
4. Association of Official Analytical Chemists (AOAC). Official Methods of Analysis. 10th ed. Washington, D.C. AOAC; c1965.
5. Association of Official Analytical Chemists (AOAC). Official Methods of Analysis. 9th ed. Washington, D.C.: AOAC; c1960.
6. Babu RG, Rao IB, Kumar KR. Response of okra to different levels of drip irrigation on growth, yield and water use efficiency. Int J Agric Eng. 2015;8(1):47-53.
7. Bahadur A, Singh DK, Nadeem MA, Singh S, Singh AK, Prasad RN, *et al*. Effect of drip irrigation scheduling and mulching on plant growth, physiology, yield, water use efficiency and weed growth in spring-summer okra (*Abelmoschus esculentus* Muench). Veg Sci. 2020;47(1):80-4.
8. Bhatti AR, Bashir N, Zafar ZU, Farooq A. Modulating infestation rate of white fly (Bemisia tabaci) on okra (Hibiscus esculentus L.) by nitrogen application. Acta Physiol Plant. 2011;33(3):843-50.
9. Chovatia KR. Effect of Azospirillum and nitrogen on growth, yield and quality of okra (*Abelmoschus esculentus* L. Moench) CV. Gujarat Okra-2. PhD Thesis, Horticulture Department, NM College of Agriculture, Navsari Agriculture University; c2005.
10. Dhankhar SK, Deswal DP, Surender Singh. Impact of weather variables on yield and yield attributes in okra under different growing environments. J Agrometeorol. 2012;14(1):54-6.
11. Fatima S, Khan MS, Nadeem M, Khan I, Waseem K, Nisar M, *et al*. Interactive effects of genotype and nitrogen on the phenology and yield determination of okra (*Abelmoschus esculentus* L.). Int J Plant Prod. 2019;13(1):73-90.
12. Feroz ZA. Impact of nitrogen and phosphorus on the growth and yield of okra (*Abelmoschus esculentus* L. Moench) in hill slope condition. Bangladesh J Agric Res. 2009;34(4):713-22.
13. Gunes A, Alpaslan M, Inal A. Critical nutrient concentrations and antagonistic and synergistic relationships among the nutrients of NFT-grown young tomato plants. J Plant Nutr. 1998;21(10):2035-47.
14. Hari, N and Ramesh C. H. 2017. Effect of yield response of Okra (Abelmoschus esculentus L. Moench) under drip irrigation system. Transstellar Journal Publications and Research Consultancy Private Limited. 7: 67-72.
15. Haris, A. A., Sunil, K., Singh, A. K and Rajan, K. 2014. Drip irrigation scheduling in Okra (Abelmoschus esculentus L. Moench). HortFlora Research Spectrum. 3 (3): 274-277.
16. Horticultural Statistics at a Glance. Available from: http://agricoop.nic.in/statistics/horticulture; c2018.
17. Horticulture Department, Telangana State. Available from: http://horticulture.tg.nic.in/; c2019.
18. Indian National Committee on Irrigation and Drainage (INCID). Drip Irrigation in India. New Delhi: INCID; 1994.
19. Job M, Vikas K, Dinmani. Study of water and nutrients requirement through drip irrigation in okra. J Pharmacogn Phytochem. 2018;7(4):3172-6.
20. Kanal S, Dutta JP, Yadav RK, Pant KN, Shrestha A, Joshi P. Response of okra (*Abelmoschus esculentus* L. Moench) to nitrogen dose and spacing on growth and yield under mulch condition in Chitwan, Nepal. J Clean WAS. 2020;4(1):40-4.
21. Khedkar DD. Efficiency in water use and yield of okra (*Abelmoschus esculentus* L.) under drip irrigation. Environ Ecol. 2018;36(3):905-10.
22. Krittika AJ, Misal NB. Study of optimum irrigation levels and fertilizer dose in drip irrigated okra crop. Ann Biol. 2018;34(2):187-90.
23. Kumar ABM, Narayanamoorthy T. Scope of drip irrigation for vegetable production in India. Indian J Appl Res. 2017;6(5):164-6.
24. Malve SH, Saini A, Rao PV. Irrigation scheduling through drip/surface method: A review on growth, yield, nutrient uptake and water productivity of wheat. Agric Rev. 2020;41(3):272-8.
25. Moniruzzaman M, Quamruzzaman AKM. Effect of nitrogen levels and picking of green fruits on the fruit and seed production of okra (*Abelmoschus esculentus* L. Moench). J Agric Rural Dev. 2009;99-106.
26. Montazer A, Behzad AB. Effect of seasonal water use and applied N fertilizer on wheat water productivity indices. Irrig Drain. 2012;61:52-59.
27. Naik MA. Studies on optimization of yield in okra (*Abelmoschus esculentus* L. Moench) through water and nutrient management under drip and mulch system. PhD Thesis, College of Horticulture, Venkataramannagudem, West Godavari–534 101 Dr. YSR Horticultural University; c2017.
28. Nair AK, Hebbar SS, Prabhakar M, Rajeshwari RS. Growth and yield performance of okra (*Abelmoschus esculentus* L. Moench) in relation to fertigation using different rates and sources of fertilizers. Int J Curr Microbiol Appl Sci. 2017;6(8):137-43.
29. Padmanabha K, Lingaiah HB, Jayappa J, Anjanappa M, Anilkumar S, Hanumanthappa DC. Effect of fertigation in okra (*Abelmoschus esculentus* L.). Trends Biosci. 2018;11(13):2353-5.
30. Parihar SS, Tiwari RB. Effect of irrigation and nitrogen level on yield, nutrient uptake and water use of late sown wheat (*Triticum aestivum* L.). Indian J Agron. 2003;48:103-7.
31. Patel N, Rajput TBS. Dynamics and modeling of soil water under sub-surface drip irrigated onion. Agric Water Manage. 2008;95:1335-49.
32. Prasad TN, Prasad UK. Effect of irrigation, crop geometry and inter crops on yield and nutrient uptake of winter maize (*Zea mays* L.). Indian J Agron. 1988;33(3):238-41.
33. Puneet S, Arun K. Influence of drip fertigation on water productivity of okra. Environ Ecol. 2016;34(4B):2157-62.
34. Rani AS, Mariappan G. Effect of drip irrigation regimes and fertigation levels on growth, yield, quality parameters, nutrient uptake and water use efficiency of Bhendi

(*Abelmoschus esculentus* L. Moench). J Pharmacogn Phytochem. 2019;2:524-7.
35. Raval CH, Patel JC, Vyas KG, Bedse RD. Effect of nitrogen levels and time of application on okra (*Abelmoschus esculentus* L. Moench). Agric Update. 2013;8(3):433-5.
36. Rekha KB, Reddy MG, Mahavishnan K. Nitrogen and water use efficiency of bhendi (*Abelmoschus esculentus* L. Moench) as influenced by drip fertigation. J Trop Agric. 2006;43:43-6.
37. Shanmugasundaram R, Savithri P. Effect of various N levels with organics and amendments on N content, uptake and yield of potato in Western Ghats of Tamil Nadu. J Indian Potato Assoc. 2000;27:127-31.
38. Shaymaa I, Shedeed S, Sahar M, Yassen AA. Effect of method and rate of fertilizer application under drip irrigation on yield and nutrient uptake by tomato. Ozean J Appl Sci. 2009;2(2):139-47.
39. Singh AK, Singh GR, Dixit RS. Influence of plant population and moisture regimes on nutrient uptake and quality of winter maize (*Zea mays* L.). Indian J Agron. 1997;42(1):107-11.
40. Sharma, P., Kausal, A., Singh, A and Garg, S. 2016. Growth and yield attributes of Okra under influence of drip irrigation. International Journal of Engineering Research and Applications. 6 (2): 85-91.
41. Sivanappan RK. Prospects of microirrigation in India. Irrig Drain Syst. 1994;8(1):49-58.
42. Sreeja K, Satasiya RM. Yield and economics of summer okra (*Abelmoschus esculentus* L. Moench) under plastic mulching and drip irrigation. Int J Adv Agric Sci Technol. 2015;7(3):42-9.
43. Sridhar V, Singh RA, Singh UN. Effect of irrigation and fertility levels on nutrient uptake, content and recovery in rabi maize (*Zea mays* L.). Madras Agric J. 1991;78(9-12):422-4.
44. Sukruth K. Nitrogen and irrigation water use efficiency by okra (*Abelmoschus esculentus* L. Moench) under fertigation compared to conventional method in alfisols. PhD Thesis, Andhra Pradesh Agricultural University, Hyderabad; c2006.
45. Telangana Irrigation Website. Available from: https://irrigation.telangana.gov.in/icad/home#tprofile
46. Telangana Water Resource Information System. Available from: bhuvan-app1.nrsc.gov.in
47. Thokal RT, Sanap PB, Thorat TN, Thaware BG, Chavan SA. Influence of irrigation regimes, crop spacing and fertilization methods on growth and yield of okra in coastal region of Maharashtra. J Agric Eng. 2020;53(3):349.
48. Tumbare, A. D and Nikam, D. R. 2004. Effect of planting and fertigation on growth and yield of green chilli (Capsicum annuum L.). Indian Journal of Agricultural Science. 72 (2): 109-111.
49. Uddin MJ, Hossain MI, Islam S, Mehraj H, Jamal Uddin AFM. Growth and yield of okra as influenced by different levels of nitrogen. Int J Bus Soc Sci Res. 2014;2(2):104-8.
50. Vadar HR, Pandya PA, Patel RJ. Effect of subsurface drip irrigation depth scheduling in summer Okra. Emergent Life Sciences Research. 2019;5:52-61.