Indian Journal of Ecology (2024) 51(3): 575-579
DOI: https://doi.org/10.55362/IJE/2024/4276

Manuscript Number: 4276
NAAS Rating: 5.38

Influence of Fertigation on Growth and Yield using Varying Rates and Sources of Fertilizers on Chilli Hybrid in Open Field Condition

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***Abstract*:** The experiment was conducted to study the effect of fertigation on the performance of chilli F_1 Hybrid 'Arka Khyati' at the ICAR-Indian Institute of Horticultural Research, Bengaluru during *kharif* of 2017 and 2018. Ten treatments comprising of varying doses, sources and frequency of fertilizer application were laid out in Randomized Block Design and replicated thrice. Pooled analysis of two years' data revealed that at 80 days after transplanting, bi-weekly fertigation @ 125:100:125 kg N: P_2O_5:K_2O ha^{-1} using water soluble fertilizers resulted in highest values for plant height (78.78 cm) and number of branches plant^{-1} (10.88). This treatment also recorded maximum values for number of fruits plant^{-1} (132.00), fruit length (9.76 cm), fruit girth (3.95 cm), ten fruit fresh weight (66.00 g), ten fruit dry weight (10.60 g) and yield (34.00 t ha^{-1}). All the fertigation treatments recorded higher yields over the conventional soil application of fertilizers to the tune of 3.63 to 76.6 per cent. Biweekly application of 100 % fertilizer dose of 125:100:125 kg N: P_2O_5:K_2O ha^{-1} through fertigation resulted in the maximum net income (Rs. 431351 ha^{-1}) and higher benefit cost ratio (1.73) whereas the conventional soil application of common fertilizers resulted in minimum net income (Rs.166454 hectare^{-1}) and benefit cost ratio of 0.76.

***Keywords*:** Chilli, fertigation, Growth, Nutrient sources, Nutrient doses, Yield, Economics

Chilli (*Capsicum annuum* L.), belonging to the solanaceae family is an important spice crop in India. The Green chilli is grown in 4.18 lakh hectares with the production of 44.17 lakh tonnes. The productivity of green chilli is approximately 10.60 t ha^{-1} in India, which is low (Anonymous 2021). The states like Andhra Pradesh, Karnataka, Bihar, Tamil Nadu, Uttar Pradesh and Maharashtra, account for three fourth of the total area. Fresh green and ripe chilli are used in flavouring of food, to make pickles, sauces and paste., Oleoresin, the essential oil is used in the food and beverage industries. The fruits of chilli are rich in vitamin A, C and minerals.

Chilli is one of the major commercial crops, however the productivity is low. Increase in production can be achieved either by bringing more area under its cultivation or by adopting improved varieties and better cultural practices. The second approach is more often preferred and practical among various cultural practices, proper fertilizer application is one of the quickest and easiest ways of increasing the yield per unit area (Natsheh and Mousa 2014). Balanced nutrition is one of the most important factors affecting the growth and productivity of the crops. The optimum levels at which the nutrients are to be applied, the placement of fertilizers and source from which they are derived are equally important to crop production as it affects the yield and quality of the produce. Fertigation is an effective means of controlling timing and placement of fertilizers and improving fertilizer use efficiency by reducing losses through leaching, volatilization and fixation in the soil to less available forms as described by Papadopoulous (1994). Hence, this experiment was conducted to study the influence of fertigation, its frequency and the source of nutrients on yield of green chilli.

MATERIAL AND METHODS

The study was conducted at the ICAR-Indian Institute of Horticultural Research, Hessarghatta, Bengaluru, Karnataka, India during *kharif* of 2017 and 2018.The experimental field is situated at 13^{0}7$^{'}$ N latitude, 72^{0}29$^{'}$E longitude and an elevation of 890 meters above mean sea level. The soil was well drained sandy loam (pH 6.60 and electrical conductivity 0.25 dSm^{-1}) characterized by medium organic carbon (0.63%), low available N (169 kg ha^{-1}), high available P (68 kg ha^{-1}) and medium available K (260 kg ha^{-1}). The soil has available water holding capacity of 130 mm in one meter soil depth. The experiment was laid out in Randomized Block Design with ten treatments and three replications. Prior to planting, uniform amount of farm yard manure @ 25.0 t ha^{-1} was applied as basal application to all the treatments. The treatment details and quantity of different fertilizers applied have been presented in Table 1 and Table 2, respectively. The entire dose of P and half of N and K were applied as basal and remaining half of N and K was side

dressed to soil in equal splits at 30 and 60 days after transplanting in T_1. Thirty-five days old seedlings of chilli hybrid "Arka Khyati" a high yielding, medium pungent, tolerant to chilli venial mottle virus cultivar were transplanted at 80-40 x 50 cm, under paired row system in the first week of July during both the years. Drip irrigation was given depending on the rate of evaporation and amount of effective rainfall received. Fertigation treatments started after two weeks of planting and fertilizers were applied through drip system at weekly and bi-weekly interval and imposed. Dissolving desired amounts of fertilizers and applied via venturi system through drip irrigation to the field. A total of 16 and 32 numbers of fertigation were given for weekly and bi-weekly interval, which was continued up to 15 days before completion of crop growth period. Recommended package of practices including agronomic and plant protection measures were adopted to raise the crop (Prabhakar *et al*.,2010). The experimental data was statistically analysed (Gomez and Gomez,1983) and compared using critical difference at five per cent probability level. Statistical analysis was done using OPSTAT, HAU, Hisar developed by Sheron (1998).

RESULTS AND DISCUSSION

Growth parameters: Significant differences among the treatments for the plant height were observed at 80 days after transplanting and harvest (Table 3). Application of 100 per cent fertilizer dose through fertigation using water soluble fertilizers at bi-weekly interval (T_7) recorded significantly taller plants at 80 DAT (78.78 cm) and at harvest (96.33 cm), which was on par with T_9 (76.89 cm), T_4(78.33 cm) and T_3 (78.70 cm) at 80 DAT and T_9 (92.00 cm), T_5(90.33 cm) and T_3 (92.33 cm) at harvest. The minimum values for plant height (71.67 and 80.00 cm) at 80 days after transplanting and at harvest, respectively was recorded with soil application of nutrients

Table 1. Treatment details in chilli

Treatment		Fertilizer	Application dose	Basal dose (Kg ha^{-1})	Top dressing (Kg ha^{-1})	Fertigation (Kg ha^{-1})	Frequency
T_1	100 % fertilizer dose (125:100:125 Kg N:P_2O_5:K_2O ha^{-1})	Common	100 % soil application	62.5:100:62.5	62.5:0:62.5		
T_2		Common	50 % NK fertigation	62.5:100:62.5		62.5:0:62.5	
T_3		WSF	100 % NPK fertigation			125:100:125	Weekly
T_4		WSF	50 % NK fertigation	62.5:100:62.5		62.5:0:62.5	Weekly
T_5	75 % fertilizer dose (93.75:75:93.75 Kg N:P_2O_5:K_2O ha^{-1})	WSF	100 % NPK fertigation			93.75:100:93.75	Weekly
T_6		WSF	50 % NK fertigation	46.8:75:46.8		46.8:0:46.8	Weekly
T_7	100 % fertilizer dose (125:100:125 Kg N:P_2O_5:K_2O ha^{-1})	WSF	100 % NPK fertigation			125:100:125	Bi-weekly
T_8		WSF	50 % NK fertigation	62.5:100:62.5		62.5:0:62.5	Bi-weekly
T_9	75 % fertilizer dose (93.75:75:93.75 Kg N:P_2O_5:K_2O ha^{-1})	WSF	100 % NPK fertigation			93.75:100:93.75	Bi-weekly
T_{10}		WSF	50 % NK fertigation	46.8:75:46.8		46.8:0:46.8	Bi-weekly

WSF: Water soluble fertilizers Top dressing - (Kg ha^{-1}): 62.5:0:62.5

Table 2. Treatment wise fertilizers applied (Kg ha^{-1}) under fertigation in chilli

Treatments	Basal dose			Fertigation			
	Urea	Single super phosphate	Muriate of potash	Urea	Muriate of potash	Sulphate of potash	19:19:19
T_1	135.5	625.0	104.5	0.00	0.00	0.00	0.00
T_2	135.5	625.0	104.5	135.5	104.5		
T_3	0.0	0.0	0.0	54.00		50.00	526.00
T_4	135.5	625.0	104.0	135.5		125.00	
T_5	0.0	0.0	0.0	40.50		37.50	394.00
T_6	102.00	469.0	78.00	102.00		94.00	
T_7	0.0	0.0	0.0	54.00		50.00	526.00
T_8	135.5	625.0	104.0	135.5		125.00	
T_9	0.0	0.0	0.0	40.50		37.50	394.00
T_{10}	102.00	469.0	78.00	102.00		94.00	

In $T_{1=}$ Top dressing - (Kg ha^{-1}): Urea -135.5 and Muriate of potash -104.5

through common fertilizers. There were no significant differences for plant height at initial stage of the growth (35DAT). However, T_7 (59.11 cm) and T_4(54.66 cm) recorded the maximum and minimum plant height. Different treatments recorded significant differences for the number of branches plant^{-1} at different growth stages. Application of 100 per cent fertilizer dose through fertigation using common fertilizers at weekly interval (T_2) recorded higher number of branches plant^{-1} (9.77) at 35 DAT, while application of 100 per cent fertilizer dose through fertigation using water soluble fertilizers at bi-weekly interval (T_7) recorded higher number of branches plant^{-1} (10.88) at 80 DAT, which remained on par with T_2, ,T_5 and T_9. At harvest T_7 and T_2 (11.33) recorded significantly higher number of branches plant^{-1} than T_1 (9.0) and T_{10} (9.33) and remained on par with remaining treatments. Application of higher dosage of water soluble fertilizers through fertigation gave best results in growth parameters like plant height and number of branches plant^{-1}, which might be due to availability of higher amount of nutrients in the root zone for growth and development of plants as nitrogen and phosphorus are considered as major nutrients required for proper growth and development of plant. Beside this, nitrogen is the main constituent of protoplasm, cell nucleus, amino acids, chlorophyll and many other metabolic processes like transpiration, Godara et al (2013). Similar results were also reported by Pandey et al (2013), Vinayak et al (2019) and Chandramohan Reddy et al (2016) in chilli crop.

Yield attributes: Yield and yield attributing parameters were significantly influenced by the treatments (Table 4). Higher

Table 3. Growth parameters of chilli as influenced by fertigation treatments (Pooled data)

Treatment	Plant height (cm)			Branches plant^{-1}		
	35 DAT	80 DAT	At harvest	35 DAT	80 DAT	At harvest
T_1	55.22	71.67	80.00	6.77	8.33	9.00
T_2	56.66	73.99	81.67	9.77	10.11	11.33
T_3	58.66	78.70	92.33	6.88	7.89	9.67
T_4	54.66	78.33	87.67	7.55	8.44	9.67
T_5	57.11	74.11	90.33	8.11	9.66	10.00
T_6	57.22	70.00	84.00	7.89	8.99	10.33
T_7	59.11	78.78	96.33	9.33	10.88	11.33
T_8	57.33	74.33	87.00	7.11	8.77	9.67
T_9	58.77	76.89	92.00	9.33	9.44	10.67
T_{10}	56.00	73.77	84.67	8.33	8.55	9.33
CD (p=0.05)	NS	4.32	6.84	1.45	1.68	1.79

DAT – days after transplanting

Table 4. Effect of fertigation treatments on yield attributing characters, yield and FUE in chilli (Pooled data)

Treatment	Number of fruits plant^{-1}	Fruit length (cm)	Fruit girth (cm)	Ten fruit weight (g)	Dry weight of ten fruits (g)	Yield (t ha^{-1})	Fertiliser use efficiency (kg kg^{-1})
T_1	82.67	8.22	3.66	30.33	7.83	19.25	55.00
T_2	84.50	8.71	3.58	33.33	8.50	19.95	57.00
T_3	118.17	9.73	3.81	64.67	9.80	32.71	93.45
T_4	107.33	9.00	3.48	33.33	8.83	22.19	63.40
T_5	110.67	9.58	3.43	54.67	9.13	29.93	114.00
T_6	92.50	8.62	3.55	42.67	8.50	21.36	81.37
T_7	132.00	9.76	3.95	66.00	10.60	34.00	97.14
T_8	109.67	9.07	3.72	35.33	8.96	29.79	85.11
T_9	111.83	9.76	3.81	59.33	9.46	32.46	123.65
T_{10}	105.17	8.63	3.53	35.33	8.76	22.74	86.62
CD (p=0.05)	22.98	1.07	0.29	21.86	0.74	5.31	

number of fruits plant^{-1} was observed in T_7 (132.00), which remained on par with T_8 (109.67), T_5 (110.67), T_9 (111.83) and T_3 (118.17). The minimum number of fruits plant^{-1}was recorded with T_1 (82.67). Higher availability of soil moisture, optimum NPK nutrients and uptake when supplied through fertigation might have increased the number of fruits per plant. Fertigation leading to better availability of the nutrients might have increased the number of primary branches, shoot growth and thereby potential sites where flower could develop. Similar results were also reported by Prabhakar et al (2010), Ramachandrappa et al (2010), Krishnamoorthy and Noorjehan (2014) and Chandramohan Reddy et al (2016) in chilli crop. Significantly higher values for fruit length (9.76 cm) was also observed in T_7 and T_9, which remained on par with most of the treatments except T_1(8.22 cm), T_6 (8.62 cm) and T_{10}(8.63 cm).As far as fruit girth was concerned the significantly highest fruit girth was recorded in T_7 (3.95 cm), which remained on par with T_3 and T_9 (3.81 cm), T_8 (3.72 cm) and T_1 (3.66 cm). T_5 recorded the minimum (3.43 cm) value for the fruit girth. Similarly, there were significant differences among the treatments for ten fruit weight and T_7 resulted in significantly higher value (66.00 g) than all other treatments except T_5 (54.67 g), T_9 (59.33 g) and T_3 (64.67 g). The minimum value for ten fruit weight was recorded with T_1 (30.33 g). Bi-weekly application of 100 per cent fertilizer dose through fertigation using water soluble fertilizers (T_7) resulted in significantly higher (10.60 g) dry weight of ten fruits than all other treatments. Weekly application of same amount of fertilizers through fertigation (T_3) recorded the second highest value (9.80 g) followed by T_9 (9.46 g). The minimum value (7.83 g) for the same recorded with soil application of nutrients. This may be due to continues nutrient supplied through fertigation in adequate doses and optimum form, which must have helped in healthy growth of plants and increased the fruit length and girth. The present findings are in accordance with the findings of Paul *et al.* (2013) in capsicum, Ramachandrappa et al (2010), Krishnamoorthy and Noorjehan (2014) and Vinayak et al (2019) in chilli.

Yield: Irrespective of dosage and source of fertilizer, fertigation treatments were superior to conventional soil application treatment with respect to yield. Among the fertigation treatments (Table 4), bi-weekly application of 100 per cent fertilizer dose through fertigation using water soluble fertilizers (T_7) resulted in significantly higher yield (34.00 t ha^{-1}) over all the other treatments except the treatment T_3, where the weekly application of same amount of fertilizer was given through the same sources (32.71 t ha^{-1}), T_9 (32.46 t ha^{1}), T_5 (29.93 t ha^{-1}) and T_8 (29.79 t ha^{-1}). All the fertigation treatments recorded higher yields over the conventional soil application of fertilizers to the tune of 3.63 to 76.6 per cent. Reducing the dosage of NK or NPK fertigation by 25 per cent reduced the yield substantially. This can be explained on the basis that fertigation saves fertilizer inputs as it permits applying fertilizers in small quantity at a time coinciding with the plants nutrient need. This contributes to an improved availability of moisture, nutrients, and uniform distribution of fertigated nutrients in the crop root zone throughout the growth stages leading to better uptake of nutrients. The enhancing effects of NPK on vegetative growth might be attributed to their vital contribution in several metabolic process in plants related to growth (Marschner 1986). It stimulates the plant vegetative growth to generate leaves, which are able to produce photosynthetic products accumulation required for fruits formation and development and subsequently fruit yield and its attributes. Gireesh et al (2020) and Vinayak et al (2019) reported the same results in chilli crop.

Fertilizer use efficiency: The fertilizer use efficiency ranged between 55.00 to 123.65 kg kg^{-1} for the fertigation treatments (Table 4).Though application of 100 per cent fertilizer dose using water soluble fertilizers at bi-weekly interval (T_7) recorded the highest yield of 34.00 t ha^{-1} but the fertilizer use efficiency was highest (123.65 kg kg^{-1}) with the treatments where the 75 per cent of fertilizer dose was given through fertigation using water soluble fertilizers at bi-weekly intervals. It was followed by T_5 (114.00 kg kg^{-1}), T_7 (97.14 kg kg^{-1}) and T_3 (93.45 kg kg^{-1}). The minimum fertilizer use efficiency was recorded in soil application of common fertilizers (55.00 kg kg^{-1}). Ramachandrappa et al (2010) also recorded higher fertilizer use efficiency at 75% recommended dose of NPK through fertigation than 100 per cent recommended NPK fertigation in green chilli.

Economics: The average data pertaining to economic returns and benefit: cost ratio related to 'Arka Khyati' a chilli hybrid for the year 2017 and 2018 are given in Table 5. 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 the fertigation treatments, application of 100 per cent fertilizer dose through fertigation on bi-weekly basis (T_7) has resulted in highest gross and net income (Rs. 680000 ha^{-1} and Rs. 431351 ha^{-1}) followed by T_3 *i.e.* same amount of fertilizer given on weekly basis (Rs. 654200 ha^{-1} and Rs. 405551 ha^{-1}). Irrespective of dosage and frequency, fertigation with water soluble fertilizers resulted in higher B:C ratio (0.94 to 1.73) compared to soil application (0.76). Krishnamoorthy and Noorjehan (2014). Gireesh et al (2020), Chand (2014) and Suman Kumari et al (2020) also reported maximum net returns and benefit: cost ratio with the application of 100% recommended dose of NPK through fertifgation.

Table 5. Economics of green chilli crop in relation to fertigation treatments

Treatment	Average yield (t ha^{-1})	Gross investment (Rs ha^{-1})	Gross income (Rs ha^{-1})	Net income (Rs ha^{-1})	B :C ratio
T_1	19.25	218546	385000	166454	0.76
T_2	19.95	218546	399000	180454	0.82
T_3	32.71	248649	654200	405551	1.63
T_4	22.19	224199	443800	219601	0.98
T_5	29.93	238419	598600	360181	1.51
T_6	21.36	220150	427200	207050	0.94
T_7	34.00	248649	680000	431351	1.73
T_8	29.79	224199	595800	371601	1.65
T_9	32.46	238419	649200	410781	1.72
T_{10}	22.74	220150	454800	234650	1.06

Sale price = Rs. 20.00/kg

CONCLUSION

The application of water soluble fertilizers @125:100:125kg $N:P_2O_5:K_2O$ ha^{-1} during the cropping period through fertigation at bi-weekly intervals resulted in higher yield (34.00 t ha^{-1}), net income of (Rs. 431351 ha^{-1}) and B:C ratio (1.73) in *kharif* grown chilli in red sandy loam soils.

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Received 30 November, 2023; Accepted 19 April, 2024