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Effect of Fertigation Using Different Rates and Sources of Fertilizers on Growth and Yield of Cucumber (*Cucumis sativus L.*) Under Open Field Condition

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Authors' contributions

This work was carried out in collaboration among all the authors. Authors AKN and SSH conceptualized, designed and executed the research work. Authors MP and MS were involved in literature search, data collection, compilation and statistical analysis of data. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted to study the effect of fertigation on the performance of cucumber variety 'Vani' at ICAR-Indian Institute of Horticultural Research, Bengaluru during *summer* of 2015 and 2016. The experiment was laid out in Randomized Block Design with three replications and consisted of ten treatments, which included different doses, sources of fertilizers and its frequency of application. The pooled analysis of two years data revealed that the application of fertilizer dose (75:56:75 kg $N:P_2O_5:K_2O$ ha^{-1}) through fertigation using water soluble fertilizers on bi-weekly basis resulted in higher values for vine length (217.50 cm), leaves $vine^{-1}$ (83.50), mean leaf area (167.67 cm^2) and mean dry leaf weight (0.532 g) at 50 days after transplanting, which remained on par with the same dose and source applied at weekly interval. These two treatments i.e T_3 and T_7 recorded higher values for the number of fruits $vine^{-1}$ (14.20 and 14.00), fruit length (19.75 and 20.75 cm), fruit girth (16.97 and 16.12 cm) and fruit weight (313.17 and 306.05 g). All the fertigation treatments

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recorded higher yields over the conventional soil application of fertilizers to the tune of 10.75 to 45.60 per cent. Among the fertigation treatments, application of 100 per cent of fertilizer dose using water soluble fertilizers at weekly interval resulted in significantly higher yield (69.50 t ha^{-1}) compared to all treatments except the treatment where the bi-weekly application of the same dose of fertilizer through the same sources (69.20 t ha^{-1}) was done. Application of 100 per cent fertilizer dose using water soluble fertilizers at weekly interval is the most efficient treatment for achieving economical cucumber fruit yield, economic return and saving water and mineral fertilizers.

Keywords: Cucumber; fertigation; growth; yield; fertilizer use efficiency and economics.

1. INTRODUCTION

Cucumber (*Cucumis sativus* L.) is native to India and has been cultivated for more than 3000 years. It contains 95-96% of water with only 4-5% dry matter. Fresh cucumbers are widely consumed mainly as salads and also eaten in a preserved form like pickled or marinated products. Cucumber contains a wide range of biologically active, non-nutritive compounds known as phyto-chemicals, such as alkaloids, flavonoids, tannins, phlobatannins, steroids and saponins, among others. It is a warm-season crop and grows best at a temperature between 18°C and 24°C. It is grown throughout the year in southern states of the country, however, in plains of northern India it is grown in summer and rainy seasons. Cucumber is a short duration (90-100 days) crop and fourth most important vegetable crop after tomato, cabbage and onion in Asia [1] and the second most important vegetable after tomato in Western Europe [2]. In India, it is grown in an area of 109 thousand hectares with a production of 1696 thousand metric tonnes and productivity of 15.55 t ha^{-1} [3]. There is a regional preference for fresh cucumbers among the consumers and its production is mostly under open field conditions. The local cultivars grown under open conditions besides the produce from protected cultivation, contributes to the total production of this crop.

Although it is one of the major vine crop grown, its yield is quite low [4]. Increase in cucumber 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 among various cultural practices, proper fertilizer application is one of the quickest and easiest ways of increasing the yield per unit area [5]. Fertilizer management is the most important agro-technique, which controls growth, yield and quality of a crop. Fertigation is supplying fertilizers along with irrigation is one of the most effective and convenient methods of supplying nutrients with water according to the specific requirements of the crop to maintain optimum soil fertility and to increase the quality of the produce. It lessens the groundwater pollution which causes ecological disturbances and health risks by fertilizer leaching and accumulation of nitrates. Scientific information on fertigation especially on summer grown cucumber is meagre. Hence, the present study was undertaken to determine the effect of fertigation with different doses of fertilizers and sources through drip irrigation for commercial production of cucumber.

2. MATERIALS AND METHODS

The experiment was conducted at ICAR-Indian Institute of Horticultural Research, Hessarghatta, Bengaluru, Karnataka, India during the *summer* of 2015 and 2016. The institute is situated at 13°7' N latitude, 72°29'E longitude and an elevation of 890 meters above mean sea level. The experimental 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, a uniform amount of farmyard manure at 25 t ha^{-1} was applied as the basal application to all the treatments as common practice. The treatment details and quantity of different fertilizers applied have been given in Table 1 and Table 2. The entire dose of P and half of N and K were applied as the basal and remaining half of N and K was side dressed to the soil in equal splits at 30 and 60 days after transplanting in T_1. Urea, 19:19:19, sulphate of potash 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 common fertilizers for treatments T_1 and T_2. The 16 days

Table 1. Fertigation treatment details in cucumber

Symbol	Treatment	Fertilizer	Application dose	Basal dose (Kg ha^{-1})	Top dressing (Kg ha^{-1})	Fertigaton (Kg ha^{-1})	Frequency
T_1	100 % fertilizer dose	Common	100 % soil application	37.5:56:37.5	37.5:0:37.5		
T_2	(75:56:75 Kg N:P_2O_5:K_2O	Common	50 % NK fertigation	37.5:56:37.5		37.5:0:37.5	Weekly
T_3	ha^{-1})	WSF	100 % NPK fertigation			75:56:75	Weekly
T_4		WSF	50 % NK fertigation	37.5:56:37.5		37.5:0:37.5	Weekly
T_5	75 % fertilizer dose	WSF	100 % NPK fertigation			56.25:42:56.25	Weekly
T_6	(56.25:42:56.25 Kg N:P_2O_5:K_2O ha^{-1})	WSF	50 % NK fertigation	28.13:42:28.13		28.13:0:28.13	Weekly
T_7	100 % fertilizer dose	WSF	100 % NPK fertigation			75:56:75	Bi-weekly
T_8	(75:56:75 Kg N:P_2O_5:K_2O ha^{-1})	WSF	50 % NK fertigation	37.5:56:37.5		37.5:0:37.5	Bi-weekly
T_9	75 % fertilizer dose	WSF	100 % NPK fertigation			56.25:42:56.25	Bi-weekly
T_{10}	(56.25:42:56.25 Kg N:P_2O_5:K_2O ha^{-1})	WSF	50 % NK fertigation	28.13:42:28.13		28.13:0:28.13	Bi-weekly

WSF: Water soluble fertilizers

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

Treatments	Basal dose			Top dressing		Fertigation			
	Urea	Single super phosphate	Muriate of potash	Urea	Muriate of potash	Urea	Muriate of potash	Sulphate of potash	19:19:19
T_1	81.50	350.00	62.63	81.50	62.63				
T_2	81.50	350.00	62.63			81.50	62.63		
T_3	0.0	0.0	0.0			41.00		38.00	294.60
T_4	81.50	350.00	62.63			81.50		75.00	
T_5	0.0	0.0	0.0			31.00		28.50	221.00
T_6	61.00	262.50	47.00			61.00		56.25	
T_7	0.0	0.0	0.0			41.00		38.00	294.60
T_8	81.50	350.00	62.63			81.50		75.00	
T_9	0.0	0.0	0.0			31.00		28.50	221.00
T_{10}	61.00	262.50	47.00			61.00		56.25	

old seedlings of cucumber cultivar "Vani" were transplanted at 100 x 60 cm spacing in the first week of April during both the years. Drip irrigation was given depending on the rate of evaporation and amount of effective rainfall received. It worked out to be 310 and 280 mm of supplemental irrigation water for the first and second year of cropping season after making necessary adjustment for the effective rainfall received. The fertigation treatments started after two weeks of planting and fertilizers were applied through a drip system at the weekly and bi-weekly interval. The treatments were imposed dissolving desired amounts of fertilizers and applied via venturi system through drip irrigation to the field. A total of 13 and 26 numbers of fertigation were given for weekly and bi-weekly interval, which was continued up to 15 days before completion of the crop growth period. Five plants per replication in each of the treatments were selected randomly for recording yield parameters. Recommended package of practices including agronomic and plant protection measures was adopted to raise the crop [6]. The experimental data were statistically analysed [7] and compared using critical difference at five per cent probability level.

2.1 Fertilizer Use Efficiency

Fertilizer use efficiency (FUE) is a critically important concept in the evaluation of crop production systems. It can be greatly impacted by fertilizer management as well as by soil and plant water management. Fertilizer use efficiency of cucumber was calculated by using the following formula

FUE (kg yield kg-NPK^{-1}) = Economic yield (kg ha^{-1}) / Total NPK applied (kg ha^{-1})

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

The data on plant growth at 50 days of transplanting, yield attributing characters at harvest and yield are presented in Table 3. The higher vine lengths were recorded (185.83 to 217.50 cm) with the treatments, where fertilizers were applied through drip irrigation in split doses compared to soil application of common fertilizers (178.67 cm) at 50 days after transplanting. Application of 100 per cent fertilizer dose through fertigation using water soluble fertilizers at bi-weekly interval (T_7) recorded significantly longest vine length (217.50 cm) than most of the treatments except T_5 (200.83 cm) and T_3 (204.17 cm).

Similarly, T_7 also recorded a significantly higher number of leaves vine^{-1} (83.50), which remained on par with only T_3 (73.00), *i.e* application of same amount of water soluble fertilizers through fertigation on weekly basis. The minimum number of leaves vine^{-1} was observed in T_{10} (56.67), which were lower than the soil application of fertilizers (58.17) as well as fertigation with normal fertilizers (58.33). Application of higher dosage of water soluble fertilizers through fertigation gave best results in growth parameters which might be due to better nutritional environment 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 the plant. Beside this, nitrogen is the main constituent of protoplasm, cell nucleus, amino acids, chlorophyll and many other metabolic processes like transpiration, [8].

The plant growth parameters such as leaf area and leaf area index play an important role in understanding photosynthesis, light interception, nutrient and water use and finally crop growth, [9] and [10]. The leaf area index is thus an important indicator of radiation and precipitation interception, energy conversion, and water balance. Ultimately, it is a reliable parameter for plant growth. This is the reason why most studies in agronomy and horticulture measure the results of interventions such as fertilizers and irrigation in terms of LAI, as well as yield.

The significantly higher mean leaf area was recorded in T_7 (167.67 cm^2) which remained on par with T_3 (163.39 cm^2), T_5 (158.51 cm^2) and T_9 (159.64 cm^2), while soil application of fertilizers recorded lowest leaf area of 141.59 cm^2. Maximum leaf area at higher fertigation rate may be attributed in better availability of sufficient quantity of nutrients especially the applied higher doses of nitrogen responsible for cell division and cell elongation during the vegetative growth. It may also be due to increased nutrient availability through fertigation resulting in better uptake and increased photosynthetic activity leading to bigger sized leaves, [11]. Similarly application of 100 per cent fertilizer dose through water soluble fertilizers either given at weekly or bi-weekly interval produced significantly higher mean fresh leaf weight (5.680 and 5.543 g), while these two treatments remained on par with

Table 3.Growth and yield parameters of cucumber as influenced by fertigation treatments (Pooled data)

Treatment	At 50 days after transplanting					LAI	Specific leaf area (cm^2g^{-1})	Specific leaf weight (mg cm^{-2})	At harvest				
	Vine length (cm)	No. of leaves $vine^{-1}$	Mean leaf area (cm^2)	Mean fresh leaf weight (g)	Mean dry leaf weight (g)				No. of fruits $vine^{-1}$	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Yield (t ha^{-1})
T_1	178.67	58.17	141.59	4.600	0.483	1.65	293.315	3.414	13.58	16.92	14.33	214.92	47.40
T_2	191.67	58.33	144.57	4.787	0.507	1.68	286.716	3.534	11.66	17.00	14.10	272.13	52.50
T_3	204.17	73.00	163.39	5.680	0.522	2.38	312.957	3.197	14.20	19.75	16.12	306.05	69.50
T_4	198.33	61.17	149.14	4.672	0.505	1.82	295.961	3.388	12.35	19.33	15.30	291.63	58.80
T_5	200.83	66.67	158.51	5.002	0.510	2.11	311.228	3.221	13.21	19.05	15.57	301.02	65.00
T_6	187.00	58.50	145.31	4.668	0.470	1.69	309.144	3.245	13.87	17.75	14.38	247.27	56.10
T_7	217.50	83.50	167.67	5.543	0.532	2.80	315.513	3.173	14.00	20.75	16.97	313.17	69.20
T_8	191.67	60.50	147.36	4.824	0.482	1.79	305.718	3.276	12.00	19.08	15.68	287.62	57.80
T_9	195.00	69.50	159.64	4.876	0.516	2.22	309.433	3.235	11.75	18.92	15.35	311.47	61.60
T_{10}	185.83	56.67	145.80	4.867	0.475	1.65	308.608	3.263	12.84	18.08	14.40	257.13	54.50
CD (p=0.05)	18.76	11.98	10.75	0.67	0.038	0.34	16.5170	0.197	1.316	2.16	1.60	58.98	9.10

T_2, T_4, T_5 and T_9 for mean dry leaf weight (0.522 and 0.532 g). Soil application of common fertilizer *i.e.* T_1 recorded lowest values for fresh leaf weight (4.600 g), while T_6 for the dry weight (0.470 g).

Significantly higher leaf area index (2.80) was recorded with T_7, while T_1 and T_{10} had minimum value of 1.65. The same treatment recorded significantly higher specific leaf area (315.513 cm^2g^{-1}), which remained on par with all other treatments except T_1 (293.315 cm^2g^{-1}) and T_2 (286.716 cm^2g^{-1}).

3.2 Yield Attributes

As far as yield attributes are concerned, the significantly higher number of fruits $vine^{-1}$ was observed in T_3 (14.20), which remained on par with T_7 (14.00), T_6 (13.87), T_1 (13.58) and T_5 (13.21). The minimum number of fruits $vine^{-1}$ was recorded with T_2 (11.66). The higher levels of fertilizer increased the number of fruits $vine^{-1}$ in the plants because of an increase in the production of flowers in the plant. Similar results were also reported by [12,13]. [14] also observed a maximum number of fruits $vine^{-1}$ with the application of higher doses of fertilizers through drip irrigation. Significantly higher values for fruit length (20.75 cm) was observed in T_7, which remained on par with most of the treatments except T_1(16.92 cm), T_2 (17.00 cm) and T_6 (17.75 cm). The treatment T_7 also resulted in significantly higher fruit girth (16.97 cm) but remained on par with T_3 (16.12 cm), T_5 (15.57 cm) and T_8 (15.68 cm). Similarly, though significantly higher fruit weight was observed in T_7 (313.17 g) *i.e*. application of 100 per cent of fertilizer dose through water soluble fertilizers on a bi-weekly basis, it remained on par with most of the treatments except T_1 (214.92 g) and T_6 (247.27 g). Soil application of nutrients using common fertilizers resulted in lowest values for fruit length (16.92 cm) and fruit weight (214.92 g), while T_2 recorded the lowest value for the fruit girth (14.10 cm). Maximum fruit length was observed in optimum fertigation level at 100 per cent fertilizer dose due to efficient uptake of fertilizer. This may be due to frequent and increased application of fertilizers supplied in fertigation in the required form directly in the vicinity of the root zone that has helped in higher nutrient uptake resulting in increased cell size and elongation and resulted in length and girth of the fruits. The results confirm with the reports of [15,16,4,12,17,18,13].

3.3 Yield

Irrespective of dosage and source of fertilizer, fertigation treatments were significantly superior to conventional soil application treatment for yield. All the fertigation treatments recorded higher yields over the conventional soil application of fertilizers to the tune of 10.75 to 46.60 per cent (Table 3). Among the fertigation treatments, application of 100 per cent fertilizer dose using water soluble fertilizers at a weekly interval (T_3) resulted in significantly higher yield (69.50 t ha^{-1}) than all the other treatments except the treatment T_7, where the bi-weekly application of the same amount of fertilizer was given through the same sources (69.20 t ha^{-1}), T_5 (65.00 t ha^{-1}) and T_9 (61.60 t ha^{-1}), where 50 % N and K of 75 per cent fertilizer dose was applied through water soluble fertilizers at the weekly and bi-weekly interval. 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 nutrients as it permits applying for fertilizer in small quantity at a time matching with the plants nutrient need. This contributes to 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 [19]. Moreover, to their role in increasing meristemic activities and its importance in the metabolism of many constituents such as amino acids, chlorophyll, auxins enzymes and general protein synthesis [20]. 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. These results are in accordance with the findings of [21], [15] and [4] that increasing NPK levels have an important role in enhancing the vegetative growth of cucumber plant. [22,18,23, 24,25,13,26,27,28] also recorded higher yields with application of higher doses of fertilizers using water soluble fertilizers through fertigation.

3.4 Fertilizer use efficiency

Application of 100 per cent fertilizer dose using water soluble fertilizers at weekly interval (T_3) highest yield (69.50 t ha^{-1}) and fertilizer use

Table 4. Economics of cucumber 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	Fertilizer use efficiency (kg kg^{-1})
T_1	47.40	186748	474000	287252	1.54	230.17
T_2	52.50	186748	525000	338252	1.81	254.83
T_3	69.50	204044	695000	490956	2.41	337.61
T_4	58.80	190121	588000	397879	2.09	285.50
T_5	65.00	190121	650000	459879	2.42	315.54
T_6	56.10	187747	561000	373253	1.99	272.29
T_7	69.20	204044	692000	487956	2.39	335.85
T_8	57.80	190121	578000	387879	2.04	280.75
T_9	61.60	190121	616000	425879	2.24	299.14
T_{10}	54.50	187747	545000	358253	1.91	264.35

Sale Price = Rs.10.00/kg

efficiency (337.61 kg kg^{-1}), followed by the same amount of fertilizer applied on biweekly basis (69.20 t ha^{-1}and 335.85 kg kg^{-1}). The treatments where the fertilizers were applied only through fertigation resulted in higher fertilizers use efficiency (T_3, T_5, T_7 and T_9) than other treatments (Table 4). Soil application or fertigation with normal fertilizers gave the minimum values for fertilizer use efficiency of 230.17 and 254.83 kg kg^{-1}. [25] also recorded maximum fertilizers use efficiency of individual nutrients with application of 100% recommended dose of NPK through fertigation.

3.5 Economics

The averaged data pertaining to economic returns and benefit: cost ratio related to 'Vani' a cultivar of cucumber for the year 2015 and 2016 are given in Table 4. 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 weekly basis (T_3) has resulted in highest gross income (Rs.695000 ha^{-1}) followed by T_7 *i.e.* same amount of fertilizer given on bi-weekly basis (Rs.692000 ha^{-1}). As far as net income is concerned, higher values were recorded with T_3 (Rs.490956 ha^{-1}) and T_7 (Rs.487956 ha^{-1}). Irrespective of dosage and frequency, fertigation with water soluble fertilizers resulted in higher B:C ratio (1.91 to 2.41) compared to soil application (1.54) and the fertigation with normal fertilizers (1.81). Chand [25] and [28] also reported maximum net returns and Cost: benefit ratio with the application of 100% recommended dose of NPK through fertigation.

4. CONCLUSION

From this study it can be concluded that application of water soluble fertilizers @75:56:75kg N:P_2O_5:K_2O ha^{-1}during the cropping period through fertigation at weekly intervals resulted in higher yield (69.5 t ha^{-1}), net income of (Rs.490956 ha^{-1}) and B:C ratio (2.41) in *summer* grown cucumber, which remained on par with application of same amount of water soluble fertilizers through fertigation on bi-weekly basis. So, this treatment has added benefit of economizing water use and reducing environmental pollution.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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