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Maximization of nutrient use efficiency and crop productivity using fertigation technology for cucumber (*Cucumis sativus* L.)

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Abstract
Effect of fertigation on crop growth, yield and fertilizer use efficiency of cucumber (*Cucumis sativus* L.) under drip irrigation" consisted of four levels of fertigation (50% RDF (T_1), 75% RDF (T_2), 100% RDF (T_3) through fertigation and 100% RDF (T_4) through soil application. Water applied was common for all the treatments and it was 100% crop ET. The growth parameters such as vine length, number of leaves per plant, stem girth, leaf area and leaf area index was at 30, 45 and 60 DAS and chlorophyll content at 30, 60 and 90 DAS, and days taken for last harvest recorded higher values under 100% crop ET with the application of 100% RDF through fertigation. The highest crop yield was recorded in the treatment receiving 100% crop ET with 100% RDF through fertigation. i.e., 111.70t ha^{-1}. The nutrient use efficiency was highest in the treatment receiving 100% crop ET with 100% RDF through fertigation (587.89 kg ha^{-1}).

Keywords: Fertigation, cucumber, nutrient use efficiency

Introduction
The cucumber is a widely cultivated plant and belongs to gourd family, i.e., Cucurbitaceous. It is a creeping vine that bears cucumiform fruits that are used as vegetable. There are three main types of cucumber: slicing, pickling, and seedless. It's high in beneficial nutrients, as well as certain plant compounds and antioxidants which prevents cancer. Also, cucumbers are low in calories and contain a good amount of water and soluble fiber, making them ideal for promoting hydration and aiding in weight loss. Cucumber is rich in nutrients and per 100 g it provides energy of 15.54 calories protein 650 mg potassium 147 mg water content 95.23 g and vitamin C 2.8 mg.

Drip irrigation is one of the advanced method of irrigation to which provide small and frequent water application directly applied in the vicinity of the plant root zone and this has attracted the interest of farming communities because of decreased water consumptions and possibilities of increasing the production. (Darwish *et al*., 2003) [3].

The application of fertilizers through drip system is observed to be more effective than the conventional methods. Better uptake of fertilizer was observed with frequent application of fertilizers in appropriate doses at proper growth stages. It also shows higher benefit - cost ratio (Janapriya *et al*., 2010) [6]. The availability of nutrients is very high therefore the efficiency is more. In this method liquid fertilizer as well as water soluble fertilizers are used and fertilizer use efficiency is increased from 80 to 90 per cent.

Fertigation is the most efficient method of fertilizer application, as it ensures application of the fertilizers directly to the plant roots (Rajput and Patel, 2002) [11]. Fertilizer management is the most important agro-technique, which controls development, yield and quality of a crop. Every attempt is therefore necessary in achieving this objective of higher water and fertilizer use efficiency. Under these circumstances, fertigation is known to be hi-tech and efficient way of applying fertilizers through irrigation system as a carrier.

A large number of experiments have been conducted to study the effect of fertigation on biological growth of plant and on yield improvement of many crops in different agro-climatic region and soil condition. About 20 to 60 percent higher yields were obtained with drip irrigation in some studies (Om Prakash *et al*., 2018) [7]. In this study influence of different level of fertigation on biological growth and yield of cucumber has been studied.

Materials and Methodology

The experiment was conducted at Zonal Agricultural and Horticultural Research Station (ZAHRS), Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences (KSNUAHS) Navile, Shivamogga.

The data on the observations made and characters studied were statistically analyzed by using Completely randomized design (CRD) with 4 level of irrigation *viz*., T_1:50 per cent of RDF through fertigation, T_2:75 per cent of RDF through fertigation, T_3: 100 per cent of RDF through fertigation and T_4:100 per cent of RDF through soil application and 3 No. of replication. Irrigation at 100 per cent ET through drip is common for all treatments. The recommended levels of fertilizer for cucumber crop are as N: 60 kg ha^{-1}, P_2O_5: 50 kg ha^{-1}, K_2O: 80 kg ha^{-1}.

The liquid fertilizer was applied by using the venturi fitted in the main line.

In drip irrigation water supply at 100 per cent ET to all the treatments. The recommended levels of fertilizer for cucumber crop are N: 60 kg ha^{-1}, P_2O_5: 50 kg ha^{-1}, P_2O_5: 50 kg ha^{-1} and K_2O: 80 kg ha^{-1}. The liquid fertilizer was applied by using the venturi fitted in the main line.

For periodical field observations, five plants were selected randomly from each treatment and were tagged. Observations such as vine length, number of leaves per plant, stem girth, chlorophyll content, leaf area and leaf area index at the time of last harvest were taken from selected five plants. The observations were taken at 15, 30, 45, 60, 90 days after sowing (DAS) and at harvest.

Results and Discussion

The experiment involved in working out the cucumber it's biometric parameters, yield parameters and fertilizer use efficiencies of different treatments.

The data pertaining to vine length are presented in Table 20. Vine length exhibited significant difference during 2020-21, 2021-22 and also in pooled data. The vine length was maximum in treatment consisting of 100% RDF (T_3) through fertigation at 30, 60 and 90 days after transplanting. This might be due to frequent and increased application of fertilizers directly in the vicinity of the root zone, that significant increases the availability and uptake of nutrients, Thus leads to increase in the cell size and cell elongation that helps in healthy and vigorous cucumber growth. N and P are considered as one of the major nutrients required for proper growth and development of plant. Beside this, nitrogen is main constituent of protoplasm, cell nucleus, amino acids, chlorophyll and many other metabolic processes like transpiration (Godara *et al*., 2013 [5] and Arinderpal *et al*., 2019) [2] observed in polyhouse cucumber.

Table 1: Vine length of cucumber as influenced by different levels of fertigation at different DAS

Treatment details	Vine length (cm)								
	30 DAS			45 DAS			60 DAS		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
T_1	216.17	218.67	217.42	348.83	351.50	350.17	374.83	379.00	376.92
T_2	229.17	231.67	230.42	359.17	362.17	360.67	381.83	386.17	384.00
T_3	242.17	244.67	243.42	380.83	382.00	381.42	403.33	412.67	408.00
T_4	205.00	208.17	206.58	323.67	325.33	324.50	363.33	365.67	364.50
S.Em. ±	2.33	1.68	1.80	4.46	4.44	4.34	1.41	2.08	1.50
C.D. @5%	6.93	4.99	5.35	13.26	13.20	12.90	4.19	6.18	4.47

The data pertaining to stem girth of cucumber is presented in Table 2. The stem girth was maximum in treatment consisting of 100% RDF through fertigation at 30 DAS. i.e., 8.70, 9.05 and 8.88 during 2020-21, 2021-22 and pooled data, respectively. The stem girth was minimum (5.87, 6.03 and 5.95 during 2020-21, 2021-22 and pooled data, respectively) in treatment T_4 i.e., 100% RDF through soil application. Similar trend were observed in 45 DAS and 60 DAS. This may be due to optimum use of water and nutrients that has helped in increasing the stem girth in the 100% RDF through fertigation treatment. This could also be due to high uptake of nutrients and build up of sufficient photosynhates enabling increase in the size of stem girth of cucumber. These results are in line with the findings of Godara *et al*. (2013) [5], Pawar *et al*. (2018) [8], Arinderpal *et al*. (2019) [2], Pramod Kumar, *et al*. (2020) [9] and Akanksha *et al*. (2020) [1] in cucumber.

Table 2: Stem girth of cucumber as influenced by different levels of fertigation at different DAS

Treatment details	Stem girth (cm)								
	30 DAS			45 DAS			60 DAS		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
T_1	6.17	6.28	6.23	7.81	7.87	7.84	8.48	8.57	8.53
T_2	7.02	7.32	7.17	8.17	8.20	8.18	9.40	9.42	9.41
T_3	8.70	9.05	8.88	9.63	9.65	9.64	10.06	10.09	10.08
T_4	5.87	6.03	5.95	6.91	7.05	6.98	7.89	8.02	7.96
S.Em. ±	0.08	0.08	0.07	0.10	0.08	0.09	0.08	0.06	0.07
C.D.@5%	0.25	0.23	0.20	0.31	0.24	0.26	0.24	0.17	0.19

Leaf area index is the ratio of leaf area to ground area occupied by the crop plant. The maximum leaf area index was observed (Table 3) in the treatment consisting of 100% RDF through fertigation at 30 DAS. i.e., 1.23, 1.24 and 1.24 during 2020-21, 2021-22 and pooled data, respectively. The leaf area index was minimum (1.13, 1.12 and 1.13 during 2020-21, 2021-22 and

pooled data, respectively) in treatment T_4 i.e., 100% RDF through soil application. The increased in leaf area index in polyhouse could be due to less light intensity in polyhouse which resulted in production of large sized leaves reported by Rajasekar *et al.* (2013) [10] in cucumber. Similar results were found by Dillip K, D., *et al.* (2018) [4] in polyhouse cucumber.

Table 3: Leaf area index (LAI) of cucumber as influenced by different levels of fertigation at different DAS

Treatment details	Leaf area index								
	30 DAS			45 DAS			60 DAS		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
T_1	1.15	1.15	1.15	1.25	1.25	1.25	1.27	1.27	1.27
T_2	1.18	1.19	1.18	1.27	1.28	1.28	1.30	1.30	1.30
T_3	1.23	1.24	1.24	1.30	1.30	1.30	1.34	1.34	1.34
T_4	1.13	1.13	1.13	1.24	1.24	1.24	1.26	1.26	1.26
S.Em. ±	1.28	1.14	1.10	1.54	1.19	1.30	1.57	1.25	1.37
C.D.@5%	3.80	3.38	3.27	4.57	3.53	3.86	4.66	3.71	4.07

Chlorophyll content was measured by using SPAD meter. The data pertaining to chlorophyll content (SPAD) of cucumber are presented in Table 4. There is a significant difference in the **c**hlorophyll content during both the years and in pooled data. At 60 DAS, higher **c**hlorophyll content was recorded in the treatment consisting of 100% RDF through fertigation i.e., 88.00, 89.17 and 88.58 during 2020-21, 2021-22 and pooled data, respectively. Lower **c**hlorophyll content (64.33.65.83, and 65.08 during 2020-21, 2021-22 and pooled data, respectively) was recorded at 60 DAS in the treatment consisting of 100% RDF through soil application. Higher chlorophyll content contributed towards higher yield by increase in photosynthetic activity, whereas higher number of node per vine increase yield per vine because in parthenocarpic cucumber, every node produced one or more number of fruits by Sasirekha (2016) [12]. This might be due to the fact that application of required fertilizers directly to the root zone which increased cell division, cell elongation and cell differentiation which led to higher photosynthetic activity.

Table 4: Chlorophyll content (SPAD) of cucumber as influenced by different levels of fertigation at different DAS

Treatment details	Chlorophyll (SPAD reading)								
	30 DAS			60 DAS			90 DAS		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
T_1	46.49	46.94	46.71	73.00	74.17	73.58	80.00	81.00	80.50
T_2	56.87	57.06	56.97	82.83	83.50	83.17	91.67	92.33	92.00
T_3	60.86	63.50	62.18	88.00	89.17	88.58	100.00	101.67	100.83
T_4	40.61	41.16	40.89	64.33	65.83	65.08	68.17	69.50	68.83
S.Em. ±	2.19	1.93	2.03	1.26	0.94	1.04	0.91	0.72	0.63
C.D. @5%	6.52	5.72	6.04	3.74	2.79	3.09	2.71	2.13	1.89

The data pertaining to fruit weight is presented in Table 28. There is a significant difference in the fruit weight during both the years and in pooled data. Maximum fruit weight was observed in the treatment consisting of 100% RDF through fertigation. i.e., 160g, 161.50g and 160.75g during 2020-21, 2021-22 and pooled data, respectively. Minimum fruit weight was (99.50g, 100.50g and 100g during 2020-21, 2021-22 and pooled data, respectively) in treatment T_4 i.e., 100% RDF through soil application. Maximum fruit length was observed in the treatment consisting of 100% RDF through fertigation. i.e., 16.68 cm, 18.42 cm and 17.55 cm during 2020-21, 2021-22 and pooled data, respectively. Maximum fruit diameter was observed in the treatment consisting of 100% RDF through fertigation. i.e., 12.05 cm, 12.42 cm and 12.23 cm during 2020-21, 2021-22 and pooled data, respectively. Maximum fruit weight and fruit length may be due to enhanced supply of nutrients through increased fertigation level in the root vicinity of plant as there is maintenance of optimum nutrient concentration in the root zone throughout the crop growth period. This increases the uptake of moisture and nutrients resulting in increasing all the growth attributes of cucumber. The increase in growth parameters further increases the photosynthetic rate and absorbed APAR which results in more translocation of photosynthates towards reproductive organ (sink) which ultimately increases the yield attributes of cucumber.

Table 5: Fruit weight, fruit length and fruit diameter of cucumber as influenced by different levels of fertigation

Treatment details	Fruit weight (g)			Fruit length (cm)			Fruit diameter (cm)		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
T_1	111.50	112.50	112.00	13.63	14.38	14.01	8.77	10.05	9.41
T_2	129.42	130.67	130.04	15.57	16.25	15.91	10.63	11.58	11.11
T_3	160.00	161.50	160.75	16.68	18.42	17.55	12.05	12.42	12.23
T_4	99.50	100.50	100.00	11.73	12.43	12.08	7.00	8.83	7.92
S.Em. ±	0.53	0.53	0.36	0.17	0.26	0.14	0.16	0.25	0.17
C.D.@5%	1.56	1.58	1.08	0.49	0.79	0.42	0.47	0.74	0.50

Number of fruits per plant (Table 6) during both the years and in pooled data. Highest number fruits per plant were observed in the treatment consisting of 100% RDF through fertigation. i.e., 21.18, 22 and 21.59 during 2020-21, 2021-22 and pooled data, respectively. Lowest number fruits per plant was (16.77, 17.08 and 16.93 during 2020-21, 2021-22 and pooled data,

respectively) recorded in treatment T_4 i.e., 100% RDF through soil application. The highest yield per plant was observed in the treatment consisting of 100% RDF through fertigation. i.e., 2.57 kg, 3.02 kg and 2.80 kg during 2020-21, 2021-22 and pooled data, respectively. The lowest yield per plant was (2.10 kg, 2.45 kg and 2.28 kg during 2020-21, 2021-22 and pooled data, respectively) in treatment T_4 i.e., 100% RDF through soil application. Highest yield per hectare was observed in the treatment consisting of 100% RDF through fertigation. i.e., 102.70 t ha^{-1}, 120.70 t ha^{-1} and 111.70 t ha^{-1} during 2020-21, 2021-22 and pooled data, respectively. The probable reason for enhanced yield might be due to cumulative effects of nutrient on vegetative growth which ultimately led to many physiological activities like increased uptake of nutrients, photosynthetic rate, vigorous growth, efficient translocation and partitioning of assimilates towards reproductive sink, which might have directly influenced the increase in yield and its characters.

Table 6: Number of fruits per plant, yield per plant and yield per plot of cucumber as influenced by different levels of fertigation

Treatment details	Number of fruits per plant			Yield per plant (kg)			Yield per ha (t ha^{-1})		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
T_1	18.52	18.95	18.73	2.32	2.63	2.48	92.70	105.30	99.00
T_2	19.45	19.87	19.66	2.41	2.73	2.58	96.50	109.30	102.90
T_3	21.18	22.00	21.59	2.57	3.02	2.80	102.70	120.70	111.70
T_4	16.77	17.08	16.93	2.10	2.45	2.28	84.00	98.00	91.00
S.Em. ±	0.15	0.24	0.13	0.04	0.05	0.03	1.40	1.90	1.30
C.D. @5%	0.45	0.70	0.39	0.10	0.14	0.10	4.20	5.60	4.00

The highest nutrient use efficiency (Table 7) was observed in the treatment consisting of 100% crop ET with 100% RDF through fertigation. i.e., 540.53 kg ha^{-1}, 635.26 kg ha^{-1} and 587.89 kg ha^{-1} of nutrients applied during 2020-21, 2021-22 and pooled data, respectively. Fertigation is supplying fertilizers along with irrigation is one of the most effective convenient methods of supplying nutrients and water according to the specific requirements of the crop to maintain optimum soil fertility and to increase the quality of the produce (Shirgure *et al.*,1999) [13]. Fertigation is the most efficient method of fertilizer application, as it ensures application of the fertilizers directly to the plant roots (Rajput and Patel, 2002) [11].

Table 7: Nutrient use efficiency of cucumber as influenced by different levels of fertigation

Treatment details	N+P+K (kg ha^{-1})		
	2020-21	2021-22	Pooled
T_1	487.89	554.21	521.05
T_2	507.89	575.26	541.58
T_3	540.53	635.26	587.89
T_4	442.11	515.79	478.95

Lowest nitrogen uptake (Table 8) was (36.40 kg ha^{-1}, 34.43 kg ha^{-1} and 35.41 kg ha^{-1} of nitrogen applied during 2020-21, 2021-22 and pooled data, respectively) in treatment T_4 i.e., 100% crop ET with 100% RDF through soil application. Highest phosphorus uptake was observed in the treatment consisting of 100% crop ET with 100% RDF through fertigation. Similarly, highest potassium uptake was observed in the treatment consisting of 100% crop ET with 100% RDF through fertigation.

Table 8: Nutrient uptake NPK (kg ha^{-1}) in cucumber fourth leaf as influenced by different levels of fertigation

Treatment details	N (kg ha^{-1})			P (kg ha^{-1})			K (kg ha^{-1})		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
T_1	37.25	36.63	36.94	6.90	6.59	6.75	41.40	42.17	41.78
T_2	42.90	41.68	42.29	8.13	7.82	7.97	44.47	42.93	43.70
T_3	47.53	49.07	48.30	9.20	8.43	8.82	44.47	45.23	44.85
T_4	36.40	34.43	35.41	6.88	7.50	7.19	34.38	33.13	33.75

Conclusion:

The growth parameters such as vine length, number of leaves per plant, stem girth, leaf area and leaf area index was at 30, 45 and 60 DAS and chlorophyll content at 30, 60 and 90 DAS, and days taken for last harvest recorded higher values under 100% crop ET with the application of 100% RDF through fertigation. Highest crop yield was recorded in the treatment receiving 100% crop ET with 100% RDF through fertigation. i.e., 102.70 t ha^{-1}, 120.70 t ha^{-1} and 111.70 t ha^{-1} during 2020-21, 2021-22 and pooled data, respectively.

Maximum nutrient use efficiency and highest nitrogen uptake was observed in treatment consisting of 100% crop ET with 100% RDF through fertigation.

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