

Original Research Article

Evaluation of the Effects of Drip Irrigation and Fertigation scheduling on Tomato Yield under Polyhouse

Abstract

In Northwestern Himalayas, there is scarcity of water owing to rugged terrain which results in lower tomato yield. Therefore to enhance the productivity of tomato, the experiment was conducted to evaluate the effects of drip irrigation and nutrient schedules on soil water dynamics and productivity of tomato under polyhouse. The treatments consisted of three drip irrigation levels viz., I₁ (Daily drip irrigation 2.0 litre/m² once in a day during first two months and 4.0 litre/m² thereafter), I₂ (Daily drip irrigation 1.0 litre/m² once in a day during first two months and 2.0 litre/m² thereafter) and I₃ (Daily drip irrigation twice a day with 6 hours interval at 1.0 litre/m²) and three nutrient schedules viz., NPK₇₅ (75% of RDF, 25% applied as basal and 75% through fertigation at 15 days interval), NPK₁₀₀ (100% of RDF, 25% applied as basal and 75% through fertigation at 7 days interval) and NPK₁₅₀ (150% of RDF, 25% applied as basal and 75% through fertigation twice a week). The results showed that the soil moisture content and soil water stock was higher under I₃ and I₁ and lower under I₂ treatments. The marketable yield (6.31 kg m⁻²), water use efficiency (WUE) (1.94 g m⁻² mm⁻¹) and NPK uptake was significantly higher in I₂ than I₁ and I₃. Among nutrient schedules, marketable yield (6.53 kg m⁻²), WUE (1.94 g m⁻² mm⁻¹) and NPK uptake were significantly higher under NPK₁₅₀ nutrient schedule than NPK₁₀₀ and NPK₇₅. The net returns (Rs. 230) and benefit:cost (B:C) (4.62) ratio was highest under I₂NPK₁₅₀ followed by I₁NPK₁₅₀ and lowest under I₃NPK₇₅. The study concluded that I₂ (Daily drip irrigation 1.0 litre/m² once in a day during first two months and 2.0 litre/m² thereafter) and NPK₁₅₀ (150% of RDF, 25% applied as basal and 75% through fertigation twice a week) was most remunerative combination due to higher marketable yield and water use efficiency under polyhouse.

Keywords: Drip irrigation, water productivity, fertigation, Tomato

Introduction

“With the increasing population and improvement in the dietary habits, the consumption of vegetables has increased. Also, in the present scenario, vegetables plays a major role by providing food and nutrition and economic stability with higher productivity in shorter maturity cycle and greater income leading to improved livelihood” [1]. “The projected demand of vegetables will be 290 million tons by 2025 which will further increase to 350 million tons by 2030” [2]. “Vegetable cultivation in Himachal Pradesh has gained significant importance owing to favourable agro-climatic conditions for growing off-season vegetables with better quality” [3]. “Low cost naturally-ventilated polyhouses provide a great scope in cultivation of the off-season crop such as tomato for year round supply” [4]. “At present, about 137 ha area in Himachal Pradesh has been brought under protected cultivation. Greenhouse farming, also known as

protected cultivation is one of the farming systems widely used to maintain a controlled environment which is suitable for optimum crop production leading to maximum profits” [5] and [6]. “The main advantage of protected cultivation is that the crops can be grown throughout the year, which is not possible in the open field cultivation due to heavy rainfall, high temperature and incidence of pest and diseases” [6]. “Irrigation is one of the most important factor that affects the yield and quality of the produce” [4]. “Water should be applied at accurate time and in proper amount. Therefore, the efficient management of water is a key to maintain optimum yield with favourable soil moisture conditions by avoiding plant moisture stress during critical crop growth stages. Several methods have been made to use irrigation water as efficient as possible under protected cultivation” [7]. “The utilization of drip irrigation methodology offers a dual advantage by conserving water resources while simultaneously enhancing crop productivity and quality. This efficacy is attributed to precise application of water directly to the root zone of plants. It not only minimizes the humidity but also provides optimal growing conditions conducive for improved crop yield” [4].

“Drip (trickle) irrigation offers the potential for precise water management as compared to furrow and sprinkler irrigation” [8]. “It also provides an opportunity to deliver nutrients in a timely and efficient manner near the root zone (Fertigation). Fertigation stands as attractive technology in modern agriculture, offering several benefits including enhancement of crop yield, improvement in fertilizer use efficiency and the maintenance of optimal nutrient and water levels at distinct crop growth stages” [9]. “The technique applies both water and fertilizer at a low rate directly to the plant root zone as per crop needs and according to crop developmental phase, thereby resulting in higher yields and better quality of the produce” [10]. “Further, it can minimize the groundwater pollution due to less leaching losses of fertilizers as compared to excessive irrigation” [11]. “Fertigation time can be scheduled as often as irrigation, several times per season. Hence, to increase crop yield and water productivity under protected cultivation, there is a need to evaluate the drip irrigation frequency based on climatic conditions and required fertigation frequency” [5].

Tomato (*Solanum lycopersicum* L.) is categorized as a low-calorie vegetable, distinguished for its excellent source of dietary fibers, minerals, vitamins and antioxidants [12]. “The antioxidants are found to be protective of various types of cancers, such as those affecting the colon, prostate, breast, lung, and pancreas” [7]. In the cultivation of greenhouse tomatoes, the indeterminate nature of the crop results in a concurrent occurrence of vegetative and reproductive stages, necessitating a continuous supply of nutrients throughout the growth cycle, to optimize the growth and yield of the crop. Therefore, employing techniques such as fertigation holds considerable promise for enhancing the efficacy of nutrient application in tomatoes under polyhouse [13]. Tomatoes, recognized as a high-value cash crop, exhibit higher nutritional demands (NPK 150:120:60). Under protected conditions, the harvesting is done in 12-15 pickings. The tomato plants are anticipated to demonstrate varying responses to different soil moisture and fertigation levels [4]. Thus, the present study was planned to evaluate the effect of

drip irrigation and NPK fertigation levels on soil moisture availability and productivity of tomatoes under polyhouse.

Material and Methods

Study Site

The study was carried out at experimental farm of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, with tomato as a test crop in naturally ventilated polyhouse. The research farm lies in wet temperature zone. The mean air temperature varies from 2°C in January to around 36°C during the months of May-June. The soil temperature drops as low as 2°C and frost incidences are common. The relative humidity in the region varies from 46 to 84 per cent. The average annual rainfall of the place is about 2500 mm. The soil of the naturally ventilated polyhouse was loam and rich in silt content. The average values of pH and OC of the surface soil (0-15 cm) were 5.67 and 12.20 g kg⁻¹, respectively. The soil was low in available N (209.01 kg ha⁻¹), high in available P (30.1 kg ha⁻¹) and medium in available K (122.2 kg ha⁻¹).

Treatment details

The experiment comprised of three irrigation and three nutrient schedules. The nine treatment combinations were imposed in a completely randomized design replicated three times. For better establishment of seedlings, drip irrigation was operated daily for 10 minutes for initial 10 days in all the strips and thereafter drip irrigation was operated as per treatments throughout crop growth period. In nutrient schedules, NPK fertilizer doses calculated as per treatments were applied as basal and through fertigation in varying intervals starting from 3rd week of transplanting to 15 days before the final harvest. The details of treatments are given in Tables 1 and 2.

Table 1: Details of treatment imposed

Treatment	Details of the treatment
A. Irrigation schedule (I)	
I ₁	Daily drip irrigation @ 2.0 litre/m ² once in a day during first two months and @ 4.0 litre/ m ² thereafter
I ₂	Daily drip irrigation @ 1.0 litre/m ² once in a day during first two months and @ 2.0 litre/m ² thereafter
I ₃	Daily drip irrigation twice a day with 6 hours interval at @ 1.0 litre/m ²
B. Nutrient schedule (NPK)	
NPK ₇₅	75% of RDF of which 25% applied as basal and rest 75% through fertigation at 15 days interval
NPK ₁₀₀	100 % of RDF of which 25% applied as basal and rest 75% through fertigation at weekly interval

NPK ₁₅₀	150 % of RDF of which 25% applied as basal and rest 75% through fertigation twice a week
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Table 2: Details of the fertilizer material applied

Treatment	Basal dose (g m ⁻²)			Fertigation dose (g m ⁻²)/ split			No of splits	Fertigation intervals (days)
	Urea	SSP	MOP	19:19:19	12:61	Urea		
NPK ₇₅	9.0	21.0	2.4	13.5	6.3	9.9	8	15
NPK ₁₀₀	12.0	28.0	3.4	8.1	3.6	6.3	16	7
NPK ₁₅₀	18.0	42.0	6.0	9.9	3.6	5.4	32	3

*Top dressing at monthly intervals.

Soil water content and water stock

“The changes in soil water content were determined by thermo- gravimetric method periodically during crop growth period. The volumetric moisture content (Θ) for different depths was calculated by multiplying the gravimetric moisture content (w/w basis) with pre-determined bulk density for that depth” [14]. The soil water stock (S) was calculated by multiplying the ‘Θ’ values with sampling depth.

Marketable yield and water use efficiency

The tomato fruits were harvested in different pickings. After every picking, the fruits were weighed to obtain the total fruit yield. The yield obtained for each treatment was divided by the quantity of water used for the respective treatments by this method. Water use efficiency was worked out and expressed in kg ha⁻¹ mm⁻¹ of water used.

$$WUE (g m^{-2}mm^{-1}) = \frac{\text{Fruit yield (g m}^{-2}\text{)}}{\text{Total amount of water used (mm)}} \dots\dots\dots (1)$$

Soil sampling and analysis

The initial soil samples were collected before transplanting of the tomato, for analyzing various physico-chemical properties of soil. Available nitrogen was determined by alkaline permanganate method [15], phosphorus by Olsen’s method [16] and available potassium in soil was extracted using neutral normal ammonium acetate method [17].

Economic analysis

The cost of cultivation, net monetary returns and benefit:cost ratio (B:C) were calculated on the basis of prevailing market price of inputs and outputs.

Statistical analysis

The analysis of variance technique (ANOVA) in completely randomized block design was employed to analyze the data statistically by using statistical software package for agricultural research workers [18].

Results and Discussion

Soil Water Content and Soil Water Stock

The soil water content (θ) determined at regular interval throughout the growth period is shown in Table 3. The ' θ ' determined at early crop growth stages (17 DAT) was 0.38 and 0.38 in I_1 , 0.37 and 0.37 $m^3 m^{-3}$ in I_2 and 0.40 and 0.39 $m^3 m^{-3}$ in I_3 at 0-0.15 and 0.15-0.30 m soil depths, respectively. The soil water content at 52 DAT was 0.34 and 0.32 $m^3 m^{-3}$ in I_1 , 0.34 and 0.30 $m^3 m^{-3}$ in I_2 and 0.35, 0.37 $m^3 m^{-3}$ in I_3 at 0-0.15 and 0.15-0.30 m soil depth. The soil water content (θ) determined on 81 DAT was 0.38, 0.36 in I_1 , 0.37, 0.36 $m^3 m^{-3}$ in I_2 , 0.39 and 0.33 in I_3 at 0-0.15 and 0.15-0.30 m soil depths, respectively. The soil water content determined on 106 DAT indicated that the ' θ ' values were 0.36, 0.36 $m^3 m^{-3}$ in I_1 , 0.36, 0.36 $m^3 m^{-3}$ in I_2 and 0.38, 0.32 in I_3 at 0-0.15, 0.15-0.30 m soil depths, respectively. The higher ' θ ' in surface layer in I_3 as compared to others may be attributed due to application of water twice a day. Similar results were reported by [4] and [19].

Table 3. Effect of drip irrigation on changes in soil water content and soil water stock ($m^3 m^{-3}$) during crop growth

Days after transplanting	Soil Water Content		Soil Water Stock	
	Soil depth (m)		Soil depth (m)	
	0-0.15	0.15-0.30	0-0.15	0.15-0.30
Irrigation level (I_1)				
17 DAT	0.38	0.38	57.6	56.6
52 DAT	0.34	0.32	51.5	48.2
81 DAT	0.38	0.36	57.0	54.0
106 DAT	0.36	0.36	54.0	54.0
Irrigation level (I_2)				
17 DAT	0.37	0.37	55.6	55.1
52 DAT	0.34	0.30	50.5	44.4
81 DAT	0.37	0.36	55.0	53.7
106 DAT	0.36	0.36	54.3	53.6
Irrigation level (I_3)				
17 DAT	0.40	0.39	60.7	58.7
52 DAT	0.35	0.37	52.6	55.0
81 DAT	0.39	0.33	58.9	49.6

106 DAT	0.38	0.32	57.7	47.5
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DAT: Days after transplanting

The soil water stock (S) calculated for 0-0.15 and 0.15-0.30 m soil depth are given in Table 3. The soil water stock values at 0-0.15 m soil depth were 57.6, 51.5, 57.0 and 54.0 mm in I₁, 55.6, 50.5, 55.0 and 54.3 mm in I₂ and 60.7, 52.6, 58.9 and 57.7 mm in I₃ at 17, 52, 81 and 106 DAT, respectively. The corresponding values of 'S' at 0.15-0.30 m depth were 56.6, 48.2, 54.0 and 54.0 mm in I₁; 55.1, 44.4, 53.7 and 53.6 mm in I₂ and 58.7, 55.0, 49.6 and 47.5 mm in I₃ at 17, 52, 81 and 106 DAT, respectively. The overall results showed that the soil water stock was higher under I₃ and I₁ and lower under I₂ at 17, 52, 81 and 106 DAT at 0-0.15m depth. In I₁ treatments, the soil water stock was higher due to higher quantity of irrigation water applied in comparison to I₂. Similar results were reported by [4] and [20].

Nutrient Uptake

The soil nutrient status at harvest is given from Table 4 to 6. The available nitrogen (N) was higher in I₁ (177.75 kg ha⁻¹) as compared to I₂ and I₃. Under different nutrient schedules, the available nitrogen (N) was statistically higher in NPK₁₅₀ treatment as compared to NPK₇₅, but it statistically at par for with NPK₁₀₀ treatment. The available phosphorus (P) was higher in I₂ (20.96 kg ha⁻¹) irrigation level as compared to other treatments. Under different nutrient schedules, the available phosphorus (P) was significantly higher in NPK₁₅₀ (24.49 kg ha⁻¹) treatment as compared to NPK₁₀₀ (19.46 kg ha⁻¹) and NPK₇₅ (15.03 kg ha⁻¹) treatment. The available potassium (K) was significantly higher in irrigation level I₂ (160.78 kg ha⁻¹) as compared to other irrigation levels. Under different nutrient schedules, the available potassium was significantly higher in NPK₁₅₀ (169.24 kg ha⁻¹) as compared to NPK₁₀₀ (143.36 kg ha⁻¹) and NPK₇₅ (133.90 kg ha⁻¹) treatment. Similar results were reported by [21], [22], [23] and [24].

Table 4: Effect of drip irrigation and nutrient schedule on available nitrogen

Nutrient Schedule	Drip Irrigation levels			Mean
	I ₁	I ₂	I ₃	
NPK₇₅	167.25	156.80	156.80	160.28
NPK₁₀₀	177.83	188.16	156.80	174.26
NPK₁₅₀	188.16	188.16	209.07	195.13
Mean	177.75	177.71	174.22	
LSD	DI	NPK	Interaction	
(P=0.05)	NS	27.589	NS	

Table 5: Effect of drip irrigation and nutrient schedule on available phosphorus

Nutrient Schedule	Drip Irrigation levels			Mean
	I ₁	I ₂	I ₃	
NPK ₇₅	16.43	14.63	14.04	15.03
NPK ₁₀₀	18.07	18.67	21.65	19.46
NPK ₁₅₀	21.65	26.43	25.39	24.49
Mean	18.72	20.96	19.91	
LSD	DI	NPK	Interaction	
(P=0.05)	0.959	0.959	1.661	

Table 6: Effect of drip irrigation and nutrient schedule on available potassium

Nutrient Schedule	Drip Irrigation levels			Mean
	I ₁	I ₂	I ₃	
NPK ₇₅	129.17	162.03	110.51	133.90
NPK ₁₀₀	141.87	156.05	132.16	143.36
NPK ₁₅₀	168.00	164.27	175.47	169.24
Mean	146.35	160.78	139.38	
LSD	DI	NPK	Interaction	
(P=0.05)	9.914	9.914	17.172	

Marketable yield and water use efficiency

The effect of drip irrigation levels and nutrient schedule on marketable yield of tomato is given in Table 7. The marketable yield was significantly higher in I₂ (6.31 Kg m⁻²) as compared to I₁ (5.97 Kg m⁻²) and I₃ (5.88 Kg m⁻²). The results indicated that the saving of at least 50% of applied water with irrigation level I₂ for attaining the similar marketable yield with I₁. The yield under different nutrient schedule was significantly higher in NPK₁₅₀ (6.53 Kg m⁻²) as compared to NPK₁₀₀ (5.84 Kg m⁻²) and NPK₇₅ (5.78 Kg m⁻²) treatment. However, NPK₇₅ treatment was statistically similar with NPK₁₀₀ treatment. Similar results were reported by [25], [26], [23], [27], [28], [29] and [13]. The interaction between irrigation levels and nutrient schedule was significant and maximum yield was in I₂NPK₁₅₀ (7.00 kg m⁻²) and minimum in I₃NPK₇₅ (5.63 kg m⁻²).

Table 7: Effect of drip irrigation and nutrient schedule on marketable yield (kg m⁻²)

Nutrient Schedule	Drip Irrigation levels			Mean
	I ₁	I ₂	I ₃	
NPK₇₅	5.80	5.90	5.63	5.78
NPK₁₀₀	5.70	6.02	5.80	5.84
NPK₁₅₀	6.40	7.00	6.20	6.53
Mean	5.97	6.31	5.88	
LSD	DI	NPK	Interaction	
(P=0.05)	0.10	0.10	0.17	

The effect of drip irrigation levels and nutrient schedule on water use efficiency in tomato is given in Table 8. The water use efficiency was significantly higher in I₂ (1.94 g m⁻² mm⁻¹) as compared to I₁ (1.83 g m⁻² mm⁻¹) and I₃ (1.86 g m⁻² mm⁻¹) treatment. Similar results were also reported by Ying et al. [30], Yaghi et al. [31] and Hakim and Chand [32]. The lowest WUE in I₁ was primarily due to higher amount of water used and produced lesser yield in comparison to other drip treatments. Under different nutrient schedules, the water use efficiency was higher in NPK₁₅₀ (1.94 g m⁻² mm⁻¹) followed by NPK₁₀₀ (1.90 g m⁻² mm⁻¹) and NPK₇₅ (1.79 g m⁻² mm⁻¹). Similar results were reported by [33] where optimal fertigation was a beneficial practice for improving water use efficiency. Similar results were also reported [24]. The higher WUE in NPK₁₅₀ was primarily due to better root growth and marketable yield. The interaction between irrigation levels and nutrient schedules was significant and maximum water use efficiency was obtained in I₂NPK₁₅₀ (2.12 g m⁻² mm⁻¹) and minimum was in I₃NPK₇₅ (1.76 g m⁻² mm⁻¹).

Table 8: Effect of drip irrigation and nutrient schedule on water use efficiency (g m⁻² mm⁻¹)

Nutrient Schedule	Drip Irrigation levels			Mean
	I ₁	I ₂	I ₃	
NPK₇₅	1.82	1.78	1.76	1.79
NPK₁₀₀	1.88	1.91	1.90	1.90
NPK₁₅₀	1.78	2.12	1.93	1.94
Mean	1.83	1.94	1.86	

LSD	DI	NPK	Interaction
(P=0.05)	0.079	0.079	0.137

Net returns and economics

The combined effects of drip irrigation levels and nutrient schedules on returns and economics in tomato are given in Table 9. The net return was higher under I₂NPK₁₅₀ (Rs. 230) followed by I₁NPK₁₅₀ (Rs. 206) and lowest under I₃NPK₇₅ (Rs. 180). The higher net returns in I₂NPK₁₅₀ and I₁NPK₁₅₀ was due to higher marketable yield. The B:C ratio was highest in I₂NPK₁₅₀ (4.62) and lowest under I₃NPK₇₅ (3.97). The higher B:C ratio in I₂NPK₁₅₀ was due to higher yields in comparison to other irrigation levels and nutrient schedules. Similar results were reported by [24] and [34].

Table 9: Effect of drip irrigation and fertigation on returns and B: C ratio

Treatments	Net return (Rs)	B: C ratio
I₁+NPK₇₅	187	4.11
I₁+NPK₁₀₀	183	4.03
I₁+NPK₁₅₀	206	4.14
I₂+NPK₇₅	191	4.20
I₂+NPK₁₀₀	195	4.31
I₂+NPK₁₅₀	230	4.62
I₃+NPK₇₅	180	3.97
I₃+NPK₁₀₀	187	4.12
I₃+NPK₁₅₀	198	3.98

Conclusions

The present study concluded that the irrigation level I₂, consisting of daily drip irrigation at a rate of 1.0 litre/m² during the initial two months, followed by a subsequent increase to 2.0 litre/m², in combination with NPK₁₅₀ fertilization (150% of RDF), was suitable combination for cultivation of tomatoes under a naturally ventilated polyhouse in the Himalayan region. This treatment exhibited higher marketable yield coupled with reduced water consumption, thereby resulting in higher water use efficiency. The I₂NPK₁₅₀ treatment resulted in significantly higher net returns

and benefit-cost ratio as compared to other treatments. Hence, we recommended for the adoption of daily drip irrigation (I₂) in combination with NPK₁₅₀ fertigation for optimal tomato production under protected conditions in Himalayan region.

References

1. Schreinemachers P, Emmy B, Simmons EB and Wopereis MCS. Tapping the economic and nutritional power of vegetables. *Global Food Security*. 2018; 16: 36-45.
2. Horticultural statistics at a glance. Department of Agriculture, Corporation and Farmers Welfare. Horticulture Statistics Division. 2020.
3. Chaudhary J and Singh HP. Diversification of Agricultural Crops in Himachal Pradesh: A Shift towards High-Value Crops. *International Journal of Current Microbiology and Applied Sciences*. 2020; 9(12): 2224-35.
4. Singh J, Sandal SK, Yousuf A and Sandhu PS. Effect of drip irrigation and fertigation on soil water dynamics and the productivity of greenhouse tomatoes. *Water*. 2020; 15: 2086.
5. Jaswal R and Sandal SK Effect of drip irrigation and NK fertigation on soil water dynamics and water productivity of strawberry under protected conditions. *Journal of Soil and Water Conservation*. 2022; 21(4): 378-384.
6. Rawat S, Bhatt L, Singh PK, Gautam P, Maurya SK, Priyanka, Sabatino L and Kumar P. Combinatorial effect of fertigation rate and scheduling on tomato performance under naturally ventilated polyhouse in Indian humid sub-tropics. *Agronomy*. 2023; 13: 665
7. Ayenan MAT, Danquah A, Hanson P, Asante IK and Danquah EY. Tomato (*Solanum lycopersicum* L.) Genotypes respond differently to long-term dry and humid heat stress. *Horticulturae*. 2022; 8: 118.
8. Naik S, Kumar SKS, Rondla SK and Kishan K. Effect of irrigation and N-fertigation levels on broccoli performance in a Polynet house. *International Journal of Environment and Climate Change*. 2021; 11(12): 261-267.
9. Yue W, Liu L, Chen S, Bai Y. and Li N. Effects of water and nitrogen coupling on growth, yield and quality of greenhouse tomato. *Water*. 2022; 14: 3665.
10. Sandal SK. and Kapoor R. Fertigation technology for enhancing nutrient use and crop productivity: An overview. *Himachal Journal of Agricultural Research*. 2015; 41: 114-121.
11. Ankush D, Singh V, Kumar V and Singh DP. Impact of drip irrigation and fertigation scheduling on tomato crop - An overview. *Journal of Applied and Natural Science*. 2018; 10: 165-170.
12. Costa JM and Heuvelink E. *The global tomato industry in tomatoes*; CABI Publishing: Wallingford, UK. 2018: 276-313.
13. Mahajan G and Singh K. Response of greenhouse tomato to irrigation and fertigation. *Agricultural Water Management*. 2006; 84: 202-206.
14. Hillel D. *Introduction to Soil Physics*. Department of Plant and Soil Science, University of Massachusetts, Amherst, Massachusetts. 1982; 57-112.

15. Subbiah BV and Asija GL. A rapid procedure for the determination of available nitrogen in soils. *Current Science*. 1956; 25: 259–260.
16. Olsen SR, Cole CV, Watanabe FS, Dean L.A. Estimation of available phosphorus by extraction with sodium carbonate. United States Department of Agriculture. 1954; 939: 19–33.
17. Jackson ML. *Soil Chemical Analysis*. Prentice Hall Inc.: Englewood Cliffs, NJ, USA, 1973.
18. Sheoran OP, Tonk DS, Kaushik LS, Hasija RC and Pannu RS. Statistical software package for agricultural research workers. Recent advances in information theory, statistics & computer applications by DS hooda & RC Hasija, Department of Mathematics and Statistics, CCS HAU, Hisar. 139-143.
19. Kumar J, Kapoor R, Sandal SK, Sharma SK and Saroch K. Effect of drip irrigation and NPK fertigation on soil-plant water, productivity, fertilizer expense efficiency and nutrient uptake of capsicum (*Capsicum annuum L.*) in an acid Alfisol. *The Indian Journal of Soil Conservation*. 2017; 45: 105–111.
20. Padmaja S, Pasha MDL, Umadevi MS, Hussain A and A Nirmala. Influence of drip irrigation and fertigation on fruit yield and water productivity of cucumber under naturally ventilated polyhouse. *International Journal of Environment and Climate Change*. 2021; 11(6): 162-168.
21. Guler, Ibriki S and Buyuk. Effects of different nitrogen rates on yield and leaf nutrient contents of drip fertigated and greenhouse grown cucumber. *Asian journal of plant Sciences*. 2006; 5(4): 657:662.
22. Ahlfoos S, Salo T, Pulkkinen T. and Tikanmaki JE. Nutrient demand and uptake by pickling cucumber under drip irrigation in northern climate. *Journal of horticultural Science and Biotechnology*. 2005; 80(4): 498-502.
23. Amer Kamal H, Midan Sally A and Hatfield Jerry L. Effect of deficit irrigation and fertilization on cucumber. Publications from USDA-ARS/UNL Faculty. 2009; 1349
24. Chand ARJ. Nutrient use efficiency and economics of salad cucumber using drip fertigation in naturally ventilated polyhouse. *IOSR Journal of Agriculture and Veterinary Science*. 2014; 7: 22–25.
25. Abdrabbo MA, Medany A, El-Moniem A and Abou-Hadid EMA. Fertigation management of cucumber plants under plastic houses. *Egyptian Journal of Horticulture*. 2005; 32(1): 113-15.
26. Guler S, Ibriki H and Buyuk G. Effects of different nitrogen rates on yield and leaf nutrient contents of drip fertigated and greenhouse grown cucumber. *Asian Journal of Plant Sciences*. 2006; 5(4): 657:662.
27. Kapoor R, Sandal SK, Sharma SK, Anil and Saroch K. Effect of varying drip irrigation levels and NPK fertigation on soil water dynamics, productivity and water use efficiency of cauliflower (*Brassica oleracea var. Botrytis*) in wet temperate zone of Himachal Pradesh. *Indian Journal of Soil Conservation*. 2013; 42: 249-254.

28. Feleafel NM, Mirdad MZ and Hassan SA. Effect of NPK fertigation rate and starter fertilizer on the growth and yield of cucumber grown in greenhouse. *Journal of Agricultural Science*. 2014; 6(9): 8-92.
29. Tekale CD, Tumbare AD, Tekale GS, Danawale NJ and Tambe ST. Effect of different fertigation levels and schedules on growth and yield of cucumber under polyhouse conditions. *International Journal of Current Research*. 2014; 6: 7353-55.
30. Long YZ, Zhu WM, Lu SJ and Lu M. Effects of different drip-irrigation tubes on tomato (*Lycopersicon esculentum*) cultivation. *China Vegetables*. 2001; 4-5.
31. Yaghi T, Arslan A and Naoum F. Cucumber (*Cucumis sativus*, L.) water use efficiency (WUE) under plastic mulch and drip irrigation. *Agricultural water management*. 2013; 128: 149-157.
32. Abdul Hakkim VM and Jisha Chand AR. Effect of drip irrigation levels on yield of salad cucumber under naturally ventilated polyhouse. *IOSR Journal of Engineering*. 2014; 4(5): 18-21.
33. Liang X, Gao Y, Zhang X, Tian Y, Zhang Z. Effect of optimal daily fertigation on migration of water and salt in soil, root growth and fruit yield of cucumber (*Cucumis sativus* L.) in solar-greenhouse. *PLoS ONE*. 2014; 9(1): 975-85.
34. Patil RV, Bhosale AB and Takte RL. Effect of drip irrigation and fertigation levels on growth and yield of gerbera under greenhouse conditions. *Ecology, Environment and Conservation Paper*. 2010; 16(2): 235-237.