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Response of tomato (*Solanum lycopersicum* L.) to different fertigation levels and scheduling under naturally ventilated polyhouse

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Abstract
A field experiment was conducted at Vegetable Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India during October to April 2020-21 and 2021-22 to study the effect of NPK fertigation levels and its scheduling on tomato under naturally ventilated polyhouse. The experiment was laid out in two factorial randomized block design with one additional treatment consisting of four fertigation levels *viz.*, F_1: 120 percent of RDF, F_2: 100 per cent of RDF, F_3: 80 per cent of RDF and F_4: 60 per cent of RDF and three fertigation scheduling *viz.*, S_1: 15, 10 and 10 per cent N, P_2O_5 and K_2O of fertigation levels between 15-45 days after transplanting (DAT), respectively, 40, 40 and 40 per cent N, P_2O_5 and K_2O of fertigation levels between 46-76 DAT, respectively, 30, 40 and 40 per cent N, P_2O_5 and K_2O of fertigation levels between 77-107 DAT, respectively, 15, 10 and 10 per cent N, P_2O_5 and K_2O of fertigation levels between 108-138 DAT, respectively, S_2: 25 per cent of each N, P_2O_5 and K_2O between 15-46 DAT, 46-76 DAT, 77-107 DAT and 108-138 DAT, respectively and S_3: 20, 20 and 20 per cent N, P_2O_5 and K_2O of fertigation levels between 15-46 DAT, respectively, 30, 30 and 30 per cent N, P_2O_5 and K_2O of fertigation levels between 46-76 DAT, respectively, 30, 30 and 30 per cent per cent N, P_2O_5 and K_2O of fertigation levels between 77-107 DAT, respectively and 20, 20 and 20 per cent N, P_2O_5 and K_2O of fertigation levels between 107-138 DAT, respectively, along with one control (soil application of RDF with surface irrigation) replicated thrice. The results indicated that fertigation of 120 and 100 per cent of RDF was found *at par* and significantly better over other fertigation levels with respect to plant growth characters, yield parameters and nutrient content. It was further concluded from the study that fertigation of 100 per cent of RDF (300:150:150 kg ha^{-1}) through scheduling S_1 was best treatment combination.

Keywords: Tomato, fertigation levels, scheduling, growth, yield, nutrient content

1. Introduction
Tomato is one of the most important and widely grown vegetable crop in the world ranking 2^{nd} in importance after Potato (FAO, 2009) [6]. It is very versatile vegetable for culinary purposes. Its fruits are eaten as raw or cooked. It is considered an important source of vitamin A, C and minerals (Hari, 1997) [9]. It is rich source of lycopene, a powerful antioxidant scavenger of free radicals, which is often associated with carcinogenesis. It may also interfere with oxidative damage to DNA and lipoproteins and inhibits the oxidation of LDL (low density lipoprotein) cholesterol (Bacalni *et al*., 2017) [3]. In India tomato is mainly grown in Uttar Pradesh, Andhra Pradesh, Orissa, Karnataka and Madhya Pradesh. In India, tomato occupies an area of about 831 thousand ha with the production of 20300 thousand MT, Andhra Pradesh is a leading producer of tomato in India (NHB, 2021) [12]. Protected cultivation is yet a new and emerging propensity for growing vegetables in India. It is a most contemporary approach to produce high value vegetables like tomato and have shown tremendous potential quantitatively and qualitatively, extend the growing season of crop and fetches good market price during off season along with higher yield and quality.

Improper irrigation water operation accounts for significant water losses in large areas in our country. Consequently, the use of modern irrigation systems in irrigation operation and scheduling is essential for the reduction of irrigation water demands. Drip fertigation, saves water and decrease nutrient leaching because drip fertigation supply water and nutrients to the plant root zones, which not only increases its use efficiency but also controls the weed germination and its growth as the water and nutrients are not applied to the areas in between the ridges. Hence also reduces the labour cost incurred in weeding and hoeing.

Efficient use of fertilizer and water is highly critical for sustained agricultural production. 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. Generally crop response to fertilizer application through drip irrigation has been excellent and frequent nutrient applications have improved the fertilizer-use efficiency (Malik *et al*., 1994) [11]. For tackling the water and nutrient management problem, it is the need of the hour to have the knowledge of implementing drip fertigation in tomato. Hence, the present study was undertaken to standardize the fertigation and its scheduling in order to harness the full potential of tomato under naturally ventilated polyhouse.

2. Materials and Methods

Pantnagar falls in the humid sub-tropical zone and situated in the *tarai* region at the foothills of Shivalik range of Himalayas. Geographically, it falls in 29 ^{0}N and 79.30 ^{0}E longitudes having an altitude of 243.84 meters above mean sea level. The climate of this place is humid subtropical with the maximum temperature ranging from 32 ^{0}C to 44 ^{0}C in summer and minimum temperature 4.4 o^{0}C in winter. The experiment was laid out in two factorial RBD with one additional treatment replicated thrice. First factor is the NPK fertigation levels (F), whereas the second factor is the scheduling of NPK through fertigation (S) along with a treatment of soil application of RDF with farmer's practices /control. The seeds of hybrid variety *Heemsona* were grown in plug trays under same polyhouse and 20-25 days old seedlings were transplanted during fourth week of October in soil on raised beds in a paired row at 60 cm x 50 cm spacing. Fertigation was done through fertilizer tank starting from 15 days after transplanting (DAT) and the fertilizer doses were changed after every 30 days interval as per the scheduling. The water-soluble fertilizers were used for fertigation. To meet the NPK requirement of farmer's practices, urea, single super phosphate and murate of potash were used. In case of conventional method of fertilization, the entire dose of P and K and one third dose of N was applied as basal. The remaining dose of nitrogen was applied in three splits at 20, 40 and 60 DAT. Observations were recorded for different plant growth and yield attributes using standard methods. The single main leader stem was maintained by regular removal of side shoots and supported by twining with plastic thread attached to overhead trellis wire. The data on various parameters studied during the course of investigation were statistically analysed applying the two stage method of control vs rest analysis suggested by Rangaswamy (2015) [14]. Wherever the treatment differences were found significant ('F' test) critical difference was worked out at five per cent probability level and then the values were furnished. The treatment differences which were not significant were denoted by "NS". Treatment details are as follows:

A) Fertigation levels (NPK) : 4
1. F_1: 120 per cent of RDF
2. F_2: 100 per cent of RDF
3. F_3: 80 per cent of RDF
4. F_4: 60 per cent of RDF

B) Scheduling of NPK fertigation throughout the growth period: 3

1. S_1

Crop growth stage	Number of splits	Nutrients applied		
		N	**P_2O_5**	**K_2O**
Stage 1 (15-45 DAT)	4	15 per cent of fertigation levels	10 per cent of fertigation levels	10 per cent of fertigation levels
Stage 2 (46-76 DAT)	4	40 per cent of fertigation levels	40 per cent of fertigation levels	40 per cent of fertigation levels
Stage 3 (77-107 DAT)	4	30 per cent of fertigation levels	40 per cent of fertigation levels	40 per cent of fertigation levels
Stage 4 (108-138 DAT)	4	15 per cent of fertigation levels	10 per cent of fertigation levels	10 per cent of fertigation levels

2. S_2

Crop growth stage	Number of Splits	Nutrients applied		
		N	**P_2O_5**	**K_2O**
Stage 1 (15-45 DAT)	4	25 per cent of fertigation levels	25 per cent of fertigation levels	25 per cent of fertigation levels
Stage 2 (46-76 DAT)	4	25 per cent of fertigation levels	25 per cent of fertigation levels	25 per cent of fertigation levels
Stage 3 (77-107 DAT)	4	25 per cent of fertigation levels	25 per cent of fertigation levels	25 per cent of fertigation levels
Stage 4 (108-138 DAT)	4	25 per cent of fertigation levels	25 per cent of fertigation levels	25 er cent of fertigation levels

3. S_3

Crop growth stage	Number of Splits	Nutrients applied		
		N	**P_2O_5**	**K_2O**
Stage 1 (15-45 DAT)	4	20 per cent of fertigation levels	20 per cent of fertigation levels	20 per cent of fertigation levels
Stage 2 (46-76 DAT)	4	30 per cent of fertigation levels	30 per cent of fertigation levels	30 per cent of fertigation levels
Stage 3 (77-107 DAT)	4	30 per cent of fertigation levels	30 per cent of fertigation levels	30 per cent of fertigation levels
Stage 4 (108-138 DAT)	4	20 per cent of fertigation levels	20 per cent of fertigation levels	20 per cent of fertigation levels

3. Results and discussion
3.1 Growth parameters
3.1.1 Plant height
The plant height was significantly influenced by various levels of NPK fertigation levels and its scheduling during both the years of study, while the interaction effect of fertigation levels and scheduling revealed non-significant effect during both the years of the study (Table 1).

During first year (2020-21), amongst the various NPK fertigation levels studied, significantly higher plant height of 322.23 cm was recorded under treatment F_1 (fertigation at 120 % of RDF) which was statistically *at par* with F_2 (fertigation at 100 % RDF). Second year and pooled analysis of data also revealed that maximum plant height of 325.49 and 324.01 cm recorded under treatment F_1 were statistically *at par* with F_2 *i.e.* 318.08 and 316.62 cm, respectively. Significantly lower plant height of 296.51 and 295.02 cm were recorded under F_4 (fertigation at 60 % of RDF) during first and second year, respectively.

Among scheduling higher plant height (319.20, 322.05 and 320.62 cm) was recorded under scheduling S_1 which was statistically *at par* with S_3 (310.59, 3313.65 and 312.12 cm) and both S_1 and S_3 were significantly better over S_2 during first year, second year and pooled data, respectively.

There was a significant difference in plant height between the control (soil application of RDF with surface irrigation) and fertigation treatments during both the years of study. Pooled data revealed that the plants under control treatment registered significantly lower value of 281.76 cm with respect to plant height as compared to 310.81 cm in fertigation treatments.

Plant height was found to increase with increasing the fertigation levels may be due to the fact that increased availability of fertilizer increased photosynthetic activity, chlorophyll formation, nitrogen metabolism and auxin contents in the plants which ultimately improved the plant height. Ameta *et al.* (2021) [2] also reported similar results where they recorded maximum plant height in polyhouse condition of tomato under fertigation at 125 per cent of RDF. The higher plant height was obtained in fertigation scheduling S_1 which might be due to the increased availability of fertilizers through fertigation during the active plant growth period which flavours.

3.1.2 Stem diameter

Table 1: Effect of NPK fertigation levels and its scheduling on growth parameters of tomato

Treatments	Plant height (cm)			Stem diameter (mm)			Days to 50 % of flowering		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Fertigation levels									
F_1	322.53	325.49	324.01	15.00	15.29	15.14	34.10	35.05	34.57
F_2	315.15	318.08	316.62	14.09	14.65	14.37	36.10	37.07	36.58
F_3	304.09	307.12	305.60	13.18	13.92	13.55	37.99	38.78	38.38
F_4	293.53	296.51	295.02	12.24	13.25	12.74	39.43	40.30	39.86
SEm ±	5.31	5.37	5.32	0.47	0.33	0.36	0.62	0.66	0.65
CD (5%)	15.51	15.66	15.52	1.38	0.97	1.05	1.82	1.93	1.91
Scheduling									
S_1	319.20	322.05	320.62	13.91	14.52	14.21	36.41	37.34	36.87
S_2	296.69	299.70	298.19	13.32	14.02	13.67	37.57	38.46	38.01
S_3	310.59	313.65	312.12	13.65	14.29	13.97	36.74	37.60	37.16
SEm ±	4.60	4.65	4.60	0.41	0.29	0.31	0.54	0.57	0.57
CD (5%)	13.43	13.57	13.44	NS	NS	0.91	NS	NS	NS
Control vs Rest									
Control	280.25	283.26	281.76	11.23	12.30	11.76	41.50	42.43	41.96
Rest	308.83	311.80	310.31	13.62	14.28	13.95	36.91	37.80	37.35
SEm ±	9.58	9.67	9.58	0.85	0.60	0.65	1.12	1.19	1.18
CD (5%)	27.97	28.24	27.97	2.50	1.74	1.90	3.28	3.48	3.44
Interaction (F×S)									
SEm ±	9.20	9.29	9.20	0.52	0.57	0.62	1.07	1.14	1.13
CD (5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS

The uptake of nutrients and subsequently promote the vegetative growth of plant in terms of height. The above findings are in agreement with Pandey (2017) [13].

Stem diameter of tomato was significantly influenced by drip fertigation levels but it was not significantly influenced by scheduling of fertigation through drip. The interaction of fertigation levels and scheduling also had non-significant impact.

Among the different fertigation levels tested, during first year (2020-21), maximum stem diameter was measured in F_1 (15.00 mm) which was statistically *at par* with F_2 (14.09 mm) while, minimum stem diameter measured in F_4 (12.24 mm). Similar trends were also recorded during second year and pooled analysis of both the years.

Analysis of data clearly revealed that there is significant variation in stem diameter in plant between control and other fertigation treatments in both the years of study. Pooled data of both the years indicated that the plants under control treatment registered significantly minimum stem diameter of 11.76 mm compared to fertigation treatments having stem diameter of 13.95 mm.

The increase in stem diameter due to fertigation might be due to the optimize use of water and fertilizer by crop as fertilizers are applied specific growth stage in the correct doses along with precise amount of water which ensures a healthy soil environment for better uptake of nutrient resulted in higher plant growth and development compared to conventional methods (Solaimalai *et al.*, 2005) [18].

3.1.3 Days to 50 per cent flowering

The data presented in Table 1 revealed that days to 50 percent flowering in tomato was significantly influenced by drip fertigation levels but it was not significantly influenced by scheduling of fertigation through drip. The interaction of fertigation levels and scheduling was also found non-significant during the investigation.

During first year (2020-21), significantly minimum days taken for 50 per cent of flowering were counted in F_4 (34.10 days), whereas significantly maximum days were recorded in F_1 (39.43 days). During second year and pooled analysis of data also revealed similar trend as observed during first year and second year. The comparison between control and fertigation treatments revealed that there was a significant variation in days taken for 50 per cent of flowering. Pooled data of both the years revealed that the days taken for 50 per cent of flowering was significantly maximum case of fertigation treatments (37.35 days) than that observed in control (41.96 days). Under reduced level of fertigation, crop experienced the nutrient stresses during the initial stage because of that the vegetative growth of crop was reduced. The judicious and frequent application of nutrients to crop extended the vegetative phase of crop results in more number of days required to 50 per cent of flowering. Similar trend was also noticed by Umamaheswarappa *et al.* (2005) [21] and Tiwari (2013) [19] in cucumber.

3.2 Yield parameters

3.2.1 Number of fruits per cluster

Number of fruits per cluster of tomato was significantly influenced by both the factors, *i.e.* different NPK drip fertigation levels and its scheduling, while non-significant effect was observed for interaction of these two factors (Table 2).

Among the different fertigation levels tested, during first year (2020-21), maximum number of fruits per cluster was measured in F_2 (4.77) which was statistically *at par* with F_1 (4.49), while minimum number of fruits per cluster was measured in F_4 (3.72).

Among the different scheduling methods, pooled data of both the year indicate significantly maximum number of fruits per cluster (4.79) was measured in S_1 followed by S_3 (4.31) while minimum number of fruits per cluster was measured in S_2 (4.05). Similar trends were also observed during first and second year of study.

The comparative performance evaluation between control and fertigation treatments revealed that they differ significantly with respect to number of fruits per cluster in both the years of study. Under control treatment the number of fruits per cluster measured was 3.39 and 3.59 as compared to 4.31 and 4.48 under fertigation treatments in first and second year, respectively. Pooled analysis of data also revealed similar trend as observed during first year and second year.

Increased number of fruits per cluster with increasing the fertigation levels may be due to the fact that higher fertigation dose influenced the plants to extend their flowering period and enlarged the duration of reproductive phase significantly over the smallest nutrient dose. Similar findings were made by Bhattarai *et al.* (2013) [4].

3.2.2 Fruit yield per plant

Table 2: Effect of NPK fertigation levels and its scheduling on yield parameters of tomato

Treatments	Number of fruits per cluster			Fruit yield per plant (kg)			Fruit yield (t ha^{-1})		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Fertigation levels									
F_1	4.49	4.74	4.62	4.23	4.36	4.30	176.24	178.34	177.74
F_2	4.77	5.00	4.89	4.71	4.85	4.78	180.29	184.78	181.96
F_3	4.24	4.33	4.29	3.62	3.71	3.67	169.62	173.01	171.29
F_4	3.72	3.84	3.78	2.98	3.11	3.05	160.18	163.56	161.85
SEm ±	0.16	0.17	0.15	0.11	0.09	0.10	2.94	3.02	2.99
CD (5%)	0.47	0.49	0.45	0.33	0.26	0.28	8.60	8.80	8.72
Scheduling									
S_1	4.65	4.94	4.79	4.49	4.59	4.54	178.68	182.06	180.37
S_2	4.00	4.11	4.05	3.37	3.47	3.42	163.01	167.23	164.68
S_3	4.24	4.38	4.31	3.80	3.97	3.89	169.56	171.80	170.68
SEm ±	0.14	0.15	0.13	0.10	0.08	0.08	2.55	2.61	2.59
CD (5%)	0.40	0.43	0.39	0.28	0.23	0.24	7.44	7.62	7.55
Control vs Rest									
Control	3.39	3.59	3.49	2.33	2.47	2.40	143.51	146.90	145.20
Rest	4.31	4.48	4.39	3.89	4.01	3.95	172.08	175.42	173.71
SEm ±	0.29	0.30	0.28	0.20	0.16	0.17	5.31	5.44	5.38
CD (5%)	0.84	0.89	0.81	0.59	0.47	0.50	15.50	15.87	15.71
Interaction (F×S)									
SEm ±	0.27	0.29	0.26	0.19	0.15	0.16	5.10	5.20	5.17
CD (5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Fruit yield per plant of tomato was significantly influenced by both the factors, *i.e.* different NPK fertigation levels and its scheduling, while the interaction of these two factors were observed to be non- significant.

As far as different fertigation levels tested, during first year (2020-21), significantly maximum fruit yield per plant was measured in F_2 (4.71 kg) followed by F_1 (4.23 kg) while significantly minimum fruit yield per plant was measured in F_4 (2.98 kg). Similar trends were also observed during second year and pooled data analysis.

Among the different scheduling methods, during first year (2020-21), maximum fruit yield per plant was measured in S_1

(4.49 kg) and was significantly better over other treatments, while statistically minimum fruit yield per plant was measured in S_2 (3.37 kg). Similar trends were also recorded during second year and with pooled data of both the years.

The comparative performance evaluation between control and fertigation treatments revealed that they differ significantly with respect to average fruit weight in both the years of study. Pooled data of both the years indicated that the plants under fertigation treatment registered 64.58 per cent higher fruit yield per plant compared to control treatment.

The maximum fruit yield per plant under fertigation with 100 per cent of RDF might be due to the uniform distribution and adequate availability of plant nutrients in root zone that triggered the growth and yield attributes of crop which ultimately reflected into better fruit development, while higher dose of nutrients promote more vegetative growth than fruit development. On the other hand conventional method of fertilizer application recorded minimum fruit yield per plant as leaching losses of nutrients because poor root development with restricted uptake of nutrients giving poor plant growth with smaller fruit size. Similar results were also reported by Singh *et al.* (2014) [17]. Shedeed *et al.* (2009) [16] also endorsed the present findings of increased yield of tomato due to enhanced photosynthesis resulting in increased fruit size and number.

3.2.3 Fruit yield per hectare

Fruit yield per hectare varied significantly due to fertigation levels and scheduling. Similar to both first and second year, pooled data of both the years indicate that the fruit yield obtained with 120 per cent of RDF (177.74 t ha^{-1}) and fruit yield obtained with 100 per cent of RDF (181.96 t ha^{-1}) applied through drip were statistically *at par*, but significantly better over 80 per cent (171.29 t ha^{-1}) and 60 per cent (161.85 t ha^{-1}) of RDF.

Fruit yield per hectare of tomato also significantly varied due to scheduling. Pooled analysis of data revealed that scheduling S_1 registered significantly higher fruit yield of 180.37 t ha^{-1} followed by S_3 (170.68 t ha^{-1}). While, minimum fruit yield of 164.68 t ha^{-1} was weighted in scheduling S_2.

On the basis of pooled data, comparison in fruit yield per hectare between control and other fertigation treatments revealed that fertigation treatments registered a significantly higher fruit yield of (173.71 t ha^{-1}) and it was higher by 19.63 per cent over the control plots (145.20 t ha^{-1}).

Application of 120 per cent of RDF through fertigation resulted in lower yield than 100 per cent RDF, though the yields recorded from 120 per cent of RDF application were statistically *at par* with yields recorded from 100 percent RDF application through fertigation. It may be due to the excessive dry matter production due to higher dose of N and K which lead to luxury consumption of K and higher accumulation of N in the leaves. It is supported by the fact that the dry matter production with the application of 120 per cent of RDF through fertigation was the highest at all the stages of crop. Similar results were reported by Jainu *et al.* (1987) [10] who studied the effects of furrow and trickle irrigation in Brinjal.

Maximum yield under scheduling S_1 might be attributed to the increase in all the yield attributing characters due to balanced application of NPK throughout the crop period which enhances the availability and uptake of nutrients both by the plants and fruits. Besides it is evident from the data that the maximum NPK uptake of plants and fruits was higher in the scheduling S_1. Present findings were also supported by Castoldi *et al.* (2009) [5] and Filho *et al.* (2017) [7].

3.3 Nutrient content in plant

3.3.1 Nitrogen content in plant

The nitrogen content of plant was significantly influenced by fertigation levels as well as scheduling during both the year of study while interaction between fertigation levels and scheduling was not found significant for both the years of study (Fig 1).

Increasing the dose of fertilizers through drip increased the nitrogen content in plant. The nitrogen content of plant found to be increased gradually from vegetative stage to flowering stage to fruit ripening stage and to harvesting stage. At the time of harvesting maximum nitrogen content of 2.40, 2.42 and 2.40 per cent was recorded in treatment F_1 statistically *at par* by 2.38, 2.40 and 2.39 per cent in F2 during first year, second year and pooled data of both the years, respectively.

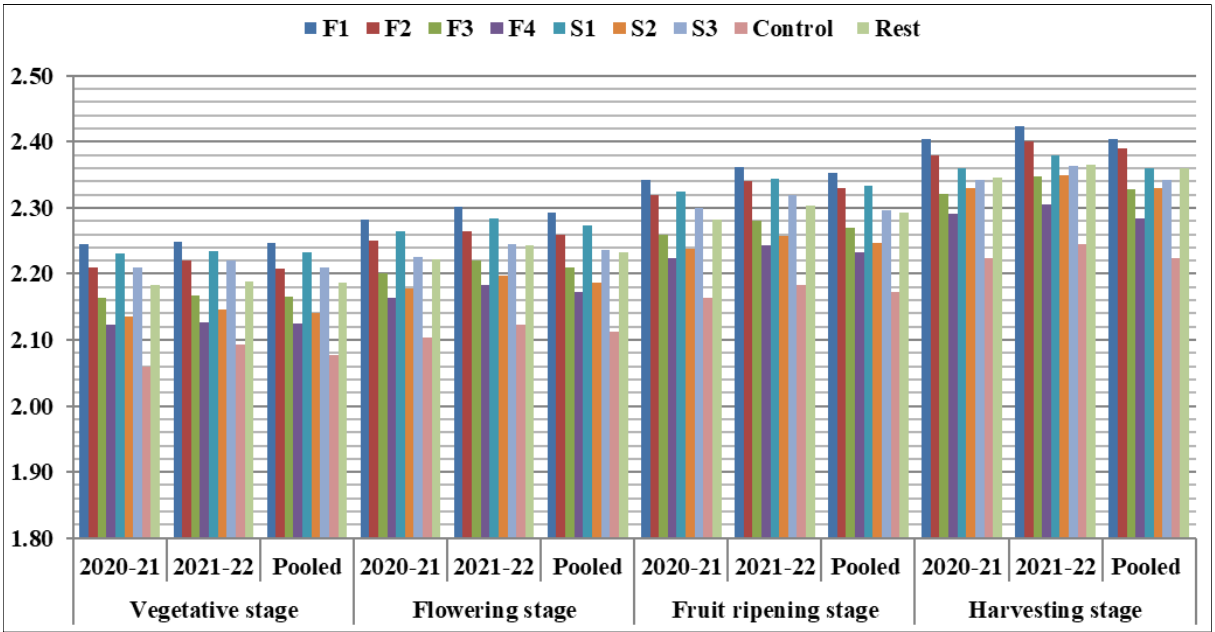

Fig 1: Effect of NPK fertigation levels and its scheduling on nitrogen content of plant

In first year (2020-21), at vegetative stage highest nitrogen content in plant was recorded in scheduling S_1 (2.23%), which was statistically *at par* with S_3 (2.21%). Likewise, in second year (2021-22), the highest nitrogen content of 2.28 per cent was recorded in scheduling S_1. Similar sequences were also evident at flowering and fruit ripening stage. At the time of harvesting, there was non-significant effect of scheduling on plant nitrogen content in both the years.

Comparison between soil application of RDF with surface irrigation (control) and fertigation treatments revealed that they differ significantly in both the years with respect to nitrogen content in plant at vegetative stage, flowering stage, fruit ripening stage and as well as at harvest. At harvesting stage, control registered a nitrogen content of 2.22, 2.24 and 2.23 per cent nitrogen in plant as compared to 2.35, 2.50 and 2.36 per cent under fertigation treatments during first year, second year and pooled data, respectively.

The higher nitrogen content in plant under fertigation treatments may be due to precise, frequent and direct application of fertilizers through drip in the root zone which led to minimum leaching losses compared to conventional method of fertilizer application and favoured higher uptake of nitrogen which ultimately increase the nitrogen content in plants. These results are similar to the results of Verma (2013) [22] in cauliflower.

3.3.2 Phosphorus content in plant

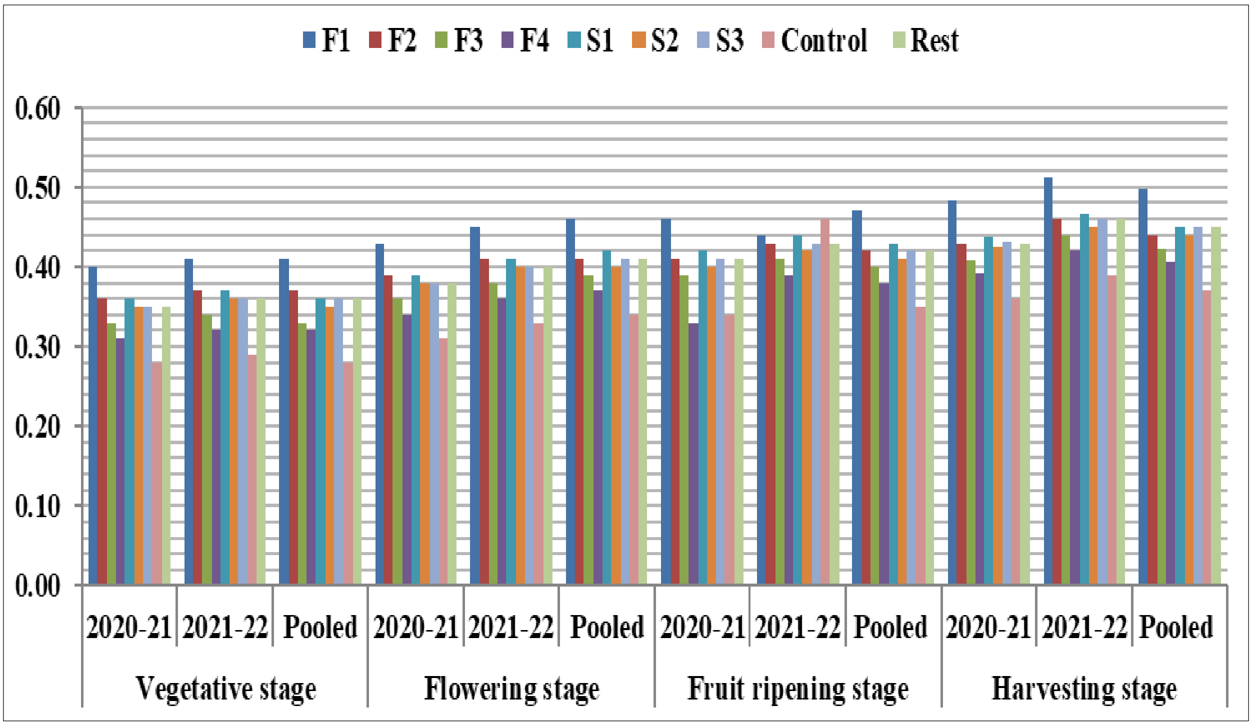

Fig 2: Effect of NPK fertigation levels and its scheduling on phosphorus content of plant

Phosphorus content in plant at vegetative stage, flowering stage, fruit ripening stage and at harvest was significantly affected by drip fertigation levels. First year, second year and pooled data of both the year indicate that phosphorus content increased gradually with the advancement of growth stage from vegetative to flowering to fruit ripening and then to harvesting stage. Among the different fertigation levels, treatment F_1 registered significantly higher phosphorus content which was *at par* with F_2.

Phosphorus content in plant was not significantly influenced by the scheduling of fertigation levels. Similarly, interaction between fertigation levels and scheduling was also found non-significant for both the years of study.

The comparison between control and fertigation treatments revealed that they differ significantly with respect to plant phosphorus content in both the years of study. Pooled data analysis showed the phosphorus content of 0.36 per cent was obtained in fertigation treatment and was significantly more than control condition (0.28 %) at vegetative stage. Pooled data analysis showed the phosphorus content of 0.75 per cent under control as compared to 0.42 per cent under fertigation treatments at fruit ripening stage. Similar trends were also observed at the time of harvesting also.

The higher phosphorus in plant was recorded with higher level of fertigation which could be ascribed to better and timely availability of water and nutrients. Due to this, the force exerted by the plants to extract water and nutrients would be less and this might have enabled the crop to put forth better nutrient content in plant (Al-Mohammadi and Al-Zu'bi, 2011) [1].

3.3.3 Potassium content in plant

Potassium content in the plant increased significantly throughout the growth period in tomato. At harvesting stage, similar to vegetative and flowering stage statistically higher value of potassium was obtained with treatment F_1 compared to other treatments but statistically *at par* with F_2 on the basis of pooled data.

The potassium content in plant was also influenced by the scheduling of fertigation levels. At vegetative stage there was no significant effect of scheduling on potassium content in plant. However, it differed significantly at flowering stage to fruit ripening stage and then to harvesting stage. At harvesting stage, the highest potassium content of 1.32 and 1.34 per cent was recorded in scheduling S_1 in both the years followed by 1.29 and 1.31 per cent in case of scheduling S_3 during first and second year, respectively.

The difference between the soil application of RDF with surface irrigation (control) and rest of the fertigation treatments was also found significant for both the years of study. At harvesting stage, it was 1.16, 1.18 and 1.17 per cent as compared to 1.28, 1.30 and 1.29 per cent under fertigation treatments during first year, second year and pooled data, respectively.

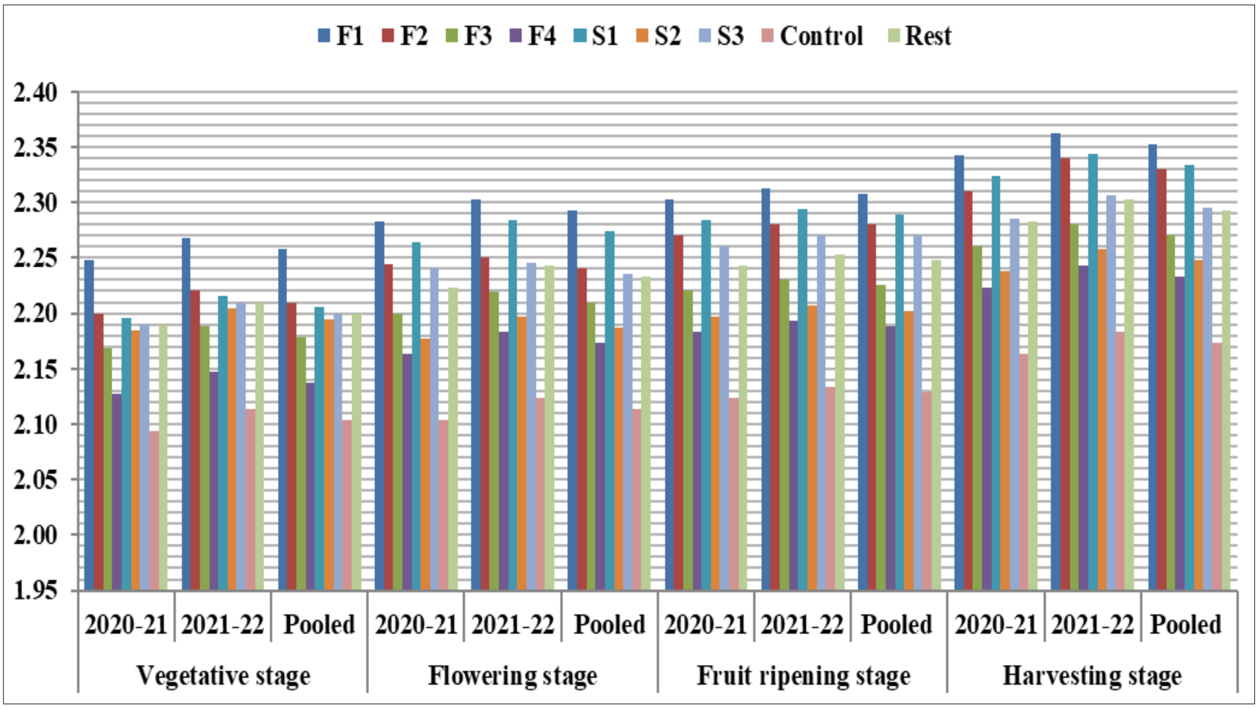

Fig 3: Effect of NPK fertigation levels and its scheduling on potassium content of plant

Significant and higher values of potassium content in plant under fertigation at 120 per cent of RDF as compared to lower level of fertigation and conventional method of fertilizer application was attributed to favorable nutrient-water interaction in the root zone, which in turn resulted in increased nutrient use efficiency and there by improved nutrient status of tomato. These results are in agreement with the finding such as Selim *et al.* (2010) [15].

3.4 Nitrogen, Phosphorus and Potassium content in fruit

Fertigation levels had a significant effect on NPK content of fruits during both the years of study, while the effect of scheduling of NPK through fertigation and their interaction had non-significant effect on NPK content of tomato fruit (Table 3).

Fertigation at 120 per cent of recommended dose registered significantly higher nitrogen content (1.95 %) statistically *at par* with 100 per cent of recommended dose (1.89%), while 60 per cent of recommended dose registered lowest value (1.78 %) on the basis of pooled data of both the years. Phosphorus content in tomato fruit was recorded significantly higher in treatment F_1 (0.40 %) followed by F_2 (0.37 %) on the basis of pooled data. During first year of study, highest potassium content 2.80 per cent was noted in treatment F_1 followed by F_2 (2.76 %). Likewise, during second year of study, highest potassium content in fruits was recorded in treatment F_1 (2.81 %) followed by 2.77 per cent in F_2.

Table 3: Effect of NPK fertigation levels and its scheduling on NPK content in fruits

Treatments	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Fertigation levels									
F_1	1.94	1.96	1.95	0.39	0.40	0.40	2.80	2.81	2.81
F_2	1.88	1.90	1.89	0.35	0.37	0.36	2.76	2.77	2.77
F_3	1.83	1.85	1.84	0.30	0.32	0.31	2.73	2.74	2.73
F_4	1.77	1.79	1.78	0.27	0.29	0.28	2.71	2.72	2.72
SEm ±	0.03	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.01
CD (5%)	0.10	0.10	0.10	0.03	0.03	0.03	0.04	0.04	0.04
Scheduling									
S_1	1.91	1.93	1.92	0.33	0.35	0.34	2.76	2.77	2.76
S_2	1.80	1.82	1.81	0.32	0.34	0.33	2.75	2.76	2.75
S_3	1.85	1.87	2.27	0.33	0.35	0.34	2.75	2.76	2.76
SEm ±	0.03	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.01
CD (5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Control vs Rest									
Control	1.68	1.70	1.69	0.21	0.23	0.22	2.68	2.69	2.68
Rest	1.85	1.87	1.86	0.33	0.35	0.34	2.75	2.76	2.76
SEm ±	0.06	0.06	0.06	0.02	0.02	0.02	0.02	0.02	0.02
CD (5%)	0.18	0.18	0.18	0.06	0.06	0.06	0.07	0.07	0.07
Interaction (F×S)									
SEm ±	0.05	0.05	0.05	0.02	0.02	0.02	0.02	0.02	0.02
CD (5%)	NS	NS	NS	NS	NS	NS	NS	NS	NS

There was a significant difference in NPK content of fruits between control and other fertigation treatments. Pooled analysis of data also revealed the minimum nitrogen content of fruit (1.69 %) in control when compared to fertigation treatments (1.86 %). Similar trend was observed in phosphorus content in fruit. In control, potassium content in tomato fruits was 2.68, 2.69 and 2.68 per cent as compared to 2.75, 2.76 and 2.76 per cent in other fertigation treatments in first year, second year and pooled analysis of data, respectively.

Significant and higher values of nitrogen, phosphorus and potassium content in fruits of tomato were observed under fertigation as compared to traditional method of irrigation and fertilization. It could be attributed to timely and better availability of water and nutrients which leads to favorable nutrient-water interaction in the root zone which in turn resulted in increased nutrient use efficiency and thereby improved nutrient status of fruit. These results are in agreement with the finding of Selim *et al.* (2010) [15] in potato. Ughade *et al.* (2016) [20] also recorded higher NPK content of fruit in tomato fertigated with higher dose of fertilizer.

4. Conclusion

Performance of tomato was significantly influenced by different drip fertigation levels and scheduling. Among the different fertigation levels, fertigation of tomato at 120 and 100 per cent of RDF was found *at par* and significantly better over other fertigation levels with respect to plant growth parameter, yield parameters and nutrient content. Among the three scheduling tested, scheduling S_1 was found best in terms of yield parameters. On the basis of pooled data, fertigation at 100 per cent of RDF with scheduling S_1 recorded higher yield was best treatment combination. Based on the overall performance, it could be concluded that under naturally ventilated polyhouse, fertigation of tomato at 300:150:150 kg N, P_2O_5 and K_2O ha^{-1} (F_2) through scheduling S_1 (15, 10 and 10 per cent N, P_2O_5 and K_2O of fertigation levels between 15-45 DAT, respectively, 40, 40 and 40 per cent N, P_2O_5 and K_2O of fertigation levels between 46-76 DAT, respectively, 30, 40 and 40 per cent N, P_2O_5 and K_2O of fertigation levels between 77-107 DAT, respectively, 15, 10 and 10 per cent N, P_2O_5 and K_2O of fertigation levels between 108-138 DAT, respectively) is the best and most economical for cultivation of tomato. Hence, the same is recommended for polyhouse cultivation.

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