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FERTIGATION SCHEDULING TO SUMMER TOMATO (*SOLANUM LYCOPERSICUM* L.) UNDER PROTECTED CULTIVATION

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ABSTRACT

Among fertigation levels fertigation of 100% RDF recorded significantly maximum growth attributes *viz.*, plant height, number of branches, number of leaflets and leaf area plant^{-1}, yield attributes *viz.*, number of fruits plant^{-1} (74.13, 67.50 and 70.82), fruit weight plant^{-1} (4.85, 4.43 and 4.64 kg) and tomato fruit yield unit^{-1} of polyhouse (15.72, 14.07 and 14.90 t) and quality parameters *viz.*, TSS, Titrable acidity, Ascorbic acid, Lycopene content, Carotene content and Pericarp thickness as compared to rest of treatments during both the years and on pooled mean, however at par with 80% RDF. Among the fertigation schedules fertigation of 12 equal splits of NPK at every 9 days interval registered significantly maximum all the growth attributes, yield attributes *viz.*, number of fruits plant^{-1} (72.54, 66.30 and 69.44), fruit weight plant^{-1} (4.80, 4.24 and 4.52 kg) and tomato fruit yield unit^{-1} of polyhouse (15.56, 13.42 and 14.49 t) and quality parameters over rest of treatments during both years and on pooled mean. Based on two years of investigation it concluded that fertigation of 80% RDF in 12 equal splits at every 9 days interval found most suitable to achieve maximum fruit yield and quality of tomato during summer season under polyhouse.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is an important and widely grown solanaceous vegetable crop around the world and belongs to the family *Solanaceae*. It is considered an important source of vitamin A, C and minerals (Hari, 1997). Apart from this, lycopene is valued for its anti-cancer property (Bose *et al.*, 2002). It acts as an antioxidant and scavenger of free radicals, which is often associated with carcinogenesis. Thus, lycopene has got great beneficial effects on human health. It may also interfere with oxidative damage to DNA and lipoproteins and inhibits the oxidation of LDL (low density lipoprotein) cholesterol.

Protected cultivation 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. These technologies are not only creates avenues at higher level, but also keeps the growers with the smaller landholdings at the higher productivity levels and retain economic relevance to agriculture. Controlled environment agriculture (CEA) is highly productive, conservative of water, fertilizers and land and also protective of the environment like the temperature, humidity, light (Jensen, 2002). By adopting protected cultivation technology, the growers can look forward to a better and additional remuneration for high quality produce. Poly house is a framed or inflated structure covered with transparent or translucent polythene papers, large enough to grow crops under partial or fully controlled environmental conditions to get optimum growth and productivity. Flowering and fruit setting in poly house were advanced by 3 to 4 days as compared to field condition. Similarly, tomato plants grown under poly house showed the best performance in terms of vegetative and reproductive development, yield contributing characters and total yield. The fruit yield obtained from the poly house was about 29% higher than open space due to optimum temperature and low relative humidity suitable for tomato production in poly house (Rasel Parvej, 2012).

Fertigation is an excellent method of optimizing the utilization of water and nutrients to improve the sustainability of poly house tomato. It allows frequent, uniform and precise application of nutrients through drip directly into the zone of maximum root activity as per need of crop which results into higher fruit yield and quality. In fertigation nutrient use efficiency could be as high as 90 per cent as compared to 40 per cent in conventional methods (Solaimalai *et al.*, 2005). Depite these improvements in the efficiency of fertilizer the timing and rate of fertigation for green house tomato is far from optimal. The concentration of NPK of the nutrient solutions and the application time and intervals are of vital importance for adequate uptake and optimal growth of tomato. However, the objective of this research is to evaluate the growth, yield and quality under different ferti gation levels and schedules under poly house condition.

MATERIALS AND METHODS

The present investigation was carried out during summer season of 2013 and 2014 at Department of Agronomy, M.P.K.V., Rahuri (M.S.). The soils of the experimental site was sandy clay in texture having pH- 7.70, organic carbon 0.53% with low in available nitrogen (254.7 kg ha^{-1}), medium in available phosphorous (19.73 kg ha^{-1}) and very high in available potassium (369.5 kg ha^{-1}). Similarly, low in iron (4.44 mg kg^{-1}) and zinc (0.49 mg kg^{-1}) and moderate in manganese (2.35 mg kg^{-1}) and copper (1.49 mg kg^{-1}). The field capacity, permanent wilting point and bulk density were 22.74%, 11.37% and 1.39 g cm^{-3}, respectively. The method used for estimation of available N in soil was Modified alkaline Permanganate (Saharawat and Buford, 1982), for Available P in soil 0.5M $NaHCO_3$ (P^H 8.5) (Olsen *et al.*, 1954) and for Available K in soil NN NH_4OAc (Knudsen *et al.*, 1982). The micronutrients *viz.*, DTPA Cu, Mn, Cu and Fe were estimated using Atomic absorption spectrophotometer (Lindsay and Norvell, 1978). The pH of soil was determined by Potentiometric method (Jackson, 1973), organic carbon by Wet oxidation method (Nelson and Sommer, 1982). The field capacity (%) and Permanent wilting point (%) were estimated by using Pressure Plate Apparatus (Richards, 1947). The Core sampler method used for determination of bulk density (Dastane, 1972). Fruit quality parameters *viz.*, pH, TSS, Titrable acidity, Ascorbic acid, Lycopene and Carotene content were analyzed with the help NIR-Spectrophotometer.

The experiment was laid out in split plot design and replicated thrice with nine treatment combinations. The treatments includes 3 fertigation levels *viz.*, (F_1-60% of RDF (180:90:90 N, P_2O_5, K_2O kg ha^{-1}), F_2-80% of RDF (240:120:120 N, P_2O_5, K_2O kg ha^{-1}) and F_3-100% of RDF (300:150:150 N, P_2O_5, K_2O kg ha^{-1}) and 3 fertigation schedules *viz.*, (S_1- 6 equal splits of RD of NPK at every 18 days interval, S_2- 9 equal splits of RD of NPK at every 12 days interval, S_3- 12 equal splits of RD of NPK at every 9 days interval). The naturally ventilated poly house (784 m^2) was oriented in north-south direction and covered with UV stabilized LDPE film of 200 micron thickness as cladding material. The four week old healthy and uniform tomato seedlings were transplanted at the spacing of 60 cm x 50 cm on the raised beds. Fertigation was started 12 days after transplanting through Automatic Fertigation Unit as per treatment. The fertigation was done by using water soluble fertilizer (19:19:19 NPK grade) and urea (46.6% N). All the agronomic practices and plant protection measures were adopted as per recommendation. Observations on different growth and yield parameters were recorded from five randomly sampled plants from each treatment.

RESULTS AND DISCUSSION

Effect of fertigation levels

A reference to two years data (Table 1) on the growth attributes studied, plant height, number of primary branches $plant^{-1}$, number of leaflets $plant^{-1}$ and leaf area $plant^{-1}$ were significantly influenced by different fertigation levels and schedules. These parameters showed better performance with increasing fertigation level and frequent application of NPK. Among the fertigation levels, the fertigation of 100% RDF recorded significantly higher growth parameters *viz.*, plant height (210.60 and 223.83 cm), number of primary branches $plant^{-1}$ (15.11 and 14.62), number of leaflets $plant^{-1}$ (80.60 and 78.65) and leaf area $plant^{-1}$ (88.07 and 97.65 dm^2), whereas minimum values of these parameters were registered with fertigation of 60% RDF. This might be due to increased supply of nitrogen, phosphorous and potassium through fertigation to the plant root zone meets the nutrition demands of cropwhich supported in maximum absorbance of moisture and nutrients by crop that accelerate the plants metabolic activities and reflected in higher cell growth. The another reason is that, increased level of fertigation leads to increased photosynthetic activities, protein synthesis and assimilate translocation due to suitable environmental conditions was provided in poly house that activates enzyme activities resulted in more growth attributes. These results were with the conformity of Kavitha *et al.* (2007), Brahma *et al.* (2009).

Fertigation of NPK with different levels significantly influenced the yield attributing parameters of polyhouse tomato. A perusal of pooled data (Table 2) indicated that fertigation of 100% RDF recorded significantly higher number of fruits $plant^{-1}$ (74.13, 67.50 and 70.82) and fruit weight $plant^{-1}$ (4.85, 4.43 and 4.64 kg) as compared to rest of the fertigation levels during both the years and on pooled mean, respectively, however it was at par with fertigation of 80% RDF. While lowest number of fruits and fruit weight $plant^{-1}$ was noticed under the fertigation of 60% RDF during the study of experimentation. This might be because of enhanced supply of nitrogen, phosphorous and potassium in the root rhizosphere increases the uptake of nutrients and favourable microclimatic conditions was optimized inside poly house with maintaining optimum temperature, CO_2 concentration, high relative humidity that enhanced luxurious growth of crop which helps to absorbed more PAR accompanied with increased enzyme actions aids in higher rate of photosynthesis and dry matter accumulation reflected in efficient translocation of sugar and starches towards reproductive parts reflected in increase in yield attributes. These results are in the line of Hasan *et al.* (2014), Singh *et al.* (2015).

Significant effect of fertigation was observed on the fruit yield of tomato inside poly house (Table 2). Pooled data averaged over the two years revealed that the fruit yield of tomato increased significantly with increasing level of fertigation. The maximum fruit yield $unit^{-1}$ of poly house (15.72, 14.07 and 14.90 t) was recorded with fertigation of 100% RDF during both the years and on pooled mean, respectively. However it was at par with 80% RDF indicating 20% saving of fertilizers. While, fertigation of 60% RDF produced significantly minimum fruit yield $unit^{-1}$ of polyhouse (11.24, 9.51 and 10.37 t) during both the years and on pooled mean, respectively. The increased magnitude in fruit yield $unit^{-1}$ of polyhouse under the fertigation of 100% RDF over 60% RDF was 28.49, 32.41 and 30.40% during both the years and on pooled mean. The 100% RDF applied through fertigation directly in the active root zone of the plant increases the nutrient use efficiency indicated through enhanced nutrient uptake by crop. As the crop grown on raised beds under poly house condition which helps to maintain the proper proportion of air:soil:water and nutrient throughout the crop growth period. The microclimate in the poly house was more favourable to increase the growth and yield attributes of tomato crop. The higher rate of photosynthate translocation from vegetative part (source) to reproductive organs (sink) might be increased the fruit size and weight which resulted in higher fruit yield of tomato. Similar findings were reported by Nagre *et al.* (2013), Patel *et al.* (2013) Kuscu *et al.* (2014).

A data speculated in (Table 3) revealed that tomato fruit quality

Table 1: Growth attributes of tomato as influenced by different treatments

Treatments	Plant height(cm)		Number of primary branches plant⁻		Number of leaflets plant^{-1}		leaf area plant^{-1} (dm^{-2})	
	2013	2014	2013	2014	2013	2014	2013	2014
A. Fertigation levels								
F_1 – 60% of RDF	200.51	216.12	13.07	13.53	93.96	93.59	128.85	127.35
F_2 – 80% of RDF	207.37	219.08	14.38	14.31	97.38	97.14	131.25	128.98
F_3 – 100% of RDF	210.60	223.83	15.11	14.62	101.30	98.16	132.63	130.85
S.Em (±)	0.93	0.52	0.19	0.08	0.30	0.32	0.37	0.48
C.D. (p=0.05)	3.64	2.06	0.76	0.32	1.18	1.26	1.48	1.89
B. Fertigation schedules								
S_1 – 6 equal splits (18 days interval)	204.38	217.52	13.24	13.91	94.49	94.90	130.16	127.88
S_2 – 9 equal splits (12 days interval)	206.68	219.54	14.34	14.20	97.19	96.71	131.06	129.10
S_3 – 12 equal splits (9 days interval)	207.42	221.97	14.99	14.36	100.96	97.28	131.51	130.20
S.Em ±	0.60	0.57	0.22	0.05	0.45	0.19	0.15	0.40
C.D. (p=0.05)	1.85	1.75	0.67	0.16	1.38	0.58	0.45	1.24
Interaction (A X B)								
C.D. (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 2: Yield attributes and yield of tomato as influenced by different treatments

Treatments	Number of fruits plant^{-1}			Fruit weight plant^{-1} (kg)			Fruit yield unit^{-1} of polyhouse(t)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
A. Fertigation levels									
F_1 – 60% of RDF	56.85	52.20	54.51	3.43	3.00	3.21	11.24	9.51	10.37
F_2 – 80% of RDF	71.96	65.40	68.68	4.61	4.24	4.43	14.96	13.42	14.19
F_3 – 100% of RDF	74.13	67.50	70.82	4.85	4.43	4.64	15.72	14.07	14.90
S.Em ±	0.77	0.74	0.54	0.07	0.05	0.04	0.22	0.17	0.18
C.D. (p=0.05)	3.04	2.91	2.16	0.27	0.21	0.16	0.85	0.67	0.74
B. Fertigation schedules									
S_1 – 6 equal splits (18 days interval)	62.16	56.90	59.55	3.81	3.53	3.67	12.44	11.20	11.82
S_2 – 9 equal splits (12 days interval)	68.24	61.80	65.03	4.28	3.91	4.09	13.92	12.38	13.15
S_3 – 12 equal splits (9 days interval)	72.54	66.30	69.44	4.80	4.24	4.52	15.56	13.42	14.49
S.Em ±	0.34	0.53	0.39	0.02	0.03	0.03	0.10	0.11	0.10
C.D. (p=0.05)	1.06	1.62	1.21	0.08	0.11	0.09	0.33	0.35	0.30
Interaction (A X B)									
C.D. (p=0.05)	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.

Table 3: Quality parameters of tomato as influenced by different treatments

Treatments	TSS (°Brix)		Titrable acidity(%)		Ascorbic acid (mg 100 g^{-1})		Lycopenecontent (mg 100 g^{-1})		Carotene content (mg 100 g^{-1})		Pericarp thickness(mm)	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
A. Fertigation levels												
F_1 – 60% of RDF	5.12	5.04	0.41	0.43	24.60	23.38	2.72	2.60	1.13	1.11	5.26	5.39
F_2 – 80% of RDF	5.30	5.21	0.43	0.45	25.67	24.29	2.79	2.70	1.19	1.15	5.81	5.94
F_3 – 100% of RDF	5.47	5.43	0.46	0.47	26.65	25.56	2.86	2.79	1.29	1.25	6.43	6.37
S.Em ±	0.03	0.04	0.004	0.003	0.15	0.21	0.02	0.02	0.01	0.01	0.07	0.08
C.D. (p=0.05)	0.13	0.14	0.01	0.01	0.60	0.83	0.06	0.07	0.04	0.06	0.26	0.31
B. Fertigation schedules												
S_1 – 6 equal splits (18 days interval)	5.18	5.09	0.42	0.43	24.94	23.89	2.75	2.63	1.15	1.16	5.50	5.69
S_2 – 9 equal splits (12 days interval)	5.31	5.22	0.43	0.44	25.60	24.32	2.79	2.70	1.21	1.17	5.80	5.92
S_3 – 12 equal splits (9 days interval)	5.40	5.37	0.45	0.46	26.38	25.02	2.83	2.76	1.25	1.20	6.21	6.08
S.Em (±)	0.02	0.03	0.002	0.003	0.12	0.16	0.01	0.01	0.008	0.01	0.06	0.04
C.D. (p=0.05)	0.08	0.09	0.006	0.009	0.37	0.50	0.03	0.03	0.024	0.03	0.17	0.14
Interaction (A X B)												
C.D. (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

parameters *viz.*,TSS, Titrable acidity, Ascorbic acid, Lycopene content, Carotene content and pericarp thickness were significantly influenced by different fertigation levels. Fertigation of 100% RDF recorded significantly superior fruit quality parameters of tomato *viz.*, TSS (5.47 and 5.43 °Brix), Titrable acidity (0.46 and 0.47 %), Ascorbic acid (26.65 and 25.56 mg 100 g^{-1}), Lycopene content (2.86 and 2.79 mg 100 g^{-1}), Carotene content (1.29 and 1.25 mg 100 g^{-1}) and Pericarp thickness (6.43 and 6.37 mm) during first and second year, while, minimum values of these parameters were noticed with fertigation of 60% RDF. The optimum quantity of nutrient supply by means of fertigation throughout the crop growth period enhanced the metabolic activities and photosynthetic rate which translocated the maximum photosynthates (food material) towards reproductive part resulted in increasing the total soluble solids, titrable acidity, ascorbic acid, lycopene content, carotene content and pericarp thickness of tomato fruit. The similar findings were reported by Kumar *et al*. (2013), Singh *et al*. (2015).

Effect of fertigation schedules

Growth attributing characters (Table 1) *viz*., plant height, number of primary branches plant^{-1}, number of leaflets plant^{-1} and leaf area plant^{-1} were significantly influenced by different fertigation schedules and revealed that fertigation of 12 equal splits of NPK at every 9 days interval up to 120 DAT registered significantly maximum growth attributes *viz*., plant height (207.42 and 221.97 cm), number of primary branches plant^{-1} (14.99 and 14.36), number of leaflets plant^{-1} (81.20 and 76.81) and leaf area plant^{-1} (87.51 and 87.51 dm^2), while lowest values of these parameters were noticed with fertigation of 6 equal splits of NPK at every 18 days interval up to 120 DAT. This might be due to frequent supply of fertilizers through drip irrigation in the vicinity of root zone up to 120 days after transplanting meet out the nutritional requirement of crop leads to maximum absorption and translocation of nutrients resulted in increased cell multiplication and enhanced the net assimilation rate and hence more plant height, number of primary branches plant^{-1}, number of leaflets as well as leaf area plant^{-1}. This might be also due to favourable microclimatic conditions created inside the poly house that enhanced photosynthesis and respiration leads to increased these attributes. These results were with the conformity of Yasser *et al*. (2009) and Feleafel and Mirdad (2013).

Different fertigation schedules significantly influenced the yield contributing characters (Table 2) *viz*., number of fruits plant^{-1} and fruit weight plant^{-1} Among the fertigation schedules, fertigation of 12 equal splits of NPK at every 9 days interval up to 120 DAT exhibited significantly maximum number of fruits plant^{-1} (72.54, 66.30 and 69.44) and fruit weight plant^{-1} (4.80, 4.24 and 4.52 kg) during both the years and on pooled mean, respectively. While lowest number of fruits plant^{-1} and fruit weight plant^{-1} was noticed under the fertigation of 6 equal splits of NPK at every 18 days interval up to 120 DAT during the period of investigation. This might be due to continuous split application of nutrients throughout the crop growth period enhanced growth attributes accompanied with more physiological activities and absorbed PAR reflected in higher photosynthetic rate and translocation of assimilates towards reproductive parts resulted an increase in yield attributes. Similar results were reported by Tumbare and Nikam (2004), Bahadur *et al*. (2006).

The fruit yield of tomato (Table 2) was significantly influenced by different fertigation schedules and found that fertigation of 12 equal splits of NPK at every 9 days interval up to 120 DAT recorded significantly higher fruit yield unit^{-1} of poly house (15.56, 13.42 and 14.49 t) during both the years and on pooled mean. While, fertigation of 6 equal splits of NPK at every 18 days interval up to 120 DAT produced significantly minimum fruit yield unit^{-1} of polyhouse (12.44, 11.20 and 11.82 t). The extent of increase in fruit yield unit^{-1} of poly house under the fertigation of 12 equal splits of NPK at 9 days interval up to 120 days after transplanting was 20.05, 16.54 and 18.43% over the fertigation of 6 equal splits of RD of NPK at every 18 days interval up to 120 days after transplanting during both the years and on pooled mean, respectively. This might be due to frequent application of required quantity of nutrients directly in vicinity of the root zone throughout crop growth period increased the nutrient use efficiency which enhanced growth and yield attributes and improved tomato fruit yield. Similarly the favourable microclimatic conditions maintained inside poly house helps to change the phase of plant from juvenile to reproductive phase and significantly contributed to higher fruit yield of tomato. These results are in the line of Tumbare *et al*. (2004), Singh *et al*. (2013).

Data illustrated in Table (3) indicated that the fertigation of 12 equal splits of NPK at every 9 days interval up to 120 DAT noticed significantly superior fruit quality parameters *viz*., TSS (5.40 and 5.37 °Brix), Titrable acidity (0.45 and 0.46 %), Ascorbic acid (26.38 and 25.02 mg 100 g^{-1}), Lycopene content (2.83 and 2.76 mg 100 g^{-1}), Carotene content (1.25 and 1.20 mg 100 g^{-1}) and Pericarp thickness (6.21 and 6.21 mm) during both the years, while, minimum values of these parameters were noticed with fertigation of 6 equal splits of NPK at every 18 days interval up to 120 DAT. The more frequent application of nutrients throughout the crop growth period enabled maximum absorption of nutrients along with water which synergistically flourished translocation of photosynthates towards reproductive parts that increased the higher mineral concentration in tomato fruit which helped in chemical interaction between organic constituents and enzymes activation, osmo-turgour reglation, metabolic and membrane transport process that resulted an increase in total soluble solids, titrable acidity, ascorbic acid, lycopene content, carotene content and pericarp thickness of tomato fruit. These findings are in the line of Mortley and Ntibashirwa (2012).

Based on two years of experimentation it is further concluded that to achieve maximum growth, yield and superior quality of tomato during summer season under polyhouse condition the fertigation of 80% RDF (240:120:120 N, P_2O_5, K_2O kg ha^{-1}) in 12 equal splits at every 9 days interval up to 120 days after transplanting found most suitable.

Interaction effects between fertigation levels and schedules

None of the growth characters and quality parameters of tomato were significantly influenced by interaction effects of fertigation levels and schedules.

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