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Techno-Economic Feasibility of Drip Fertigating Tomato Under Naturally Ventilated Polyhouse

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Abstract: *A two years of experiment was conducted at Post Graduate Research Farm, Department of Agronomy, Mahatma Phule Krishi Vidyapeeth, Rahuri (M.S.) to study the effect of fertigation levels and schedules on yield and monetary returns of tomato (Solanum lycopersicum L.) under naturally ventilated polyhouse. The treatments include three fertigation levels viz.,* F_1*- 60% of RDF (180-90-90 kg N-P-K/ha),* F_2*- 80% of RDF (240-120-120 kg N-P-K/ha) and* F_3*-100% RDF (300-150-150 kg N-P-K/ha) and three fertigation schedules viz.,* S_1*- 6 equal splits of RD of NPK at every 18 days interval up to 120 DAT,* S_2*- 9 equal splits of RD of NPK at every 12 days interval up to 120 DAT,* S_3*- 12 equal splits of RD of NPK at every 9 days interval up to 120 DAT. Based on two years of investigation it could be concluded that fertigation of 80% of RDF (240-120-120 kg N-P-K/ha) in 12 equal splits at every 9 days interval up to 120 days after transplanting found most suitable to achieve maximum tomato fruit yield, net monetary returns per unit of polyhouse (784 m*^{2}*) during summer season under naturally ventilated polyhouse condition.*

Keywords: *Economics, Fertigation, Polyhouse, Scheduling, Tomato, Yield.*

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. By adopting protected cultivation technology, the growers can look forward to a better and additional remuneration for high quality produce. 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). The fruit yield obtained from the polyhouse was about 29% higher than open space due to optimum temperature and low relative humidity suitable for tomato production in polyhouse (Rasel Parvej, 2012).

Fertilizer is the most critical input which seriously affects the both yield of crop and cost of cultivation. Fertigation is an excellent method of

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optimizing the utilization of water and nutrients to improve the sustainability of polyhouse 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. In addition it saves the fertilizers, time and labour. 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 fertilizer use efficiency, application timing and rate of fertilizers through drip for greenhouse tomato is far from optimal. As tomato is heavy feeder crop it responds well to increased NPK application through drip. However it is very necessary to determine the the time and frequency of fertilizer application at appropriate stages of crop. Looking to the changing climatic scenario of protected cultivation the awareness among the farming community increasing day by day because in open field condition fruit yield and returns/unit land are poor due to aberrant weather situation arises frequently.

In this direction polyhouse is the best alternative for higher production of tomato and ultimately maximum monetary returns/unit of polyhouse during off season. No much information is available on this issue, hence, the study was focused to examine the frequency and rate of fertilizer application for maximizing tomato fruit yield and obtaining the better monetary returns under controlled environment.

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.). Geographically, the site is situated between 19°47′ and 19°57′ N latitude and between 74°19′ and 74°32′ E longitude. The altitude varies from 495 to 555 m above the mean sea level. 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), medium in available phosphorous (19.73 kg/ha) and very high in available potassium (369.5 kg/ha). Similarly, low in iron (4.44 mg/kg) and zinc (0.49 mg/kg) and moderate in manganese (2.35 mg/kg) and copper (1.49 mg/kg). 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, for Available P in soil 0.5 M $NaHCO_3$ (P^H 8.5) and for Available K in soil NN NH_4OAc. The micronutrients *viz*., DTPA Cu, Mn, Cu and Fe were estimated using Atomic absorption spectrophotometer. The pH of soil was determined by Potentiometric method, organic carbon by Wet oxidation method. The field capacity (%) and Permanent wilting point (%) were estimated by using Pressure Plate Apparatus. The Core sampler method used for determination of bulk density.

The experiment was laid out in split plot design and replicated thrice with nine treatment combinations. The gross and net size of experimental plot was 8 m × 3 m. The treatments includes 3 fertigation levels *viz*., F_1-60% of RDF (180-90-90 kg N-P-K/ha), F_2-80% of RDF (240-120-120 kg N-P-K/ha) and F_3-100% RDF (300-150-150 kg N-P-K/ha) 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 polyhouse (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 × 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

Fertigation of NPK with different levels significantly influenced the yield attributing parameters of

Table 1
Yield attributes and yield of tomato as influenced by different treatments

Treatments	*Number of fruits plant^{-1}*			*Polar circumference (cm)*			*Equatorial circumference (cm)*			*Avg. fruit weight (g)*			*Fruit weight /plant (kg)*			*Fruit yield/unit of polyhouse (784 m^2) (t)*		
	2013	*2014*	*Pooled*	*2013*	*2014*	*Pooled*	*2013*	*2014*	*Pooled*	*2013*	*2014*	*Pooled*	*2013*	*2014*	*Pooled*	*2013*	*2014*	*Pooled*
A. Fertigation levels																		
F_1 – 60% of RDF	56.85	52.20	54.51	4.80	4.64	4.72	4.23	4.24	4.23	62.02	60.13	61.07	3.43	3.00	3.21	11.24	9.51	10.37
F_2 – 80% of RDF	71.96	65.40	68.68	4.91	4.69	4.80	4.38	4.29	4.34	65.85	65.93	65.89	4.61	4.24	4.43	14.96	13.42	14.19
F_3 – 100% of RDF	74.13	67.50	70.82	5.15	4.89	5.02	4.48	4.40	4.44	67.02	66.98	67.00	4.85	4.43	4.64	15.72	14.07	14.90
S.Em ±	0.77	0.74	0.54	0.01	0.03	0.01	0.01	0.01	0.01	0.32	0.27	0.28	0.07	0.05	0.04	0.22	0.17	0.18
C.D. (p=0.05)	3.04	2.91	2.16	0.05	0.12	0.05	0.04	0.06	0.04	1.25	1.06	1.14	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	4.81	4.66	4.74	4.24	4.25	4.24	62.83	63.20	63.02	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	4.94	4.73	4.84	4.39	4.30	4.35	64.42	64.49	64.44	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	5.10	4.83	4.96	4.46	4.37	4.42	67.63	65.34	66.50	4.80	4.24	4.52	15.56	13.42	14.49
S.Em ±	0.34	0.53	0.39	0.02	0.02	0.01	0.01	0.01	0.008	0.19	0.12	0.17	0.02	0.03	0.03	0.10	0.11	0.10
C.D. (p=0.05)	1.06	1.62	1.21	0.07	0.07	0.03	0.03	0.03	0.03	0.60	0.38	0.69	0.08	0.11	0.09	0.33	0.35	0.30
Interaction (A × B)																		
C.D. (p=0.05)	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.

polyhouse tomato. A perusal of pooled data (Table 1) indicated that fertigation of 100% RDF recorded significantly higher number of fruits/plant (74.13, 67.50 and 70.82), polar circumference (5.15, 4.89 and 5.02 cm), equatorial circumference (4.48, 4.40 and 4.44 cm), average fruit weight (67.02, 66.98 and 67.00 g) and fruit weight/plant (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 yield attributes were 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 polyhouse 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 fruit yield of tomato inside polyhouse (Table 1). 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 of polyhouse (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 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 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 polyhouse condition which helps to maintain the proper proportion of air:soil:water and nutrient throughout the crop growth period. The microclimate in the polyhouse 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).

The economic evaluation of tomato crop was assessed in terms of gross monetary returns, net monetary returns and B:C ratio are presented in Table 2. The gross monetary returns/unit of polyhouse was influenced significantly due to the different fertigation levels. Fertigation of 100% RDF recorded significantly maximum gross monetary returns/unit of polyhouse (Rs. 220093, 211064 and 215578) as compared to 60% RDF (Rs. 157297, 142611 and 149954) during both the years and on pooled mean. However it was at par with 80% RDF (Rs. 209495, 201257 and 205376) during both the years and on pooled mean.

The net monetary returns/unit of polyhouse was influenced significantly due to the different fertigation levels. Fertigation of 100% RDF recorded significantly maximum net monetary returns/unit of polyhouse (Rs. 159810, 150474 and 155142) than 60% RDF (Rs. 99547, 84555 and 92051) during both the years and on pooled mean, however it was at par with 80% RDF (Rs. 150478, 141934 and 146206) during both the years. Fertigation of 100% RDF recorded maximum B:C ratio/unit of polyhouse (3.65, 3.48 and 3.57) as compared to 60 (2.72, 2.46 and 2.59) and 80% RDF (3.55, 3.39 and 3.47) during both the years and on mean basis. This might be due to higher level of fertigation throughout the crop growth period increases the fruit yield/unit of polyhouse having good economical market price resulted in increased the gross, net returns/unit of polyhouse. These results are in accordance with those reported by Ashoka (2005), Kavitha *et al*. (2007), Gupta *et al*. (2009), Prabhakara *et al*. (2010), Imamsaheb *et al*. (2011), Vasu and Reddy (2013), Brahma *et al*. (2014).

Table 2
Economics of tomato/unit of polyhouse (784 m²) as influenced by different treatments

Treatment	*Gross monetary returns (Rs/unit of polyhouse)*			*Cost of cultivation (Rs/unit of polyhouse)*			*Net monetary returns (Rs/unit of polyhouse)*			*B:C ratio*		
	2013	*2014*	*Pooledmean*	*2013*	*2014*	*Mean*	*2013*	*2014*	*Pooledmean*	*2013*	*2014*	*Mean*
A. Fertigation levels												
F_1 – 60% of RDF	157297	142611	149954	57750	58056	57903	99547	84555	92051	2.72	2.46	2.59
F_2 – 80% of RDF	209495	201257	205376	59017	59323	59170	150478	141934	146206	3.55	3.39	3.47
F_3 – 100% of RDF	220093	211064	215578	60283	60590	60437	159810	150474	155142	3.65	3.48	3.57
S.Em.±	3043	2563	1787	–	–	–	3043	2563	1787	–	–	–
C.D. at 5%	11966	10079	7026	–	–	–	11966	10079	7026	–	–	–
B. Fertigation schedules (RD of NPK up to 120 DAT)												
S_1 – 6 equal splits (18 days interval)	174104	167991	171047	59017	59323	59170	115088	108668	111878	2.94	2.82	2.88
S_2 – 9 equal splits (12 days interval)	194943	185651	190297	59017	59323	59170	135926	126328	131127	3.30	3.12	3.21
S_3 – 12 equal splits (9 days interval)	217837	201290	209563	59017	59323	59170	158820	141967	150394	3.68	3.39	3.54
S.Em.±	1338	1712	1398	–	–	–	1338	1712	1398	–	–	–
C.D. at 5%	4127	5280	4312	–	–	–	4127	5280	4312	–	–	–
Interaction (A X B)												
C.D. at 5%	Sig.	Sig.	Sig.	–	–	–	Sig.	Sig.	Sig.	–	–	–
General mean	195628	184977	190303	59017	59323	59170	136611	125654	131133	3.30	3.11	3.21

Price of fruit= Rs. 14 kg^{-1} (2013), Rs 15 kg^{-1} (2014)

Effect of Fertigation Schedules

Different fertigation schedules significantly influenced the yield contributing characters (Table 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 (72.54, 66.30 and 69.44), polar circumference (5.10, 4.83 and 4.96 cm), equatorial circumference (4.46, 4.37 and 4.42 cm), average fruit weight (67.63, 65.34 and 66.50 g) and fruit weight/ plant (4.80, 4.24 and 4.52 kg) during both the years and on pooled mean, respectively. While lowest values of these parameters were 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 1) 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 of polyhouse (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 of polyhouse (12.44, 11.20 and 11.82 t). The extent of increase in fruit yield/unit of polyhouse 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 in Table 2 showed the economic evaluation of tomato assessed in terms of gross monetary returns, net monetary returns and B:C ratio. The gross monetary returns unit^{-1} of polyhouse was influenced significantly due to the different fertigation schedules. Fertigation of RD of NPK in 12 equal splits at every 9 days interval up to 120 DAT recorded significantly higher gross monetary returns/unit of polyhouse (Rs. 217837, 201290 and 209563) than 6 equal splits at every 18 days interval (Rs. 174104, 167991 and 171047) and 9 equal splits at every 12 days interval (Rs. 194943, 185651 and 190297) during both the years and on pooled mean.

The net monetary returns/unit of polyhouse was influenced significantly due to different fertigation schedules. Fertigation of RD of NPK in 12 equal splits at every 9 days interval up to 120 DAT obtained significantly higher net monetary returns/unit (Rs. 158820, 141967 and 150394) than 6 equal splits at every 18 days interval (Rs. 115088, 108668 and 111878) and 9 equal splits at every 12 days interval (Rs. 135926, 126328 and 131127) during both the years and on pooled mean. Fertigation of RD of NPK in 12 equal splits at every 9 days interval up to 120 DAT recorded higher B:C ratio/unit of polyhouse (3.68, 3.39 and 3.54) than 6 equal splits at every 18 days intervals (2.94, 2.82 and 2.88) and 9 equal splits at every 12 days interval (3.30, 3.12 and 3.21) during both the years and on mean basis, respectively.

This might be due to continuous split application of nutrients throughout the crop growth period increases the fruit yield/unit of polyhouse with reasonable good economical price during summer season resulted in increased the gross, net returns/unit of polyhouse. These results are in accordance with those reported by Gupta *et al*. (2009), Prabhakara *et al*. (2010), Imamsaheb *et al*. (2011), Vasu and Reddy (2013) and Brahma *et al*. (2014).

Based on two years of experimentation it is further concluded that to achieve maximum tomato fruit yield and net monetary returns/unit of polyhouse during summer season the fertigation of 80% RDF (240-120-120 kg N-P-K/ha) in 12 equal splits at every 9 days interval up to 120 days after transplanting found most suitable.

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