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Economic feasibility of water soluble fertilizer in drip irrigated tomato (*Lycopersicon esculentum*)

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ABSTRACT

Response of water soluble fertilizer with drip irrigation was tested to study effects on growth, yield and quality of hybrid tomato (*Lycopersicon esculentum* Mill.) cv. Vaibhav and compared with conventional method for 3 years (2008 to 2010) at the Research Farm of Mahatma Phule Agricultural University, Rahuri (Maharashtra), India. The experiment was laid out in a randomized block design with seven treatments replicated three times. Application of water soluble fertilizer through drip irrigation at 100, 80 and 60% of recommended dose in fourteen equal splits at 8-days interval saved 20–40% fertilizer as compared to the farmer's practice where nitrogen was applied in two equal splits (at planting and 1 month thereafter). Similarly, 14.6% increase in yield with 58% water saving in tomato as compared to farmer's practice was obtained when only drip irrigation is used. The 80% recommended dose of fertilizer through drip showed 40% increase in yield over surface irrigation. The quality of tomato was improved significantly due to fertigation through drip. The study indicated that yield of tomato can be increased sizably by applying only 'N' through drip irrigation and P and K as per conventional practice than only drip irrigation. The continuous availability of nutrients in splits throughout the growth period of tomato resulted into superior yield and quality of tomato. The fertigation resulted into maximum net seasonal income, total net income and net extra income over control and maximum water productivity when 100% fertilizers were applied through drip, however it were on par with the economical parameters obtained at 80% fertilizer application.

Key words: Fertigation, Drip irrigation, Splits, Tomato, Water soluble fertilizers

Efficient method and schedule of irrigation and fertilizer application plays an important role in achieving higher yield, saving water and fertilizer. The drip irrigation is a highly efficient method of water application, which is also ideally suited for controlling the placement and supply of water-soluble fertilizers (Or and Coelho 1996). Drip fertigation is the simultaneous and efficient application of water and nutrients which is more advantageous for raising vegetable crops. Because of the way the water is applied in a drip system, traditional surface applications of fertilizer are sometimes ineffective. So, fertilizers should be applied in a form that becomes available easily with crop demand for maximum utilization of nutrients (Boyhan *et al.* 2001). Similar to frequent application of water, optimum split applications of fertilizer improves quality and quantity of crop yield than the conventional practice through drip. Nitrogen can be applied easily with drip irrigation because the urea, main source of N is completely water soluble. Further, the fertigation is more efficient means of applying nutrients that are liable to leaching such as NO_3 and K_2O than conventional broadcasting. However, other nutrients like phosphorous can also be applied through drip irrigation system if available in soluble form (Hebbar *et al.* 2004).

Among different vegetables, tomato (*Lycopersicon esculentum* Mill.) responds well to irrigation and appreciable yield can be possible through drip irrigation. Drip irrigation scheduled at every second day frequency with fertigation can maximize yield of tomato. It can save water and fertilizer to large extent (Shaymaa *et al.* 2009, Singandhupe *et al.* 2003). The uptake of NPK, recovery and fertilizer use efficiency in drip irrigation is higher over furrow irrigation (Sanchita *et al.* 2010). Considering the water saving up to 50%, approximately 50% saving on initial investment of drip set can be achieved as the same set can irrigate double area (Dalvi *et al.* 1999). Tomato also responds well to additional fertilizer applied and it is reported to be a heavy feeder of NPK (Hebbar *et al.* 2004).

In recent years, liquid, solid or water soluble fertilizers are used as a strong alternative to straight fertilizers. The major advantage of these water soluble fertilizers is that they

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are completely soluble in water and can be applied through drip system in many splits with an ease without any harmful effects to crop or land. Though, water soluble fertilizers proved their superiority over conventional fertilizers but they are costly from economic point of view. With the increasing prices of fertilizers it has become necessary to save fertilizers to reduce cost of cultivation and to maintain soil health. Hence this study was conducted to study the economic viability of drip irrigation in conjunction with water soluble fertilizer on hybrid tomato in medium clay soil of western Maharashtra.

MATERIALS AND METHODS

The field experiment was conducted for three consecutive seasons from 2007 to 2010 at research farm of Inter Faculty Department of Irrigation Water Management, Mahatma Phule Krishi Vidyapeeth, Rahuri, Agroclimatically, the area falls under the scarcity zone of Maharashtra with annual average rainfall of 520 mm which is mostly erratic and uncertain in nature. The experimental plot was uniform and leveled with well drained, medium black clay soil alkaline in nature with pH 8.8. The soil depth was 60 cm with infiltration rate and organic carbon as 0.6 cm/hr and 0.64% respectively. The soil texture was clayey with 10.75% coarse sand, 33.75% silt and 55% clay with medium depth. The bulk density of soil was 1.28 $g/cm^3$and electrical conductivity was 0.17 dS/m. The soil was having available N (178.8 kg/ha), and P (15.7 kg/ha) and high in available K (560 kg/ha) content. The soil was having good drainage with moisture contents at field capacity, permanent wilting point and available soil moisture as 28.36, 14.17 and 14.19%, respectively. The field experiment was laid out in Randomized Block Design (RBD) with seven treatments replicated thrice. The treatment details were as follows: Drip with 100% WSF in 14 equal weekly splits; drip with 80% WSF in 14 equal weekly splits; drip with 60% WSF in 14 equal weekly splits; drip with 100% conventional fertilizers (N through drip in fourteen equal weekly splits and P and K through soil at planting); drip with 100% CF (N, P, K through soil as per conventional practice); surface irrigation with 100% conventional fertilizer; farmer's practice [Conventional fertilizers @ 400:200:200 NPK kg/ha].

The recommended dose of fertilizer considered for tomato was 300:150:150 N: P_2O_5 : K_2O, g/plant for all the treatments except T_7. In treatment T_7, all the 'N' was applied through urea in 14 equal splits at an interval of 7 days. The tomato seedlings cv Vaibhav was planted during 2nd week of December and was harvested during the 1st week of April for three consecutive years from 2008-2010. Planting was done in paired row with (0.60-1.80 m) with 0.60 m row to row and 1.80 m spacing between pairs and 0.45 m plant to plant spacing. The fertigation was done using water soluble grades as urea, urea phosphate and muriate of potash through automized fertizet system (Galicol make, Israel) at weekly interval. Adequate plant protection measures were adopted as and when required. The amount of water (litres/day) to be applied through drip irrigation was calculated by the climatological approach method (Doorenbos and Pruitt 1977). The reference evapotranspiration was estimated using Evapotranspiration Monitoring Station (ICT International make, Australia) installed at research farm. Considering the crop factor as per stages (Allen *et al.* 1988) and wetted area factor, the water requirement of the cotton was computed using following equation.

$$V = \text{ETr} \times \text{Kc} \times \text{Ls} \times \text{Es} \times \text{Ws}/\eta$$

where, V, Volume of water applied (l/day/plant); ETr, Reference evapotranspiration (mm/day); Kp, Pan coefficient (0.7); Kc, Crop coefficient; Ls and Es, lateral and emitter spacing; Wa, wetted area factor (0.6); η, emission uniformity of the system (91%).

The single lateral lines of 16 mm diameter LDPE pipes were laid along the crop rows and each lateral served two rows of crop. The laterals were provided with on-line dripper of 4 lph discharge capacity at a pressure of 1 kg/cm^2. The spacing between two adjacent lateral and emitter within plot was 1.8 m and 0.6 m, respectively. The average emission uniformity of drip irrigation system was estimated as 91 per cent for all treatments. In drip system water was applied on alternate day while in surface irrigation, irrigation 60 mm depth of irrigation was applied at 50 mm of cumulative pan evaporation.

RESULTS AND DISCUSSION

Growth

All the biometric characters pooled over the three years were found maximum in drip irrigated and fertigated treatments as compared to conventional method of irrigation (Table1). The pooled data revealed that maximum (228 cm) plant height was observed in T_1 (100% WSF). However, it was on par with plant height in T_2 (80% WSF) and significantly superior over all remaining treatments. The conventional practice (T_6) produced minimum plant height (199.63 cm). The continuous supply of adequate quantity of water and more availability of nutrient resulted into increased growth parameters in tomato. As regards to number of branches, maximum branches/plant (12.95) were observed in T_1 but it was on par with T_2 (11.89) and T_3 (11.16). Minimum number of branches (9.68) was found in conventional practice (T_6). Similarly, maximum and significantly superior plant spread (78.84 cm) was also recorded in treatment T_1 and lowest value of plant spread was recorded in T_6 (67.41 cm). The significantly lower values of growth contributing characters were obtained for all the parameters in conventional practice.

Yield and yield contributing characters

Data pooled over three years (Table 1) indicated that

Table 1 Growth and yield contributing characters of tomato as influenced by water soluble fertilizers (pooled data of three years)

Treatment	Plant height (cm)	No. of branches/plant	Plant spread (cm)	No. of fruits/ plant	Wt. of fruits/ plant (kg)	Yield (tonnes/ha)
T_1 100% WSF	228.00	12.95	78.84	56.74	2.09	52.47
T_2 80% WSF	224.17	11.89	76.20	52.27	1.98	49.07
T_3 60% WSF	216.38	11.16	74.04	48.71	1.66	45.76
T_4 100% CF+DI (NTD)	210.47	10.78	72.43	44.33	1.62	43.21
T_5 100% CF+DI	201.80	10.19	70.86	42.86	1.54	40.80
T_6 100% CF+SI	199.63	9.68	67.41	40.61	1.45	35.99
T_7 Farmer's practice	202.11	9.90	68.54	38.84	1.42	34.48
SE ±	2.98	0.27	0.73	1.31	0.19	1.69
CD (P=0.05)	9.21	2.09	2.09	3.63	0.38	3.42

WSF, Water soluble fertilizers; CF, conventional fertilizers; NTD, nitrogen through drip; DI, drip irrigation; SI, surface irrigation

treatment T_1 (100% WSF) produced maximum number of fruits (56.74), which were significantly superior over all other treatments. It was followed by T_2 (80% WSF) and T_3 (60% WSF). The farmer's practice (T_7) produced minimum number of fruits (38.84) than all other treatments (Table 1). Pooled mean weight of fruit was found maximum in treatment T_1 (2.09 kg) however, it was on par with treatment T_2 (1.98 kg) and significantly superior over all other treatments.

The pooled yield data (Table 1) revealed that maximum and significantly superior tomato yield (52.47 tonnes/ha) was obtained in treatment T_1 where 100% WSF were applied through drip but it was on par with T_2 (80% WSF). It was followed by T_3 (60% WSF) and T_4 (only N through drip). The treatment T_3 (60% WSF) produced significantly higher tomato yield (45.76 tonnes/ha) than T_5 (drip with 100% conventional fertilizers, 40.13 tonnes/ha) and thus, it indicated that the fertigation technique can save fertilizers up to 40%. The increase in yield in drip irrigated and fertigated treatments were mainly due to better and adequate supply of water and nutrients at the right time and at right place. The yield in treatment T_7 (farmer's practice) was 35.02 tonnes/ha and was less than T_6 (conventional irrigation with RD of fertilizers, 36.55 tonnes/ha); it indicated that additional dose of fertilizer had not helped in increasing the fruit yield.

Quality of fruits

The quality parameters, viz. pH, TSS, acidity and lycopene content in tomato were varied significantly due to irrigation and fertigation practices (Table 2). The treatment T_1 recorded the maximum and statistically superior values of all the parameters than all others treatments. The continuous availability of soil moisture under drip system during the growth period of tomato improved the quality parameters. Surface irrigated treatments resulted into inferior values of quality parameters of tomato. Increased moisture stress and non-availability of nutrients as per requirement might have affected the quality parameters in conventional treatments.

Table 2 Quality parameters of tomato as influenced by water soluble fertilizers (pooled data of three years)

Treatment	pH	TSS	Acidity	Lycopene
T_1 100% WSF	4.32	4.41	0.65	0.54
T_2 80% WSF	4.27	4.33	0.94	0.48
T_3 60% WSF	4.22	4.20	1.01	0.46
T_4 100% CF+DI (NTD)	4.16	4.02	1.12	0.43
T_5 100% CF+DI	4.14	3.80	1.19	0.43
T_6 100% CF+SI	4.09	3.52	1.54	0.42
T_7 Farmer's practice	4.04	3.43	1.63	0.41
SE ±	0.098	0.018	0.031	0.018
CD (P=0.05)	0.293	0.037	0.095	0.037

WSF, Water soluble fertilizers; CF, conventional fertilizers; NTD, nitrogen through Drip; DI, drip irrigation; SI, surface irrigation

Water-use

The conventional method of irrigation used maximum amount of water (885.09 mm) and drip method (Table 3) used 370.86 mm water. Thus, saving of water to the extent of 58.12% was recorded due to drip method with 14.59% increase in tomato yield. The application of 100% WSF with drip resulted into 49.81% increase in yield with 58.12% saving in irrigation water over farmer's practice. The maximum field water-use efficiency of 1.44 q/ha-mm was recorded in drip with 100% WSF treatment, whereas lowest FWUE of 0.39 q/ha-mm was recorded in farmer's practice treatment (Table 3).

Cost economics

The pooled data of three years regarding net seasonal income, benefit: cost ratio, total net income, net extra income over surface, water productivity and pay back of period of drip as influenced by different treatments is presented in Table 4. The total seasonal cost of cultivation was computed by adding the seasonal cost of drip irrigation and operational cost. The seasonal cost of drip system for 0.60-1.8 m paired

Table 3 Water use by tomato (average of three years)

Treatment		Water applied (mm)	Effective rainfall (mm)	Total water use (mm)	Field water use efficiency (q/ha-mm)	% water saving	% increase in yield
T_1	100% WSF	366.43	4.43	370.86	1.44	58.12	49.81
T_2	80% WSF	366.43	4.43	370.86	1.34	58.12	40.11
T_3	60% WSF	366.43	4.43	370.86	1.26	58.12	37.32
T_4	100% CF+DI (NTD)	366.43	4.43	370.86	1.19	58.12	21.46
T_5	100% CF+DI	366.43	4.43	370.86	1.12	58.12	14.59
T_6	100% CF+SI	880.70	4.43	885.10	0.42		4.36
T_7	Farmer's practice	880.70	4.43	885.10	0.39		

WSF, Water soluble fertilizers; CF, conventional fertilizers; NTD, nitrogen through drip; DI, drip irrigation; SI, surface irrigation

row planting for tomato was estimated as ₹ 11 148/considering 6 months crop period. It is revealed from Table 4 that more cost of cultivation was estimated in fertigation treatments because of high market cost of water soluble fertilizers. The seasonal cost of surface irrigation treatment was slightly lower than drip with conventional fertilizer.

Net seasonal income and B:C ratio

Maximum net seasonal income of ₹ 238 402 was obtained in treatment T_1 (100% WSF) and was at par (₹ 224 483) with treatment T_2. Minimum net seasonal income of ₹ 151 746 was observed in farmer' s practice (Table 4). Maximum B:C ratio of 4.65 was observed in T_4 (Drip with all N through drip in 14 splits) followed by 4.32 in T_5 (drip irrigation with conventional fertilizer). The fertigation using water soluble fertilizer recorded relatively lower B:C ratio (4.12 to 4.32) due to high market price of water soluble fertilizer. The minimum B:C ratio of 3.75 was observed in farmer's practice.

Total net income

The drip irrigation for tomato resulted into 61% water saving over conventional method of irrigation. Thus, it can bring 1.39 ha of additional area under irrigation. The total net income calculated taking into consideration the additional area that can be brought under irrigation due to water saving in drip was found to the extent of ₹ 568 958 in treatment T_1 (100% WSF through drip), which was significantly superior than any other treatments except T_2 (80% WSF through drip).

Net extra income and payback period

The drip irrigation without fertigation (T_5) produced ₹ 37 372/ha net extra income over control (T_7). The 100% fertigation treatment (T_1) resulted into ₹ 86 656 net extra income per ha over farmer's practices (T_7) which was at par with T_2 (₹ 72 637). The higher payback period were found when drip coupled with fertigation in treatments T_1, T_2 and T_3 (0.6-0.4 year) showed that cost of fertigation can be recovered in less than one season.

Water productivity

The net income obtained per unit of water was improved

Table 4 Economical feasibility of fertigation to tomato (pooled over of three years)

Treatment	Total seasonal cost (₹/ha)	Net seasonal income (₹/ha)	Total net income (₹)	B:C ratio	Net extra income over control (₹)	Payback period of drip (years)	Net profit/ cm of water use (₹)
100% WSF	76 418	238 402	568 958	4.12	86 656	0.6	6 428
80% WSF	70 057	224 383	535 500	4.2	72 637	0.5	6 050
60% WSF	63 598	210 983	503 520	4.32	59 236	0.4	5 689
100% CF+DI (NTD)	55 682	203 498	485 658	4.65	51 752	0.4	5 487
100% CF+DI	55 682	189 118	451 340	4.4	37 372	0.3	5 099
100% CF+SI	52 512	163 428	163 428	4.11	11 682	0.0	1 846
Farmer's practice	55 154	151 746	151 746	3.75	0	0.0	1 714
SE ±		7 590	22 473	0.17	7 800		671.2
CD (P=0.05)		23 000	56 382	0.48	24 000		2 069.5

WSF, Water soluble fertilizers; CF, conventional fertilizers; NTD, nitrogen through drip; DI, drip irrigation; SI, surface irrigation considerably to ₹ 5 099 per ha-cm in drip method of irrigation as compared to ₹ 1 846 in surface method of irrigation. The water productivity was improved to greater extent of ₹ 6 428 per ha-cm of water in treatment T_1 (100% WSF through drip) but it was at par with T_2 (₹ 6 389.6 per ha-mm of water). Thus, drip coupled with fertigation showed its usefulness in using water three times more productively than conventional method of irrigation and fertilizer application.

CONCLUSIONS

Water soluble fertilizers resulted into higher growth, yield and good quality of tomato. Among different fertigation treatments, the treatment T_1, where 100% WSF applied through drip resulted into better growth, yield contributing characters, and quality parameters. However, it was at par with 80% WSF application (T_2). The application of water soluble fertilizers through drip resulted into 40% saving in fertilizer. The drip used lowest water and resulted into 58% water saving with 14.60% increase in yield; whereas drip with 100% WSF resulted into 50% increase in yield with 58% water saving. The quality of tomato was improved significantly due to fertigation through drip. The application of 100% WSF through drip resulted into maximum net seasonal income (₹ 238 402), total net income (₹ 568 958), net extra income over control (₹ 86 656) and maximum water productivity of ₹ 6 428 per ha-cm of water which was at par with 80% WSF treatments. Thus, application of 80% recommended dose of fertilizer through drip in 14 equal weekly splits is recommended for better growth, yield, quality, water and economical returns from hybrid tomato.

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