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Drip Irrigation and Fertigation Technology for Improved Yield, Quality, Water and Fertilizer Use Efficiency in Hybrid Tomato

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ABSTRACT

Study was carried out for improve yield, quality and water/fertilizer use efficiency in tomato hybrid SH-TH-1 under drip irrigation and fertigation technology at the experimental farm of Division of Olericulture, SKUAST-K, Shalimar, Srinagar. The experimental layout was carried out in factorial randomized block design with four replications of 16 treatment combinations. Surface irrigation and manual fertilizer application were treated as control. Irrigation was given based on the estimated crop water requirement following alternate day irrigation schedule for drip irrigation while the surface irrigation was given according to the locally adopted frequency. Drip irrigation at 80% ET and fertigation with 60% recommended NPK significantly enhanced fruit yield of (989.3 q/ha), higher water use efficiency (49.9 q/ha-cm) and fertilizers use efficiency (10.9, 18.3 and 27.4 q/kg NPK, respectively). Average fruit weight, fruit length and fruit diameter also exhibited higher values (53.0 g, 4.48 cm and 4.75 cm, respectively with the same treatment combination. However quality characteristics like TSS, vitamin C, lycopene content and total sugar were found much improved with the treatment combination of 80% ET through drip and 80% recommended NPK through fertigation.

Keywords: Micro-irrigation, tomato, quality production, fertilizers use efficiency

INTRODUCTION

Per capita availability of total renewable water in India is going to decline from 2,133 m^3 in 1998 to 1,289 m^3 in 2050, i.e. 1.6 times less. About 83% of the fresh water resources in India are currently being used for agriculture. So, there is a tremendous pressure on agriculture sector to reduce its share of water and at the same time to improve total production by enhancing productivity with increased water use efficiency (Pandey *et al*., 2012). Kashmir is rich in its water resources and there are several methods to apply irrigation to the region. Most of the orchard crops exist in the uplands where the scarcity of water is felt largely by the farmers throughout the year. Drip irrigation can be very effectively utilized in such land situation of the region. Drip irrigation provides an efficient method of water/fertilizer delivery and allows precise timing and uniform distribution of water and applied nutrients (Pandey *et al*., 2013). Tomato responds well to higher irrigation region. The sufficient application fertilizer and convenient irrigation techniques are very important factor affecting yield and quality of the tomato crop. Controlled watering through drip and efficient nutrient management through fertigation, not only improves the production but quality as well due to better control over soil and water borne diseases (Singh and Pandey, 2014). Minimum use of pesticide is assured due to control and efficient water and nutrient management practices, which needs to be improved for export and domestic use. In this context, the present study was conducted to generate the specific area for yield, quality benefits and effective use of irrigation water for Kashmir region.

MATERIALS AND METHODS

The experiment was conducted during kharif 2007 at the experimental farm of Division of Olericulture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar (J&K). The experiment was laid out in randomized block design (factorial) and replicated four times with sixteen treatment combinations. The treatments include four levels of irrigation water viz; 100%, 80% & 60% ET

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through drip and 100% surface irrigation; and four levels of fertilizers viz; 100%, 80% & 60% of recommended NPK through fertigation and 100% recommended NPK through manual (150:90:60 kg/ha). Surface irrigation and manual fertilizers application were treated as control. Irrigation schedule for drip irrigation was based on estimated crop water requirement using pan evaporation data, crop coefficient, pan coefficient and percentage wetted area of the crop root zone (Table 1).

Table 1: Average pan evaporation, monthly effective rainfall, crop factor and volume of water applied during the cropping period.

Month	Average Pan Evaporation (mm/day)	Effective Rainfall (mm/month)	Crop Factor	Volume of Water Applied (cm)
May, 2007	3.8	33.5	0.4 (17.5.07 to 31.5.07)	0.75
June, 2007	4.7	52.3	0.4 (1.6.07 to 10.6.07) 0.7 (11.6.07 to 30.6.07)	4.87
July, 2007	4.5	54.0	0.7 (1.7.07 to 20.7.07) 1.1 (21.7.07 to 31.7.07)	4.99
Aug., 2007	5.0	46.4	1.1 (1.8.07 to 29.8.07) 0.9 (30.8.07 to 31.8.07)	9.45
Sept., 2007	3.5	23.2	0.9 (1.9.07 to 25.9.07)	4.72

The volume of water required under drip irrigation system was computed using following equation (Eq.1).

$$V = [DE \times CF \times AA \times PC]/IE \qquad [Eq.1]$$

Where, V= Volume of water required (liter/plant/day), DE = Daily Pan Evaporation (mm), CF = Crop Factor, AA = Area Allotted per Plant (m^2), PC = Pan Coefficient and IE = Irrigation efficiency as a decimal. The data on average pan evaporation (E_p), monthly effective rainfall (R_e) and volume of water 'V' applied month-wise during the cropping period is given in table 1. The crop factor (CF) for various growth stages was selected (Doornbos *et al.*, 1984). The pan factor value was 0.75 as suggested for USDA class A pan. The area allotted per plant was 0.24 m^2.

Twenty-five days old seedlings of tomato hybrid SH-TH-1 were transplanted on 17th May, 2007 with 3 rows per plot at the spacing of 60x40 cm comprising total 27 plants per plot. The drip system was laid out parallel to the crop rows and each lateral with emitter distance at 40 cm and 2.2 liter per hour (lph) discharge rate served by each emitters. The amount of water actually applied by way of drip irrigation system was based on climatologically approach. Irrigation was scheduled on alternate days in case of drip irrigation and surface irrigation was given according to the locally adopted frequency. Fertigation with recommended fertilizer dose i.e. 150:90:60 kg NPK/ha was given according to the treatments in 10 split doses at 10 days interval beginning 10 days after transplanting. However, in case of manually fertilized plots, half dose of nitrogen (urea) and full doses of phosphorus (SSP) and potassium (MOP) were applied as basal dose. While, the remaining half dose of nitrogen was applied in two spits at 30 and 45 days after transplanting as top dressing. All other packages of practices were adopted as recommended for the region. Volumetric method was used for calculating the uniformity coefficients of drip irrigation system (Raina *et al.*, 1998). All the quality parameters were determined using standard procedures. The water use efficiency was computed by dividing yield (q/ha) with total water applied (cm) including effective rainfall. The fertilizer use efficiency was worked out separately for N, P and K by dividing total yield (q/ha) with total fertilizer applied (kg/ha).

RESULTS AND DISCUSSION

During the experimentation, the uniformity coefficient of drip irrigation system was found to be 93.5% which indicate the excellent performance of drip irrigation system in supplying water uniformity throughout lateral lines. The response of various treatments on yield and quality were recorded and analyzed statistically. Water use efficiency and fertilizer use efficiency was also worked out. The salient results are discussed as under.

Yield and yield components

The results of the experiment revealed that drip irrigation levels exhibited a significant effect on yield and yield components of tomato hybrid SH-TH-1. Data presented in table 2 revealed that drip irrigation at 80% ET recorded maximum average fruit weight (49.7g) and fruit yield (893.4 q/ha) whereas the minimum average fruit weight (40.0 g) and fruit yield (657.3 q/ha) was observed with 100% surface irrigation. The increase in tomato yield under drip irrigation system may be due to the availability of water all the time when needed around the root zone at very low moisture tension. Singh and Kumar (2007) also reported the maximum fruit weight and tomato yield with 80% ET. Similar findings

Table 2: Effect of drip irrigation on yield, quality and water use efficiency in tomato.

Treatment	Yield (q/ha)	Av. fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Pericarp thickness (cm)	TSS (%)	Vit C content (mg/100 g)	Acidity (%)	Lycopene content (mg/100 g)	Total Sugar (%)	pH	Dry Matter Content (%)	**Water applied (cm)**	**WUE (q/ha-cm)**
I_1	786.9	46.4	4.30	4.35	0.43	4.67	15.3	0.30	6.01	3.63	4.31	4.97	24.8	31.7
I_2	893.4	49.7	4.35	4.57	0.42	4.92	17.8	0.27	7.01	3.77	4.45	5.06	19.8	45.1
I_3	743.7	44.2	4.35	4.56	0.41	4.87	16.8	0.26	6.46	3.70	4.39	5.01	14.8	50.2
I_4	657.3	40.0	4.25	4.26	0.39	4.49	13.9	0.23	5.56	3.44	4.24	4.45	35.7	18.4
CD at 5%	45.51	2.45	0.10	0.15	0.02	0.27	0.87	0.02	0.14	0.09	0.56	0.34	-	-

I_1 = 100% ET through drip irrigation; I_2 = 80% ET through drip irrigation; I_3 = 60% ET through drip irrigation; I_4 = 100% Surface irrigation.

are also reported by Raina *et al.* (1999) and Elkner and Kaniszenski (1995).

Results depicted in table 3 revealed that the response of various fertigation levels in tomato hybrid SH-TH-1 showed that among the various levels of fertigation, 60% recommended NPK through fertigation (F_3) produced maximum fruit weight (48.4g) and fruit yield (863.9 q/ha) whereas the minimum fruit weight (42.0 g) and fruit yield (661.9 q/ha) was observed with 100% recommended NPK as manual. These results suggest that the tomato crop requires lesser amount of fertilizer through fertigation. Badra and Yazied (2007) also reported that tomato show higher response to fertilizers especially nitrogen, but application of excessive rates negatively affect the yield and its components.

In case of interaction (Table 4), results revealed that the combined effect of drip irrigation and fertigation proved superior to their individuals effects. Among different treatment combinations, the treatment combination of 80% ET through drip + 60% recommended NPK through fertigation recorded maximum average fruit weight (53.0 g) and fruit yield (989.3 q/ha). Similar finding are also reported by Riazeian and Mahdavi (2005).

Quality Characteristics

Drip irrigation and fertigation treatment significantly influenced the quality characteristics of tomato (Table 2 and Table 3). Quality of tomato is mostly judged in terms of vitamin C content, TSS, lycopene content and sugar content. Among various irrigation levels, drip irrigation at 80% ET recorded higher values for fruit length (4.35 cm), fruit diameter (4.57 cm), total soluble solids (4.92%), Vitamin C content (17.8 mg/100g), lycopene content (7.01 mg/ 100 g) and total sugar (3.77 %). However, pericarp thickness (0.43 cm) and titrable acidity (0.30%) were found maximum with 100 % ET trough drip. Samra (2005) also observed the better quality of tomato in terms

Table 3: Effect of fertigation on yield, quality and fertilizer use efficiency in tomato

Treatment	Yield (q/ha)	Av. fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Pericarp thickness (cm)	TSS (%)	Vit C content (mg/100 g)	Acidity (%)	Lycopene content (mg/100 g)	Total Sugar (%)	pH (%)	Dry matter content (%)	**NUE (q/kg N)**	**PUE (q/kg P)**	**KUE (q/kg K)**
F_1	751.4	44.7	4.27	4.38	0.43	4.70	15.4	0.29	6.06	3.57	4.35	5.08	5.01	8.35	12.53
F_2	803.9	45.3	4.39	4.50	0.42	4.85	17.4	0.27	7.13	3.80	4.39	4.92	5.36	8.93	13.40
F_3	863.9	48.4	4.43	4.59	0.40	4.77	16.4	0.26	6.56	3.73	4.39	4.88	5.75	9.60	14.40
F_4	661.9	42.0	4.16	4.27	0.39	4.63	14.5	0.24	5.29	3.45	4.27	4.61	4.41	7.35	11.03
CD at 5%	45.51	2.45	0.10	0.15	0.02	0.27	0.87	0.02	0.14	0.09	0.56	0.34	-	-	-

F_1 = 100% RFD through fertigation; F_2 = 80% RFD through fertigation; F_3 = 60% RFD through fertigation; F_4 = 100% RFD through manual application.

Table 4: Interaction effect of drip irrigation and fertigation on yield, quality, WUE and FUE in tomato

Treatment combinations	Yield (q/ha)	Av. fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Pericarp thickness (cm)	TSS (%)	Vit C content (mg/100 g)	Acidity (%)	Lycopene content (mg/100 g)	Total Sugar (%)	pH	Dry matter content (%)	Water applied (cm)	**WUE (q/ha-cm)**	**NUE (q/kg N)**	**PUE (q/kg P)**	**KUE (q/kg K)**
I_1F_1	791.2	42.21	4.25	4.28	0.45	4.68	14.85	0.32	5.80	3.58	4.31	5.24	24.8	31.9	5.27	8.79	13.18
I_1F_2	847.8	45.35	4.39	4.43	0.44	4.75	16.83	0.31	7.05	3.80	4.36	5.08	24.8	34.1	7.06	11.77	17.66
I_1F_3	862.1	48.51	4.45	4.55	0.41	4.70	15.93	0.29	6.32	3.74	4.35	5.05	24.8	34.7	9.57	15.96	23.94
I_1F_4	652.3	40.92	4.13	4.18	0.43	4.55	13.75	0.28	4.90	3.42	4.25	4.52	24.8	26.3	4.34	7.24	10.87
I_2F_1	839.8	49.76	4.28	4.45	0.44	4.90	17.23	0.30	6.84	3.69	4.48	5.13	19.8	42.4	5.59	9.33	13.99
I_2F_2	925.3	50.56	4.45	4.68	0.43	5.03	18.93	0.29	7.91	3.95	4.52	5.05	19.8	46.7	7.71	12.85	19.27
I_2F_3	989.3	53.00	4.48	4.75	0.40	4.93	18.15	0.28	7.15	3.88	4.48	5.13	19.8	49.9	10.99	18.32	27.48
I_2F_4	824.0	45.84	4.23	4.40	0.41	4.85	16.95	0.25	6.19	3.57	4.35	4.97	19.8	41.6	5.49	9.15	13.73
I_3F_1	708.7	43.21	4.38	4.58	0.44	4.86	16.43	0.29	6.28	3.64	4.40	5.10	14.8	47.8	4.72	7.87	11.81
I_3F_2	766.5	45.14	4.41	4.60	0.43	4.92	18.00	0.27	7.10	3.85	4.46	5.04	14.8	51.79	5.11	8.51	12.77
I_3F_3	832.2	46.54	4.43	4.65	0.41	4.91	17.43	0.26	6.95	3.79	4.43	5.10	14.8	56.22	5.54	9.24	13.87
I_3F_4	672.2	42.18	4.23	4.43	0.38	4.82	15.53	0.24	5.52	3.55	4.31	4.82	14.8	45.4	4.48	7.46	11.20
I_4F_1	667.9	38.96	4.20	4.23	0.42	4.40	13.48	0.27	5.35	3.38	4.22	4.85	35.7	18.7	4.45	7.42	11.13
I_4F_2	680.7	40.54	4.33	4.30	0.41	4.71	16.10	0.25	6.50	3.60	4.25	4.55	35.7	19.0	5.67	9.45	14.18
I_4F_3	779.1	45.78	4.38	4.45	0.39	4.56	14.43	0.23	5.85	3.51	4.32	4.28	35.7	21.8	8.65	14.42	21.64
I_4F_4	544.4	35.12	4.10	4.10	0.35	4.32	11.98	0.20	4.57	3.27	4.20	4.16	35.7	15.2	3.62	10.08	9.07
CD at 5%	91.03	4.90	0.21	0.30	0.04	0.55	1.75	0.04	0.29	0.18	0.11	0.69	-	-	-	-	-

I_1 = 100% ET through drip irrigation; I_2 = 80% ET through drip irrigation; I_3 = 60% ET through drip irrigation; I_4 = 100% Surface irrigation.
F_1 = 100% RFD through fertigation; F_2 = 80% RFD through fertigation; F_3 = 60% RFD through fertigation; F_4 = 100% RFD through manual application

of above mentioned characteristics. Due to regular water supply through drip irrigation, crop plants can complete all metabolic process at appropriate time. The adequate moisture supply also helps in keeping various enzyme systems active. Therefore, quality of the produce is better in drip irrigated crops as compared to surface irrigated crops.

Fertigation levels (Table 3) also exhibited a significant effect on quality characteristics of tomato hybrid SH-CH-1. Fertigation with 80% recommended NPK through drip produced significantly maximum values for TSS (4.85%), vitamin C (17.4 mg/ 100 g), lycopene content (7.13 mg/ 100 g) and total sugar (3.80 %). Our findings are in accordance with the findings by Silva *et al* (1999), Alcantar *et al.* (1999), Shi *et al.* (1999) and Hongxia *et al.* (2003). Pericarp thickness and titrable acidity were found maximum (0.43 cm and 0.29 %) with 100 % recommended NPK through fertigation. Whereas 60% recommended NPK through fertigation noticed relatively higher average fruit weight (48.4 g), fruit length (4.43 cm) and fruit diameter (4.59 cm). Similarly findings were also reported by Badra and Yazied (2007) and Colla *et al.* (2003).

In case of combined effect of drip irrigation and fertigation, more improvement in quality parameters was observed (Table 4). Application of fertilizers through fertigation improves fertilizer use efficiency as well as agronomic efficiency compared to the traditional method of fertilizer application resulting in substantial improvement in quality parameters as well. The results revealed that among various treatment combination, 80% ET through drip + 80% recommended NPK through fertigation was found superior over rest of the treatment combinations in terms of TSS (5.03%) vitamin C content (18.93 mg/100g), lycopene content (7.91 mg/100 g) and total sugar (3.95%). The improved quality with conjunctive use of drip irrigation and fertigation might be due to the facts that drip irrigation and fertigation permits better use of water and nutrients, lower leaching losses and more controllable application of nutrients as compared to other nutrient and water supply methods. These results are in line with the finding of Alcanter *et al.* (1999), Elkner *et al.* (2001) and Samra (2005). However, the treatment combination of 100% ET through drip + 100% recommended NPK through drip noticed much improvement in pericarp thickness (0.45 cm) and titrable acidity (0.32%). Our findings are in agreement with the findings of Colla *et al.* (2003). The characteristics like fruit length and fruit diameter showed a different trend as these characteristics are related with total yield and thereby recording the maximum values (4.48 cm and 4.75 cm) with the treatment combination of 80 % ET through drip + 60 % recommended NPK through fertigation. Similar findings were also reported by Badra and Yazied (2007).

Water and Fertilizer Use Efficiency

Besides having the advantage of yield and quality improvement, drip irrigation and fertigation noticed a substantial decrease in consumptive use of water and fertilizer, thereby leading to higher water and fertilizer use efficiency in comparison with normal practice of irrigation and fertilizer application (Table 2 and Table 3). Drip irrigation levels had a favorable and significant influence on water use efficiency in tomato var. SH-TH-1. Drip irrigation at 80% and 60% ET were at par and found significantly superior to drip irrigation at 100% ET drip and surface irrigation with the water use efficiency (45.1q/ha-cm and 50.25 q/ha-cm). Higher yield and lower rate of water loss through evaporation and less water use are the main reasons for increasing the water use efficiency. The minimum water use efficiency (18.4q/ha-cm) was observed with surface irrigation because of the excessive moisture in the root zone of the crop, hence restricting the uptake of nutrients. These results are in conformity with the results of Raina *et al.* (1998), Asokaraja (1998) and Veerana *et al.* (2001).

Tomato is highly responsive to fertilizers but applications of excessive rates not have only negative effect on quality, but it also reduces the fertilizer use efficiency. However, application of fertilizers through fertigation can overcome the negative effects on quality and improve fertilizer use efficiency. Highest fertilizer use efficiency (5.75q/kg N, 9.60q/kg P and 14.40 q/kg K) in tomato was observed with 60% recommended NPK through fertigation and the lower fertilizer use efficiency (4.41 q/kg N, 7.35 q/kg P and 11.03 q/kg K) was noticed with the traditional method of fertilizer application (Table 3). The lower fertilizer use efficiency in traditional method of fertilizer might be because of non-uniform distribution and inadequate availability of nutrients and moisture in the root zone, which is responsible for lower uptake of nutrients. Similar results are reported by Papadopoulos *et al.* (2004), Veeranna *et al.* (2001) and Haltgl *et al.* (2002).

In case of combined effects of drip irrigation and fertigation, the treatment combination of 80% ET through drip + 60% recommended NPK through drip recorded maximum water use efficiency (49.9 q/ha-cm) and fertilizer use efficiency 10.99q/kg N, 18.32q/kg P and 27.48 q/kg K. These results are in agreement with the results of Singandhupe *et al.* (2003) and Riazeian and Mahdavi (2005).

CONCLUSION

It can be concluded that both drip irrigation and fertigation if managed properly with appropriate amount of water and fertilizer then yield and quality improvement of tomato is sure besides water and fertilizer saving

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