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Full Length Research Paper

Drip irrigation and black polyethylene mulch influence on growth, yield and water-use efficiency of tomato

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A two year field study was conducted during 2001-2002 and 2002-2003 on sandy loam soil to investigate the effect of drip irrigation and black polyethylene mulch compared with surface irrigation, on growth, yield, water-use efficiency and economics of tomato *(Lycopersicon esculentum* Miller). Drip irrigation at 80% evapo-transpiration (ET) crop based on pan evaporation applied gave significantly higher fruit yield (45.57 tonnes/ha) compared with the surface irrigation (29.43 tonnes/ha). Use of black polyethylene mulch plus drip irrigation further raised the fruit yield to 57.87 tonnes/ha. Plant height, leaf area index, dry matter production, fruit weight and yield increased significantly with the use of drip irrigation alone and in conjunction with polyethylene mulch compared to surface irrigation alone or with mulch. Water-use efficiency under drip irrigation alone, drip irrigation with polyethylene mulch and surface irrigation was 0.97, 1.23 and 0.42 tonne/ha-cm, respectively. Among different irrigation levels, drip irrigation at 80% ET resulted in higher net returns (34431 Rs/ha) and benefit cost ratio (1.76) in tomato. However, maximum net returns (51386 Rs/ha) and benefit cost ratio (2.03) was found with drip irrigation at 80% ET coupled with polyethylene mulch compared to other treatments. Drip irrigation besides giving a saving of 38% water resulted into 55% higher fruit yield compared to surface irrigation.

Key words: Drip irrigation, pan evaporation, black polyethylene, fruit yield, tomato.

INTRODUCTION

Drip irrigation has proved its superiority over other conventional method of irrigation, especially in the cultivation of fruits and vegetables due to precise and direct application of water in root zone. A considerably saving in water, increased growth, development and yield of vegetables under drip irrigation has been reported (Bhella 1988; Bafna et al., 1993; Raina et al., 1999; Imtiyaz et al., 2000). The use of black polyethylene mulch in vegetable production has been reported to control the weed incidence, reduces nutrient losses and improves the hydrothermal regimes of soil (Ashworth and Harrison, 1983; Chakarborty and Sadhu, 1994; Singh, 2005). However, limited information is available regarding the effect of drip irrigation alone and in conjunction with polyethylene mulch as compared to surface irrigation on growth and yield of tomato *(Lycopersicon esculentum* Miller). As tomato is the most important vegetable crop, such information is required for developing new strategies for intensive production of vegetables. Therefore, the present investigations were undertaken to study the effect of different levels of drip irrigation with and without polyethylene mulch on growth, yield, water-use efficiency and economics of tomato.

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MATERIALS AND METHODS

A field experiment was conducted during winter season of 2001-2002 and 2002- 2003 at research farm of Central Institute of Post Harvest Engineering and Technology, Abohar (lat 30^0 09' N, long. 74^0 13'E, 185.6 m above mean sea level), Punjab, India. The soil of the experimental plot was sandy loam in texture having pH 8.4, poor in organic carbon and available nitrogen, medium in phosphorus and rich in potash content. The following eight treatments were applied in a randomized black design and replicated thrice: T_1: Drip irrigation with 100% evapo-transpiration (ET) based on pan evaporation; T_2: drip irrigation with 80% ET; T_3: drip irrigation with 60% ET; T_4: surface irrigation; T_5: T_1 + black polyethylene mulch; T_6: T_2 + black polyethylene mulch; T_7: T_3 + black polyethylene mulch and T_8: T_4 + black polyethylene mulch.

Table 1. Pan evaporation, crop factor, effective rainfall and irrigation depth at 100 ET during the experimental period (Pooled data of two years).

Month	Average pan evaporation (mm/day)	Crop factor	Effective rainfall (mm)	Irrigation depth at 100% ET (cm)
December (after 15 Dec)	2.37	0.90	-	2.56
January	1.37	0.90	0.6	2.87
February	2.56	1.02	10.7	5.43
March	3.34	1.02	11.6	7.86
April	6.28	1.05	9.3	14.76
May (up to 22 May)	7.69	0.85	6.8	15.12

Table 2. Effect of different treatments on growth parameters and fruit weight of tomato (Pooled data of two years).

Treatments	Plant height (cm)	Leaf area index	Plant dry matter (g)	Fruit weight (g)
T_1	80.4	3.14	34.1	76.4
T_2	83.1	3.26	38.4	79.6
T_3	74.6	2.86	27.5	69.8
T_4	69.4	2.53	21.1	62.3
T_5	83.4	3.71	41.3	81.7
T_6	85.5	3.89	46.6	86.6
T_7	79.4	3.38	34.3	75.9
T_8	75.3	2.97	27.5	68.1
LSD (P = 0.05)	3.1	0.14	4.3	5.0

The volume of water for 100% ET based on pan evaporation was computed using the following equation.

$$V = \sum (Ep \times Kc \times Kp \times A \times N - Re \times A)$$

Where, V= volume of water required for 100%; ET= Ep, average monthly pan evaporation (mm/day); Kc = crop factor; Kp = pan factor; A = area of plot (m^2); N = number of days; Re = effective rainfall (mm); $\sum$ = signifies total of all the crop season.

The data on average pan evaporation, monthly effective rainfall, volume of water applied for 100% ET during the experimental period is presented in Table 1. The crop factor values for different crop stages were computed based on the existing relative humidity and wind velocity (Doorknobs et al., 1984). The pan factor value was 0.75 as suggested by USDA class A pan. The area of plot was 9.0 m^2 and N is number of days in a month for which the volume of applied water needs to be calculated. A buffer zone spacing of 1.5 m was provided between the plots. In the treatment of surface irrigation (T_4) and surface irrigation + black polyethylene mulch (T_8), 14 irrigations each of 5 cm depth were applied.

35 days old seedlings of tomato cv. Rupali were transplanted on the 15th of December of both years. This was done using row to row and plant to plant distance of 100 and 50 cm, respectively. All the recommended cultural and plant protection operations were followed to raise the healthy crop. For mulching, black polyethylene film of 50 µ thickness was spread manually over the prepared field and tomato seedlings were transplanted by making holes of 5 cm diameter on the film. Lateral drip lines having emitters at 50 cm distance with a discharge rate of 4 liters/h were placed in each row of plants both in unmulched treatments and below the polyethylene mulch treatments. Volumetric method was used for calculating the uniformity coefficients (Uc) of drip irrigation system (Raina et al., 1999). Data were recorded on plant height, leaf area index, fruit weight and fruit yield using standard methods. After the final harvest, the plants were cut at soil surface and the dry weight of top growth (stem and leaves) were determined after complete drying at 60°C. The water use efficiency was computed by dividing tomato yield with total water applied (cm). For economic analysis, total cost of production (fixed and operating costs of drip irrigation system) under different irrigation schedules with and without mulch was estimated (Imtiaz et al., 2000). The total cost of production was calculated by adding fixed cost, operating cost and cost of cultivation. The gross returns for different treatments were calculated taking into account the wholesale prices of tomatoes. The net returns were calculated considering gross returns and total cost of production. The benefit cost ratio (B:C) was estimated dividing gross return by total cost of production for each treatment.

RESULTS AND DISCUSSION

The uniformity coefficient (Uc) of drip irrigation system was found to be 92.5% during the experimentation. The high values of uniformity coefficients indicated excellent performance of drip irrigation system in supplying water uniformly throughout the lateral lines during the experiment. The data on growth parameters like plant height, leaf area index (LAI) and dry matter (Table 2) indicated that drip irrigated treatments, irrespective of mulch and unmulched treatments, produced significantly higher plant height, leaf area index (LAI) and dry matter of the plant over surface irrigation. Drip irrigation without mulch with 100 (T_1), 80 (T_2) and 60 (T_3) percent of ET

Table 3. Effect of different treatments on fruit yield (tones/ha) water use efficiency and benefit : cost ratio of tomatoes (pooled data of two years).

Treatments	Yield (t/ha)	Water applied (cm)	Water use efficiency (t/ha-cm)	Gross returns (Rs/ha)	Net returns (Rs./ha)	Benefit: cost ratio
T_1	42.02	52.4	0.80	73535	27909	1.61
T_2	45.57	43.1	1.06	79747	34431	1.76
T_3	34.52	33.7	1.02	60410	15407	1.34
T_4	29.43	70.0	0.42	51502	19146	1.59
T_5	52.58	52.4	1.00	92015	41819	1.83
T_6	57.87	43.1	1.34	101272	51386	2.03
T_7	43.75	33.7	1.30	76562	26989	1.54
T_8	36.06	70.0	0.51	63105	26183	1.71
LSD (P = 0.05)	2.85	-	-	-	-	-

Rs: Indian Rupees (one US$ = 45 Indian rupees).

increased the dry weight of plant by 61.6, 82.0 and 30.3%, respectively, over surface irrigation. The corresponding value for drip irrigation with black polyethylene mulch with these levels were 50.2, 69.5 and 24.7% higher than surface irrigation plus mulch. Application of mulch in surface irrigation also increased the dry matter by 30% over unmulched surface irrigation. Plant height and leaf area index also followed similar trends as that of dry matter production (Table 2). Bhella (1988), Bafna et al. (1993) and Raina et al. (1999) also reported significantly higher plant growth of tomato with drip irrigation compared to surface irrigation.

Irrespective of mulching, significantly higher fruit weight was observed with drip irrigation compared to surface irrigation (Table 2). Drip irrigation without mulch with 100 (T_1) and 80 (T_2) percent of ET increased the fruit weight by 22.6 and 27.8%, respectively, over surface irrigation (Table 2). The corresponding increase with drip plus mulch (T_5 and T_6) was 19.9 and 27.1% respectively over surface irrigation plus mulch (T_8). Fruit weight was highest with 80% of ET irrigation level compared to other irrigation levels either with or without mulch. Surface irrigation recorded least fruit weight without mulch. Elkner and Kaniszewski (1995) also observed significantly higher fruit weight of tomato under drip irrigation as compared to control practices.

The data on fruit yield (t/ha) of tomato (Table 3) indicated that drip irrigation gave significantly higher yield over surface irrigation, irrespective of mulching. Drip irrigation without mulch with 100 (T_1), 80 (T_2) and 60 (T_3) percent of ET increased the fruit yield by 42.8, 54.8 and 17.3%, respectively, over surface irrigation (T_4). The corresponding value for drip irrigation plus plastic mulch with these levels (T_5, T_6 and T_7) was 45.8, 60.5 and 21.3% higher than surface irrigation plus mulch (T_8). Application of black plastic mulch in surface irrigation (T_8) also increased fruit yield by 22.5% over unmulched surface irrigation (T_4).

The increased yield under drip irrigation might have resulted due to better water utilization (Manfrinato, 1974), higher uptake of nutrients (Bafna et al., 1993) and excellent soil-water relationship with higher oxygen concentration in the root zone (Gornet et al., 1973). Surface irrigation resulted in wastage of water in deep percolation, leaching of available plant nutrients and poor aeration resulting in poor yield (Raina et al., 1999). Our results are in accordance with the earlier findings of Bhella (1988) who observed 70% higher tomato yield under drip irrigation as compared to surface irrigation. Bafna et al. (1993) and Raina et al. (1999) also reported increase in tomato yield with drip irrigation to the extent of 40% compared to surface irrigation.

A comparison of different levels of irrigation indicated maximum tomato yield with 80% of ET both under mulch (T_6) and unmulched (T_2) conditions (Table 3). Raina et al. (1999) also observed highest tomato yield where irrigations through drip were applied at 80% pan evaporation. However, Locascio et al. (1989) reported the water requirement of tomato under drip irrigation is about 50% of pan evaporation on fine sandy soil but between 50 to100% pan evaporation values on the fine sandy loam soil.

Application of black polyethylene mulch increased the yield under all levels of irrigation though the response was comparatively higher under treatment T_5 and T_6 (Table 3). Higher yield under mulch treatments might be due to its favorable effect on weed control. There was complete elimination of weeds under black polyethylene mulch, whereas in unmulched plots weeding was done manually seven times during both years of experimenttation. Chakaraborty and Sadhu (1994) and Singh (2005) also reported complete elimination of weeds with the use of black polyethylene. The higher fruit yield under polyethylene mulch may also be ascribed to reduced nutrient losses due to weed control and improved hydrothermal regimes of soil (Ashworth and Harrison, 1983; Bhella, 1988; Singh, 2005).

The total depth of irrigation water applied varied from 33.7 to 70.0 cm under different treatments (Table 3). Drip irrigation, both with and without polyethylene mulch, registered higher water use efficiency as compared to surface irrigation. Highest water use efficiency (WUE) was observed with drip irrigation at 80% ET with mulch (1.34 tonnes/ha-cm) or without mulch (1.06 tonnes/ha-cm) compared to other levels of irrigation with or without mulch. Considering the average value for all tried levels of irrigation, drip irrigation without mulch gave water-use efficiency of 0.97 tonnes/ha-cm as against 0.42 tonne/ha-cm under surface irrigation. The corresponding value for drip plus mulch and surface irrigation plus mulch were 1.23 and 0.51 tonne/ha-cm respectively. Since, the rate of water loss through evaporation from soil surface was much lower under drip irrigation, water-use efficiency was higher as compared to surface irrigation. A comparison of different levels of irrigation indicates maximum water use efficiency with 80% of ET both under mulch (T_6) and unmulched (T_2) conditions (Table 3). The result confirms the earlier findings of Bafna et al. (1993) and Raina et al. (1999) on water-use efficiency of drip irrigated tomato crop.

Total cost of production, gross returns, net returns and benefit: cost ratio of tomato as effected by different treatments is presented in Table 3. Drip irrigation with and without polyethylene mulch registered higher net returns and benefit: cost ratio as compared to surface irrigation. Among different irrigation levels, drip irrigation at 80% ET (T_2) resulted in maximum returns (34431 Rs/ha) and higher benefit: cost ratio (1.76) in tomato. However, highest net returns (51386 Rs/ha) and benefit: cost ratio (2.03) was found with drip irrigation at 80% ET with polyethylene mulch (T_6). This was due to the fact that irrigation at 80% of ET and coupled with mulch resulted in optimum plant growth and development with improvement in water use efficiency.

Conclusion

The present study indicated that drip irrigation at 80% ET with polyethylene mulch resulted in significantly highest yield, water use efficiency and maximum benefit: cost ratio in tomato. The drip system besides giving a saving of 39% water resulted in 55% higher fruit yield of tomato as compared to surface irrigation. Hence drip irrigation system is a very effective and efficient method of irrigation for raising tomato crop especially on light texture sandy loam soil.

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