Journal of Research & Development, Vol. 11 (2011) *ISSN 0972-5407*

Tomato Yield and its Maximization as Influenced by Micro Irrigation Supplies and Planting Pattern in Heavy Soils of Central India

Prashant Shrivastava, Govind Singh Rajput and Siddarth Nayak

Department of Soil and Water Engineering, College of Agricultural Engineering, Jawaharlal Nehru Krishi Vishwa Vidayalaya Jabalpur MP India 482004

ABSTRACT

A field experiment was conducted to study the influence of micro-irrigation supplies and planting pattern on tomato (*Lycopercicum esculentum*) yield response in heavy soils. Four levels of irrigation [viz. irrigation at 0.6, 0.8, 1.0, 1.2 times Crop Evapo-Transpiration (ET_c)] through micro-tubes (discharge: 6 lph), two planting patterns [viz. Paired-row, Four–row] and Pusa Ruby variety of tomato were selected for the study. Irrigation was scheduled on alternate days. Observations on yield revealed that irrigation level, planting pattern, and their interaction significantly influenced the tomato yield. Highest yield of 324.19 q ha^{-1} was obtained in the treatment under irrigation at 1.0 times ETc combined with four row planting. Studies on yield response to irrigation showed that highly deficit irrigation (at 0.6 times ET_c) as well as surplus irrigation (1.2 times ET_c) had lower yield response to irrigation as compared to those of the treatments at irrigation at 0.8 and 1.0 times ET_c. Highest yield response to irrigation was observed in irrigation at 0.8 times ETc combined with paired-row planting, followed by irrigation at 1.0 times ETc combined with four-row planting. Analysis on maximization of production revealed that tomato yield can be maximized under paired-row planting when irrigation is applied at 0.98 times crop evapotranspiration, and under four-row planting when irrigation is applied at 1.087 times crop evapotranspiration.

Key words: Tomato yield, micro-irrigation, planting pattern, evapotranspiration, heavy soils

INTRODUCTION

Water needs of humans and animals are relatively small – the average human drinks about four liters a day. But producing the same person's daily food can take up to 5000 litres a day. That is why the production of food and fibre crops claims the biggest share of freshwater withdrawn from natural sources for human use, or some 70% of global withdrawals (Anonymous, 2003) Recent development report *World Agriculture: towards 2015/30* (Anonymous, 2003) projects that global food production will need to increase by 60 % to close nutritional gaps, cope with the population growth and accommodate changes in diets over the next three decades. To achieve this increase in food production, among other things, there is need to cover more-and-more area under irrigation.

To increase irrigation's contribution to food production, improved efficiency in the use of irrigation is the need of the hour. In other words the ratio 'crops-per-drop' has to be increased. In this regard the drip/micro-irrigation technology has a major role to play. Under drip irrigation the plants are effectively 'spoon-fed' the optimal amount of water (and often fertilizer) when they need it.

Though the drip/micro irrigation technology is relatively simple, it does require high initial investment in which the drip laterals and emitters account for a major portion of the installation costs. Little manipulation in crop planting pattern without any significant loss of yield may possibly reduce high cost component. However this has to be synchronized with micro-irrigation supplies and other location specific factors.

The above supports of the basis of the research work accounted in this paper. In the experiment reported below, response of tomato yield and its maximization as influenced by micro-irrigation supplies and planting pattern in heavy soils of central India was studied.

MATERIAL AND METHODS

The experiment was carried out during January to April 2000, at Instructional Farm of College of Agricultural Engineering, J.N. Krishi Vishwa Vidyalaya, Jabalpur. Jabalpur is situated at 23°09' N Latitude and 79°57' E Longitude with an altitude of 393m above mean sea level. Jabalpur's climate is characterized by dry summer and cold winter. Soil of the study area is clay overlaid with a thin layer of clay-loam having an average bulk density of 1.95 g cc^{-1}; field capacity and wilting point are 40 per cent and 16 per cent respectively, on dry weight basis; infiltration capacity is 0.67cm hr^{-1} Four levels of irrigation [viz. irrigation at 0.6, 0.8, 1.0 and, 1.2 times Crop Evapo-Transpiration (ET_c) designated as I_1, I_2, I_3 and, I_4 respectively] as main treatment, and two planting patterns [viz. Paired-row (P_1) and, Four–row (P_2)] as sub-treatment were selected. In all, there were eight combinations of irrigation level and planting pattern viz. I_1P_1, I_1P_2, I_2P_1, I_2P_2, I_3P_1, I_3P_2, I_4P_1, and I_4P_2.

Treatments were laid with 30m long laterals (LDPE pipe,∅ 16mm) under both paired-row and four-row planting patterns. Micro-tubes (∅ 1.2mm), having a discharge 6 l hr^{-1} at 1.0 kg cm^{-2} operating pressure , were punched and coiled around the laterals at 45cm regular spacing matching plant-to-plant spacing within the rows of tomato. Row-to-row distance was 40cm.

The main treatments were grouped in 4 main-plots representing irrigation levels. Size of each main-plot was 30m x 8.2m and represented one of the four irrigation levels. Each main-plot was further sub divided into sub-plots of size 30m x 2.4m, and 30m X 4.8m containing two pairs of 'paired-row' and 'four-row' plantings respectively. In each sub-plot, the effective width of the P1 and P2 was kept as 120cm and 240cm respectively, to maintain same plant population i.e. 36,666 plants per hectare. In the $P_{1,}$ one lateral served two rows of the plants and was placed in the middle of the two rows; whereas in $P_{2,}$ one lateral served four rows of plants and was placed in the middle of the two inner rows. Eventually each micro-tube in the paired-row planting pattern served two plants while each micro-tube in the four-row planting pattern served four plants.

Irrigation was scheduled on alternate days using daily crop coefficient values for tomato and evaporation data measured from a Sunken-Pan evaporimeter installed on the experimental plot. An operating pressure of 1.0 kg cm^{-2} was maintained throughout the experimental period.

Pusa Ruby variety of tomato (*Lycopersicum esculentum*) was taken for the study. Twenty days old tomato seedlings were transplanted on January 6^{th}, 2000.

Recommended practices for cultivation of tomato were adopted. Picking of ripe tomatoes commenced on March 20th, 2000 and continued till April 21st, 2000. Observations on yield were taken. Analysis of variance was carried out for the yield data. Yield response to irrigation (YRI) for each treatment was computed as ratio of crop yield (q ha^{-1}) to the total depth (cm) of irrigation applied.

Response curve for yield with respect to irrigation level was obtained by deriving the quadratic production function of a parabola – $y = ax^2 + bx + c$, where y = yield of tomato in q/ha, a = regression coefficient of square of irrigation level, b = regression coefficient of irrigation level, c = constant, x = variable representing irrigation level (Bhadauria *et al.,* 1977). The maximization of production was calculated from the above mentioned production function. Maximization of production (y) with respect to irrigation level can be achieved by equating the first derivative of the above mentioned function to zero, provided the second derivative of the function < 0. In this case the first derivative, $dy/dx = b-2cx$ and the second derivative, $d^2y/dx^2 = -2c$. Therefore the level of maximization can be calculated as $dy/dx = b – 2c = 0$, or $x = b/2c$.

RESULTS AND DISCUSSION

Yield observations revealed that irrigation level, planting pattern, and their interaction significantly influenced tomato yield. Among irrigation levels, I3 gave highest yield followed by I4, I2, and I1 (Table 1). Among planting patterns P2 gave yield higher than P1. Treatment I3P2 (324.19 qha-1) gave maximum yield whereas treatment I1P2 (149.99 q ha-1) gave minimum yield.

Table 1. Effect of irrigation level, planting pattern and their interaction on tomato yield (q/ha).

Treatment	P_1	P_2	Average
I_1	167.71	149.99	158.85
I_2	294.58	253.16	273.87
I_3	312.66	324.19	318.43
I_4	276.00	309.99	293.00
Average	262.74	259.33	

Yield response to irrigation

Under the paired-row planting, I_2 level of irrigation showed highest yield response to irrigation (YRI) (10.18 q ha^{-1} cm^{-1}) followed by I_3, I_1 and I_4 level of irrigation in that order of decreasing response (Table 2). Under the four-row planting, it was observed that irrigation level I_3 offered highest YRI (8.96 q ha^{-1} cm^{-1}) followed by I_2, I_4 and I_1.

Table 2 Yield response to irrigation under paired row planting

Irrigation level	Depth of irrigation applied, cm	Planting pattern	Fruit Yield, q ha^{-1}	Yield Response to irrigation q ha^{-1}cm^{-1}
I_1	21.68	P1	167.71	7.73
		P2	149.99	6.91
I_2	28.91	P1	294.58	10.18
		P2	253.16	8.75
I_3	36.14	P1	312.66	8.65
		P2	324.19	8.96
I_4	43.37	P1	276.00	6.63
		P2	309.99	7.14

Among the treatments, I_2P_1 had the highest YRI (10.18 q ha^{-1} cm^{-1}) where as the treatment I_4P_1 showed lowest YRI (6.63 q ha^{-1} cm^{-1}). The other six treatments gave intermediate values of YRI. On comparing the treatments under same irrigation level, it was noted that except in the case of treatments under I_4 level of irrigation, the YRI of paired-row planting were higher than those of the corresponding four-row planting under the remaining three irrigation levels i.e. I_1, I_2, and I_3.

Observations revealed that highly deficit irrigation (I_1) as well as surplus irrigation (I_4) had lower YRI (ranging from 6.63 to 7.73 q ha^{-1} cm^{-1}) as compared to those of the treatments at irrigation at I_2 and I_3 lavel (ranging from 8.65 to 10.18 q ha^{-1} cm^{-1}). Highest YRI was observed in irrigation at 0.8 times ETc combined with paired row planting, followed by irrigation at 1.0 times ETc combined with four row planting.

Thus, in case of scarcity of water , irrigation at 0.8 times ETc combined with paired row planting must be adopted, otherwise irrigation at 1.0 times ETc combined with four row planting must be adopted. However, maximum yield was obtained in the treatment under irrigation at1.0 times ETc combined with four row planting.

Maximizing of production under paired row planting pattern

Response curve for yield with respect to irrigation level under paired row planting gave the relation:

$$y = -1025.00x^2 + 2017.00x - 671.30 \text{ -----------(1)}$$

In order to get maximum yield (y) the equation (1) can be differentiated with respect to the input (x) as

$$dy/dx = - 2050x + 2017.00 \qquad \text{---------(2)}$$

Again differentiating Equation (2) with respect to the input (x) we get

$d^2y/dx^2 = - 2050$

i.e. $d^2y/dx^2 < 0$ Thus equation (2) can be equated to zero

⇨ $dy/dx = - 2050x + 2017 = 0$ --------------(3)

⇨ or $x = 0.98$

or x = irrigation at 0.98 times crop ETc under paired row planting.

Maximizing of production under four row planting pattern

For irrigation level under four row planting following response curve for yield with respect to irrigation level was obtained:

$y= - 737.50x^2 + 1603.50x - 549.60$ -------------(4)

Differentiating equation (4) for yield maximization,

$dy/dx = - 1475.00x + 1603.50$ ---------(5)

Equation (5) can be equated to zero because the second derivative of the above function is < 0: ($d^2y/dx^2 = -1475$). Thus the equation (5) can be written as

$dy/dx = - 1475x + 1603.50 = 0$

⇨ or $x = 1.087$

or x = irrigation at 1.087 times crop ETc under four row planting

Thus the tomato yield can be maximized under:

a) paired row planting when irrigation is applied at 0.98 times crop evapotranspiration, and
b) four row planting when irrigation is applied at 1.087 times crop evapotranspiration.

CONCLUSIONS

Irrigation level, planting pattern and their interaction significantly affected the tomato yield. Highest yield (324.19 q ha^{-1}) was obtained in the treatment under irrigation at1.0 times ETc combined with four row planting. Treatment under irrigation at 0.6 times ETc and combined with four planting gave lowest yield (149.99 q ha^{-1}). It might be that the reduced rate of irrigation water application was not generally sufficient to cover all evaporative demands and caused a stress condition that adversely affected yield.

Studies on yield response to irrigation showed that highly deficit irrigation (irrigation at 0.6 times ET_c) as well as surplus irrigation (irrigation at 1.2 times ET_c) had lower YRI as compared to those of the treatments at irrigation at 0.8 and 1.0 times ET_c. Highest YRI was observed in irrigation at 0.8 times ETc combined with paired row planting, followed by irrigation at 1.0 times ETc combined with four row planting. Thus, under paired row planting the irrigation at 0.8 times of ET_c was found suitable , while under four row planting, irrigation at 1.0 times ET_c proved better..

Analysis on maximization of production revealed that tomato yield can be maximized under paired row planting when irrigation is applied at 0.98 times crop evapotranspiration, and under four row planting when irrigation is applied at 1.087 times crop evapotranspiration.

ACKNOWLEDGEMENTS

Authors are grateful for the facilities provided by College of Agricultural Engineering, Jabalpur, for providing necessary facilities for the experiment. Help provided by Dr. Sanjay Sharma, Scientist, JNKVV during the course of research work is duly acknowledged.

REFERENCES

Anonymous, 2003. FAO AG 21, *Magazine Spotlight Water Management*: towards 2030,

Anonymous, 2003. FAO Development report- *World Agriculture*: towards 2015/30

Bhadauria, S.S. and Verma, S.S. 1977. Relative efficacy of soil and foliar application of urea, and the economic optima for the production of wheat. Phil. Agr, **60**:431-438.