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Effect of Plant Spacing, Irrigation and Fertilizer Levels on Growth and Yield of Brinjal (*Solanum melongena* L.) under Drip Irrigation Systems in Lateritic Soils of Konkan Region of Maharashtra

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An experiment was conducted at A.I.C.R.P. on Water Management Dapoli Centre in lateritic soils of Konkan region of Maharashtra during the years 2009-10 to 2011-12 to study the effect of plant spacing, irrigation and fertilizer levels on growth and yield of brinjal. The experiment was laid out in split plot design with 18 treatments and three replications. The growth parameters showed non significant effect with imposed crop spacing treatments. In case of yield, the plant spacing S3 i.e.175cm-50cm×50cm spacing at 60 percent PE + 100 percent recommended dose (150:50:50 NPK) of water soluble fertilizer recorded maximum brinjal yield of 32.34 t ha^{-1} as compared to all other treatments. The water use efficiency among the treatments ranged from 136.92 kg ha-cm^{-1} to 2111.45 kg ha-cm^{-1}. Maximum water use efficiency (2111.45 kg ha-cm^{-1}) was observed in planting density S_3 at 0.2 PE with 100 percent recommended dose of fertilizers indicating that brinjal can also be grown under water stress conditions with the yield loss of about 5 t/ha. The B:C ratio of 2.41 was observed in plant spacing S_3 (175cm-50cm×50cm) at 0.6 PE with 100 percent recommended dose of fertilizers. This indicates that, the plant spacing S_3 (175cm-50cm×50cm) is superior and cost effective for growing brinjal under drip irrigation in lateritic soils of Konkan region of Maharashtra. The plant spacing S_3 reduced drippers and laterals by about 50% as compared to traditional spacing.

(***Key words:*** *Brinjal, Plant spacing, Drip irrigation, Growth and yield, Water use efficiency)*

The total area under irrigation in Maharashtra state is only 18.5 percent and it is estimated that after full development of water resources the irrigated area in the state may not exceed 30 percent with the adoption of conventional surface irrigation methods. Bringing more area under irrigation is the need of the time and it will largely depend on the efficiency of water use. In this context, micro-irrigation particularly drip irrigation system is an answer to achieve not only higher productivity and water use efficiency but also to achieve sustainability. The drip irrigation system keeps the soil moisture nearer to field capacity and this system also increases fertilizer use efficiency after avoiding losses through leaching, volatilization and fixing of nutrients in the soil (Nakayama and Bucks, 1986). Drip irrigation is one of the major components in precision agriculture. Maharashtra has largest area under micro-irrigation. The research carried out by Padmakumari and Sivanappan (1978) reported that brinjal with drip irrigation required only 24 cm of water as against 69 cm of water in conventional method. Mane *et al.*, (1986) conducted field trial at M.P.K.V, Rahuri and reported that drip irrigation for brinjal saved 58 per cent water as compared to furrow irrigation. The highest water use efficiency (77.2 kg ha-mm^{-1}) recorded under drip irrigation than furrow method of irrigation. Patil (1999) conducted a field experiment to study the effect of fertigation on growth and yield of brinjal at M.P.K.V., Rahuri and showed that the application of 100 per cent liquid fertilizer to brinjal through drip irrigation system recorded the highest fruit yield as compared with straight fertilizers and surface irrigation. Tumbare (2004) carried out an experiment on brinjal to study the impact of planting technique and fertigation on yield of Kharif brinjal at M.P.K.V., Rahuri. The results revealed that growth attributing characters viz. plant height, number of branches found significantly higher in paired row planting 60-120×60cm than normal planting 90cm x 60cm. Kadam *et al.*, (2007) conducted an experiment on brinjal at M.P.K.V., Rahuri on sandy clay loam soil and observed significantly superior individual weight of fruit (g), fruit yield (t ha^{-1}) in the 100 per cent of RDF treatment followed by 75 and 50 per

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cent RDF, respectively. Also the work carried out by Muralikrishnasamy *et al.*, (2008) on drip irrigation and fertigation in chillies showed that, drip irrigation at 50 percent PE along with fertigation at recommended level of N and K resulted in higher yield and less water consumption compared to surface irrigation.

Brinjal is one of the most common, popular and principal vegetable crops grown throughout the country except in higher altitudes. Brinjal is low in calories and fats, contains mostly water, some protein, fiber and carbohydrates. It is a good source of minerals and vitamins and is rich in total water soluble sugars, free reducing sugars, amide proteins among other nutrients. Keeping in this in mind the present investigation was undertaken at Agronomy Farm, AICRP on water management, Dapoli centre to study the effect of planting density, irrigation and fertilizer levels under drip irrigation system in lateritic soil of Konkan region of Maharashtra.

MATERIALS AND METHODS

A field experiment was conducted at the Dapoli centre of All India Co-ordinated Research Project on Water Management in lateritic soils of Konkan region of Maharashtra during rabi seasons of the years 2009-10 to 2011-12. The soil was sandy clay loam with pH 5.5, very high in organic carbon content (18.45 g kg^{-1}), low in available nitrogen content (232 kg ha^{-1}), very low in available phosphorous content (6.11 kg ha^{-1}) and very high in available potassium content (369.6 kg ha^{-1}). The experiment was laid in split plot design with 18 treatments and three replications. The main plot treatments were different plant spacing (three) S_1 (75cm x 75cm), S_2 (75cm-50cm x 90cm) and S_3 (175cm-50cm × 50cm). The irrigation levels were 0.6 PE, 0.4 PE and 0.2 PE i.e. I_1, I_2 and I_3 respectively and sub plot treatments were fertigation levels (two) viz.100 percent, 80 percent i.e. F_1, F_2 respectively, of recommended dose (150:50:50, N:P:K). There were two controls (check basin) with manual application of recommended dose of fertilizer and without fertilizer in combination of surface irrigation at 1.0 IW/CPE ratio, respectively which kept separated beside main and sub-main treatments. The effect of tested crop spacing on saving of lateral and dripper with meager change in plant population is given in the Table 1.

FYM @ 20 t ha^{-1} was applied each year uniformly after preparing the plots of required size before transplanting. The brinjal seedlings of variety CHES – 309 (Suwarna Pratibha) were transplanted in the fourth week of December every year. The discharge of dripper was 4 LPH with different spacing between two drippers. Pre-transplantation irrigation of 6 cm depth was applied to all plots irrespective of the treatments during each year. For all treatments of drip irrigation NPK dose was applied fortnightly through water soluble fertilizers namely 19:19:19 grade and remaining quantity of N was given through urea as per the treatment. Fertigation was given through the venturi provided in system of 0.75 inches. For the control treatment (C_2), fertilizer was given in three splits. For control treatment (C_2) i.e.100 per cent RDF was applied as soil application, 1/3rd quantity of N and 100 per cent P, K were applied as a basal dose and remaining 2/3rd

Table 1. *Details of plot size, plant population of brinjal and percent saving in laterals and drippers*

Plant spacing	Plot size (m)	Plant population per ha	% saving as compared to spacing S_1	
			Dripper	Lateral
S_1 = 75cm x 75cm	8.25m x 7m	17778 per ha	–	–
S_2 = 75cm-50cm x 90cm	8.75m x 7m	17760 per ha	50	41
S_3 = 175cm-50cm x 50cm	10.75m x 7m	17600 per ha	49	67

Table 2. *Total depth of water applied for different irrigation levels to brinjal crop*

Irrigation levels	Depth of water applied (ha-cm)				Saving in water (%) over control
	2009-10	2010-11	2011-12	Mean	
I_1 = 0.6 PE	34.96	36.3	45.2	38.82	41.7
I_2 = 0.4 PE	23.31	24.2	30.1	25.87	61.2
I_3 = 0.2 PE	11.65	12.1	15.0	12.92	80.6
Control	65.0	60.0	75.0	66.67	

quantity of N was applied at 30, 60 and 90 DAT through manual application of solid fertilizers viz., Urea, SSP and MOP. For control (C_1) no fertilizer was given, which was kept as absolute control. The recommended plant protection measures were imposed during the crop growth. The yield was recorded in 10-12 pickings each year.

RESULTS AND DISCUSSION

Irrigation requirement

The experiment on brinjal crop was undertaken during rabi seasons of 2009-10 to 2011-12 to determine the cost effective layout and water requirement for maximizing the productivity. The irrigation water applied during each growing season, their means and percentage of water saving under each irrigation level in drip irrigation over check basin irrigation method are presented in Table 2.

The amount of irrigation water applied to brinjal crop varied with the evaporation during each season. The average irrigation water applied under furrow irrigation system was 66.67 ha-cm, while the mean of irrigation water applied through micro-irrigation ranged from 12.92 ha-cm to 38.82 ha-cm during crop seasons. Thus, water saving under drip irrigation system ranged from 41.7 to 80.6 per cent over check basin irrigation method.

Growth and yield parameters of brinjal

The growth parameters like plant height, number of leaves, number of branches per plant and yield were observed for the treatments incorporated during the year 2009-10 to 2011-12. The data were recorded and analysed statistically using SAS 9.3 software, and are presented in Table 3.

Table 3. *Effect of planting density, irrigation and fertilizer levels on growth parameters and yield of brinjal (average of 2009-10, 2010-11 and 2011-12)*

Treatments	Plant height (cm)	Number of leaves/plant	Number of branches/plant	Yield (t ha^{-1})
A. **Planting density**				
S_1	85.98	111.11	13.52	22.60
S_2	85.83	113.24	14.55	23.86
S_3	85.31	114.59	15.2	28.06
SEm +	1.33	1.38	0.25	0.31
CD at 5%	NS	NS	0.74	0.92
B. **Irrigation levels**				
I_1 = 0.6 PE	84.51	112.90	14.75	25.94
I_2 = 0.4 PE	86.35	114.40	13.96	24.87
I_3 = 0.2 PE	86.25	111.63	14.55	23.70
SEm +	1.13	1.0	0.29	0.32
CD at 5%	NS	2.96	0.88	0.96
C. **Fertilizer levels**				
F_1 - 100% RDF	85.61	112.98	14.64	25.74
F_2 - 80% RDF	85.80	112.97	14.21	23.93
SEm +	1.46	2.41	0.14	0.098
CD at 5%	NS	NS	NS	NS
D. **Control (average value)**				
C_1 - Absolute control	76.54	89.74	11.83	9.13
C_2 - 100% RDF	82.55	95.98	11.96	18.76
E. **Interaction Effects**				
1. Planting density x Irrigation levels	NS	NS	NS	NS
2. Planting density x Fertilizer levels	NS	NS	NS	NS
3. Irrigation levels x Fertilizer levels	NS	NS	NS	NS
4. Planting density x Irrigation levels x Fertilizer levels	Sig.	Sig.	NS	Sig.

1. Impact on growth parameters

The data on effects of planting, irrigation levels and fertilizer levels on average growth parameters of brinjal during the 2009-10 to 2011-12 cropping seasons are presented in Table 3. The plant height and number of leaves did not vary significantly due planting density, while the maximum number of branches observed in S3 was significantly varied with respect to S1 and S2. The irrigation levels did not influence plant height and number of leaves per plant. However, irrigation water applied at I_2 level showed maximum plant height (86.35) as compared to the rest (I_1 and I_3). The variations in plant height and number of leaves per plant were observed to be non-significant due to varied levels of fertilizer doses.

2. Impact on yield

S_3 spacing produced significantly higher yield (28.06 t/ha) as compared to the S_1 and S_2 treatment. Irrigation level I_1 (0.6PE) produced significantly higher brinjal yield (25.94 t/ha). The effect of fertilizer levels of yield of brinjal was found to be non-significant, however, the treatment F_1 (100% RDF) has produced comparatively higher yield (25.74 t/ha) than that of the F_2 treatment.

3. Interaction effect

The data on interaction effect of planting density, irrigation levels and fertilizer levels are presented in Table 3. The plant height, number of leaves, number of branches and yield of brinjal were found to be non significant. The average yield

Table 4. *Pooled mean yield of brinjal (t/ha) as affected by different spacing, irrigation and fertigation treatments and water use efficiency duirng 2009-10 to 2011-12 cropping seasons*

Treatments	Yield (t ha^{-1})	Total water applied (ha-cm)	W.U.E. (kg/ha-cm)
$S_1I_1F_1$	23.96	38.82	617.20
$S_1I_1F_2$	22.58	38.82	581.65
$S_1I_2F_1$	24.21	25.87	935.83
$S_1I_2F_2$	21.52	25.87	831.85
$S_1I_3F_1$	21.89	12.92	1694.27
$S_1I_3F_2$	21.44	12.92	1659.44
$S_2I_1F_1$	25.70	38.82	662.02
$S_2I_1F_2$	22.81	38.82	587.58
$S_2I_2F_1$	25.17	25.87	972.94
$S_2I_2F_2$	23.18	25.87	896.01
$S_2I_3F_1$	22.99	12.92	1779.41
$S_2I_3F_2$	23.30	12.92	1797.83
$S_3I_1F_1$	32.34	38.82	833.07
$S_3I_1F_2$	28.24	38.82	727.46
$S_3I_2F_1$	28.15	25.87	1088.13
$S_3I_2F_2$	26.99	25.87	1043.29
$S_3I_3F_1$	27.28	12.92	2111.45
$S_3I_3F_2$	25.32	12.92	1953.70
C_1 (ab. control)	9.13	66.67	136.94
C_2	18.76	66.67	281.38

Table 5. *Water saving and increase in yield of brinjal in different irrigation levels over control during the study period*

Irrigation level	Depth of water applied (cm)	% water saving over control	Crop yield (t ha^{-1})	Increase in yield over control (%)
I_1 = 0.6 PE	38.82	41.78	24.29	22.76
I_2 = 0.4 PE	25.87	61.19	23.86	21.37
I_3 = 0.2 PE	12.92	80.6	23.30	19.48
Control	66.67	–	18.76	–

obtained were found to be non-significant due to the interaction of planting density and irrigation levels, planting density and fertilizer levels and irrigation levels and fertilizer levels. From the yield data (Table 4) it is observed that, maximum yield of 32.34 t/ha was observed in S3I1F1 treatment followed by $S_3I_1F_2$ treatment (28.24 t ha^{-1} t ha^{-1}). The minimum yield (9.13 t ha^{-1}) was found in C_1 (absolute) control treatment.

Water use efficiency

Water use efficiency is the ratio of yield obtained in a particular treatment to the depth of water applied. The maximum water use efficiency (WUE) of 2111.45 kg/ha-cm was observed in $S_3I_3F_1$ treatment followed by 1953.70 kg/ha-cm in $S_3I_3F_2$ treatment (Table 4). The minimum water use efficiency of 136.94 Kg/ha-cm was noticed in control (C_1) treatment. The maximum per cent increase in yield as influenced by irrigation levels under drip system was found to be 22.76 percent over check basin. The water saving in drip irrigation levels as compared to check basin was observed ranging from 40 to 80 (Table 5).

Economics

The benefit cost ratio under various treatment combinations has been calculated. The maximum benefit cost ratio of 2.41 was observed under drip irrigation at 0.6 PE with 100% recommended dose of fertilizer i.e. at $S_3I_1F_1$ treatment. The maximum net monetary returns of Rs 3.78 lakh/ha was observed in $S_3I_1F_1$ treatment and minimum net monetary returns of Rs 1.93 lakh/ha was observed in control treatment.

CONCLUSIONS

Drip irrigation with spacing of 175cm-50cm×50cm was observed to be better in achieving maximum yield of brinjal in Konkan region of Maharashtra. The total water requirement for brinjal has been deduced to be 39 ha-cm (3900 m^3 ha^{-1}) when drip irrigation was practiced. Water saving under drip irrigation system ranged from 40 to 80 percent over the conventional check basin irrigation method. The maximum benefit cost ratio of 2.41 was realised under drip irrigation at 0.6 PE with plant spacing of 175cm-50cm x 50cm and 100% RDF.

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