Irrigation and Fertigation Scheduling under Drip Irrigation in Brinjal (*Solanum melongena* L.) Crop

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Abstract

Field experiments were conducted (Field No. NC-17) at Agricultural Research Station, Bhavanisagar during 2007 and 2008 to maximize the water and fertilizer use efficiency in brinjal crop. The experiments were laid out in factorial randomized block design with nine treatments which included three irrigation levels 100, 75 and 50% of pan evaporation (PE) along with three fertigation levels, viz. 125, 100 and 75% of recommended N and K fertigation through drip irrigation and replicated thrice. In brinjal, higher yields (42.33 t ha^{-1} in I crop and 37.90 t ha^{-1} in II crop) were recorded in treatment drip irrigation at 75% of PE with fertigation of 75% of recommended N and K with maximum shoot length and number of branches plant^{-1}. The highest water use efficiency of 111.5 kg ha^{-1} mm^{-1} and N, K use efficiency were recorded in drip irrigation at 75% of PE with fertigation of 75% of recommended N and K. The maximum benefit-cost ratio was noted in drip irrigation at 75% of PE with fertigation of 75% of recommended N and K (2.9 and 2.5, respectively) in both the years of study.

1. Introduction

The available water resource of Tamil Nadu state in India is only 3% of the country. The average rainfall in Tamil Nadu is 958.5 mm (India Meteorological Department, 2008) as against the average rainfall of 1200 mm (The Pulse of Indian Agriculture, 2008) in the country. Water is the vital source for crop production and is the most limiting factor in Indian agricultural scenario. Though India has the largest irrigation network, the irrigation efficiency has not been achieved more than 40%. The per capita water availability, in terms of average utilizable water resources in the country, has dropped from 6008 m^3 in 1947 to 1250 m^3 now and is expected to dwindle down to 760 m^3 (Singh, 2006). There are 140 mha of arable land in India of which 41.2 mha are being irrigated (Ramah, 2008).

Due to water scarcity, the available water resources should be very effectively utilized through water saving irrigation technologies. The need of the hour is, therefore, to maximize the production unit^{-1} of water. Hence, further expansion of irrigation may depend upon the adoption of new systems such as pressurized irrigation methods with the limited water resources. Amongst those pressurized irrigation methods, drip irrigation has proved its superiority over other methods of irrigation due to the direct application of water and nutrients in the vicinity of root zone.

In India, the potential for the drip irrigation system is estimated to be 21.27 mha (Narayanamoorthy, 2008). Water saving from drip irrigation system varied from 12 to 84% for different crops besides increasing the production of crops. Maharastra and Tamil Nadu are the leading states using drip irrigation system in India (Ramah, 2008).

Vegetable production in Indian agricultural scenario has wider scope for increasing the income of the marginal and small farmers. Vegetables have vast potential in foreign exchange by the export of value added food commodities. India is the second largest vegetable producer next to China, with an estimated production of about 50.09 mt from an area of 4.5 mha at an average production of 11.3 t ha^{1}. India shares about 12% of the world output of vegetables from about 2.0% of cropped area in the country (Sidhu, 2008). To be more competitive in today's market of vegetables, the vegetable growers are looking for new ways to achieve superior quality produce with higher yields than the conventional methods. Presently, the vegetable crop production suffers mainly on the availability of water and nutrients. The water and fertilizer use efficiency through drip fertigation method can be maximized by the improved techniques introduced.

2. Materials and Methods

The field experiments were conducted at Agricultural Research Station, Bhavanisagar, Erode, Tamil Nadu during 2007 and 2008.

The field is located at 11^0 29$^/$ N latitude, 77^0 08$^/$ E longitude with an altitude of 256 m above sea level. The mean annual rainfall is 696 mm and mean temperature is 27.5^{0}C. The soil of the experimental area belongs to sandy loam in texture. The physical properties of soil and irrigation water are given in Table 1.

2.1. Design and treatments

The experiment was laid out in a Factorial Randomized Block

Table 1: Physical properties of the soil and irrigation water

Particulars	Soil	Water
pH	7.8	7.2
EC ($dS.m^{-1}$)	0.17	1.1
Bulk density ($kg\ m^{-3}$)	1.42	-
Infiltration rate ($cm\ h^{-1}$)	1.98	-
Field capacity (%)	21.8	-
Permanent wilting point (%)	10.8	-
Available N ($kg\ ha^{-1}$)	229	-
Available P ($kg\ ha^{-1}$)	10.1	-
Available K ($kg\ ha^{-1}$)	179	-
Total suspended solids (ppm)	-	404
Ca ($meq\ l^{-1}$)	-	57.2
Mg ($meq\ l^{-1}$)	-	73.8
Organic carbon (%)	-	0.34

Design with nine treatments which included two factors such as irrigation level and fertigation level and replicated thrice.

Factor I. Irrigation levels
I_1-Drip irrigation at 100% of pan evaporation (PE)
I_2-Drip irrigation at 75% of PE
I_3-Drip irrigation at 50% of PE
Factor II. Fertigation levels
F_1-Fertigation at 125% of recommended N and K
F_2-Fertigation at 100% of recommended N and K
F_3-Fertigation at 75% of recommended N and K

2.2. Irrigation scheduling

The daily PE data was used for scheduling irrigation, and irrigations were given once in three days interval through drip irrigation system.
Lateral spacing =1.5 m
Emitter spacing =0.6 m
Area coverage emitter^{-1} =0.6 x 1.5=0.9 m^2
Emitter capacity = 4 l h^{-1}
Depth of irrigation (discharge ÷ area) =

$$\frac{4}{1000} \bullet \frac{1}{0.9} \bullet 1000 = 4.4\ mm\ h^{-1}$$

2.3. Fertigation scheduling

The fertigation was given at weekly intervals. The entire phosphorus was applied as basal, and N and K were applied through fertigation with twelve equal splits from 3rd week to 14th week after planting. The recommended dose of N, P and K for brinjal is given in Table 2.

Table 2: Fertilizer requirement for brinjal (recommended N: P: K is 100:50:30 kg ha^{-1})

Treatments (%)	Fertilizer required (g)			
	Urea		White potassium chloride (KCl)	
	Split^{-1}	Total	Split^{-1}	Total
125	428	5136	98	1181
100	342	4109	79	945
75	257	3082	59	709

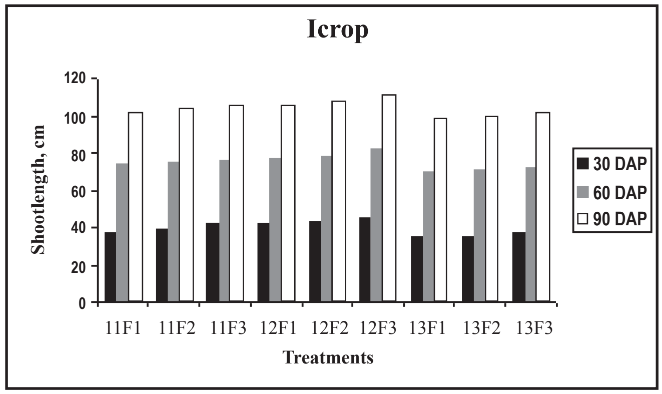
2.4. Planting

Healthy Namdhari hybrid brinjal (*Solanum melongena* L.) seedlings were planted in paired row geometry at 70 x 60 cm^2 spacing.
First season of planting (crop I): 2007 (06.07.2007 to 07.11.2007)
Second season of planting (crop II): 2008 (22.06.2008 to 06.10.2008)

3. Results and Discussion

3.1. Effect of irrigation and fertigation levels on biometric parameters

Irrigation and fertigation levels significantly influenced the growth characters such as shoot length and number of branches in brinjal. The graphical representation of biometric observations for I and II crops are given in Figure 1 and 2.



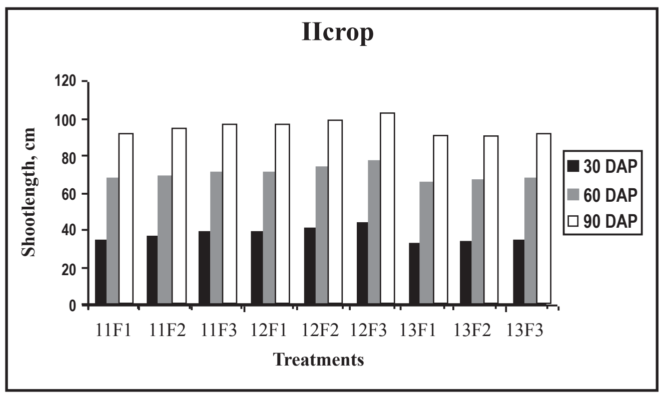


Figure 1: Influence of irrigation and fertigation levels on shoot length in brinjal

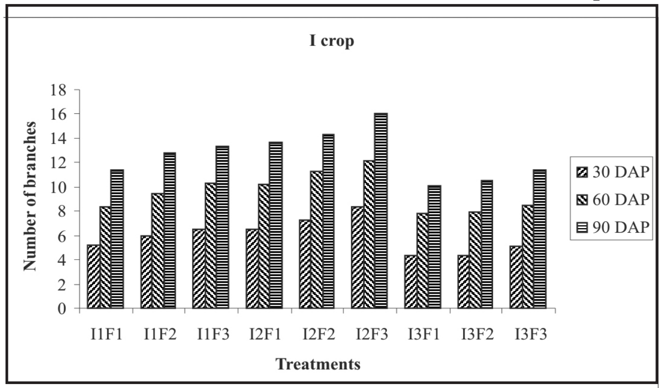
During 2007, the maximum shoot length of 45.2, 82.0 and 111.3 cm at 30, 60 and 90 days after planting (DAP) and number of branches plant^{-1} of 8.3, 12.1 and 16.0 at 30, 60 and 90 DAP, respectively were observed in drip irrigation at 75% of PE with 75% of recommended N and K whereas the least shoot length (34.4, 70.0 and 99.1 at 30, 60 and 90 DAP, respectively) and less number of branches plant^{-1} (4.3, 7.8 and 10.1 at 30, 60 and 90 DAP, respectively) were recorded in drip irrigation at 50% of PE with 125% of recommended N and K. The improved growth characters in I_2F_3 might be due to optimum availability of nutrients and moisture.

A similar trend was observed in the II crop (2008) also.

3.2. Effect of irrigation and fertigation levels on the yield

Irrigation and fertigation levels had a pronounced effect on brinjal yield during both the years of study.

Among the three levels of drip irrigation experimented, I_2 (drip irrigation at 75% of PE) registered the highest yield (39.87 t ha^{-1} in I crop and 36.63 t ha^{-1} in II crop) and was superior over I_1 (36.60 t ha^{-1} in I crop and 32.70 t ha^{-1} in II crop) and I_3 (32.51 t ha^{-1} in I crop and 27.68 t ha^{-1} in II crop). This might be due to the optimum use of irrigation water. The similar results were recorded in II crop also (Table 3).



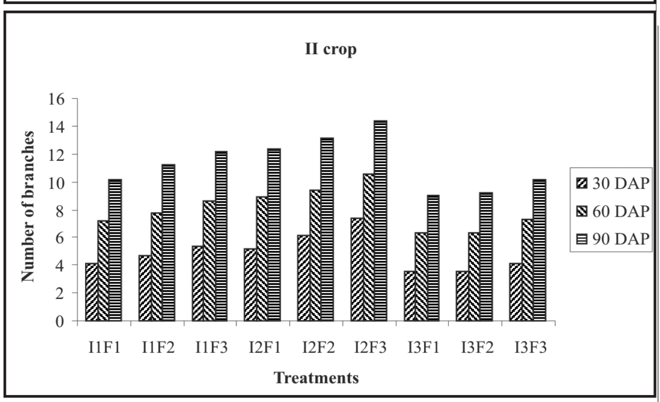


Figure 2: Influence of irrigation and fertigation levels on number of branches $plant^{-1}$ in brinjal

Table 3: Effect of irrigation and fertigation levels on the yield of brinjal

Treat-ments	Yield (t ha^{-1})							
	I crop				II crop			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
I_1	35.05	36.29	38.48	36.60	31.06	32.67	34.38	32.70
I_2	37.90	39.37	42.33	39.87	34.48	35.81	37.90	36.63
I_3	31.33	31.62	34.57	32.51	25.62	27.33	30.10	27.68
Mean	34.76	35.76	38.46	-	30.39	31.94	34.13	-
	SED		CD (p=0.05)					
	I crop	II crop	I crop	II crop				
I	0.16	0.14	0.34	0.31				
F	0.16	0.14	0.34	0.31				
IF	0.27	0.25	0.58	0.53				

Among different fertigation levels, the highest yield (38.46 t ha^{-1} in I crop and 34.13 t ha^{-1} in II crop) was observed in F_3 (drip fertigation at 75% recommended N and K) and was superior over F_1 (34.76 t ha^{-1} in I crop and 25.62 t ha^{-1} in II crop) and F_2 (35.76 t ha^{-1} in I crop and 31.94 t ha^{-1} in II crop). The highest yield might be due to the application of optimum fertilizer required by the crop. The same trend was observed in II crop also (30.39, 31.94 and 34.14 t ha^{-1} in F_1, F_2 and F_3, respectively).

The influence of irrigation and fertilizer levels reflected on the yield of brinjal in both the years. During I crop (2007) the maximum yield of 42.33 t ha^{-1} was recorded in treatment drip irrigation at 75% of PE with fertigation of 75% of recommended N and K compared to other treatments. The lowest yield of 31.33 t ha^{-1} was observed in drip irrigation at 50% of PE with fertigation of 125% recommended N and K which was inferior to all the other combinations. The reason for the lowest yield might be due to lesser uptake of nutrients by plants under low moisture regime (drip irrigation at 50% PE) even though the applied fertilizer was high. During II crop also, the same trend was noticed in the yield. The maximum yield of 37.90 t ha^{-1} was observed in I_2F_3 whereas the lowest yield of 25.62 t ha^{-1} was recorded in I_3F_1.

3.3. Water use efficiency (WUE)

The influence of irrigation and fertigation levels on water use efficiency (WUE) for I and II crops are furnished in Table 4. During I crop, the highest WUE of 111.5 kg ha^{-1} mm^{-1} was recorded in I_2F_3. The reason for maximum water use efficiency in I_2F_3 might be due to lesser water use compared to I_1F_1. Manjunatha et al. (2004) reported similar findings that the WUE was higher (59.9 kg ha^{-1} mm^{-1}) in 0.8 Evapotranspiration (ET) compared to 1.0 ET (54.7 kg ha^{-1} mm^{-1}) in brinjal. During II crop, the highest WUE of 96.2 kg ha^{-1} mm^{-1} was observed in I_2F_3 whereas the least WUE of 69.1 kg ha^{-1} mm^{-1} was recorded in I_1F_1.

Similar results were reported by Bao-Zhong and Yuvan (2003) and they observed the maximum WUE of 3.73 kg ha^{-1} mm^{-1} in drip irrigation at 75% PE than 100% PE (3.37 kg ha^{-1} mm^{-1}) and 50% PE (3.43 kg ha^{-1} mm^{-1}). Edna Antony and Singandhupe (2004) found that the maximum WUE of 59.9 kg ha^{-1} mm^{-1} was recorded in drip irrigation at 0.8 ET compared to drip irrigation at 1.0 ET (54.7 kg ha^{-1} mm^{-1}) and 1.2 ET (59.0 kg ha^{-1} mm^{-1}) in capsicum. Drip irrigation level of 75% Epan coupled with 25 kg N ha^{-1} fertigation under drip irrigation was the optimum combination for maximizing WUE and yields of peas grown on sandy loam soil in Himachal Pradesh of India (Malik and Kumar, 1996).

3.4. Fertilizer use efficiency (FUE)

The influence of fertigation levels of N and K on fertilizer use efficiency (FUE) is presented in Table 5 for I and II crops. Increased FUE such as Nitrogen Use Efficiency (NUE) and Potassium Use Efficiency (KUE) with the decreased level of fertilizer doses were observed in both crops. The highest

Table 4: Water use efficiency (WUE) in brinjal										
Treatments	I crop					II crop				
	Depth of irrigation (mm)	Effective rainfall (mm)	Total water used (mm)	Yield (kg ha^{-1})	WUE (kg ha^{-1} mm^{-1})	Depth of irrigation (mm)	Effective rainfall (mm)	Total water used (mm)	Yield (kg ha^{-1})	WUE (kg ha^{-1} mm^{-1})
$I_1 F_1$	322.3	122.2	444.5	35048	78.8	276.1	173.4	449.5	31063	69.1
$I_1 F_2$	322.3	122.2	444.5	36286	81.8	276.1	173.4	449.5	32667	72.9
$I_1 F_3$	322.3	122.2	444.5	38476	86.6	276.1	173.4	449.5	34381	76.5
$I_2 F_1$	257.6	122.2	379.8	37905	99.8	220.7	173.4	394.1	34476	87.5
$I_2 F_2$	257.6	122.2	379.8	39365	103.6	220.7	173.4	394.1	35810	90.9
$I_2 F_3$	257.6	122.2	379.8	42333	111.5	220.7	173.4	394.1	37905	96.2
$I_3 F_1$	188.2	122.2	310.4	31333	100.9	165.5	173.4	338.9	25619	75.6
$I_3 F_2$	188.2	122.2	310.4	31619	101.8	165.5	173.4	338.9	27333	80.8
$I_3 F_3$	188.2	122.2	310.4	34571	111.4	165.5	173.4	338.9	30095	88.8

NUE of 564.4 and 505.4 kg kg^{-1} of N was recorded in I_2F_3 in I and II crop, respectively.

The similar trend was observed in KUE in I and II crops. The maximum KUE of 1881.5 and 1648.7 kg kg^{-1} of K was observed in I_2F_3 in I and II crops, respectively. As the fertilizer levels decreased, the FUE increased when there was less yield difference. Similar findings were observed by Selvaraj (1997), Singhandhupe et al. (2003), Hongal and Nooli (2007), Arunadevi (2005), and Badr and Abou Ei-Yaized (2007).

3.5. Cost economics

The life of the drip material was taken as 10 years, interest at 12% on fixed cost, and the repair and maintenance cost at 1% of fixed cost were taken into consideration to work out the cost economics.

Table 5: Fertilizer use efficiency (FUE) in brinjal								
Treatments	Fertilizer applied (kg ha^{-1})		I crop			II crop		
	N	K	Yield (kg ha^{-1})	NUE (kg $kg^{-1}$of N)	KUE (kg kg^{-1} of K)	Yield (kg ha^{-1})	NUE (kg kg^{-1} of N)	KUE (kg kg^{-1} of K)
$I_1 F_1$	125.0	37.5	31063	280.4	934.6	31063	248.5	828.4
$I_1 F_2$	100.0	30.0	32667	362.9	1209.5	32667	326.7	1088.9
$I_1 F_3$	75.0	22.5	34381	513.0	1710.1	34381	458.4	1528.0
$I_2 F_1$	125.0	37.5	34476	303.2	1010.8	34476	275.8	919.4
$I_2 F_2$	100.0	30.0	35810	393.7	1312.2	35810	358.1	1193.7
$I_2 F_3$	75.0	22.5	37905	564.4	1881.5	37905	505.4	1684.7
$I_3 F_1$	125.0	37.5	25619	250.7	835.6	25619	205.0	683.2
$I_3 F_2$	100.0	30.0	27333	316.2	1054.0	27333	273.3	911.1
$I_3 F_3$	75.0	22.5	30095	461.0	1536.5	30095	401.3	1337.6

The fixed cost of installation of drip system was INR 67,100 ha^{-1} for all the treatments with the lateral spacing of 1.5 m and emitter spacing of 0.6 m along the lateral. Total operational cost of brinjal crop for whole season was worked out at INR 5,121 ha^{-1} (one-third of the total operational cost of INR 15,372 ha^{-1} was taken as operational cost for brinjal crop as three crops could be raised in a year). The cost of cultivation for brinjal crop was worked out at INR 82,000 ha^{-1}. Hence the total seasonal cost was INR 87,121 ha^{-1}. Benefit-cost ratios of I and II crops were calculated by dividing the net income by the total seasonal cost (Table 6).

It is observed from the table that the highest net income was realized in I_2F_3 for I and II crops (INR 2,51,546 and 2,16,117, respectively) compared to other treatments whereas the lowest was recorded in I_3F_1 (INR 1,63,546 and 1,17,831, respectively). The benefit-cost ratio (BCR) was worked out for all the treatments using net income generated and seasonal total cost of brinjal crop. The maximum BCR was noted in I_2F_3 in both the years of study (2.9 and 2.5, respectively). The lowest BCR of 1.8 and 1.4 were recorded in I and II crop, respectively in I_3F_1.

4. Conclusion

In brinjal, higher yields (42.33 t ha^{-1} for I crop and 37.90 t ha^{-1} for II crop) were recorded in treatment I_2F_3 (drip irrigation at 75% of PE with fertigation of 75% of recommended N and K) with maximum shoot length and number of branches $plant^{-1}$. The maximum BCR was noted in I_2F_3 (drip irrigation at 75% of PE with fertigation of 75% of recommended N and K) in both the years of study (2.9 and 2.5, respectively). It is concluded that for brinjal crop drip irrigation at 75% of PE with fertigation of 75% of recommended N and K is recommended for getting higher yield, water use efficiency,

Table 6: Benefit-cost ratio (BCR) in brinjal

Treatments	Seasonal total cost (INR ha^{-1})	Selling price (INR t^{-1})	I crop				II crop			
			Yield (t ha^{-1})	Income from produce (INR ha^{-1})	Net income (INR ha^{-1})	BCR	Yield (t ha^{-1})	Income from produce (INR ha^{-1})	Net income (INR ha^{-1})	BCR
$I_1 F_1$	87121	8000	35.05	280381	193260	2.2	31.06	248508	161387	1.9
$I_1 F_2$	86896	8000	36.29	290286	203165	2.3	32.67	261333	174212	2.0
$I_1 F_3$	86671	8000	38.48	307810	220689	2.6	34.38	275048	187927	2.2
$I_2 F_1$	87121	8000	37.90	303238	216117	2.5	34.48	275810	188689	2.2
$I_2 F_2$	86896	8000	39.37	314921	227800	2.6	35.81	286476	199355	2.3
$I_2 F_3$	86671	8000	42.33	338667	251546	2.9	37.90	303238	216117	2.5
$I_3 F_1$	87121	8000	31.33	250667	163546	1.9	25.62	204952	117831	1.4
$I_3 F_2$	86896	8000	31.62	252952	165831	1.9	27.33	218667	131546	1.5
$I_3 F_3$	86671	8000	34.57	276571	189450	2.2	30.10	240762	153641	1.8

N and K use efficiency and net returns.

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