International Journal of Agriculture Sciences
ISSN: 0975-3710&E-ISSN: 0975-9107, Volume 8, Issue 48, 2016, pp.-2030-2032.
Available online at http://www.bioinfopublication.org/jouarchive.php?opt=&jouid=BPJ0000217

Research Article

YIELD, WATER USE EFFICIENCY AND ECONOMIC EVALUATION OF DRIP IRRIGATED BRINJAL (*Solanum melongena* L.) AS AFFECTED BY SINGLE AND DOUBLE INLET LATERALS AND SUB MAIN SIZES

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Received: June 16, 2016; Revised: July 03, 2016; Accepted: July 04, 2016; Published: October 18, 2016

Abstract- Experiment was conducted during three growing seasons (2011 to 2013) in Jamunali village of Chhendipada block in Angul district of Odisha, India in a farmer's field to study the effect of five different single and double inlet lateral connections with three different commonly available sub-main pipe sizes (40, 50 and 63 mm) on yield and economics of drip irrigated brinjal (*Solanum melongena* L.) crop. Maximum yield and WUE of 399.48 q/ha and 880.58 kg / ha-cm have been observed in case of double inlet system connected with two sub-mains of 63 mm diameter and the lateral connecting to both the sub-mains at two ends laid on two sides of the field (T_{15}). Minimum yield (380.67 q/ha) and WUE (839.11 kg / ha-cm) values have been found in case of single inlet laterals laid on one side of sub main of 40 mm diameter (T_1). Economic analysis shows maximum value of Net Present Value (NPV), Benefit Cost ratio (B:C), Internal Rate of Return (IRR) and minimum Pay Back Period (PBP) in case of treatment where laterals have been laid and looped on one side of the sub-main with size 40 mm (T_2, NPV – Rs. 649488/-, B:C – 3.11, IRR – 67.29%, PBP–2.66 years). Similarly, minimum value of NPV, B:C, IRR and maximum value of PBP have been observed for treatment where laterals have been connected to two sub-main pipes of dia 63 mm laid at two sides of the experimental plot (T_{15}, NPV – Rs. 523824/-, B:C – 2.13, IRR – 41.02, PBP – 4.03 years) in spite of maximum yield due to increase in cost of the system. Hence, the system where laterals are looped on one side of sub-main pipe with dia 40mm (T_4) is considered as the best one with respect to economic indicator values. Similarly, it is also observed that when single inlet systems are converted to the corresponding double inlet systems by looping the laterals (L_1 to L_2 and L_3 to L_4), yield and economics become better with incorporation of some minimal cost towards in-line laterals and connectors.

Keywords- Benefit cost ratio, Internal rate of return, Net present value, Payback period, Water use efficiency

Citation: Mohanty B., et al., (2016) Yield, Water Use Efficiency and Economic Evaluation of Drip Irrigated Brinjal (*Solanum melongena* L.) as Affected by Single and Double Inlet Laterals and Sub Main Sizes. International Journal of Agriculture Sciences, ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 8, Issue 48, pp.-2030-2032.

Academic Editor / Reviewer: Dr Arvind Singh Tomar, Subrat Kumar Behera, Prabhat Ch Pradhan, Er Rajinkumar Jadavbhai Patel

Introduction

Drip irrigation is considered as the most advanced and efficient method of irrigation system for supplying water precisely to the root zone of plants as per their requirement resulting in enhancement of yield. In 2050, an increase in water consumption up to 11% and duplication in food production needs have been predicted [1]. Hence, drip irrigation can find a pivotal role to meet the demand. In the conventional drip system, laterals are connected to the sub-main, run along the rows of crop and are closed at the extreme end by end cap or line end. Lateral being connected to the sub-main at one end, water enters into the lateral at this end, hence termed as single inlet type. But when the laterals would connect the sub-main pipe at both the ends, allowing water to flow from sub-main to the laterals from the two connecting ends or inlets, it would be termed as double inlet drip system. In drip irrigation system, laterals being more in length and less in diameter pose a major concern of frictional head loss in the system. Methodology to reduce head loss in the laterals would certainly be the area of interest. Installation of the double inlet drip system is an effort in this line on which the present study is based on.

In wheat crop, water consumption is maximum at booting and flowering period. Drip irrigation provides the correct amount of water, which helps in increase of grains per spike and grain weight, thus increase yield and WUE [2].

By increasing irrigation uniformity and uniformity coefficient, water use efficiency can be enhanced [3]. Distribution uniformity refers to how uniformly the irrigation system distributes water through the emitters (in case of drip system). Good distribution uniformity leads to efficient irrigation and results in an increase of water use efficiency [4].

Drip irrigation along with polyethylene mulch gave highest water use efficiency. Net return, incremental net return and incremental benefit-cost ratio were recorded maximum of 50% water application with straw mulch. The study revealed that drip irrigation clubbed with mulch increases land and water productivity [5,6]. Drip irrigation has been found to be effective in resource saving, increasing yield and profit. Hence, the promotion of drip irrigation should be focused as a policy matter in areas having scarcity of water and labour with predominance of wider-spaced crops [7].

The study reveals that uniformity of irrigation affects the crop yield [8]. A model developed by Lopez-Mata [9] simulates the effect of irrigation uniformity on crop yield. In maize crop, an increase in uniformity of irrigation increase yield by 4% for common irrigation strategy and 6.8% for the optimal irrigation schedule suggested by the model. Increase in uniformity of irrigation from 75% to 95% may increase gross margin up to 27% in the case of maize crop.

Though double inlet drip irrigation system seems to be more efficient and cost-effective in comparison to singe inlet system, not much work has been done in the field of research to verify its impact in the field condition. Nayak [10] made a theoretical analysis of frictional head loss in both single and double inlet portable drip irrigation unit and concluded that the frictional head loss in the single inlet

system is 7.216 times of that for a double inlet system and suggested replacement of the single inlet system in stationary drip unit with a double inlet system for reducing frictional head loss considerably.

Materials and Methods

Field experiments were conducted during three seasons from month of January to June for three continuous years (2011 to 2013) in a farmer's field. The experimental site is located at Jamunali village of Chhendipada block in Angul district of Odisha, India (21^0 2' 41" N latitude, 84^0 50' 14" E longitude and an altitude of 217 m above mean sea level). The area comes under Mid-Central Table Land Zone of Odisha. The soil of the experimental field is of loamy sand type (85.2 % sand, 3.2 % silt and 11.6 % clay). The field capacity, wilting point and bulk density of the soil are observed to be 14.7 %, 4.9 % and 1.53 gm/cm^3 respectively. Water from the existing dug well was used for irrigation purpose to the plant through drip irrigation system. Experiment was conducted in brinjal (var. Tarini) crop irrigated through in-line drip system with lateral spacing (row - row) of 1.2 m and plant to plant spacing of 0.6 m. Split plot design with three replications was followed by taking three commonly available sub-main pipe sizes i.e. 40 mm, 50 mm and 63 mm in the main plots. Similarly five different types of lateral connections in which two were of single inlet type and three were of double inlet type had been taken in the sub-plots making the total number of treatments to be fifteen (15). Details of the treatments along with line diagram of different lateral connections have been presented in [Table-1]. Field preparation, application of FYM (150 q / ha), seedling raising and planting in the main field, application of fertilizer (150:75:75), bio-fertilizer, plant protection measures were taken up as per recommendations. Yield data for all the treatments and for all the three crops were collected. Water use efficiency (WUE) was calculated for all the treatments taking into consideration of the yield per unit volume of water used. Present worth analysis has been done considering the initial investment, cost of water source with pumping unit and drip irrigation system, present rate of bank interest, inflation, yield, income etc. for different treatments. Economic indicators like Net Present Value (NPV), Benefit-Cost ratio (B:C), Pay Back Period (PBP) and Internal Rate of Return (IRR) have been determined for all the treatments.

Table-1 *Experimental lay out in the field*

Sub-main size → / Lateral connection / Sub plots ↓	Main plots		
	S_1 (Sub-main size –40mm)	S_2 (Sub-main size – 50mm)	S_3 (Sub-main size – 63mm)
L_1	S_1L_1 (T_1)	S_2L_1 (T_6)	S_3L_1 (T_{11})
L_2	S_1L_2 (T_2)	S_2L_2 (T_7)	S_3L_2 (T_{12})
L_3	S_1L_3 (T_3)	S_2L_3 T_8)	S_3L_3 (T_{13})
L_4	S_1L_4 (T_4)	S_2L_4 (T_9)	S_3L_4 (T_{14})
L_5	S_1L_5 (T_5)	S_2L_5 (T_{10})	S_3L_5 (T_{15})

Results and Discussion

Yield and WUE of brinjal under different treatments

The yield of drip irrigated brinjal as affected by different sub-main pipe sizes and different lateral connections is presented in [Table-2]. Amongst the different lateral connections, the double inlet system where laterals were connected to two sub-main pipes laid on both sides of the plot (L_5) gave a maximum mean yield of 398.74 q / ha and minimum yield (381.65 q / ha) was observed in case of a single inlet system where the laterals are laid on one side of the sub-main pipe provided at one side of the plot (L_1). Similarly, amongst the different sub-main pipe sizes, 63 mm size (S_3) has got the maximum mean yield of 393.14 q / ha and minimum value (390.70 q / ha) has been obtained for 40 mm sub-main pipe size (S_1). Hence, combining the two factors, S_3L_5 (T_{15}) gives maximum yield (399.48 q/ha) and minimum yield (380.67 q/ha) is observed in case of S_1L_1 (T_1). Yield increases when the single inlet system with lateral connection at one side of the sub-main (L_1) is converted to double inlet type by looping the laterals (L_2) for a particular sub-main size from a mean value of 381.65 q / ha to 393.29 q / ha (increase of 11.64 q / ha, 3.05%). Similarly, for the single inlet system where sub-main pipe is laid in the centre of the plot and the laterals are laid on both sides of the sub-main (L_3), when converted to double inlet system by looping the laterals on both sides of the sub-main (L_4), yield increases from a mean value of 387.23 q / ha to 398.41 q / ha (increase of 11.18 q / ha, 2.9%). Less head loss in case of double inlet, system leading to more uniformity and required level of irrigation water application is responsible for the increase in yield of brinjal. The water use efficiency of drip irrigated brinjal crop as affected by different treatments has been presented in [Table-3]. The result shows a similar trend as that of yield. Maximum WUE in observed in case of S_3L_5 (T_{15}) and minimum value of WUE is found in case of S_1L_1 (T_1).

Table-2 *Yield of brinjal (q / ha) as affected by different treatments*

	L_1	L_2	L_3	L_4	L_5	Mean
S_1	380.67	392.15	385.32	397.24	398.10	390.70
S_2	381.78	393.53	386.24	398.58	398.65	391.76
S_3	382.49	394.18	390.12	399.42	399.48	393.14
Mean	381.65	393.29	387.23	398.41	398.74	391.86

	S	L	S x L	L x S
SEM±	NS	3.659	NS	NS
$CD_{0.05}$	NS	10.679	NS	NS

Table-3 *Water Use Efficiency (WUE) of brinjal (kg / ha-cm) as affected by different treatments*

	L_1	L_2	L_3	L_4	L_5	Mean
S_1	839.11	864.42	849.36	875.64	877.54	861.21
S_2	841.56	867.46	851.39	878.59	878.75	863.55
S_3	843.13	868.89	859.94	880.44	880.58	866.60
Mean	841.27	866.92	853.57	878.23	878.95	863.79

	S	L	S x L	L x S
SEM±	NS	8.066	NS	NS
$CD_{0.05}$	NS	23.539	NS	NS

Economic evaluation as affected by different treatments:

Economic analysis has been done for different sub-main sizes and different lateral connections. The data on different economic indicators have been presented in [Table-4]. The result shows that amongst the sub-main sizes, sub-main size of 40 mm (S_1) gives the maximum mean value of NPV, BC ratio and IRR values (Rs. 609371, 2.82 and 59.78%, respectively) and minimum PBP of 3.00 years. Sub-main size of 63 mm (S_3) is proven to be least economic as far as the indicators are concerned. Similarly, amongst the different lateral connections, L_2 (double inlet system where laterals are looped at one side of sub-main laid at one side of the plot) has got the maximum mean value of NPV, BC ratio and IRR values (Rs. 648626, 3.07 and 66.24%, respectively) and minimum PBP of 2.70 years. The double inlet system where the laterals are connected to two sub-mains laid on both sides of the plots at two ends (L_5) have been proven to be the least economically as far as the values of the indicators are concerned. The single inlet system, when converted to double inlet system by looping laterals lay on one side of the sub-main pipe present at the side of the plot (L_1 to L_2), the system becomes more economical. Similarly, the single inlet system when converted to double inlet system by looping laterals laid on both sides of the sub-main present at the centre of the plot (L_3 to L_4), the economics of the system improves. Amongst all the treatments, the treatment with sub-main size of 40mm and laterals looped at one side of sub-main present at the side of the plot (S_1L_2) is considered to be the best treatment amongst all with respect to economic parameters (NPV – Rs. 647463, B:C – 2.95, IRR – 63.19%, PBP – 2.81 years).

Table-4 *Economic parameters as affected by different sub main pipe sizes and lateral connections across sub-main sizes:*

	Fixed cost (Rs.)	Variable cost (Rs.)	Gross return	Net return	Present worth cash outflow (Rs.)	Present worth net return (Rs.)	Net Present Value (NPV), Rs.	Pay Back Period (PBP), Yr.	Benefit Cost ratio (B:C)	Internal Rate of Return (IRR), %
S_1	236065	155034	2344176	1347836	341740.66	951111.64	**609370.98**	**3.00**	**2.82**	**59.78**
S_2	244052	157803	2350536	1354196	351615.02	955599.63	**603984.61**	**3.08**	**2.77**	**58.26**
S_3	246714	159614	2355228	1358888	355508.16	958910.58	**603402.42**	**3.10**	**2.75**	**57.84**
					Across lateral connections:					
L_1	210332	148551	2289880	1293540	311580.87	912797.22	**601216.34**	**2.84**	**2.93**	**62.99**
L_2	211372	149779	2359720	1363380	313454.19	962080.39	**648626.21**	**2.70**	**3.07**	**66.24**
L_3	227330	155459	2317360	1321020	333283.19	932188.71	**598905.52**	**2.98**	**2.80**	**59.41**
L_4	229410	157913	2390480	1394140	337029.81	983786.44	**646756.63**	**2.85**	**2.92**	**62.30**
L_5	332940	175717	2392460	1396120	452758.34	985183.64	**532425.31**	**3.93**	**2.18**	**42.21**

Cost of cultivation – Rs. 99,634 / ha. Selling price – Rs. 600 / q Rate of bank interest - 12%, Inflation rate - 6%

Conclusion

From the experiment, it may be concluded that the performance of the double inlet system in terms of yield is more than the corresponding single inlet systems. Single inlet systems can be converted to double inlet systems just by looping the laterals for getting better yield, WUE, income and economics. The double inlet system where two sub-main pipes are laid on both sides of the field and laterals are connected to the sub-main pipes at both the ends is found to give maximum yield. But, in this case the cost of the system is increased substantially and hence shows poor values of economic indicators. Economic evaluation reveals that the double inlet system where laterals are looped and laid at one side of the sub-main pipe with **dia** 40mm gives best result with respect to indicators like NPV, PBP, B:C and IRR values. Though we cannot conclude solely on the basis of economic parameters and both hydraulic and economic parameters need to be considered, the idea can be taken one step forward to bring suitable modification in the traditional drip irrigation design to convert single inlet system to double inlet system for achieving better performance in terms of yield and economics.

Conflict of Interest: None declared

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