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Growth, yield and water use efficiency in drip irrigated brinjal (*Solanum melongena* L.) as affected by single and double inlet drip laterals

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■ **ABSTRACT :** Experiments were carried out during three growing seasons of 2011 to 2013 in the farmer's field at village Jamunali of Chhendipada block in the district Angul, Odisha, India. 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 growth characteristics, yield and water use efficiency of drip irrigated brinjal (*Solanum melongena* L.) crop was studied. Maximum value of biometric observations such as plant height, girth at base, number of branches and leaves per plant, leaf area, root volume, root spreading diameter were found higher in case of double inlet system in comparison to single inlet system. Maximum tap root diameter, rooting depth, fruit length and fruit weight were found to be insignificant irrespective of the size of the submains connected with the laterals. However, except fruit weight all other plant characteristics were significant respective to the type of lateral connections. Water supplied through drip laterals connected with two submains of 63 mm diameter each at both sides of the plot showed better growth indicator parameters amongst the treatments. This performance also reflected in the case of yield and water use efficiency in cultivation of brinjal crop (*Solanum melongena* L.). Maximum yield (399.48 q/ha) and water use efficiency (880.58 kg/ha-cm) have been observed in case of double inlet system with two sub-mains of 63mm diameter and the lateral connecting to both the sub-mains at two ends (T_{15}). Minimum biometric values, yield (380.67 q/ha) and WUE (839.11 kg/ha-cm) have been found in case of single inlet laterals laid on one side of sub main of 40 mm diameter (T_1). Similarly, it is established that when single inlet systems with laterals laid at one side or both sides of the sub-main are converted to the corresponding double inlet systems by looping the laterals (L_1 to L_2 and L_3 to L_4), the growth parameters and yield of the system increases which is very easy to be achieved just by incorporating some minimal cost towards in-line laterals and connectors.

■ **KEY WORDS :** Single inlet lateral, Double inlet lateral, Yield, Water use efficiency

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Drip irrigation is considered as the most advanced and efficient method of irrigation system for supplying water precisely to the root zone of the plants as per their requirement resulting in enhancement of yield. In 2050 an increase in water consumption upto 11 per cent and duplication in food production needs have been predicted (UNESCO-WWAP, 2003). Hence, drip irrigation can find a pivotal role to meet the increasing demand for water and food production.

The irrigation system performance is evaluated in the study area on the basis of adaptability, efficiency and distribution uniformity. The distribution uniformity is a parameter to indicate the irrigation system's capability to apply the same application rate to a surface and sprinkler methods, or to discharge the same water volume from each emitter for the drip irrigation method. Without an appropriate uniformity distribution it is impossible to irrigate in appropriate and efficient manner and with good water use efficiency. In drip irrigation system application of water should be uniform. In fact, with scarce distribution uniformity some zones will be over-watered and other zones will be under watered (Burt *et al.,* 1997; Camp *et al.,* 1997 and Lameck *et al.,* 2011). The part receiving more water cause deep percolation losses and the other part receiving less water involves poor plant growth and fewer yields. This is affected mainly by the pressure variation and hydraulic properties of the emitters. The hydraulic properties of the emitters include the emitter design, discharge rate, quality and temperature of water etc. The flow rate of emitters is affected by the pressure variation in the laterals which is caused due to friction loss.

Common irrigation uniformity and efficiency measures can be related to expected yields from non-uniform irrigation of certain hypothetical crops. The relationship between performance measures and expected yield lends physical significance to irrigation uniformity measures and suggests useful generalisations of traditional uniformity and efficiency measures that are directly related to crop yield (Solomon, 1984). Also distribution efficiency critically influenced the quality and profit in drip irrigated tomato. Decrease in uniformity leads to reduction in dry matter production per unit land. Incentives to switch to new systems or management practices are able to raise the distribution uniformity which result more from profit losses than increases in water price (Santosh, 1996).

Considerable improvements can be achieved in water use efficiency under the concept of increasing irrigation uniformity and uniformity co-efficient (Sepaskhah and Ghahraman, 2004) which can affect the crop yield and influence more or less heavily the environmental impact of the irrigation (Salmeron *et al.,* 2012).

The application of the developed model which simulates the uniformity effect on yield and the repercussion on gross margin (GM) to a maize crop in Albacete (Spain) indicated that for the same irrigation depth, an increase in uniformity of water in the soil (CU) corresponds to a 4 per cent increase in yield for the common irrigation strategy in the area, and a 6.8 per cent increase in yield for the optimal irrigation schedule established by the model. Improvement of CU from 75 to 95 for the common irrigation depth applied to maize may increase GM upto 27 per cent (Lopez-Mata *et al.,* 2010).

In the conventional drip system, laterals are connected to the sub-main and run along the rows of crops and are closed at the extreme end by end cap or line end. Lateral connected to the sub-main at one end and water moves through the lateral from the connecting end, hence, termed as single inlet type. When the laterals are connected with 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, length of laterals is much more and diameter of laterals is much less in comparison to the length of sub-main and main pipe lines. 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 (Mohanty, 2011 and Nayak, 2007). He made theoretical analysis of frictional head loss in both single and double inlet laterals using Williams and Hazen formula and concluded that frictional head loss in single inlet system is 7.22 times that in case of double inlet system and suggested replacement of single inlet system in stationary drip unit with double inlet system for reducing frictional head loss considerably. This would result in reduction of pump capacity and also will reduce the cost of the drip system by reducing the main and sub-main pipe sizes.

Though double inlet drip irrigation system seems to be hydraulically more efficient in reducing frictional head loss compared with singe inlet system, not much work has been done in the field of research to verify its impact in the field condition. With the above hypothetical analysis, the work was undertaken in the farmers' field to study the effect of five different single and double inlet lateral connections with three different commonly available sub-main pipe sizes.

■ METHODOLOGY

Field experiments were conducted from month of January to June during three seasons for three consecutive years (2011 to 2013) in a farmers' 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, India. The physical and chemical properties of the soil in the experimental field are presented in Table A.

Table A : Physical and chemical properties of soil of the experimental field

Properties	Values
Mechanical analysis	
– Sand (%)	85.2%
– Silt (%)	3.2%
– Clay (%)	11.6%
Soil texture	Loamy sand
Field capacity	14.7%
Permanent wilting point	4.9%
Available water (AW)(%)	9.8%
Bulk density (g cm^{-3})	1.53
pH	5.5
EC (ds/m)	1.2
Organic content (g/kg)	0.62

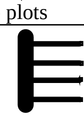
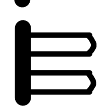
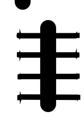
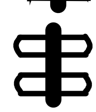
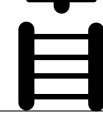
Water from the existing dug well was used for irrigation purpose to the plant through drip irrigation system. The pH, electrical conductivity and turbidity of the irrigation water were tested in the laboratory and found to be 5.73, 1.30 ds/m and 1.0 NTU, respectively. Experiment was conducted with brinjal (cv. TARINI) as test crop irrigated through in-line drip system with lateral spacing (row to row spacing) of 1.2 m and plant to plant spacing of 0.6 m. The Penman – Monteith equation was used to estimate the water requirement of brinjal crop considering the meteorological data of the study area. Irrigation system components consisted of control head, pumping and filtration unit and the distribution system. An electricity operated 1.5 HP pumpset (Crompton and Greaves, mono-block) with back flow prevention device, pressure regulator, pressure gauges, control valves, main (75mm) and sub-main pipes (63, 50 and 40mm) were employed for pumping, filtration and conveyance of irrigation water to the field.

Laterals of 16 mm diameter embedded with emitters (in line) were laid in rows with spacing of 0.6m for application of irrigation water in the experimental plot. Discharge capacity of the emitters is 2 lph operated at a pressure of 1.0 bar. Split plot design with three replications was followed by taking three different commonly available sub-main pipe sizes *i.e.*, 40 mm (S_1), 50 mm (S_2) and 63 mm (S_3) in the main plots. Similarly five different types of lateral connections (Table B) in which two of single inlet type and three of double inlet type were taken in the sub-plots making the total number of treatments to be fifteen. The details of the experimental layout along with line diagram of different lateral connections are presented in Table C.

Table B : Lateral connections used in the experiment

Lateral connection notation	Description
L_1	Lateral laid on one side of sub-main, open to sub-main at one end and closed at the other end - single-inlet type
L_2	Lateral looped at one side of sub-main, open to sub-main at both the ends - double inlet type
L_3	Sub-main laid at the middle of the plot, lateral laid at both sides of sub-main, open to sub-main at one end and closed at the other end - single-inlet type
L_4	Sub-main laid at the middle of the plot, lateral laid at both sides of sub-main in loops, open to sub-main at both the ends – double inlet type
L_5	Two sub-mains laid at both sides of the plot, lateral connected to two sub-mains - double-inlet type

Table 3 : Details of experimental layout with line diagrams

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})

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 standard recommendations.

Determinants of study :

Biometric characteristics of brinjal crop such as plant height, girth at base, number of branches/plant, number of leaves/plant, root diameter at base, leaf area, root volume, fruit length and weight etc. were observed for the selected plants under different treatments. Root diameter at base and fruit length were measured with the help of slide caliper. Leaf area meter was used to measure the leaf area of brinjal plant. Root volume was measured by dipping the entire rooting system of the selected individual plant in a measuring cylinder filled with water. The volume of water displaced indicated the volume of roots of the corresponding plant. The rooting system of the selected plants were taken out by digging the soil without any damage and were washed with water to remove the soil. The radial spreading diameter of the roots were measured with the help a scale by dipping the entire rooting system in to water filled in a water tub.

Yield of the crop from a particular treatment was calculated by summing up the yield from all the plucking at different periods of that treatment. Water use efficiency was calculated by dividing the quantity of water utilised by the crop during the growing period with the yield. Total quantity of water utilised by the crop was estimated accounting the depth of irrigation, rainfall, deep percolation loss, runoff loss, loss due to evaporation and change in SMC between the starting and harvesting period of the cropping season.

■ RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Effect of irrigation treatments on biometric characteristics :

The effect of the irrigation treatments on different yield attributing factors like height and girth of plant, number of branches and leaves per plant, leaf area, root volume, root diameter at base, root spreading diameter, depth to root penetration, fruit length and weight etc. are presented in Table 1. Amongst the three different sub-main sizes, S_3 exhibited maximum values of growth parameters such as height and girth of plant, number of branches per plant, number of leaves per plant, leaf area, root volume, root spreading diameter, rooting depth, fruit length, fruit wt. (79.97 cm, 10.96 cm, 14.08, 84.08, 135.68 cm^2, 81.33 cm^3, 4.30 cm, 42.47 cm, 38.38 cm, 13.91 cm and 71.84 g, respectively). Similarly these values were found to be minimum in case of S_1 (78.86 cm, 10.68 cm, 13.66, 83.02, 134.50 cm^2, 80.20 cm^3, 4.21 cm, 41.90 cm,

Table 1 : Growth parameters of brinjal crop under different sub-main sizes and lateral connections

Treatments	Height of plant (cm)	Girth of plant (cm)	No. of branches/ plant	No.of leaves / plant	Leaf area (cm^2)	Root volume (cm^3)	Max^m tap root diameter (cm)	Rooting dia. (cm)	Rooting depth (cm)	Fruit length (cm)	Fruit wt. (g)
Across sub-main sizes :											
S_1	78.86	10.68	13.66	83.02	134.50	80.20	4.21	41.90	38.27	13.82	71.48
S_2	79.24	10.84	13.88	83.55	135.08	81.00	4.25	42.20	38.36	13.86	71.64
S_3	79.97	10.96	14.08	84.08	135.68	81.33	4.30	42.47	38.38	13.91	71.84
S.E. ±	0.008	0.026	0.007	0.067	0.067	0.154	NS	0.076	NS	NS	NS
C.D. P=0.05	0.030	0.101	0.026	0.262	0.262	0.604	NS	0.300	NS	NS	NS
Across lateral connections:											
L_1	76.97	10.43	12.70	81.47	131.40	79.00	4.09	40.62	38.17	13.67	70.60
L_2	79.30	10.87	13.90	83.90	135.77	81.33	4.23	42.50	38.27	13.87	71.70
L_3	77.94	10.73	13.50	82.24	134.50	79.67	4.13	41.60	38.26	13.72	71.40
L_4	80.90	10.93	14.40	84.77	136.30	81.67	4.36	42.90	38.47	13.93	71.83
L_5	81.67	11.17	14.87	85.37	137.47	82.56	4.47	43.33	38.53	14.13	72.73
S.E. ±	0.040	0.042	0.055	0.095	0.092	0.390	0.040	0.074	0.047	0.042	NS
C.D. P=0.05	0.117	0.124	0.160	0.279	0.268	1.140	0.116	0.216	0.137	0.122	NS

NS=Non-significant

38.27 cm, 13.82 cm and 71.48 g, respectively). S_2 exhibited values intermediate between the values found for S_3 and S_1. Amongst the five different lateral connections, L_5 showed maximum values of the growth parameters (81.67 cm, 11.17 cm, 14.87, 85.37, 137.47 cm^2, 82.56 cm^3, 4.47 cm, 43.33 cm, 38.53 cm, 14.13 cm and 72.73 g, respectively) whereas minimum values are exhibited in case of L_1 (76.97 cm, 10.43 cm, 12.70, 81.47, 131.40 cm^2, 79.00 cm^3, 4.09 cm, 40.62 cm, 38.17 cm, 13.67 cm and 70.60 g, respectively). Hence, combining the two variables, *i.e.*, the sub-main pipe size (main plot) and the lateral connections (sub plot), it is established that the treatment S_3L_5 (T_{15}) was the best and the treatment S_1L_1 (T_1) was the worst with respect to plant growth. The interactions between different lateral connections with different sub-main pipe sizes were found to be insignificant with respect to the growth parameters *viz.,* plant height, number of branches and leaves per plant, leaf area and rooting volume. When the single inlet system L_1 was converted to the corresponding double inlet system L_2 by looping the laterals, values of growth parameters got increased. Considering the height of the plant, it was increased from an average value of 76.97 cm to 79.30 cm. Similarly other parameters excepting fruit weight (variations were not significant) also showed increasing trend with conversion from single to double inlet system by looping the laterals. Similar trend of increase in growth parameters were observed when the single inlet system L_3 was converted to double inlet system L_4 by looping the laterals on both sides. Amongst various lateral connections, L_5 has got the maximum values of growth parameters. Amongst the sub-main sizes within one type of lateral connection, the variation was also in increasing trend from S_1 to S_3 and were found to be significant except a few parameters like root diameter at base, rooting depth, fruit length and fruit weight where the variations were not significant.

Yield of brinjal and WUE 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, maximum mean value of yield 398.74 q / ha and minimum yield of 381.65 q/ha were observed in L_5 (double inlet system where laterals are connected to two sub-main pipes laid on both sides of the plot and in L_1 (single inlet system where laterals are connected on one side of the sub-main pipe laid at one side of the plot).

Similarly, amongst the different sub-main pipe sizes,

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
S.E. ±		NS		3.659	NS	NS
C.D. (P=0.05)		NS		10.679	NS	NS

NS=Non-significant

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
S.E. ±		NS		8.066	NS	NS
C.D. (P=0.05)		NS		23.539	NS	NS

NS=Non-significant

63mm size (S_1) has got the maximum mean yield (393.14 q / ha) over other pipe sizes and minimum value (390.70 q / ha) has been obtained for 40mm sub-main pipe size (S_1). Amongst all the treatments, maximum yield of 399.48 q/ha was obtained in case of S_3L_5 (T_{15}) and minimum yield (380.67 q/ha) was obtained from S_1L_1 (T_1). Increase in yield from a mean value of 381.65 q / ha to 393.29 q / ha (increase of 11.64 q / ha, 3.05%) was observed when the single inlet system with lateral connection at one side of the sub-main (L_1) was converted to double inlet type by looping the laterals (L_2) for a particular sub-main size. Similarly, for the single inlet system where sub-main pipe was laid in the centre of the plot and the laterals were laid on both sides of the sub-main (L_3) converted to double inlet connection by looping the laterals on both sides of the sub-main (L_4), yield increased from a mean value of 398.41 q / ha to 387.23 q / ha (increase of 11.18 q / ha, 2.9%). More uniformity and required level of irrigation water application due to less head loss, double inlet systems provided good water distribution environment leading to higher yield in comparison to single inlet systems. The effect of first factor on yield of brinjal was not significant. The effect of second factor was significantly positive. Highest yield was observed in L_5 (398.74 q/ha) and also at par with L_4 (398.41 q/ha) The yield was 3 per cent and 2.9 per cent higher when L_1 was converted to L_2 and L_3 to L_4, respectively.

The water use efficiency of drip irrigated brinjal crop as affected by different treatments has been presented in Table 3. The result showed similar trend as that of yield. Maximum WUE was observed in case of S_3L_5 (T_{15}) and minimum value of WUE was found in case of S_1L_1 (T_1). The effect of first factor was non–significant. The second factor was significant. The highest WUE was observed in L_5 which was very close to L_4 in comparison to all other lateral connection systems. Similar work related to the present investigation was also carried out by Ughade and Mahadkar (2014) on brinjal, Kumar and Mall (2012) on sugarcance, Kumar and Sahu (2013) on cabbage and Sathish *et al*. (2014) on paparika.

Summary and conclusion :

From the experimental study it is concluded that performance of the system in terms of yield was more in case of double inlet systems than the corresponding single inlet systems. Single inlet systems can be converted to double inlet systems just by looping the laterals and enhance the system performance in terms of growth parameters and hence, the yield and WUE. Maximum brinjal yield as well as WUE was obtained in double inlet system where two sub-main pipes were laid on both sides of the field and laterals were connected to the sub-main pipes at both the ends and also it was at par with the double inlet system where laterals were looped on both sides of sub-mains laid in the centre of the field.

Hence, 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 higher yield and water use efficiency.

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