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Productivity and profitability of tomato (*Solanum lycopersicum*) under drip fertigation and emitter types

PRABHAT CHANDRA PRADHAN[1], BALRAM PANIGRAHI[2] and BASUDEV BEHERA[3]*

Odisha University of Agriculture and Technology, Bhubaneswar, Odisha 751 003, India

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ABSTRACT

A field experiment was conducted during winter 2014 and 2015 in Jagatsinghpur district of Odisha to study the effect of different fertigation levels and emitter types on productivity, input use efficiency and profitability of tomato (*Solanum lycopersicum* L.). The three levels fertigation, i.e. recommended dose (125-75-100 kg N-P_2O_5-K_2O/ha) of fertiliser (RDF), 80% RDF and 60% RDF and four types of emitters, viz. online pressure compensating, online non-pressure compensating, inline pressure compensating and inline non-pressure compensating drippers were tested in split-plot design with three replications. Water soluble fertilisers, viz. urea, urea phosphate with sulphate of potash and sulphate of potash were used for fertigation. The maximum fruit yield of 59.8 t/ha, water-use efficiency of 21.17 kg/m^3 water, benefit:cost ratio of 3.75 and internal rate of return of 62.16% and the minimum payback period of 2.26 years were recorded in fertigation with 100% RDF through online pressure compensating emitters. Fertiliser-use efficiency increased with decrease in fertigation level and the maximum value of 270.1 kg fruit/kg of NPK was recorded with 60% RDF through online pc emitters.

Keywords: Inline dripper, Non-pressure compensating, Net present value, Online dripper

Water scarcity is the major constraint in crop production. Only 27.5% of cultivated area is irrigated during winter in Odisha, India by surface irrigation methods with low irrigation efficiency (GoI 2013). The advanced methods of irrigation would increase irrigation efficiency considerably (Panigrahi *et al.* 2011). The benefits of drip irrigation include better crop survival, enhanced yield and improved crop quality (Prasad *et al.* 2003, Kumar *et al.* 2005, Sharma *et al.* 2007). In recent years, farmers of Odisha have adopted drip irrigation mainly for horticultural and plantation crops. Mohanty *et al.* (2016) reported water saving to the tune of 45% and yield improvement up to 32% in brinjal with drip irrigation compared to conventional furrow irrigation. Fertigation through drip system meets crop nutrient demand in real time. Fertigation reduces the fertilizer requirement and at the same time increases the yield in most of the vegetables. Drip fertigation in Assam lemon in alluvial sandy loam soils of Jorhat gave the maximum benefit-cost ratio of 4.17 (Barua *et al.* 2014). The real time fertilizer application results in higher nutrient-use efficiency and reduced fertilizer dose. Different types of emitters are used in drip system for controlled release of water to the root zone. They differ in emission uniformity influencing water and nutrient use. Tayel *et al.* (2013) tried eight different types of emitters with reclaimed water and recommended pressure compensating emitters of short flow path for drip irrigation.

India ranks the second in the production of vegetables contributing 12% of world production. The rising population in the country provides little scope for horizontal expansion of the area under vegetables. Tomato (*Solanum lycopersicum* L.) is the second most commercial vegetable crop grown in India after potato. The productivity of tomato in Odisha is 14.3 t/ha in contrast to global and national (India) productivity of 25.09 and 21.2 t/ha (GoI 2017). It is imperative to economise the use of water and fertiliser in crops through drip-fertigation techniques. Hence the present study was undertaken to determine the effect of different levels of NPK-fertigation and emitter types on productivity, input use efficiency and profitability of tomato.

MATERIALS AND METHODS

The field experiment was conducted for two consecutive winter and summer of 2013–14 and 2014–15 at farmers' field of village Khadala (20° 15'N latitude and 86° 10'E longitude), Jagatsinghpur district of Odisha, India. The area comes under East and South Eastern Coastal Plains Zone of Odisha. This region is characterized by hot and humid

Present address: [1]Precision Farming Development Centre, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha; [2]College of Agricultural Engineering and Technology, Bhubaneswar, Odisha; [3]Institute of Agricultural Sciences, SOADU, Bhubaneswar, Odisha. *Corresponding author e-mail: bdbehera1@rediffmail.com.

climate. The experimental site had well-drained sandy clay loam (75.8% sand, 2% silt and 22.2% clay) soil having *p*H of 6.08. The bulk density of soil was 1.28 g/cc and electrical conductivity was 0.05 dS/m. The soil of the site had available N of 288.5 kg/ha (medium), P of 13.05 kg/ha (medium) and K of 132.9 kg/ha (medium). The field capacity and permanent wilting point of soil was found to be 24.6% and 7.4%, respectively.

The field experiment was laid out in split-plot design with 12 treatment combinations replicated thrice. The three fertigation levels, viz. F_1 =100% RDF, F_2 = 80% RDF and F_3 = 60% RDF were allocated to main plots and four types of emitters, viz. E_1 = online non-pressure compensating (online npc), E_2 = online pressure compensating (online pc), E_3 = inline non-pressure compensating (inline npc) and E_4 = inline pressure compensating (inline pc) were allocated to sub plots. The 30 days old tomato seedlings were planted on 4 January 2014 and 3 January 2015 during the 1st and the 2nd year, respectively with row to row spacing of 1.2 m and plant to plant spacing of 0.4 m and fertiliser dose of 125,75 and 100 kg/ha N, P_2O_5 and K_2O, respectively. The fertigation was applied during four growth stages of the crop, i.e. stage I-crop establishment from 0-20 days after transplanting (DAT), stage II- crop development stage from 21-50 DAT, stage III - mid season from 51-80 DAT and stage IV - late season from 81-110 DAT. Fertigation was done using water soluble grades of urea (46:0:0), urea phosphate with sulphate of potash or SOP (18:18:18) and sulphate of potash (0:0:50) through ventury injector at weekly intervals. During stage I, 83 kg urea phosphate with SOP (18:18:18) was applied in three splits, while in stage II, 166 kg urea phosphate with SOP (18:18:18) + 65 kg urea was applied in four equal splits. In stage III, 166 kg urea phosphate with SOP (18:18:18) + 43.5 kg urea was applied in four equal splits. In stage IV, 50 kg sulphate of potash was applied in four equal splits. Gross and net plot sizes were 10.0 m × 4.8 m and 8.4 m × 2.4 m, respectively. The single lateral lines of 12 mm diameter pipes were laid along the crop rows and discharge capacity of each dripper in all the treatments was equal, i.e. 2 l per hour (lph). The spacing between two adjacent laterals and emitter within plot was 1.2 m and 0.4 m, respectively.

Agronomic practices and plant protection measures were adopted as per standard recommendations. The amount of water (l/day) applied through drip irrigation system to each plant was calculated using following equation (Pawar *et al*. 2013)

$$V = ET_o \times K_c \times L_s \times E_s \times W_s / \eta \qquad (1)$$

where, V= volume of water applied (l/day/plant), ETo = reference crop evapotranspiration (mm/day) calculated by Penman-Monteith method (Allen *et al.* 1994), K_c = crop coefficient; L_s and E_s = lateral and emitter spacings taken as 1.2 and 0.4 m, respectively, Ws = percentage wetted area factor and η = emission uniformity of the system. The average emission uniformity of drip system was estimated and found to be 90% for all treatments and so in Eq (1), while calculating the value of *V*, the Emission Uniformity (η) was taken as 0.9 for all treatments. The values of K_c of tomato were taken as 0.45, 0.75, 1.15 and 0.8, respectively, for stage I, II, III and IV and the values of Ws were assumed as 0.3, 0.45, 0.6 and 0.8 for the respective stages (Panigrahi *et al.* 2011). In drip system water was applied on alternate day. Daily water applied per plant for stage I, II, III and IV were 0.3, 1.1, 4.1 and 3.4 litre during the 1st year of experimentation and 0.4, 1.0, 4.4 and 3.4 litre during the second year of experimentation. Considering the number of plants/unit area, the water requirement for the area was found out.

Yield of tomato were recorded treatment wise. The ripe fruits of tomato were harvested on alternate day during 2nd to 4th week of April of each year. Water-use efficiency (WUE) (kg/m^1) was calculated by dividing marketable fruit yield with the depth of irrigation water used (Wang *et al.* 2007, Zotarelli *et al.* 2009). Fertiliser-use efficiency (FUE) was worked out by dividing total yield with total fertiliser applied (kg/ha).

Economic analysis: The various economic indices were computed considering the fixed cost, recurring cost, present rate of bank interest, inflation and yield. The indices, viz. net present value (NPV), benefit-cost ratio (BCR) and payback period (PBP) were computed by using equations given by Reddy *et al*. (2008), while internal rate of return (IRR) values were estimated by using formula given by Suresh (2009).

RESULTS AND DISCUSSION

Yield: Among fertigation levels, fertigation of 100% RDF recorded the maximum tomato fruit yield of 57.47 t/ha (pooled data of yield over two years) and proved significantly superior to other fertigation levels (Table 1). Fertigation at 100% level recorded 2.9% and 21.9% higher fruit yield than fertigation levels of of 80 and 60%, respectively. The results are in conformity with findings of Hebbar *et al.* (2004) and Rajaram *et al.* (2013) who reported the maximum fruit yield of tomato at 100% RDF with drip irrigation. Under online drip systems, pc emitters recorded fruit yield of 55.4 t/ha as against 52.89 t/ha due to npc emitters. The pc emitters recorded 4.7% higher fruit yield than npc emitters. Similarly, under inline drip system, pc emitters gave fruit yield of 53.87 t/ha as against 51.77 t/ha for npc emitters. The pc emitters gave fruit yield of 54.6 t/ha as compared to 52.33 t/ha in case of npc emitters registering an yield hike by 4% in case of pc emitters as compared to npc emitters. The increase in yield for pc emitters was due to better emission uniformity of drippers for irrigation water and fertilizer application. Interaction effects of fertigation levels and emitter types were found significant, Fertigation at 100% RDF through online pressure compensating emitters gave the maximum fruit yield of 59.82 t/ha and proved significantly superior to all other treatment combinations.

Water use by the crop

The seasonal water requirement in 2014 and 2015

Table 1 Effect of fertigation levels and emitter types on fruit yield, water-use efficiency and fertiliser-use efficiency of tomato (pooled over two years)

Treatment	Online npc (E_1)	Online pc (E_2)	Inline npc (E_3)	Inline pc (E_4)	Mean
		Fruit yield (t/ha)			
F_1- 100% RDF	57.14	59.82	55.22	57.72	57.47
F_2- 80% RDF	55.04	57.74	54.31	56.26	55.84
F_3-60% RDF	46.48	48.64	45.78	47.62	47.13
Mean	52.89	55.40	51.77	53.87	53.48
SEm(±)	F= 0.15, E= 0.09, F×E= 0.23, E×F= 0.17				
LSD (P=0.05)	F= 0.58,E =0.27,F×E =0.81,E×F= 0.46				
		Water-use efficiency (kg/m³)			
F_1- 100% RDF	20.22	21.17	19.54	20.43	20.34
F_2- 80% RDF	19.48	20.43	19.20	19.95	19.76
F_3-60% RDF	16.45	17.22	16.20	16.86	16.68
Mean	18.72	19.61	18.31	19.08	18.93
SEm(±)	F= 0.05,E= 0.03,F×E= 0.08,E×F= 0.06				
LSD (P=0.05)	F= 0.18,E= 0.10,F×E= 0.27,E×F= 0.17				
		Fertiliser-use efficiency (kg/kg of NPK)			
F_1- 100% RDF	190.48	199.33	184.13	192.52	191.62
F_2- 80% RDF	229.27	240.63	226.17	234.48	232.64
F_3-60% RDF	258.12	270.10	254.35	264.67	261.81
Mean	225.96	236.69	221.55	230.56	228.69
SEm(±)	F= 8.47,E= 4.31,F×E= 12.31,E×F= 7.47				
LSD (P=0.05)	F= 33.26,E= 12.81,F×E= NS,E×F= NS				

F×E =Fertigation levels in same or different types of emitters; E×F = Emitter types in same levels of fertigation.

were 27.87 cm and 28.62 cm, respectively with a mean of 28.26 cm. The maximum use of water was 13.37 cm during mid-season stage followed by 10.69, 3.42 and 0.78 cm during late season stage, crop development stage and crop establishment stage, respectively. It is to be noted that in both the years, there were no rainfall during the crop growing season.

Input use efficiency: The input use efficiency, viz. water use efficiency and fertiliser-use efficiency for tomato were computed for both 2014 and 2015. Among fertigation levels, 100% fertigation recorded the maximum water use efficiency of 20.34 kg/m^3 of water (Table 1). Among different emitters used in the experiment, online pc emitter proved to be the best with the maximum WUE of 19.61 kg/m^3 of water. The interaction effects of fertigation levels and emitter type were found significant for WUE and application of 100% RDF through online pc recorded the maximum WUE of 21.7 kg/m^3 among all combinations (Table 1). Similar results were reported by Cetin *et al.* (2008), Pawar *et al.* (2013) and Kuscu *et al.* (2014) in tomato.

The values of FUE increased with decrease of fertigation levels. Application of 60% fertigation recorded the maximum FUE of 261.81 kg/kg of NPK registering increases of 36.6 and 11.75% over 100% and 80% fertigation, respectively. In case of emitters, the online pc emitters recorded the maximum FUE of 236.69 kg/kg of NPK reflecting increases of 4.7%, 6.8% and 2.6%, respectively, over online npc, inline npc and inline pc. The interaction effects of fertigation and emitters were found significant for this trait. Application of 60% fertigation through online pc emitters recorded recorded the maximum FUE 270.10 kg/kg of NPK and proved superior to all other treatment combinations. The results are in conformity with the findings of Badr *et al.* (2012), Kumar *et al.* (2013) and Gupta *et al.* (2014).

Table 2 Comparative economics of different levels of fertigation and types of emitters in tomato

Treatment	Investment/ha				Net return (×10³ ₹/ha)	Payback period (Years)	IRR (%)	B:C ratio
	Initial (×10³ ₹)	CC (×10³ ₹)	Electricity (₹)	R & M (₹)				
F_1E_1	248.80	87.98	902	4970	140.42	2.35	59.86	3.60
F_1E_2	257.99	87.98	902	5160	151.22	2.26	62.16	3.75
F_1E_3	244.86	87.98	902	5799	132.82	2.45	57.54	3.46
F_1E_4	257.46	87.98	902	5149	142.82	2.39	58.86	3.55
F_2E_1	248.80	82.26	902	4970	137.74	2.40	58.73	3.54
F_2E_2	257.99	82.26	902	5160	148.54	2.30	61.07	3.68
F_2E_3	244.86	82.26	902	5799	134.94	2.41	58.45	3.52
F_2E_4	257.46	82.26	902	5149	142.94	2.39	58.91	3.55
F_3E_1	248.80	76.48	902	4970	109.52	3.06	46.58	2.81
F_3E_2	257.99	76.48	902	5160	117.92	2.92	48.61	2.93
F_3E_3	244.86	76.48	902	5799	106.72	3.91	46.1	2.78
F_3E_4	257.46	76.48	902	5149	113.98	3.03	46.87	2.83

F_1, F_2, F_3 = 100%, 80%, 60% NPK fertigation; E_1, E_2, E_3, E_4= Online npc, Online pc, Inline npc, Inline pc; CC, Cost of cultivation; R & M, Repair & maintenance; IRR, Internal rate of return.

Economics: Application of 100% drip fertigation through online pc emitter based drip systems gave maximum internal rate of return of 62.16% followed by 61.07% in case of 80% drip fertigation through online pc based system (Table 2). The benefit-cost ratio also recorded highest value of 3.75. Application of 100% drip fertigation with pc emitters recorded the maximum benefit-cost ratio of 3.75 closely followed by 3.68 in case of 80% drip fertigation through pc emitters. Application of 100% drip fertigation through online pc emitters recorded the minimum payback period of 2.26 years. This was due to weekly splitting of fertiliser dose and uniform emission of emitters that led to higher input use efficiency, better yield and higher profitability.

It is concluded that application of 100 % recommended dose of fertilizer of 125-75-100 kg N-P_2O_5-K_2O/ha recorded the maximum fruit yield of 59.82 t/ha, the maximum water use efficiency of 21.17 kg/m^3, net return of ₹151.22×10^3/ha, the minimum payback period of 2.26 years, the maximum internal rate of return of 62.16% and the maximum B:C ratio of 3.75 and hence recommended for tomato cultivation in Odisha.

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