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Productivity and quality response of tomato (*Lycopersicum esculentum* L.) under different fertigation levels and emitter types in a tropical region of eastern India

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Abstract
Field experiments were conducted during winter seasons of 2014 and 2015 in Jagatsinghpur district of Odisha, India to study the effect of different fertigation levels and emitter types on productivity and quality of tomato. The experiments were laid out in split plot design with twelve treatments which were replicated three times. The three levels of fertigation *i.e.* fertigation with 100% recommended dose of fertiliser (RDF), 80% RDF and 60% RDF were applied through four types of emitters viz. online pressure compensating (online pc), online non pressure compensating (online npc), inline pressure compensating (inline pc) and inline non pressure compensating (inline npc) . The fertigation levels were allocated to main plots and the emitter types were allocated to sub plots. Water soluble fertilisers viz. urea, urea phosphate and sulphate of potash were used for fertigation in the experiment. Significantly the maximum tomato yield of 59.8 t/ha was recorded for treatment with application of 100% RDF through online pc emitters based drip irrigation system. Similarly significantly the highest length of fruit 5.76 cm, fruit girth of 6.8 cm, highest Total soluble solid (TSS) content of 4.45 ^{0} brix and lycopene content of 6.39 mg/100g was recorded in the above mentioned treatment.

Keywords: Online, inline, pressure compensating, non-pressure compensating, water soluble fertiliser

Introduction
Water and fertiliser are the two most important inputs affecting crop production. The share of irrigation water in agriculture is decreasing day by day due to stiff competition from other sectors of life. In the current scenario, there is a wide gap between availability of water and requirement for irrigation. Water supply is the major constraint in crop production during winter season. The economy of the study region is mainly agrarian and crop production is dependent on assured irrigation. In Odisha, only 27.5% of cultivated area during winter is irrigated by surface irrigation methods (Anonymous, 2013) [3]. The surface irrigation which is commonly used in the study region results in low irrigation efficiency and build up of salinity and drainage problem. Efficient use of water by advanced methods of irrigation like drip and sprinkler would contribute to better management of water in agriculture and increase in irrigation efficiency (Sahoo *et al*., 2010 [24]; Panigrahi *et al*., 2011 [17]).
The benefits of drip irrigation include better crop survival, minimal yield variability and improved crop quality (Martin *et al*., 1994 [15]; Prasad *et al*., 2003 [16]; Kumar *et al*., 2005 [13]; Sharma *et al*., 2007 [23], Paul *et al*., 2013 [21]). In recent years, farmers of Odisha, India are adopting drip irrigation mainly for horticultural and plantation crops. Field experiment conducted by Tiwari *et al.* (2003) [26] reported 54% higher yield and 40% reduced water application through drip irrigation compared to furrow irrigation. Impact of drip irrigation on capsicum was tested by Antony and Singandhupe (2004) [2]. They reported the maximum yield in drip irrigation at 100% evapotranspiration rate in loamy soil of humid sub tropical region.
An experiment conducted by Shirgure and Srivastav (2014) [25] during 2007-2010 on Nagpur mandarin exhibited more fruit yield and better produce quality in drip irrigation than flow irrigation. Several research workers viz. Brahma *et al.* (2010) [6], Gupta *et al.* (2015) [8], reported higher yield and better quality of tomato under drip fertigation. Tayel *et al.* (2013) [27] tried eight different types of emitters and recommended pressure compensating emitters of short flow path for drip irrigation.

In fertiliser scenario, India is the second largest consumer of fertilisers in the world after China. India imports 20% of nitrogenous fertilisers, 90% of phosphatic fertilisers and almost 100% of potassic fertilisers to meet its consumption need. (Anonymous, 2015) [5]. Further, fertiliser use efficiency is low due to lack of precision in fertiliser application. The use efficiencies of nitrogenous, phosphatic and potassic fertiliser in India are 50, 30 and 50%, respectively.

In drip fertigation, the water soluble fertilisers are applied to the root zone of plants which enhances application efficiency due to small quantity of fertilisers applied in frequent intervals. Fertigation reduces the fertiliser requirement and at the same time increases the yield in most of the vegetables. Two day irrigation interval with 100 kg N ha^{-1} in lettuce resulted in the maximum yield of 43.06t/ha at Indian Agriculture Research Institute, New Delhi. (Patil *et al.,* 2012) [18]. Although a number of experiments have been conducted on fertigation with nitrogen (Zotarelli *et al.,* 2009 [28]; Brahmas et al., 2010 [6]; Badr *et al.* 2012 [7]), and NK (nitrogen-potash) fertigation (Kadam *and Sahane.,* 2001 [11]; Hebber *et al.,* 2004 [9]; Krishnasamy *et al., 2*006 [12]; Jat *et al.,* 2011 [10]), information on NPK (nitrogen-phosphorous-potash) fertigation through various emitters in drip irrigation system are lacking and needs investigation.

India ranks second in the production of vegetables contributing 12% of world production. But the present vegetable production and consumption rate of 145g/head/day are far below the actual demand of 230g/head/day of vegetables. Tomato (*Lycopersicum esculent L.*) is the second most commercial vegetable crop grown in India only after potato. The state (Odisha) productivity of tomato is 14.3 t/ha in contrast to global and national (India) productivity of 25.09 and 21.2 t/ha respectively (Anonymous, 2014) [4]. Among various factors, tomato responds well to water and nutrients. It is imperative to economise the use of water and fertiliser in all crops, especially in vegetables through efficient method of drip-fertigation. Hence the present study was undertaken to determine the effect of NPK-fertigation at three levels and four types of emitters on productivity and quality of fruits.

Materials and Method

The field experiments were conducted for two consecutive winter seasons of 2014 and 2015 at farmers' field of village Khadala, Jagatsinghpur district of Odisha, India. The area comes under East and South Eastern coastal zone of Odisha with latitude of 20^0 15'N and longitude of 86^0 10'E longitude. The mean annual rainfall is 1514 mm distributed over 66 rainy days. The rainfall occurs mainly due to South –West monsoon from mid-June to mid-October. The average maximum and minimum temperatures are 30.5 and 23.4^0C, respectively and average relative humidity varies from 67 to 84%.

The experimental site had well drained sandy clay loam soil having pH of 6.08. The bulk density of soil was 1.32 gm/cc and electrical conductivity was 0.05dS/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 on weight basis.

The field experiment was laid out in split plot design with twelve treatment combinations replicated three times. The three levels of fertigation levels viz.F1 =100% (recommended dose of fertiliser (RDF), F2 = 80% RDF and F3 = 60% RDF were allocated to main plots and four types of emitters viz. E1 = online non-pressure compensating (online npc), E2 = online pressure compensating (online pc), E3 = inline non-pressure compensating (inline npc) and E4 = inline pressure compensating (inline pc) were allocated to sub plots.

The gross and net plot sizes were 10.0 m x 4.8 m and 8.4 m x 2.4m, respectively. Tomato seedlings of 30 days old were planted on 4 January 2014 and 3 January 2015 respectively in consecutive years. The crop in all treatments had row to row spacing of 1.2 m and plant to plant spacing of 0.4 m. The single lateral lines of 12 mm diameter low density polyethylene (LDPE) pipes were laid along the crop rows and discharge capacity of each dripper in all the treatments was same *i.e.* 2 lit per hour (lph). The spacing between two adjacent laterals and emitter within plot was 1.2 m and 0.4 m, respectfully. The layout of the field experiments is illustrated in Fig. 1.

The soil test based recommended fertiliser dose of 125, 75 and 100 kg/ha N, P_2O_5 and K_2O, respectively, was applied to the crop. The weekly fertigation schedule was applied in four growth stages of the crop through ventury injector as shown in Table 1.

Table 1: Fertigation schedule in tomato

Stage of Crop	Duration	Fertilizer Grade	Weekly scheduled per plot
Crop establishment	20 days	18:18:18	266g
Crop development	30 days	18:18:18 46:0:0	166 g 84 g
Mid-season	30 days	18:18:18 46:0:0	166 g 50 g
Late season	30 days	0:0:50	50 g

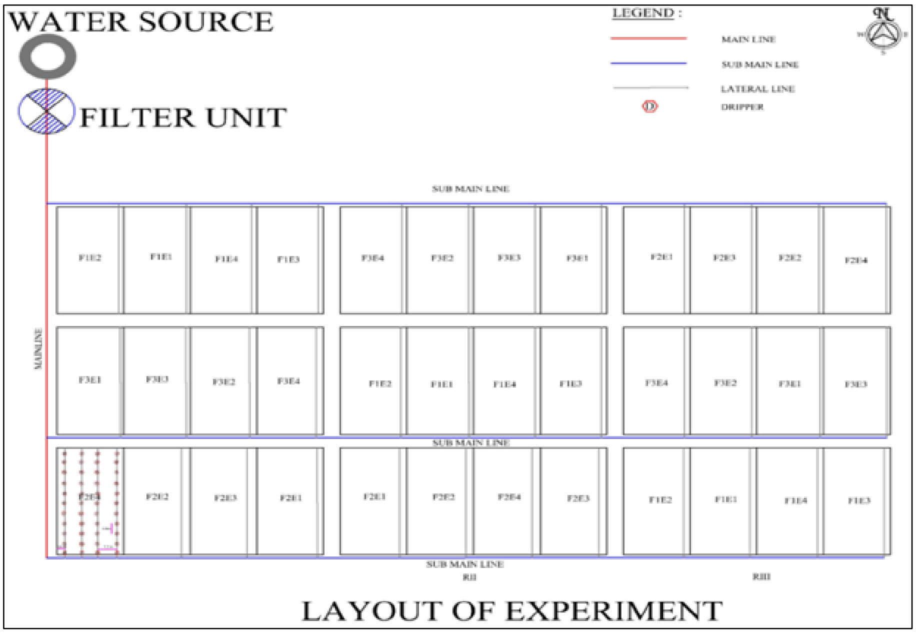

Fig 1: Layout of field experiment

In the experiment all agronomical and plant protection measures were adopted as per standard recommendations. The amount of water (lit/day) applied through drip irrigation system to each plant was calculated using following equation (Pawar *et al*, 2013) [20]

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

Where, V = volume of water applied (lit/day/plant), ETo, = reference crop evapotranspiration (mm/day) calculated by Penman-Monteith method (Allen *et al.*, 1994) [1], 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 percent .So for all treatments while calculating the value of *V*, we use η as 0.9 for all treatments. The values of K_c of tomato for various growth stages were taken as 0.45, 0.75, 1.15 and 0.8 and values of Ws were assumed as 0.3, 0.45, 0.6 and 0.8 for crop establishment, crop development, mid-season and late season stages, respectively (Panigrahi *et al.*, 2011) [17].

Yield of tomato were recorded for each treatment. The ripe fruits of tomato was harvested on alternate day during 2nd to 4th week of April of each year. Also ripen fruits were taken for measurement of length of fruit and girth of fruit. Similarly fruits were taken for assessment of total soluble solids and lycopene content. TSS content of fresh undiluted fruit juice was measured with a hand held refractometer and was expressed in ºBrix. Similarly lycopene content was measured by spectrophotometer. The pooled data of yields and quality parameter were done statistical analysis (ANOVA) for all treatments.

Results and Discussion

Yield

Among fertigation levels, fertigation of 100% RDF (F_1) recorded the maximum tomato fruit yield of 57.47 t/ha (pooled over two years) irrespective of types of all emitters and proved significantly superior to other fertigation levels (Table 2). Fertigation at 100% level recorded 2.9 and 21.9% higher fruit yield than fertigation levels of 80 and 60% of recommended dose of fertilisers, respectively. The results are in conformity with findings of Hebbar *et al.* (2004) [9] and Rajaram *et al.* (2013) [22] who reported the maximum fruit yield of tomato at 100% RDF with drip irrigation at Bangalore and Thoppur (Tamil Nadu), respectively.

In case of online drip systems, pressure compensating emitters (55.4 t/ha) resulted 4.7% higher fruit yield than pressure non - compensating emitters (52.9 t/ha). Similarly, considering inline drip system, pressure compensating emitters resulted fruit yield of 53.9 t/ha as against 51.8 t/ha in pressure non-compensating emitters. Inline pressure compensating emitters recorded 4% higher yield over than pressure non-compensating emitters. The pressure compensating emitters on an average recorded fruit yield of 54.6 t/ha as compared to 52.3 t/ha in pressure non-compensating emitters. The increase in yield for pressure compensating emitters was due to better emission uniformity of drippers with respect to 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 59.8 t/ha and proved significantly superior to all other treatment combinations.

Quality parameters of Tomato fruits

The pool data of different fruit quality parameters like length of fruit, girth of fruit, total soluble solids (TSS) and lycopene content of tomato for different treatments comprising of fertigation levels and emitter types are presented in Table 3 along with ANOVA data. Fruit Parameter viz length of fruit pooled over two years i.e. 2014 & 2015 and averaged over emitters, 100% RDF fertigation level (F1) recorded significantly highest length of fruit i.e. 5.61cm which is 3.5% and 21.4% higher length as compared to 80% RDF and 60% RDF respectively. Averaged over fertigation levels, online pc emitters (E2) resulted highest fruit length of 5.36 cm and recorded 3.5, 6.4 & 1.3% higher fruit length over on line npc, inline npc and inline pc emitters based irrigation system, respectively. The interaction effect of fertigation levels and emitter types on fruit length were found significant. Application of 100% RDF fertigation through online pc emitters gave significantly maximum fruit length of 5.76 cm followed by 5.7 cm which occurred in case of inline pc emitter (Table 3a). With regard to fruit girth of tomato with the pooled data over two years and averaged over emitter types , 100% RDF fertigation recorded significantly highest girth of fruit of 6.77 cm and recorded 4.6% and 28.95% higher values over 80% and 60% RDF respectively. Averaged over fertigation levels online pc emitter recorded the highest girth of 6.30 cm followed by 6.24 cm in case of inline pc emitter based system. The interaction effect of emitter and fertigation levels showed the largest girth of tomato of 6.88 cm in case of 100% fertigation followed by 80% fertigation levels. In case of the quality parameter like total soluble solids (TSS) pooled over two years and averaged over emitters, 100% RDF fertigation recorded significantly the highest value of 4.24 whereas online npc and inline pc emitter showed TSS values of tomato at par but inline npc resulted the lowest. Similar results were reported by Kumar *et al.*(2013) [14].The interaction effect of fertigation level and emitter types indicated highest TSS values of 4.45 in case of 100% RDF through online pc emitter based drip system (Table 3b).

Another quality parameter i.e. lycopene content of ripen fruits pooled over two years and are shown in Table 3.The 100% RDF fertigation recorded the highest lycopene content of 6.19 which is 6.47% higher than 80% RDF and 20.4% higher over 60% fertigation level. This results are in conformity with the results shown by Power *et al*. (2013) [19].Among emitters online pc resulted significantly highest value of 5.91 followed by 5.75 in case of inline pc. Both inline npc and inline pc emitters resulted lycopene value which are at par.

Table 2: Effect of fertigation levels and emitter types on fruit yield (t/ha) of tomato

Treatment	Online npc (E1)	Online pc (E2)	Inline npc (E3)	Inline pc (E4)	Mean
100% RDF Fertigation (F1)	57.14	59.82	55.22	57.72	57.47
80% RDF Fertigation(F2)	55.04	57.74	54.31	56.26	55.84
60% RDF Fertigation(F3)	46.48	48.64	45.78	47.62	47.13
Mean	52.89	55.40	51.77	53.87	53.48
	F	E	F×E	E×F	
SEm (±)	0.15	0.09	0.23	0.17	
LSD (P=0.05)	0.58	0.27	0.81	0.46	

FxE = Fertigation levels in same or different types of emitters
ExF = Emitter types in same levels of fertigation

Table 3(a): Effect of fertigation levels and emitter types on fruit quality (length and girth of fruit)

Treatment	Online npc (E1)	Online pc emitters (E2)	Inline npc emitters (E3)	Inline pc emitters (E4)	Mean
	Length of fruit, cm				
100% RDF Fertigation (F1)	5.56	5.76	5.44	5.70	5.61
80% RDF Fertigation(F2)	5.38	5.60	5.19	5.51	5.42
60% RDF Fertigation(F3)	4.61	4.72	4.49	4.66	4.62
Mean	5.18	5.36	5.04	59.29	5.29
	F	E	F×E	E×F	
SEm(±)	0.01	0.02	0.03	0.03	
LSD (P=0.05)	0.051	0.046	0.098	0.079	
	Girth of fruit, cm				
100% RDF Fertigation (F1)	6.74	6.81	6.63	6.88	6.77
80% RDF Fertigation(F2)	6.54	6.60	6.40	6.59	6.53
60% RDF Fertigation(F3)	5.30	5.49	4.97	5.24	5.25
Mean	6.19	6.30	6.00	6.24	6.18
	F	E	F×E	E×F	
SEm(±)	0.02	0.03	0.06	0.05	
LSD (P=0.05)	0.092	0.082	0.184	0.152	

Table 4(b): Effect of fertigation levels and emitter types on fruit quality (TSS and Lycopene content)

Treatment	Online npc (E1)	Online pc emitters (E2)	Inline npc emitters (E3)	Inline pc emitters (E4)	Mean
	TSS ,^{0}Brix				
100% RDF Fertigation (F1)	4.40	4.45	4.38	4.43	4.41
80% RDF Fertigation(F2)	4.35	4.39	4.34	4.37	4.36
60% RDF Fertigation(F3)	3.84	3.89	3.80	3.82	3.84
Mean	4.20	4.24	4.17	4.21	4.20
	F	E	F×E	E×F	
SEm(±)	0.01	0.04	0.01	0.01	
LSD (P=0.05)	0.018	0.012	0.029	0.02	
	Lycopene content, mg/100g				
100% RDF Fertigation (F1)	6.12	6.39	6.03	6.24	6.19
80% RDF Fertigation(F2)	5.73	6.10	5.60	5.84	5.82
60% RDF Fertigation(F3)	5.11	5.25	5.04	5.18	5.14
Mean	5.65	5.91	5.56	5.75	5.72
	F	E	F×E	E×F	
SEm(±)	0.02	0.02	0.18	0.04	
LSD (P=0.05)	0.60	0.069	0.70	0.119	

Conclusions

The study revealed that the application of water soluble fertilisers through pressure compensating emitters has increased the fruit yield of tomato as well as quality parameters. Among different treatments, the treatment with 100% recommended dose of fertilisers of NPK when applied through online pressure compensating emitters based drip system resulted maximum yield of 59.8t/ha. Similarly the quality parameters viz. Length of fruit, girth of fruit, TSS and lycopene content recorded significantly higher values of 5.8cm, 6.8cm, 4.45^{0}brix and 6.39mg/100g respectively with 100% RDF applied through online pc emitters. Thus, weekly application of 100% RDF through online pc dripper based system is recommended for better yield and quality of tomato grown in tropical region of Odisha.

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