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Earliness to flowering and picking with reference to branch numbers in processing tomato varieties as influenced by planting density and fertigation

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Abstract
The Abhinav variety recorded the highest number of secondary branches (10.31), and also it took lowest number of days to first flowering (39.03) with highest fruit yield per hectare (4.85 tonnes). Planting density at 75 cm x 40 cm (S_3) recorded significantly the lowest number of days to first flowering (40.03) and first fruit picking (79.57) from the day after transplanting. The highest number of primary and secondary branches (13.60), (12.67) with highest number of days to first flowering (45.20 days)and first fruit picking (45.20 days) more over with highest yield per hectare (84.63 tonnes) were recorded with the maximum fertigation level (F_3) 180N: 90P: 90K kg per ha. Among interaction combinations, the highest number of days to first flowering and first fruit picking was recorded by the combination of variety Abhinav + 120 cm x 40 cm (S_1) + 180N: 90P: 90K kg per ha (47.86), (91.73) days after transplanting

Keywords: Tomato, picking, flowering, branches, yield, planting density, fertigation

1. Introduction
Tomato (*Solanum lycopersicum*) is one of the most important vegetable plants in the world. It originated in western South America, and domestication is thought to have occurred in Central America. Numerous varieties of tomato are widely grown in temperate climates across the world. It is ranked among the top three vegetable crops namely cabbage, tomato and onions in their order of importance. It also ranked at the top of all fruits and vegetables as a source of vitamins and minerals which plays a major role in human nutrition. It is an excellent source of phosphorus, iron and vitamin A, B and C. As a vegetable it constitutes an important component in man's diet, especially in developing countries. However, per capita consumption of vegetables in developed countries tends to be higher than in developing countries, possibly because people in developed countries have a better appreciation of the nutritional value of vegetable crops.

2. Details Experimental
A field experiment on the "effect of planting density and fertigation on growth, flowering and yield in processing varieties of tomato (*Solanum lycopersicum* L.)" was conducted with an objective of finding out the most suitable variety, planting density and fertigation level at Jain Irrigation Systems Ltd., chittoor. The results obtained are presented in this paper.

3. Results and Discussion
3.1 Number of primary branches per plant
Significant differences were observed in the number of primary branches per plant (Table 1) due to planting density, fertigation levels and their interactions at different days after transplanting. The main effect fertigation, two way interaction planting density x fertigation and three way interaction were found significant at 30, 60, 90 and 120 DAT. Planting density at 60 cm x 60 cm (S_2) recorded significantly the highest number of primary branches (13.48) on par with 75 cm x 40 cm (S_3) (13.28). The lowest number of primary branches was recorded by the planting density at 120 cm x 40 cm (S_1) (11.99). Application of 180N: 90P: 90K kg per ha (F_3) recorded the highest number of primary branches per plant (13.60) which was followed

by 150N: 75P: 75K kg per ha (F_2) (12.92) on par with the application of 120N: 60P: 60K kg per ha (F_1) (12.25).

3.2 Number of secondary branches per plant

Significant differences were observed in the number of secondary branches per plant (Table 2) due to variety, planting density, fertigation levels and their interactions at all growth stages. Among the varieties Abhinav recorded the highest number of secondary branches (10.31) at 120 DAT. Planting density at 120 cm x 40 cm (S_1) recorded significantly the highest number of secondary branches (10.94) which was followed by 60 cm x 60 cm (S_2) (9.16) which was on par with the planting density at 75 cm x 40 cm (S_3) (8.75). Application of 180N: 90P: 90K kg per ha (F_3) recorded the highest number of secondary branches plant (12.67) which was followed by 150N: 75P: 75K kg per ha (F_2) (9.91) and the lowest number of secondary branches was observed with the application of 120N: 60P: 60K kg per ha (F_1) (6.18). Similar increase in number branches due to higher nutritional levels was also reported by Gireesh and Malabasari (2014) [5]. The number of primary branches was minimum at the highest population density. The results were contradictory to those of Khan *et al.* (2000) [1]. The contradictory results were felt to be due to variation in soil fertility status, climatic conditions or species differences. The reason for having less number of secondary branches at higher planting density was also attributed to be due to more competition among plants for light, space and nutrients at higher seed rates (Prabhavathi, 2005) [3].

3.3 Days to first flowering

The variations observed in days to first flowering (Table 3) due to variety, planting density, fertigation combinations and their interactions were found to be significant. Among the varieties, Abhinav recorded the lowest number of days to first flowering (39.03). Planting density at 75 cm x 40 cm (S_3) recorded the least number of days to first flowering (40.03) followed by 60 cm x 60 cm (S_2) (41.01).The highest number of days to first flowering was recorded by the spacing at 120 cm x 40 cm (S_1) (41.45) This might be due to the availability of good sunshine and nutrients in the soil resulting in the accumulation of more photosynthates and induction of early flowering at the planting density at 75 cm x 40 cm and 60 cm x 60 cm. Plants oriented at 120 cm x 40 cm had spent maximum amount of energy in vertical growth as evident from Table 4.1. These results are in close conformity with the findings of Singh (2004) [2]. Application of 120N: 60P: 60K kg per ha (F_1) recorded the earliest first flowering (37.04) followed by 150N: 75P: 75K kg per ha (F_2) (40.25). The highest number of days to first flowering (45.20) was registered by the application of 180N: 90P: 90K kg per ha (F_3).

3.4 Days to first picking

Significant variations were observed in days to first picking due to variety, planting density, fertigation level and their interactions (Table 4). Among the varieties, Abhinav recorded the highest number of days to first picking (80.93 days). Planting density at 120 cm x 40 cm (S_1) recorded significantly the longest duration to first picking (81.12 days) which was on par with 60 cm x 60 cm (S_2) (80.70 days). The lowest number of days taken for first picking was recorded by the planting density at 75 cm x 40 cm single row (S_1) (79.57 days). Application of 180N: 90P: 90K kg per ha (F_3) recorded the highest number of days taken for first picking (84.63 days) whereas the least number of days taken for first picking (78.56 days) was recorded by the application of 150N: 75P: 75K kg per ha (F_2) which was on par with 120N: 60P: 60K kg per ha (F_1) (78.21 days). The interaction effects of planting density x fertigation level and variety x planting density x fertigation level was found significant. Early fruit setting coupled with exposure of fruits to sunlight and better aeration could be the reasons for early picking at the orientations of 60 cm x 60 cm and 75 cm x 40 cm. Singh (2004) [2] also reported similar findings.

3.5 Fruit yield per hectare (tonnes)

The fruit yield per plot (Table 5) exhibited significant differences due to variety, planting density, fertigation level and their interactions. Among the varieties Abhinav recorded the highest fruit yield ha^{-1} (4.85). Planting density at 75 cm x 40 cm (S_3) recorded significantly the highest fruit yield ha^{-1} (5.33 tonnes) which was followed by 60 cm x 60 cm (S_2) (4.21 tonnes). The lowest fruit yield ha^{-1} was recorded by the planting density at 120 cm x 40 cm (S_1) (3.78 tonnes). This might be due to higher plant population per unit area at narrow spacing. A positive correlation was reported between stand density and yield and negative one between stand density and individual plant productivity. These results are in agreement with Charlo *et al.* (2007) [4]. Application of 180N: 90P: 90K kg per ha (F_3) recorded the highest fruit yield ha^{-1} (5.33 tonnes) followed by 150N: 75P: 75K kg per ha (F_2) (4.44 tonnes). The lowest fruit yield ha^{-1} (3.55 tonnes) was recorded by the application of 120N: 60P: 60K kg per ha (F_1).

Table 1: Number of primary branches as influenced by variety, planting density and fertigation in processing tomato

Planting density (B)	Fertigation (C)	Variety (A)											
		30 DAT			60 DAT			90 DAT			120 DAT		
		Alankar	Abhinav	*Mean*	Alankar	Abhinav	*Mean*	Alankar	Abhinav	*Mean*	Alankar	Abhinav	*Mean*
S_1 (120cm x 40 cm) (2.08 plants per m^2)	F_1 (120N:60P:60K)	5.47	6.33	5.90	7.47	8.00	7.73	10.33	9.20	9.76	10.93	10.33	10.63
	F_2 (150N:75P:75K)	8.87	7.20	8.03	9.73	11.40	10.56	10.60	12.27	11.43	11.80	13.40	12.60
	F_3 (180N:90P:90K)	8.00	8.00	8.00	11.47	10.67	11.07	12.53	11.60	12.06	12.60	12.93	12.75
	Mean	7.44	7.17	*7.30*	9.55	10.02	*9.70*	11.15	11.02	*11.08*	11.77	12.22	*11.99*
S_2 (60 cm x 60 cm) (2.78 plants per m^2)	F_1 (120N:60P:60K)	6.40	6.47	6.43	8.33	10.00	9.16	9.13	11.00	10.06	10.60	11.67	11.13
	F_2 (150N:75P:75K)	7.73	4.93	6.33	14.93	9.13	12.03	15.87	12.47	14.17	16.00	13.20	14.60
	F_3 (180N:90P:90K)	8.60	6.60	7.60	12.67	13.73	13.20	14.33	14.47	14.40	14.13	15.33	14.73
	Mean	7.57	6.00	*6.78*	11.97	10.95	*11.46*	13.11	12.64	*12.87*	13.57	13.40	*13.48*
S_3 (75 cm x 40 cm) (3.33 plants per m^2)	F_1 (120N:60P:60K)	6.67	6.67	6.67	9.27	12.93	11.10	9.93	15.40	12.66	10.87	16.20	11.53
	F_2 (150N:75P:75K)	7.73	5.40	6.56	13.00	9.80	11.4	13.33	10.93	12.13	13.87	12.20	13.03
	F_3 (180N:90P:90K)	7.60	5.93	6.76	11.00	13.73	12.36	11.53	16.47	14.00	12.20	14.40	13.30
	Mean	7.33	6.00	*6.66*	11.09	12.15	*11.62*	11.59	14.26	*12.92*	12.31	14.26	*13.28*
For Comparing varieties (A) and Fertigation (C)													
F_1 (120N:60P:60K)		7.66	6.35	7.01	10.35	10.40	10.37	11.02	11.40	11.21	12.08	12.42	*12.25*
F_2 (150N:75P:75K)		6.62	5.97	6.30	10.55	10.02	10.28	12.04	12.35	12.20	12.60	13.24	*12.92*
F_3 (180N:90P:90K)		8.06	6.84	7.45	11.71	12.71	12.21	12.80	14.17	13.48	12.97	14.22	*13.60*

Mean	7.45	6.39	*6.92*	10.87	11.04	*10.95*	11.95	12.64	*12.29*	*12.55*	*13.29*	*12.92*
Factors	*S Em±*	CD at 5%		*S Em±*	CD at 5%		*S Em±*	CD at 5%		*S Em±*	CD at 5%	
Variety (A)	0.15	0.45		-	*NS*		-	*NS*		-	*NS*	
Planting density (B)	-	*NS*		0.14	0.42		0.37	1.08		0.33	0.97	
Fertigation (C)	0.19	0.55		0.14	0.42		0.37	1.08		0.33	0.97	
A X B	-	*NS*		0.20	0.59		0.53	1.52		-	*NS*	
B X C	0.33	0.96		0.25	0.73		0.65	1.87		0.58	1.68	
A X C	-	*NS*		0.20	0.59		-	*NS*		-	*NS*	
A X B X C	0.47	1.36		0.36	1.03		0.92	2.64		0.83	2.38	

Table 2: Number of secondary branches as influenced by variety, planting density and fertigation in processing tomato

Planting density (B)	**Fertigation (C)**	**Variety (A)**											
		30 DAT			**60 DAT**			**90 DAT**			**120 DAT**		
		Alankar	**Abhinav**	***Mean***	**Alankar**	**Abhinav**	***Mean***	**Alankar**	**Abhinav**	***Mean***	**Alankar**	**Abhinav**	***Mean***
S_1 (120 cm x 40 cm) (2.08 plants per m^2)	F_1 (120N:60P:60K)	0.00	0.00	0.00	1.83	1.21	1.52	4.07	4.13	4.10	5.80	6.13	5.96
	F_2 (150N:75P:75K)	0.67	3.20	1.93	1.67	8.07	4.87	5.13	15.80	10.46	8.07	20.07	14.07
	F_3 (180N:90P:90K)	1.30	2.07	1.55	3.13	4.67	3.90	8.73	12.73	10.73	11.13	14.47	12.80
	Mean	0.65	1.75	*1.20*	2.21	3.28	*2.74*	5.97	10.89	*8.42*	8.33	13.55	*10.94*
S_2 (60 cm x 60 cm) (2.78 plants per m^2)	F_1 (120N:60P:60K)	0.00	0.00	0.00	1.75	1.51	1.63	4.93	4.93	4.93	6.60	6.80	6.70
	F_2 (150N:75P:75K)	0.67	0.67	0.67	2.98	2.53	2.75	6.40	4.87	5.63	7.80	6.80	7.30
	F_3 (180N:90P:90K)	2.74	2.60	2.67	6.20	4.73	5.46	12.47	10.60	11.53	14.67	12.33	13.50
	Mean	1.13	1.09	*1.11*	3.64	2.92	*3.28*	7.93	6.80	*7.36*	9.69	8.64	*9.16*
S_3 (75 cm x 40 cm) (3.33 plants per m^2)	F_1 (120N:60P:60K)	0.00	0.00	0.00	1.11	1.54	1.32	3.93	4.60	4.26	6.00	5.80	5.90
	F_2 (150N:75P:75K)	0.00	0.00	0.00	1.75	2.33	2.04	6.73	5.80	6.26	9.60	7.13	8.36
	F_3 (180N:90P:90K)	2.20	2.21	2.20	3.93	5.53	4.73	8.00	12.20	10.10	10.13	13.33	11.73
	Mean	0.73	0.73	*0.73*	2.26	3.13	*2.69*	6.22	7.53	*6.87*	8.57	8.75	*8.75*
For Comparing varieties (A) and Fertigation (C)													
F_1 (120N:60P:60K)		0.00	0.00	0.00	1.56	1.42	1.49	4.31	4.55	4.43	6.13	6.24	*6.18*
F_2 (150N:75P:75K)		0.44	1.28	0.86	2.13	4.31	3.22	6.08	8.82	7.45	8.48	11.33	*9.91*
F_3 (180N:90P:90K)		2.08	2.29	2.18	4.42	4.97	4.70	9.73	11.84	10.78	11.97	13.37	*12.67*
Mean		0.84	1.19	*1.01*	2.70	3.57	*3.13*	6.71	8.40	*7.55*	*8.86*	*10.31*	*9.58*
Factors		*S Em±*	CD at 5%		*S Em±*	CD at 5%		*S Em±*	CD at 5%		*S Em±*	CD at 5%	
Variety (A)		0.06	0.18		0.06	0.17		0.05	0.16		0.21	0.61	
Planting density (B)		0.07	0.22		0.07	0.21		0.07	0.20		0.26	0.75	
Fertigation (C)		0.07	0.22		0.07	0.21		0.07	0.20		0.26	0.75	
A x B		0.11	0.31		0.10	0.30		0.10	0.28		0.37	1.06	
B x C		0.13	0.38		0.13	0.37		0.12	0.35		0.45	1.30	
A x C		0.11	0.31		0.10	0.30		0.10	0.28		0.37	1.06	
A x B x C		0.19	0.54		0.18	0.53		0.17	0.49		0.64	1.84	

Table 3: Days to first flowering as influenced by variety, planting density and fertigation in processing tomato

Planting density (B)	**Fertigation (C)**	**Variety (A)**		
		Alankar	**Abhinav**	***Mean***
S_1 (120cm x 40 cm) (2.08 plants per m^2)	F_1 (120N:60P:60K)	30.66	37.20	33.93
	F_2 (150N:75P:75K)	45.20	38.40	41.80
	F_3 (180N:90P:90K)	49.40	47.86	48.63
	Mean	41.75	41.15	*41.45*
S_2 (60 cm x 60 cm) (2.78 plants per m^2)	F_1 (120N:60P:60K)	43.26	34.60	38.93
	F_2 (150N:75P:75K)	42.60	40.33	41.46
	F_3 (180N:90P:90K)	50.73	34.53	42.63
	Mean	45.53	36.48	*41.01*
S_3 (75 cm x 40 cm) (3.33 plants per m^2)	F_1 (120N:60P:60K)	40.33	36.20	38.26
	F_2 (150N:75P:75K)	37.53	37.46	37.50
	F_3 (180N:90P:90K)	43.93	44.73	44.33
	Mean	40.99	39.46	*40.03*
For Comparing varieties (A) and Fertigation (C)				
F_1 (120N:60P:60K)		38.08	36.00	*37.04*
F_2 (150N:75P:75K)		41.77	38.73	*40.25*
F_3 (180N:90P:90K)		48.02	42.37	*45.20*
Mean		*42.63*	*39.03*	*40.83*
Factors		*S Em±*	CD at 5%	
Variety (A)		0.07	0.20	
Planting density (B)		0.08	0.25	
Fertigation (C)		0.08	0.25	
A x B		0.12	0.35	
B x C		0.15	0.43	
A x C		0.12	0.35	
A x B x C		0.21	0.61	

Table 4: Days to first picking influenced as by variety, planting density and fertigation in processing tomato

Planting density (B)	Fertigation (C)	Variety (A)		
		Alankar	**Abhinav**	***Mean***
S_1(120cm x 40 cm) (2.08 plants per m^2)	F_1 (120N:60P:60K)	78.33	76.80	77.56
	F_2 (150N:75P:75K)	79.26	78.20	78.73
	F_3 (180N:90P:90K)	82.40	91.73	87.06
	Mean	80.00	82.24	*81.12*
S_2(60 cm x 60 cm) (2.78 plants per m^2)	F_1 (120N:60P:60K)	79.33	79.20	79.26
	F_2 (150N:75P:75K)	78.86	77.80	78.33
	F_3 (180N:90P:90K)	82.66	86.33	84.50
	Mean	80.29	81.11	*80.70*
S_3(75 cm x 40 cm) (3.33 plants per m^2)	F_1 (120N:60P:60K)	77.33	78.26	77.80
	F_2 (150N:75P:75K)	78.93	78.26	78.60
	F_3 (180N:90P:90K)	82.33	82.33	82.33
	Mean	79.53	79.62	*79.57*
For Comparing varieties (A) and Fertigation (C)				
F_1 (120N:60P:60K)		78.33	78.08	*78.21*
F_2 (150N:75P:75K)		79.02	78.08	*78.56*
F_3 (180N:90P:90K)		82.46	86.80	*84.63*
Mean		*79.94*	*80.93*	*80.46*
Factors		*S Em±*		CD at 5%
Variety (A)		0.12		0.34
Planting density (B)		0.14		0.42
Fertigation (C)		0.14		0.42
A x B		0.20		0.60
B x C		0.25		0.73
A x C		0.20		0.60
A x B x C		0.36		1.04

Table 5: Fruit yield (tonnes) per ha as influenced by variety, planting density and fertigation in processing tomato

Planting density (B)	Fertigation (C)	Variety (A)		
		Alankar	**Abhinav**	***Mean***
S_1 (120 cm x 40 cm) (2.08 plants per m^2)	F_1 (120N:60P:60K)	66.11	79.83	72.97
	F_2 (150N:75P:75K)	75.62	125.83	100.73
	F_3 (180N:90P:90K)	77.22	136.09	106.66
	Mean	72.98	113.92	93.45
S_2 (60 cm x 60 cm) (2.78 plants per m^2)	F_1 (120N:60P:60K)	97.09	86.41	91.75
	F_2 (150N:75P:75K)	102.87	113.90	108.39
	F_3 (180N:90P:90K)	106.28	118.19	112.23
	Mean	102.08	106.17	104.12
S_3 (75 cm x 40 cm) (3.33 plants per m^2)	F_1 (120N:60P:60K)	84.06	113.05	98.56
	F_2 (150N:75P:75K)	108.36	132.31	120.33
	F_3 (180N:90P:90K)	179.45	172.43	175.94
	Mean	123.96	139.26	131.61
For Comparing varieties (A) and Fertigation (C)				
F_1 (120N:60P:60K)		82.42	93.10	87.76
F_2 (150N:75P:75K)		95.61	124.02	109.82
F_3 (180N:90P:90K)		120.98	142.24	131.61
Mean		99.67	119.78	109.73
Factors		*S Em±*		CD at 5%
Variety (A)		2.77		7.97
Planting density (B)		3.39		9.76
Fertigation (C)		3.39		9.75
A x B		4.80		13.80
B x C		5.88		16.90
A x C		4.80		13.80
A x B x C		8.31		23.91

4. Conclusions

As it is observed in case of growth and flowering parameters, the fruit yield was found to be highest in case of Abhinav compared to Alankar establishing the superiority of the genotype. The branching capacity of tomato was improved by increasing fertigation levels. The maximum number of primary and secondary branches per plant was obtained by giving nutrients at the highest dose which can be attributed to the more vigorous growth at highest fertigation level. Increasing density decreased the number of secondary branches on account of the higher plant density and taller plants. Plants spaced at 60 cm x 60 cm were having a reasonable amount of space, light and little competition from neighbouring plants and as a result they were late to initiate flowering and took a lot of time for completion of flowering phase and also vested with greater amount of time to

translocate their photosynthates into reproductive parts or clusters which might be the reason for good growth of individual clusters and bearing more number of fruits in them. In the case of fertigation dose since, the greatest fertigation dose influenced the plants to extend their flowering period and enlarged the duration of reproductive phase significantly over the smallest nutrient dose.

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