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Effect of planting density and fertigation on growth, flowering and yield in processing varieties of tomato

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Abstract
The var. Abhinav was recorded the lowest number of days to 50% flowering (59.40 days) with highest fruit yield per plot (970.24 kg). Planting density at 75 cm x 40 cm (S_2) recorded significantly the lowest number of days to 50% flowering (59 days) followed by 60 cm x 60 cm (S_3). The highest number of days to 50% flowering (61.70 days) was recorded by 120 cm x 40 cm. Application of 180N: 90P: 90K kg per ha (F_3) recorded the highest plant height (133.30 cm), canopy spread (40.74 cm), leaves (40.21), highest number of days to 50% flowering (66.01 days) and fruit yield per plot (1066.04 kg) followed by 150N: 75P: 75K kg per ha (F_2). The lowest readings of these parameters were recorded by the application of 120N: 60P: 60K kg per ha (F_1). Among three way interactions, the lowest number of days to 50% flowering was recorded by the combination of variety Abhinav + 75 cm x 40 cm (S_3) + 120N: 60P: 60K kg per ha (54.26 days).

Keywords: Tomato, canopy spread, days to 50% flowering, yield, planting density, fertigation

1. Introduction
Tomato cultivation is one of the most profitable agriculture businesses. Cultivating tomato is an excellent option for those looking to harvest a commercially important crop four times a year. Tomato farming is possible both in traditional farming and greenhouse farming. Botanically called *Solanum licopersicum*, tomato plants are actually vines. If given adequate support they can grow up to 6 feet tall in traditional farming. Although they are perennials, when reared in greenhouses they can live up to 3 years. The vines are covered with short hairs all over and the flowers are yellow in color with red coloured attractive fruit with highest vitamin C. Various products like jam, Ketchup, Sauce, Puree, Pickles can also me made when glut of market is available due to these reasons it is number one processing vegetable.

2. Details Experimental
The present investigation on the Effect of planting density and fertigation on growth, flowering and yield in processing varieties of tomato was in chittoor. The major objectives of the study were to find out the better variety, planting density, fertigation level for optimum growth, flowering and yield in tomato under agro climatic conditions of chittoor. The results obtained along with relevant discussion are presented in this paper.

3. Results and Discussion
3.1 Plant height (cm)
The data on plant height (Table 3.1) revealed that there were significant differences due to variety, planting density, fertigation level and their interactions. The main effects due to the above factors were found significant at 90 and 120 days after transplanting (DAT). Similarly, the interaction effects between varieties, planting density and fertigation level was also found significant at 90 and 120 days after transplanting (DAT). The fertigation level was significant at all growth stages of the crop.

Among the varieties Abhinav recorded the highest plant height (133.84 cm) at 120 DAT. Planting density at 120 cm x 40 cm (S_1) recorded significantly the highest plant height (130.10 cm) followed by 60 cm x 60 cm (S_2) (123.94 cm). The lowest plant height was recorded by the planting density at 75 cm x 40 cm (S_3) (121.17 cm). Similar observations were also reported by Raghav (2000) [1] and Kumar (2001) [2].

Application of 180N: 90P: 90K kg ha (F_3) recorded the highest plant height (133.30 cm) and the lowest plant height (114.47 cm) was recorded by the application of 120N: 60P: 60K kg ha (F_1). The plant height increased from 86.93 cm at 30 DAT to 125.07 cm at 120 DAT. Among the varieties Abhinav was found to show superior values throughout the study. This may be perhaps due to its inherent genetic potential compared to Alankar. These results are in conformity with those of Singh *et al.* (2005) [3].

The combination of variety Abhinav, planting density at 120 cm x 40 cm coupled with F_3 level (180N: 90P: 90K kg ha) exhibited superior performance which might be due to very less competition and a high level of nutrient availability.

3.2 Canopy spread (cm)

Data on canopy spread of a plant (Table 3.3) revealed significant differences due to fertigation levels at 30, 60, 90 and 120 DAT. However there was no significant difference in main the effects of variety and planting density. Application of 180N: 90P: 90K kg per ha (F_3) recorded the highest canopy spread (40.74) which was followed by 150N: 75P: 75K kg per ha (F_2) (38.53). The lowest canopy spread (34.62) was recorded by the application of 120N: 60P: 60K kg per ha (F_1).

3.3 Number of leaves per plant

Data on number of leaves per plant (Table 3.4) revealed significant differences due to variety, planting density, fertigation levels and their interactions. At 30, 60, 90 and 120 DAT, the three main effects and the three way interaction effects were significant, but the two way interaction effect of variety x fertigation was non-significant. Among the main effects, the var. Abhinav recorded the highest number of leaves (41.90) at 120 DAT. Planting density at 120 cm x 40 cm (S_1) recorded significantly the highest number of leaves (42.18) followed by 60 cm x 60 cm (S_2) (36.98) which was on par with the planting density at 75 cm x 40 cm (S_3) (36.67). Application of 180N: 90P: 90K kg per ha (F_3) recorded the highest number of leaves (40.21) which was on par with 150N: 75P: 75K kg per ha (F_2) (39.80). The lowest number of leaves (35.76) was recorded by the application of 120N: 60P: 60K kg per ha (F_1).

Plants which were widely spaced produced significantly more leaves and wider canopies. This might be because the wider spacing reduced the competition for soil nutrients, moisture, carbon dioxide and light among the plants. This probably enhanced photosynthesis which resulted in the production of more leaves and wider canopies. (Dawuda *et al.* 2011) [7]. Kamboj *et al.* (2015) [9] also reported similar findings.

Likewise, the increase in the fertigation levels positively increased the plant height and canopy spread which was also supported by (Venkatesan *et al.* 2014). Similar findings were also reported by Odubanjo *et al.* (2011) [6].

3.4 Days to 50% flowering

Significant variations were observed in days to 50% flowering (Table 4.7) due to variety, planting density, fertigation levels and some of their interactions. Among the varieties, Abhinav recorded the earliest days to 50% flowering (59.40). Planting density at 75 cm x 40 cm (S_3) recorded the lowest number of days to 50% flowering (59.00) followed by 60 cm x 60 cm (S_2) (59.28). Maximum number of days to 50% flowering was recorded by the planting density at 120 cm x 40 cm (S_1) (61.70). Similar findings were reported by Monirul *et al.* 2011. Application of 120N: 60P: 60K kg ha (F_1) recorded the earliest occurrence of 50% flowering (55.73) followed by 150N: 75P: 75K kg per ha (F_2) (58.24). Maximum number of days to 50% flowering (66.01) was recorded by the application of 180N: 90P: 90K kg per ha (F_3). It is evident from the above results on flower initiation and 50% flowering that the application of nutrients at the highest dose resulted in spending maximum time for the development of sufficient vegetative frame work to bear the load of crop. A deeper insight on the reproductive and yield parameters would explain how the higher fertigation doses that accumulated sufficiently stronger vegetative frame work behaved in respect of flower and fruit production. Similar delay in flowering at higher nutritional doses was also reported by Manoj *et al.* (2013) [8].

3.5 Fruit yield per plot (kg)

The fruit yield per plot (Table 3.5) exhibited significant differences due to variety, planting density, fertigation level and their interactions. Among the varieties Abhinav recorded the highest fruit yield per plot (970.24 kg). Planting density at 75 cm x 40 cm (S_3) recorded significantly the highest fruit yield per plot (1066.05 kg) which was followed by 60 cm x 60 cm (S_2) (843.39 kg) The lowest fruit yield per plot was recorded by the planting density at 120 cm x 40 cm (S_1) (756.94 kg). 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 per plot (1066.04 kg) followed by 150N: 75P: 75K kg per ha (F_2) (889.50 kg). The lowest fruit yield per plot (710.84 kg) was recorded by the application of 120N: 60P: 60K kg per ha (F_1).

The trend in individual plant productivity in respect of planting density overturned when it comes to per plot yield of fruit and fruit yield ha^{-1}. As mentioned earlier, this is only due to more number of plants though yielded relatively lesser fruits per plant, could contribute to a higher gross figures per unit area or per plot or per hectare. However, an examination of interactions between planting density and fertigation level at per plot and per hectare level revealed that enhanced fertigation dose boosted the yield significantly from the lowest level 120N: 60P: 60K to higher level 180N: 90P: 90K kg per ha. Manoj *et al.* (2013) [8] reported similar results on tomato var. Azad T-6.

Table 3.1: Plant height (cm) 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)	81.13	90.93	86.03	98.99	110.59	104.79	106.41	119.45	112.93	115.05	120.66	117.85
	F_2 (150N:75P:75K)	86.41	84.93	85.67	109.67	103.79	106.73	115.96	131.24	123.60	120.71	132.98	126.84
	F_3 (180N:90P:90K)	96.15	93.40	94.77	111.51	108.53	110.02	114.80	171.44	143.12	116.96	174.29	145.62
	Mean	87.89	89.75	*88.82*	*106.70*	*107.63*	*107.16*	*112.37*	*140.71*	*126.54*	*117.57*	*142.64*	*130.10*
S_2 (60 cm x 60 cm) (2.78 plants per m^2)	F_1 (120N:60P:60K)	82.57	75.41	78.99	102.40	97.33	99.86	109.15	126.87	118.01	112.31	128.53	120.42
	F_2 (150N:75P:75K)	84.82	92.24	88.53	97.83	108.91	103.37	103.15	139.43	121.29	103.35	142.48	122.91
	F_3 (180N:90P:90K)	92.98	93.84	93.41	124.03	113.80	118.91	122.45	131.18	126.81	124.25	132.75	128.50
	Mean	86.79	87.16	*86.97*	*108.08*	*106.68*	*107.38*	*111.58*	*132.49*	*122.03*	*113.30*	*134.58*	*123.94*
S_3 (75 cm x 40 cm) (3.33 plants per m^2)	F_1 (120N:60P:60K)	82.37	73.23	77.80	99.20	93.13	96.16	97.12	107.95	102.53	100.46	109.85	105.15
	F_2 (150N:75P:75K)	84.25	89.50	86.87	105.32	103.23	104.27	114.20	147.59	130.89	115.91	149.29	132.60
	F_3 (180N:90P:90K)	88.70	91.99	90.34	101.95	103.50	102.72	136.36	112.09	124.22	137.77	113.79	125.78
	Mean	85.10	84.90	*85.00*	*102.15*	*99.95*	*101.05*	*115.89*	*122.52*	*119.20*	*118.04*	*124.31*	*121.17*
For Comparing varieties (A) and Fertigation (C)													
F_1 (120N:60P:60K)		82.02	79.85	80.94	100.19	100.34	100.27	104.22	118.08	111.15	109.27	119.67	*114.47*
F_2 (150N:75P:75K)		85.16	88.88	87.02	104.27	105.30	104.79	111.10	139.41	125.26	113.32	141.58	*127.45*
F_3 (180N:90P:90K)		92.60	93.07	92.84	112.49	108.61	110.55	124.53	138.23	131.38	126.32	140.27	*133.30*
Mean		86.59	87.27	*86.93*	105.65	104.75	*105.20*	113.28	131.91	*122.59*	*116.30*	*133.84*	*125.07*

Factors	*S Em±*	CD at 5%	*S Em±*	CD at 5%	*S Em±*	CD at 5%	*S Em±*	CD at 5%
Variety (A)	-	*NS*	-	*NS*	0.61	1.76	0.26	0.77
Planting density (B)	-	*NS*	1.75	5.04	0.75	2.16	0.33	0.94
Fertigation (C)	1.77	5.10	1.75	5.04	0.75	2.16	0.33	0.94
A x B	-	*NS*	-	*NS*	1.06	3.06	0.46	1.34
B x C	-	*NS*	-	*NS*	1.30	3.74	0.57	1.64
A x C	-	*NS*	-	*NS*	1.06	3.06	0.46	1.34
A x B x C	-	*NS*	4.30	12.36	1.84	5.30	0.80	2.32

Table 3.2: Canopy spread (cm) 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)	12.45	12.46	12.45	23.44	23.79	23.61	30.22	36.34	33.28	30.61	32.76	31.68
	F_2 (150N:75P:75K)	15.09	15.75	15.42	29.96	29.50	29.73	37.50	41.44	39.47	38.34	38.92	38.63
	F_3 (180N:90P:90K)	18.16	18.01	18.05	33.09	32.59	32.84	41.89	41.98	41.93	42.18	42.51	42.34
	Mean	15.23	15.40	*15.31*	28.83	28.62	*28.72*	36.53	39.92	*38.22*	37.04	38.06	*37.55*
S_2 (60 cm x 60 cm) (2.78 plants per m^2)	F_1 (120N:60P:60K)	11.53	11.50	11.51	24.43	24.26	24.34	29.20	38.24	33.72	34.06	34.82	34.44
	F_2 (150N:75P:75K)	12.96	12.89	12.92	25.47	24.88	25.17	30.67	32.75	31.71	39.60	40.26	39.93
	F_3 (180N:90P:90K)	16.31	16.66	16.48	26.73	27.07	26.90	33.87	48.14	41.00	39.86	41.99	40.92
	Mean	13.60	13.68	*13.64*	25.54	25.40	*25.47*	31.24	39.71	*35.51*	37.84	39.02	*38.43*
S_3 (75 cm x 40 cm) (3.33 plants per m^2)	F_1 (120N:60P:60K)	14.88	14.71	14.79	24.60	25.29	24.94	34.50	34.21	34.35	36.63	38.86	37.74
	F_2 (150N:75P:75K)	16.84	17.54	17.19	27.25	24.85	26.05	32.33	33.02	32.67	37.54	36.57	37.05
	F_3 (180N:90P:90K)	20.85	20.12	20.48	30.05	31.07	30.56	38.04	38.69	38.36	39.25	38.71	38.98
	Mean	17.52	17.45	*17.48*	27.30	27.07	*27.18*	34.95	35.30	*35.12*	37.80	38.04	*37.92*
For Comparing varieties (A) and Fertigation (C)													
F_1 (120N:60P:60K)		12.95	12.89	12.92	24.15	24.44	24.29	31.30	36.26	33.78	33.76	35.48	*34.62*
F_2 (150N:75P:75K)		14.96	15.39	15.17	27.55	26.41	26.98	33.50	35.73	34.61	38.49	38.58	*38.53*
F_3 (180N:90P:90K)		18.43	18.26	18.35	29.95	30.24	30.09	37.93	42.93	40.43	40.42	41.06	*40.74*
Mean		15.45	15.51	*15.48*	27.22	27.03	*27.12*	34.24	38.31	*35.27*	*37.56*	*38.37*	*37.96*

Factors	*S Em±*	CD at 5%	*S Em±*	CD at 5%	*S Em±*	CD at 5%	*S Em±*	CD at 5%
Variety (A)	-	*NS*	-	*NS*	1.01	2.92	-	*NS*
Planting density (B)	0.07	0.20	0.25	0.74	-	*NS*	-	*NS*
Fertigation (C)	0.07	0.20	0.25	0.74	1.24	3.58	0.41	1.19
A x B	-	*NS*	-	*NS*	-	*NS*	-	*NS*
B x C	0.12	0.35	0.44	1.28	-	*NS*	0.71	2.06
A x C	0.10	0.28	-	*NS*	-	*NS*	-	*NS*
A x B x C	0.17	0.50	-	*NS*	-	*NS*	-	*NS*

Table 3.3: Number of leaves per plant 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)	24.13	25.53	24.83	38.27	33.47	35.87	17.73	44.60	31.16	28.93	42.33	35.63
	F_2 (150N:75P:75K)	17.13	24.40	20.76	34.60	34.60	34.60	27.73	38.80	33.26	37.47	47.93	42.70
	F_3 (180N:90P:90K)	13.33	17.07	15.20	33.00	23.20	28.10	41.07	38.80	39.93	35.27	61.17	48.22
	Mean	18.19	22.33	*20.26*	35.29	30.42	*32.85*	28.51	40.73	*34.62*	33.89	50.47	*42.18*
S_2 (60 cm x 60 cm) (2.78 plants per m^2)	F_1 (120N:60P:60K)	15.93	14.53	15.23	23.73	21.07	22.40	64.27	25.33	44.80	30.47	35.20	32.83
	F_2 (150N:75P:75K)	18.20	25.60	21.90	42.93	43.53	43.23	28.27	35.53	31.90	43.00	31.80	37.40
	F_3 (180N:90P:90K)	23.13	14.73	18.93	33.80	25.33	29.56	24.27	24.80	24.53	37.53	43.60	40.56
	Mean	19.08	18.28	*18.68*	33.48	29.97	*31.72*	38.93	28.55	*33.74*	37.00	36.86	*36.93*
S_3 (75 cm x 40 cm) (3.33 plants per m^2)	F_1 (120N:60P:60K)	25.33	25.00	25.16	42.33	32.93	37.63	28.40	31.20	29.80	29.73	38.80	34.26
	F_2 (150N:75P:75K)	23.20	25.67	24.43	29.67	33.87	31.77	22.47	17.33	19.90	35.90	38.87	37.38
	F_3 (180N:90P:90K)	10.20	24.13	17.16	16.93	29.53	23.23	26.60	42.73	34.66	39.27	37.47	38.37
	Mean	19.57	24.93	*22.25*	29.64	32.11	*30.87*	25.82	30.42	*28.12*	34.96	38.38	*36.67*
For Comparing varieties (A) and Fertigation (C)													
F_1 (120N:60P:60K)		22.55	25.37	23.96	36.64	41.17	38.91	24.80	37.11	30.95	33.88	37.64	*35.76*
F_2 (150N:75P:75K)		13.15	18.57	15.86	24.60	24.55	24.57	43.97	35.62	39.80	35.00	44.61	*39.80*
F_3 (180N:90P:90K)		21.15	21.60	21.37	31.26	32.68	31.97	24.82	26.97	25.90	36.96	43.46	*40.21*
Mean		18.96	21.82	*20.39*	30.83	32.80	*31.81*	31.20	33.23	*32.21*	*35.28*	*41.90*	*38.59*

Factors	*S Em±*	CD at 5%	*S Em±*	CD at 5%	*S Em±*	CD at 5%	*S Em±*	CD at 5%
Variety (A)	0.26	0.75	0.34	0.98	0.13	0.39	0.90	2.58
Planting density (B)	0.32	0.92	0.42	1.20	0.16	0.48	1.10	3.16
Fertigation (C)	0.32	0.92	0.42	1.20	0.16	0.48	1.10	3.16
A x B	0.45	1.31	0.59	1.70	0.23	0.68	1.55	4.48
B x C	0.55	1.60	0.72	2.09	0.29	0.84	1.90	5.48
A x C	0.45	1.31	0.59	1.70	0.23	0.68	-	*NS*
A x B x C	0.79	2.27	1.02	2.95	0.41	1.18	2.70	7.76

Table 3.4: Days to fifty percent 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)	62.80	55.33	59.06
	F_2 (150N:75P:75K)	58.00	60.46	59.23
	F_3 (180N:90P:90K)	66.40	67.20	66.80
	Mean	62.40	61.00	*61.70*
S_2 (60 cm x 60 cm) (2.78 plants per m^2)	F_1 (120N:60P:60K)	49.93	55.46	52.70
	F_2 (150N:75P:75K)	63.86	55.06	59.46
	F_3 (180N:90P:90K)	65.60	65.80	65.70
	Mean	59.80	58.78	*59.28*
S_3 (75 cm x 40 cm) (3.33 plants per m^2)	F_1 (120N:60P:60K)	56.60	54.26	55.43
	F_2 (150N:75P:75K)	56.06	56.00	56.03
	F_3 (180N:90P:90K)	66.06	65.00	65.53
	Mean	59.57	58.42	*59.00*
For Comparing varieties (A) and Fertigation (C)				
F_1 (120N:60P:60K)		56.44	55.02	55.73
F_2 (150N:75P:75K)		59.31	57.17	58.24
F_3 (180N:90P:90K)		66.02	66.00	66.01
Mean		60.59	59.40	*59.99*

Factors	*S Em±*	CD at 5%
Variety (A)	0.07	0.21
Planting density (B)	0.09	0.25
Fertigation (C)	0.09	0.25
A x B	-	*NS*
B x C	0.15	0.44
A x C	0.12	0.36
A x B x C	0.22	0.63

Table 3.5: Fruit yield (kg) per plot 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)	535.46	646.60	591.03
	F_2 (150N:75P:75K)	612.53	1,019.23	815.88
	F_3 (180N:90P:90K)	625.48	1,102.35	863.91
	Mean	591.16	922.73	*756.94*
S_2 (60 cm x 60 cm) (2.78 plants per m^2)	F_1 (120N:60P:60K)	786.40	699.95	743.17
	F_2 (150N:75P:75K)	833.21	922.63	877.92
	F_3 (180N:90P:90K)	860.85	957.32	909.09
	Mean	826.82	859.96	*843.39*
S_3 (75 cm x 40 cm) (3.33 plants per m^2)	F_1 (120N:60P:60K)	680.90	915.71	798.31
	F_2 (150N:75P:75K)	877.68	1,071.73	974.71
	F_3 (180N:90P:90K)	1,453.58	1,396.68	1,425.13
	Mean	1,004.05	1,128.04	*1,066.05*
For Comparing varieties (A) and Fertigation (C)				
F_1 (120N:60P:60K)		667.59	754.09	710.84
F_2 (150N:75P:75K)		774.47	1,004.53	889.50
F_3 (180N:90P:90K)		979.97	1,152.12	1,066.04
Mean		807.34	970.24	*888.79*

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

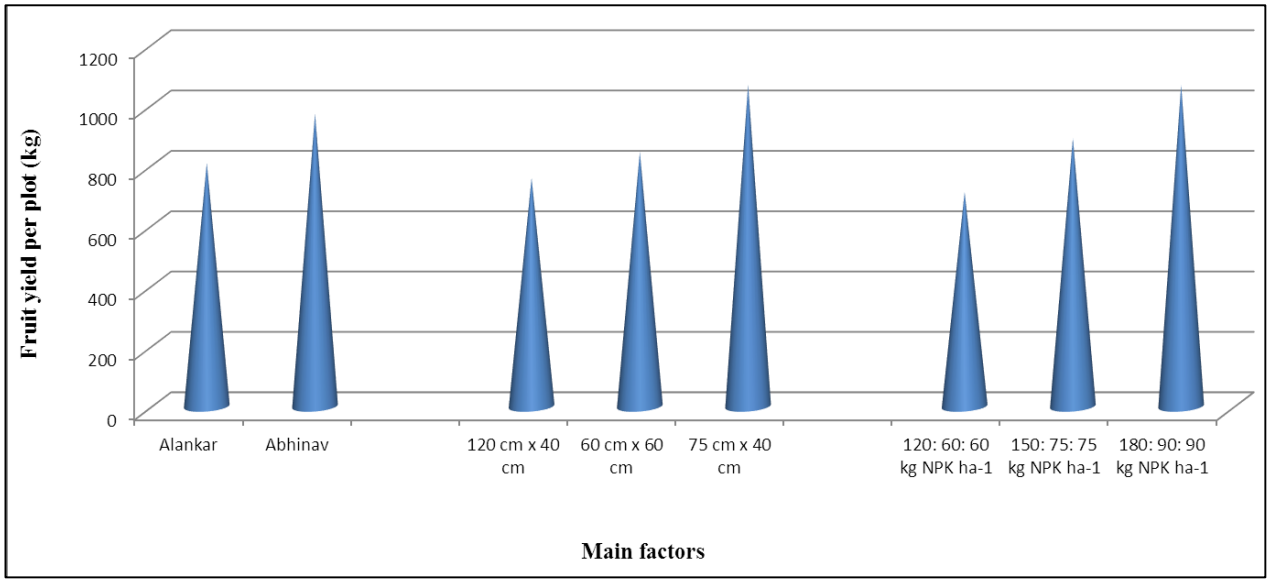

Fig. 1. Effect of variety, planting density and fertigation level on the fruit yeild per plot (kg) in processing tomato

4. Conclusions

The experiment in the study was to find out the effect of variety, planting density and fertigation level on growth, flowering and yield in tomato. Plant height, number of leaves, canopy spread, Days to fifty % flowering and fruit yield per plot was found highest in case of Abhinav Variety. Wider spacing resulted in more canopy spread and number of leaves Compared to other two spacings. However spacing 75 cm x 40 cm (S_3) which accommodated highest number of plants per unit area resulted less number of days to 50% flowering compared to other two spacings with highest fruit yield per plot. With the increase in the fertigation levels of N P K the fruit yield per plot were increased with other vegetative parameters.

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