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RESEARCH PAPER

Response of semi-determinate and indeterminate hybrids of tomato (*Lychopersicon esculentum* Mill.) to pruning and spacing grown under cover

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Abstract : The undercover tomato trial was conducted at Indian Institute of Horticultural Sciences, Bangalore. This study was conducted to determine the response of semi-determinate and indeterminate hybrids of tomato to pruning and spacing grown under cover. The results indicated that the plant height was the highest in closer spacing at 30 (92.58 cm) 60 (135.98 cm), 90 (185.25 cm) days after planting and at final harvest (221.35 cm), whereas maximum leaf area (4045.92 cm^2 and 5705.73 cm^2) was observed in V_2 at both first and last harvest. Maximum dry matter (35.31 to 38.48%) was observed in leaves followed by flowers and fruits stem and root at first harvest. Maximum (45.18 to 50.4%) dry matter was observed in flower and fruits followed by stem, leave and root at final harvest. Sun 7611 (V_2) recorded the highest biomass accumulation (22.76 g, 77.81 g and 158.37 g) at vegetative phase, first harvest and at final harvest which was significantly different from Arka Abhijith (V_1). Fruit set percentage was higher in Arka Abhijith (59.43%) than Sun 7611 (54.57) more number of flowers formed fruits in single stemmed plants (59.24%) compared to double stemmed plants (54.76%). Among spacing treatments per cent fruit set did not differ significantly. Further fruit yield was significantly higher in P_2 (2.23 kg) than P_1 (1.96 kg). Maximum fruit yield per plant was obtained in S_3 (2.44 kg) followed by S_2 (2.03 kg) and the least was observed in S_1 (1.81 kg) which were significantly different. However, yield per hectare was significantly improved under closer spacing.

Key Words : Semi-determinate, Indeterminate, Pruning, Spacing

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INTRODUCTION

Prospects of increasing vegetable production in India by increasing cultivable land under vegetables are limited. What is needed is to produce more vegetables in limited available land in order to meet future demands. There are various means and ways to achieve anticipated target of vegetable production by using hybrid technology and improved agro techniques. Another potential approach is production of vegetables under protected conditions (Verma, 1999).

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Protected cultivation of vegetables in India has just started recording an annual growth rate of 30 per cent. Protected cultivation involves protection of different production stages mainly from adverse environmental conditions such as extreme temperature, hail storm, scorching sun, heavy rains, snow etc. Some studies on capsicum, tomato, cucumber have shown encouraging results. It has been observed that the tomato fetches high price early or late in the season. The prices crash in the middle of the season when there is a glut in the market. It has become difficult to get high productivity of superior quality fruits under open conditions, especially during off season but the crop is damaged due to adverse weather conditions and insect pests and diseases when there is great demand. This has made many tomato growers to re-examine the costs and benefits of various production practices. The adoption of optimum spacing and proper pruning and training are very important to get early, high and quality fruits, of tomato especially when grown under cover apart from protecting the crop from both biotic and abiotic stresses.

MATERIAL AND METHODS

The experiment was carried out at the division of vegetable crops, Indian Institute of Horticultural Research (IIHR), Hessarghatta, Bangalore and field is located at an altitude of 890 m above mean sea level. It has a latitude of 13°,58° N and longitude of 78° E. The experiment was carried out in a low cost, naturally ventilated polyhouse (E-W orientation) of 137.5 m^2 area. The polyhouse had the dimensions of 25 m length and 5.5 m width, having a side height of 2.5 m and central height of 3.7 m. An UV stabilized high density polyethylene film (HDPE) of (200µ) 800 guage was used as cladding material for the polyhouse. Both the sides of polyhouse were covered with rambo net (40 mesh) for natural ventilation and protection against pests. Shade net (50%) was also provided inside the polyhouse to reduce temperature and light intensity, whenever required. The experiment consisted of two hybrids, one semideterminate (Arka Abhijith; V_1) another indeterminate (Sun 7611; V_2), two different pruning methods (Single stem -P_1 and Double stem -P_2) and three spacing (S_1:60 x 20 cm S_2:60 x 30 cm and S_3:60 x 40 cm). The experiment was laid out Factorial Randomized Complete Block Design. Land area inside the polyhouse was thoroughly dug to a depth of 30 cm a month prior to planting. Raised beds of 1 m width and 20 cm height were prepared with a walking space of 45 cm between the beds. Beds were incorporated with well decomposed farm yard manure and basal dose of inorganic fertilizers were mixed thoroughly (Anonymous, 1999).

RESULTS AND DISCUSSION

The findings of the present study as well as relevant discussion have been presented under following heads:

Growth parameters :

Plant height :

Maximum plant height (Table 1) was observed in Sun 7611 which differed significantly from Arka Abhijith at all the growth stages. Plant height did not differ significantly among pruning methods, at all the stages. Further plant height was significantly superior (92.58 cm, 135.98 cm, 185.25 cm, 221.35 cm) in closer spacing (60 x 20 cm) followed by medium (60 x 30 cm) and wider spacing (60 x 40 cm), at 30, 60, 90 days after transplanting and at final harvest. The increase in the plant height of Sun 7611 was due to maximum chlorophyll a (1.87 mg/g fresh weight). Nourishing chlorophyll b (0.68 mg/g fresh weight) and chlorophyll a/b (2.74) was noticed in Sun 7611.

Higher values were recorded in single stemmed plants for plant height at all the stages of crop growth. The increase in height may be due to pinching of secondary branches at their emergence and ultimately diverting the flow of nutrients and manufactured material towards apical growing point (Mangal and Kasim, 1987). Plant height was the highest in closer spacing at 30 (92.58 cm), 60 (135.98 cm), 90 (185.25 cm) days after planting and at final harvest (221.35 cm). Rajewar *et al*. (1981) also reported that the plants which were spaced closer grew taller.

Leaf area (cm^2) :

Maximum leaf area (4045.92 cm^2 and 5705.73 cm^2) was observed in V_2 at both first and last harvest (Table 2). Among pruning methods P_2 gave the maximum leaf area at both the stages, which differed significantly from P_1. Leaf area was significantly superior in wider spacing (S_3) (3886.63 cm^2 and 5378.95 cm^2) followed by medium (S_2) and the least leaf area was observed in closer (S_1) spacing at first and last harvest.

Significant difference was observed in leaf area with all treatments interaction except VS at first harvest. Among interaction treatment VP, V_2P_2 gave highest

(4380.63 cm^2 and 6119.97 cm^2) leaf area at first and last harvest. Maximum leaf area (4045.92 cm^2) at first harvest and (5705.73 cm^2) at final harvest (158.37 g). The results in the present study also corroborate the observations of other study (Georgiova, 1971) which indicated significant difference among varieties differing in growth habit for various growth parameters like leaf area. Plants spaced wider had the highest photosynthetic rate (10.78 µmol ms^{-1}) may be because better exposure to sun that leads to maximum leaf area.

Dry matter partitioning :

The pattern of dry matter distribution to different plant parts was almost the same in both the hybrids. Maximum dry matter (35.31 to 38.48%) was observed in leaves followed by flowers and fruits, stem and root at first harvest. Maximum (45.18 to 50.4%) dry matter was observed in flower and fruits followed by stem, leave and root at final harvest. Leaf dry matter accumulation decreased at final harvest. The pattern of dry matter distribution to different plant parts was similar in both the hybrids. Bhatt and Rao (1988) observed that semi-determinate varieties studies did not differ in dry matter distribution to different plant parts(Table 3a and Table 3b).

Biomass accumulation (g):

The data on biomass accumulation (g) at vegetative and reproductive stages of crop growth are presented in Table 4 .

The biomass accumulation increased with time in both the hybrids from 16.88 g to 101.6 g in case of Arka Abhijith and in Sun 7611. Biomass accumulation increased from 22.76 g to 158.37 g from vegetative phase to final harvest.

Sun 7611 (V_2) recorded the highest biomass accumulation (22.76 g, 77.81 g and 158.37 g) at vegetative phase, first harvest and at final harvest which was significantly different from Arka Abhijith (V_1).

Between pruning methods P_2 (double stem) gave significantly higher (21.22 g, 67.08 and 141.60 g) biomass accumulation at vegetative phase, first harvest and final harvest than P_1 (single stem). Further wider spacing (S_3) gave the highest biomass accumulation (20.30 g, 64.69 g and 136.23g) at vegetative phase, first harvest and last harvest which were significantly different from other two spacing treatments. The least biomass accumulation (19.42 g,

Table 1: Effect of pruning and spacing on plant height (cm) at different stages of crop growth in tomato hybrids grown under cover

Treatments	30 DAT	60 DAT	90 DAT	Final harvest
V_1	78.10	100.04	124.95	126.39
V_2	98.64	158.19	219.19	295.40
F-test	*	*	*	*
S.E.±	1.49	1.79	2.08	2.39
C.D. (P=0.05)	4.37	5.24	6.10	7.01
P_1	89.85	129.01	171.48	213.24
P_2	86.89	129.21	172.66	208.54
F-test	NS	NS	NS	NS
S.E.±	1.49	1.79	2.08	2.39
C.D. (P=0.05)				
S_1	92.58	135.98	185.25	221.35
S_2	89.13	128.70	167.73	208.49
S_3	83.41	122.65	163.23	202.83
F-test	*	*	*	*
S.E.±	1.82	2.19	2.55	2.93
C.D. (P=0.05)	5.35	6.42	7.47	8.59

V_1 : Arka Abhijith V_2 : Sun 7611

P_1 : Single stem P_2 : Double stem

S_1 : 60 x 20cm S_2 : 60 x 30cm

S_3 : 60 x 40cm DAT : days after transplanting

NS= Non-significant

Table 2 : Effect of pruning and spacing on leaf area (cm^2) at different stages of crop growth in tomato hybrids grown under cover

Treatments	First harvest	Last harvest
V_1	3589.18	4737.21
V_2	4045.92	5705.73
F-test	*	*
S.E.±	8.89	6.46
C.D. (P=0.05)	27.67	20.10
P_1	3414.46	4933.27
P_2	4220.64	5509.68
F-test	*	*
S.E.±	8.89	6.46
C.D. (P=0.05)	27.89	20.10
S_1	3733.99	5062.90
S_2	3832.02	5222.56
S_3	3886.63	5378.95
F-test	*	*
S.E.±	10.88	7.91
C.D. (P=0.05)	33.89	24.61

Table 3a : Effect of pruning and spacing on dry mass partitioning (%) at first harvest in tomato hybrids grown under cover

Treatments	Leaf	Stem	FI / Fruit	Root
$P_1V_1S_1$	35.88	28.13	33.61	2.38
$P_1V_1S_2$	37.30	27.57	33.70	1.43
$P_1V_1S_3$	37.40	26.69	33.10	2.81
$P_2V_1S_1$	38.14	25.14	34.86	1.86
$P_2V_1S_2$	36.22	26.43	35.42	1.93
$P_2V_1S_3$	36.78	26.19	34.90	1.23
$P_1V_2S_1$	36.30	25.19	36.88	1.63
$P_1V_2S_2$	38.44	26.30	34.16	1.08
$P_1V_2S_3$	38.21	24.46	35.87	1.36
$P_2V_2S_1$	37.41	26.15	35.11	1.33
$P_2V_2S_2$	38.48	26.47	33.76	1.29
$P_2V_2S_3$	35.31	26.53	36.64	1.52

Table 3b : Effect of pruning and spacing in tomato hybrids last harvest on percentage dry mass partitioning (%)

Treatments	Leaf	Stem	FI / Fruit	Root
$P_1V_1S_1$	22.80	26.84	47.92	2.44
$P_1V_1S_2$	20.49	28.75	48.26	2.50
$P_1V_1S_3$	21.98	25.94	48.71	3.37
$P_2V_1S_1$	21.03	27.64	48.45	2.88
$P_2V_1S_2$	22.10	29.07	46.00	2.83
$P_2V_1S_3$	22.69	28.54	45.91	2.86
$P_1V_2S_1$	22.16	29.70	45.18	2.96
$P_1V_2S_2$	22.80	28.34	46.01	2.85
$P_1V_2S_3$	23.60	26.57	46.76	3.07
$P_2V_2S_1$	23.84	27.49	45.88	2.79
$P_2V_2S_2$	20.12	26.67	50.40	2.81
$P_2V_2S_3$	23.22	26.21	47.43	3.14

Table 4 : Effect of pruning and spacing on biomass accumulation (g) at different stages of crop growth in tomato hybrids grown under cover

Treatments	Vegetative	First harvest	Last harvest
V_1	16.88	43.02	101.60
V_2	22.76	77.81	158.37
F-test	*	*	*
S.E.±	0.15	0.54	0.58
C.D. (P=0.05)	0.47	1.69	1.81
P_1	18.42	53.74	118.37
P_2	21.22	67.08	141.60
F-test	*	*	*
S.E.±	0.15	0.54	0.58
C.D. (P=0.05)	0.47	1.69	1.81
S_1	19.42	56.76	124.33
S_2	19.74	59.78	129.40
S_3	20.30	64.70	136.23
F-test	*	*	*
S.E.±	0.19	0.66	0.71
C.D. (P=0.05)	0.58	2.07	2.22

VP	*	*	1.24	0.41	3.87	1.28
VS	NS	NS	1.49	0.73	-	-
PS	NS	NS	1.49	0.73	-	-

Varieties	*	0.98	2.88
Pruning	*	0.98	2.88
Spacing	*	1.20	3.53
VP	*	1.39	4.07
VS	NS	1.70	-
PS	NS	1.70	-

NS= Non-significant

Table 5 : Effect of pruning and spacing on fruit yield (kg) per plant of tomato hybrids grown under cover

Spacing	Varieties		Pruning		Mean
	V_1	V_2	P_1	P_2	
S_1	1.56	2.06	1.72	1.89	1.81
S_2	1.72	2.34	1.91	2.15	2.03
S_3	1.98	2.91	2.25	2.64	2.44
Mean	1.75	2.44	1.96	2.23	

Varieties	Pruning		Mean
	P_1	P_2	
V_1	1.69	1.82	1.75
V_2	2.23	2.64	2.44
Mean	1.96	2.23	

	F-test	S.E.±	C.D. (P=0.05)
Varieties	*	0.05	0.13
Pruning	*	0.05	0.13
Spacing	*	0.06	0.16
VP	*	0.07	0.19
VS	*	0.08	0.23
PS	NS	0.08	

NS= Non significant

56.76 g and 124.33g) was recorded in closer spacing (S_1). Internodal length was higher in single stemmed plants at 30, 60 and 90 days significantly which might be because of was due to slower growth rate at later stages leaf area and biomass accumulation was higher in double stemmed plants, as single stemmed plants were subjected to higher degree of pruning, which decreased total number of leaves and plant size.

Number of fruits per plant and per cent fruit set :

It is evident from the table that Sun 7611 produced more number of fruits (43.11) than Arka Abhijith (19.21). Between pruning treatments plants having two stems recorded higher number of fruits (34.25) compared to single-stemmed plants (28.06) which were significantly different. Plants spaced wider produced more number of fruits (34.29) per plant followed by medium (30.62) and closely spaced plants (28.65). There was significant difference in treatment interaction VP, among which V_2P_2 recorded the highest number of fruits per plant (47.53) and the least was recorded in V_1P_1 (17.44). Treatment interactions VS and PS did not vary significantly.

Fruit set percentage was higher in Arka Abhijith (59.43%) than Sun 7611 (54.57) more number of flowers formed fruits in single stemmed plants (59.24%) compared to double stemmed plants (54.76%). Among spacing treatments per cent fruit set did not differ significantly.

Fruit yield per plant and per hectare :

Tables 5 indicates that, V_2 gave higher (2.44 kg) yield per plant, which was significantly different from V_1 (1.75 kg).

Further fruit yield was significantly higher in P_2 (2.23 kg) than P_1 (1.96 kg). Maximum fruit yield per plant was obtained in S_3 (2.44 kg) followed by S_2 (2.03 kg) and the least was observed in S_1 (1.81 kg) which were significantly different. The data on yield per hectare is presented in Table 5. Higher yield per hectare was obtained from V_2 (141.1 t/ha) which is significantly different from V_1 (102.68 t/ha). Fruit yield per hectare was significantly different among pruning methods, P_2 gave significantly higher (129.4 t/ha) yield than P_1 (114.38 t/ha). Among spacing treatments S_1 gave the highest (150.97 t/ha) fruit yield per hectare followed by S_2 (112.84 t/ha) and S_3 (101.85 t/ha) which were significantly different (Table 6)

It is likely that pruning of axillary shots might have helped in diverting the flow of nutrients towards apical

Table 6 : Effect of pruning and spacing on fruit yield (tonnes) per hectare of tomato hybrids grown under cover

Varieties	Pruning		Spacing			Mean
	P_1	P_2	S_1	S_2	S_3	
V_1	98.94	106.42	129.90	95.64	82.49	102.68
V_2	129.83	152.37	172.04	130.04	121.22	141.10
Mean	114.38	129.40	150.97	112.84	101.85	

Spacing	Pruning		Mean
	P_1	P_2	
S_1	143.54	158.41	150.97
S_2	106.06	119.62	112.84
S_3	93.55	110.15	101.85
Mean	114.38	129.40	

	F-test	S.E.±	C.D. (P=0.05)
Varieties	*	2.08	6.09
Pruning	*	2.08	6.09
Spacing	*	2.55	7.46
VP	*	2.94	8.62
VS	NS	3.60	
PS	NS	3.60	

NS=Non-significant

growing point, improving plant growth and ultimately more assimilation of material like carbohydrates and proteins (Mangal and Kasim, 1987) resulting in higher fruit yield. Maintaining optimum population is necessary for optimum utilization of green house floor area. Optimum plant population helps to utilize available space, moisture in the soil and solar radiation efficiently which enables the crop to give higher yields.

Fruit yield per plant was significantly reduced under closer plant spacing (1.8 kg) and increased as in-row spacing increased. Maximum (2.44 kg) fruit yield per plant was recorded in plants with wider spacing. However, yield per hectare was significantly improved under closer spacing because of having more number of plants per unit area as compared to medium and wider plant spacing. The results are in agreement with the findings of Takahashi and Sasaki (1981) and Mangal and Kasim (1987).

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