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To study the impact of date of transplanting, spacing and training systems on developmental stages and dry matter accumulation in tomato production under protected conditions

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Abstract
The developmental stages and dry matter accumulation of tomato affected by date of transplanting, spacing and training systems under protected condition was studied at the Research Farm of Department of Agricultural Engineering, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur during summer season of 2013 and 2014 in two separate experiments inside the naturally ventilated playhouses. In this experiment, treatments comprised of three dates of transplanting (15th March, 30th March and 15th April), two spacing (60 cm x 30 cm and 75 cm x 30 cm) and two training systems (two shoots and three shoots) was laid out in a randomized block design with three replications. Plants grown at wider spacing of 75 cm x 30 cm took significantly lesser number of days for flower initiation, 50 per cent flowering, fruit setting and days to first picking, more number of fruits per plant than 60 cm x 30 cm spacing.

Keywords: Protected cultivation, training systems, dry matter accumulation, transplanting

Introduction
India is the second largest producer of vegetable crops in the world. However, the production is much less than the requirement if balanced diet is provided to every individual. To cater the future vegetable needs in India, the present production of 156.33 million tonnes is to be raised to 225 million tonnes by 2020 and 350 million tonnes by 2030 (Anonymous, 2011) [1]. There are different ways and means to achieve this target viz., bringing additional area under vegetable crops, using hybrid seeds and use of improved agro-techniques etc. Another potential approach to be emphasized is the perfection and promotion of protected cultivation of vegetable crops (Rajasekar *et al.* 2013) [2].
There is a lot of potential for increasing the area manifold under low cost greenhouses in peri-urban areas for production of high value low volume vegetables during off-season to take benefit of the high price of the produce (Phookan and Saikia 2003) [3] and to setup the vegetable production and improve its quality.
Tomato cultivation had tremendously increased due to its multifarious uses like raw for salads, cooked alone or mixed with other vegetables and processed in many forms such as soup, sauce catch-up and preservative etc. The high market price is attributed to the heavy demand from the urban consumers. There is a good demand for export too. The export market needs fruits with longer shelf life, attractive colour with good taste. However, the supply is inadequate due to the low productivity of the crop (Sezen *et al.* 2006) [4].
Time of transplanting is one of the important factors as optimum date of transplanting brings about proper growth and development of plants resulting in maximum yield of the crop and economic use of land (Islam *et al.* 2010) [5]. Furthermore, spacing and training also helps in improving the performance as well as yield of the crop.

Materials and Methods
This study "Study the impact of date of transplanting, spacing and training systems on developmental stages and dry matter accumulation in tomato production under protected conditions" was conducted at the Research Farm of Department of Agricultural Engineering, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur during summer season of 2013 and 2014 in two separate experiments inside the naturally ventilated playhouses. In this experiment, treatments comprised of three dates of transplanting (15th March, 30th March and 15th April), two spacing (60 cm x 30 cm and 75 cm x 30 cm) and two training systems (two shoots and three shoots) was laid out in a randomized block design with three replications.

In this experiment the most promising and high yielding hybrid (Naveen 2000 plus) was grown inside naturally ventilated polyhouse of size 15 m x 7 m (L x B) during the summer season of 2013 and 2014. Monthly variation in temperature and relative humidity inside the polyhouse was recorded during the entire period of investigation. Before sowing the crop, a composite soil sample (0-15 cm depth) was taken from the experimental site and important physical and chemical characteristics of the soil were determined by standard methods. Sand, silt and clay at the initiation of the experiment was 29.2, 36.1 and 34.5 % respectively. The soil texture was silty clay loam. Soil pH and organic matter during 2013 was 5.6 and 0.7 per cent and in 2014 was 5.8 and 0.8, respectively. During 2013, available N, P and K were 263.2, 16.4 and 219.3 kg ha^{-1}. In the next year (2014) the nutrient status of available N, P and K were 275.2, 19.2 and 228.2 kg ha^{-1}.

The seeds of Naveen 2000 plus was sown in plastic plug trays by using soilless media having cocopeat, perlite and vermiculite in the ratio of 3:1:1, respectively inside the naturally ventilated polyhouse to get healthy and disease free seedlings of tomato. 25-35 days old seedlings were transplanted inside the naturally ventilated polyhouse equipped with drip irrigation system on different dates.

Table 1: Date of nursery sowing and transplanting of seedlings in the year 2013 and 2014

Number of transplanting	Date of sowing of nursery		Date of transplanting		Seedling age (days)	
	2013	2014	2013	2014	2013	2014
D_1	10^{th} February	8^{th} February	15^{th} March	15^{th} March	33	35
D_2	1st March	2nd March	30^{th} March	30^{th} March	30	28
D_3	18^{th} March	17^{th} March	15^{th} April	15^{th} April	25	26

Before transplanting, beds were prepared. These beds were thoroughly sterilized with 4 per cent formalin (1 litre of 40 per cent commercial formalin in 7 litre of water). Beds were covered with black polyethylene sheet for 7 days after formalin application. Then polyethylene sheet was removed and soil raked well for a week in order to remove the fumes of formalin.

The basal dose of N, P and K @ 100 kg ha^{-1} from straight fertilizers was applied in the form of urea (21.5 g m^{-2}), single super phosphate (62.5 g m^{-2}) and muriate of potash (16.5 g m^{-2}). Remaining dose of 150:150:150 kg ha^{-1} NPK was applied with water soluble fertilizer (polyfeed 19:19:19) starting from 3^{rd} week after transplanting and up to 15 days prior to final harvest. Fertigation was done twice a week. The plants were irrigated daily with drip irrigation system, one dripper was provided for each plant. Plants were watered regularly before 12 noon or late evening. Other cultural practices and standard plant protection measures were also adopted from time to time to ensure healthy crop stand.

After one month of transplanting, the lateral shoots were pinched out (pruned) at their emergence and two healthy lateral shoots preferably at first node of the plants to obtain double shoot plants. Two healthy lateral shoots preferably at first and second node of the plants were retained to obtain triple shoot plants. Days to flower initiation were recorded by number of days taken from the date of transplanting to flower initiation was recorded and the mean value was expressed in days to first flowering. The experimental area was visited every day when the initiation of flowering started and number of days were counted from the date of transplanting to the day when 50 per cent plants flowered. Harvest Duration (number of days) were recorded by period from first picking to last picking formed the base for ascertaining the harvest duration in days. The dry matter accumulation (g/plant) was determined from the five randomly selected plants from each plot at final harvest. These plants were air dried for 3-4 days, and then these were dried at 70^0C in a forced air draft oven till a constant weight was attained. Dry weight of different plant parts (leaf, stem and fruits) were recorded and dry matter in (g/plant) was then worked out by simple mathematical calculation.

Results and Discussions

Days taken to flower initiation

Tomato crop transplanted on 30^{th} March took significantly lesser number of days (30.1and 34.1) to initiate flowering in comparison with the crop transplanted on 15^{th} March (33.9 in 2013 and 37.0 in 2014) and 15^{th} April (37.3 in 2013 and 41.2 in 2014) during both the years. This could be because of appropriate temperature (25^0C) prevailing during 30^{th} March, which was found to be favorable for hormonal activation responsible for flowering. Low temperature in 15^{th} March and higher in 15^{th} April planting prolonged the vegetative growth and resulted in longer duration for flower initiation. Similar effect of temperature on days to first flowering have been reported by Hamma *et al.* (2012) [6].

An examination of data revealed that plant spacing had significant influence on the number of days taken to flower initiation. The wider spacing of 75 cm x 30 cm took significantly lesser number of days (31.1 and 35.6 in 2013 and 2014, respectively) for flowering than closer spacing of 60 cm x 30 cm. This might be due to availability of good sunshine and nutrients in the soil resulting in the accumulation of more photosynthesis and induction of early flowering compared to closer spacing. The results are in close conformity with the findings of Singh (2004) [7].

Training systems also had significant influence on days to first flowering. Plants trained to two shoots took lesser number of days (31.7 in 2013 and 34.8 in 2014) to first flowering than plants trained to three shoots (35.8 in 2013 and 40.0 in 2014). This might be due to early shift in vegetative to reproductive stage in plants trained to two shoots. The availability of more photosynthates because of two shoots were maintained per plant. These results are in conformity with the findings of (Ara *et al.* 2007) [8] who have also reported that plants with two shoots take minimum days to flowering initiation.

Table 1: Developmental stages as influenced by different treatments

Treatment	Flower initiation		Days taken to 50% flowering		Days taken to first picking		Harvest duration		Fruit set (%)	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Date of transplanting										
15th March	33.9	37.0	39.9	43.0	70.5	73.4	56.8	59.5	76.4	79.4
30th March	30.1	34.1	36.1	40.1	67.7	70.0	50.5	53.4	75.8	78.6
15th April	37.3	41.2	43.3	47.2	75.2	77.8	48.3	49.9	72.3	75.3
SEm±	0.3	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.4	0.5
CD (P=0.05)	0.8	0.8	0.8	0.8	0.7	0.8	1.3	1.4	1.2	1.3
Spacing										
60 cm X 30 cm	36.4	39.2	42.4	45.2	73.9	76.2	50.7	53.4	75.2	77.9
75 cm X 30 cm	31.1	35.6	37.1	41.6	68.3	71.3	53.0	55.1	74.5	77.6
SEm±	0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.4	0.3	0.3
CD (P=0.05)	0.6	0.7	0.7	0.7	0.6	0.6	1.1	1.2	NS	NS
Training systems										
Two shoot	31.7	34.8	37.7	40.8	67.5	70.1	54.8	56.9	75.0	78.3
Three shoot	35.8	40.0	41.8	46.0	74.7	77.4	48.9	51.6	74.7	77.2
SEm±	0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.4	0.3	0.3
CD (P=0.05)	0.6	0.7	0.7	0.7	0.7	0.7	1.1	1.2	NS	NS

Days to 50 per cent flowering

Data recorded on the days taken to 50% flowering showed that the plants transplanted on 30th March took significantly lesser number of days to 50% flowering (36.1 and 40.1 in 2013 and 2014, respectively) in comparison with the crop transplanted on 15th March (39.9 and 43.0 in 2013 and 2014, respectively) and 15th April (43.3 and 47.2 in 2013 and 2014, respectively) during both the years. The reason for the earliest flowering in case of the plants transplanted on 30th March might be due to favorable temperature and good sunshine resulting in the accumulation of more photosynthesis and induction of early flowering as compared to the plants transplanted on 15th March and 15th April. Hossain *et al.* (2013) [9] have also reported similar findings.

It can be construed that spacing had significant effect on the days taken to 50 per cent flowering. Plants spaced at 75 cm x 30 cm apart were earliest in achieving 50 per cent flowering (37.1 in 2013 and 41.6 in 2014) and took significantly lesser number of days to 50 per cent flowering than 60 cm x 30 cm (42.4 and 45.2 in 2013 and 2014, respectively) spacing. The reason for the earliest 50 per cent flowering in case of wider spacing of 75 cm x 30 cm might be due to availability of good sunshine and more uptake of nutrients resulting in the accumulation of more photosynthesis and induction of early flowering compared to closer spacing. The results are in close conformity with the findings of Singh (2004).

Training systems also had significant influence on days to 50 per cent flowering. Plants trained to two shoots took significantly lesser number of days (37.7 in 2013 and 40.8 in 2014) to 50 per cent flowering than plants trained to three shoots (41.8 days in 2013 and 46.0 days in 2014). The early flowering in two shoot plants might be due to the availability of more photosynthates as only two shoots were maintained per plant. Similar results were also reported by (Ara *et al.* 2007).

Days taken to first picking

Data recorded on the days taken to first picking showed that the plants transplanted on 30th March took significantly lesser number of days to first picking (67.7 days and 70.0 days in 2013 and 2014, respectively) in comparison with the crop transplanted on 15th March (70.5 days and 73.4 days in 2013 and 2014, respectively) and 15th April (75.2 and 77.8 in 2013 and 2014, respectively) during both the years. The reason for the earliest picking in case of the plants transplanted on 30th March might be due to favorable temperature and good sunshine resulting in the accumulation of more photosynthesis and induction of early picking as compared to the plants transplanted on 15th March and 15th April. Tiwari (1996) [10] have also reported similar findings.

It can be construed that crop planted at different spacing exerted significant influence on days taken for first picking. The wider spacing of 75 cm x 30 cm took significantly lesser (68.3 days and 71.3 days in 2013 and 2014, respectively) number of days to first picking than closer spacing of 60 cm x 30 cm. The latter two spacings also differed significantly. Early fruit setting coupled with exposure of fruits to sunlight and better aeration could be the reasons for early picking at wider spacing of 75 cm x 30 cm. Singh (2004) also reported similar findings.

Different training systems also had a significant effect on days taken to first picking. Plants trained to two shoots took significantly lesser (67.5 days in 2013 and 70.1 days in 2014) number of days than plants trained to three shoots (74.7 days and 77.4 days in 2013 and 2014). The two training systems also differed significantly. Early fruit setting coupled with exposure of fruits to sunlight and aeration could be the reasons for early picking in plants trained to double shoot. Similar results were also reported by Ara *et al.* (2007).

Harvest duration (days)

Prolonged harvest duration is an important aspect to catch an early market in one hand and to avoid gluts in the market on the other hand to ensure maximum returns. A keen observation of the data revealed that dates of transplanting had significant effect on harvest duration which was maximum in 15th March followed by 30th March and 15th April transplanting. Low average temperature during flowering and fruiting prolonged the duration of anthesis and fruit setting in 15th March transplanting. During the period of flowering and fruit setting, the weekly average temperature was low which might have resulted in prolonged harvest duration in both the years. In 30th March and 15th April transplanting flowering and fruit setting period coincided with the high ambient temperature resulting in reduced harvest duration. Hossain *et al.* (2013) reported that the flowering in tomato ranged between 4-6 weeks under favorable cool and dry conditions which in the present study was observed in 15th March planting.

An examination of data revealed that plant spacing had significant influence on harvest duration. The wider spacing of 75 cm x 30 cm resulted in prolonged harvest duration than closer spacing of 60 cm x 30 cm. Also reported by Ara *et al.* (2007)

Various training systems had significant influence on harvest duration. Maximum (54.8 days and 56.9 days in 2013 and 2014, respectively) harvest duration was noticed when plants were trained to two shoots which was significantly higher than plants trained to three shoots. Similar results were also observed by Khoshkam *et al.* (2014) [11].

Fruit set (%)

The percentage of fruit set differed significantly due to different dates of transplanting. Crop transplanted on 15th March observed maximum fruit setting (76.4 % in 2013 and 79.4 % in 2014) which was significantly higher than the crop transplanted on 30th March and 15th April during both the years. This was consequence of production of more flowers per plant and favourable temperature and good sunshine during crop growth and development. These results are in conformity with the findings of Singh *et al.* (2015) [12]. It is apparent that neither the plant spacing nor the training system significantly influenced the fruit set (%) in either of the years.

Dry matter accumulation (g/plant)

An examination of data revealed that transplanting of the crop on 15th March registered significantly higher dry matter accumulation over the crop transplanted on 30th March and 15th April. The latter two dates of sowing (30th March and 15th April) also differed significantly during both the years. On an average, 15th March planting recorded an increase of (9.22 percent in 2013 and 10.04 per cent in 2014) and (22.41 per cent in 2013 and 21.28 per cent in 2014) dry matter accumulation over 30th March and 15th April transplanting, respectively. The reason for the higher dry matter accumulation by the plants transplanted on 15th March might be due to higher physiological activity of plants which resulted in more production and accumulation of photosynthates within the plant. The results are in conformity with the findings of Nagalakshmi *et al.* (2001) [13].

Table 2: Dry matter accumulation at harvest as influenced by different treatments

Treatment	Dry matter accumulation (g/plant)	
	2013	2014
Date of transplanting		
15th March	210.8	214.8
30th March	193.0	195.2
15th April	172.2	177.1
SEm±	4.7	4.9
CD (P=0.05)	14.1	14.7
Spacing		
60 cm X 30 cm	180.6	184.0
75 cm X 30 cm	203.4	207.4
SEm±	4.3	4.4
CD (P=0.05)	12.9	13.1
Training systems		
Two shoot	201.8	204.8
Three shoot	182.2	186.6
SEm±	4.3	4.4
CD (P=0.05)	12.9	13.1

A critical appraisal of the data revealed that the plant spacing caused significant variation in dry matter accumulation and it was observed that with the increase in plant spacing the dry matter accumulation increased significantly. Highest dry matter accumulation was recorded at wider spacing of 75 cm x 30 cm (203.4 g/plant and 207.4 g/plant in 2013 and 2014, respectively) which was significantly higher than 60 cm x 30 cm. The reason for the higher dry matter accumulation at wider spacing may be due to higher physiological activity of plants in wider spacing, which resulted in more production and accumulation of photosynthates within the plant.

The training systems also significantly influenced the dry matter accumulation in tomato plant. Plants trained to two shoots contained significantly more dry matter (201.8 g/plant in 2013 and 204.8 g/plant in 2014) than three shoot trained plants. It may be due to higher physiological activity of trained plants which resulted in more production and accumulation of photosynthates within the two shoot trained plants.

Conclusions

- Tomato crop transplanted on 30th March took significantly lesser number of days to initiate flowering in comparison with the crop transplanted on 15th March and 15th April during both the years respectively.
- The wider spacing of 75 cm x 30 cm took significantly lesser number of days for flowering than closer spacing of 60 cm x 30 cm. Plants trained to two shoots took lesser number of days to first flowering than plants trained to three shoots.
- 15th March registered significantly higher dry matter accumulation over the crop transplanted on 30th March and 15th April. Plants trained to two shoots contained significantly more dry matter than three shoot trained plants. Interaction effect was not found to be significant on dry matter accumulation.

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