Effect of crop management practices on growth, yield, quality, economics and Buckeye rot, *Alternaria* disease of tomato (*Solanum lycopersicum* L.) var. Solan Lalima

ABSTRACT

A study was carried out for two successive years (2017/2018 and 2018/2019) in the Research Farm of Vegetable Science, Dr YSP, UHF, Nauni, Solan, HP. The maximum value for number of flower clusters per plant (12.64), number of fruits per cluster (6.51), fruit weight (80.47 g), number of fruits per plot (140.71 kg) and yield per hectare (992.94 q) were obtained in treatment module $P_1M_1T_1$ (raised bed, black polythene mulch and two stem training system). Pericarp thickness (4.99 mm), TSS (5.10 degree Brix) and lycopene content (6.42 mg per 100 g of fresh fruit) was also found best for the same treatment combination. The incidence of buckeye rot (3.46 %) and *Alternaria leaf bight* (2.80 %) was minimum in $P_1M_1T_1$ (raised bed, black polythene mulch and two stem training system). The treatment combination $P_1M_1T_1$ (raised bed, black mulch and two stem training system) also produced highest cost benefit ratio (3.84 %).

Key words: Planting methods, Polythene mulch, Marketable maturity, Training systems, Yield

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most popular and widely grown an important vegetables crop in the world, ranking second followed by potato. The tomato belongs to the nightshade family (Solanaceae). It is a highly nutrition fruit; low in fat and contains no cholesterol or sodium content. This crop has achieved tremendous popularity especially in recent years with the discovery of lycopene's anti-oxidative activities and anti-cancer functions. The use of herbicides and other chemicals in agriculture are becoming limited, because of their expense and environment issues which have recently caused much concern. Therefore, new approaches to control weeds and improve yield are necessary both for assuring an adequate crop yield and for respecting the environment. Sustainable management practices, such as raised bed planting methods, mulching applications and suitable training systems can improve crop conditions, soil fertility and environmental conditions too. At present, cultivation of tomato in open fields on flat beds is a wide spread practice but the tomato crop grown on flat beds is exposed to various abiotic and biotic stresses. Therefore, it is not possible to produce high quality tomato in terms of size, shape, and colour, free from diseases and pests as compared to raised bed planting.

The major concern associated with the raised bed planting system is enhancement of the productivity and saving of the irrigation water. Potential agronomic advantages of raised beds include improved soil structure due to reduced compaction through controlled trafficking, reduced water logging and timely machinery operations due to better and improved surface drainage. Warmth in raised beds is higher than on level soil and this increases the rate of growth of the seedlings, thus reducing their susceptibility to diseases compared to slow emergence. Beds also create an opportunity for mechanical weed control and improved fertilizer placement (Naresh *et al.,* 2010 and Singh *et al.,* 2010). Typical irrigation savings range from 18 to 30-50 per cent (Singh *et al*., 2010), improved nutrient management and cultivation as it also avoids the incidence of soil borne diseases as less soil is disturbed in this system of planting specially during monsoons. Also raised bed and mulched raised bed planting decreases water consumption, increase water use efficiency and produce higher yields (Zhang *et al.,* 2007).

Mulching is effective mean of microclimatic modifications, both under protected as well as open conditions. Mulching is an important practice used in many horticultural crops that entails placing of organic or synthetic material on the soil close to the plants to provide a more favourable environment for growth and development (Nagalakshmi *et al.*, 2002). Plastic mulch has been used increasingly in agriculture, since the middle of 20^{th} century. Most of the mulches whether organic or synthetic types, are helpful in reducing disease incidence, controlling weed population, reducing the impact of falling rain drops, regulating soil temperature and conserving soil moisture among others, resulting in increased yield and earlier harvest (Hill *et al.,* 1982; Shogren, 2000; Schonbeck, 1998 and Schonbeck and Evanylo, 1998). Black mulch warms the soil by absorbing light and transferring heat by conduction method to the underlying soil layers, provided that the mulch is in close contact with the soil (Unger, 1984).

Among various agro-techniques, training system play a crucial role in quality fruit production of tomato as training helps in preventing the overcrowding and reduces the competition between and within the plants for nutrients, light and water thus helps in avoiding poor fruit set and delayed maturity. Also, these factors by improving air circulation through the plants especially in humid areas prevent the proliferation of disease. Similarly, training and pruning in later stages of plant growth reduces the competition amongst fruits for sunlight and photosynthesis products therefore imparts for growth and development of the plant (Gao *et al*., 1973). Patel *et al*. (1987) pointed out that indeterminate plants have unnecessary leaf load and can be severely pruned without effecting yield. By proper training system more number of plants can be accommodated per unit area thereby increasing the yields. Hence, to obtain a good quality produce and production during off season, there is a need to cultivate tomato (*Solanum lycopersicum* L.) with better planting methods, mulching and training systems.

MATERIALS AND METHODS

Two experiments were conducted during 2017-18 and 2018-19 at the Research Farm of Vegetable Science, Dr YSP and Forestry, Nauni, Solan, HP, India (**35°5' N latitude and 77°11' E longitude at an elevation of 1270 m above msl**). The cultivar used for the study was 'Solan Lalima' a self pollinated indeterminate variety developed by selection. Black polyethylene mulch and silver/black mulch of 50µ (200 gauge thickness) were applied in different plots according to the treatment combinations.

The experiment was laid out in a Randomized Block Design (Factorial) with three replications comprising of twelve treatment combinations of planting mehods *viz.* raised bed and flat bed, mulch materials *viz.* black polythene mulch and silver/black mulch and training systems *viz.* two stem training system and three stem training system for both the years. The experimental field was ploughed thoroughly with the help of a tractor followed by planking well in advance before transplanting. Seedlings were transplanted on 12th April, 2017 and 12th April, 2018 at a spacing of 90 cm x 30 cm in a plot having dimensions of 1.8 m x 6.3 m, accommodating 42 plants per plot.

Table 1: Detail of treatments used in the studies

S. No.	Treatment code	Treatment details		
1	$P_I M_1 T_I$	Raised bed	+ Black mulch	+ Two stem training
2	$P_I M_1 T_2$	Raised bed	+ Black mulch	+ Three stem training
3	$P_I M_2 T_1$	Raised bed	+ Silver/black mulch	+ Two stem training

4	$P_I M_2 T_2$	Raised bed + Silver/black mulch + Three stem training
5	$P_I M_3 T_1$	Raised bed + No mulch + Two stem training
6	$P_I M_3 T_2$	Raised bed + No mulch + Three stem training
7	$P_2 M_1 T_I$	Flat bed + Black mulch + Two stem training
8	$P_2 M_1 T_2$	Flat bed + Black mulch + Three stem training
9	$P_2 M_2 T_1$	Flat bed + Silver/black mulch + Two stem training
10	$P_2 M_2 T_2$	Flat bed + Silver/black mulch + Three stem training
11	$P_2 M_3 T_1$	Flat bed + No mulch + Two stem training
12	$P_2 M_3 T_2$	Flat bed + No mulch + Three stem training

Fertilization, stacking and crop protection measures were adopted as per the package of cultivation practices.

Data collected

Number of flower clusters per plant, number of fruits per cluster, fruit weight (g), yield per plot (kg), yield per hectare (q) were recorded from five randomly selected plants for all the characters including quality attributes. Quality of tomato was determined by measuring pericarp thickness (mm), TSS, lycopene (mainly for flavors) content. Total soluble solids (TSS) were recorded with the help of a hand refrectrometer. Content of total lycopene was estimated spectrophotometrically using Anthrone method. This investigation was carried out using three randomly selected plants of each treatment of each replication.

The incidence of Buckeye rot was recorded as per cent of infected fruits in ten randomly marked plants at each harvest and average incidence was worked out with the following derivation.

$$\text{Incidence of Buckeye rot (\%)} = \frac{\text{Number of infected fruits per plot}}{\text{Total number of fruits per plot}} \times 100$$

The severity of *Alternaria* leaf blight was recorded as per cent infected plants in ten randomly marked plants. The economics of treatments is the most important consideration for making any recommendation to the farmer for its adoption. Gross return was worked out for each treatment on the basis of market price of the produce at the time when the produce was ready for sale. Net return (Rs/ha) was calculated by deducting cost of cultivation (Rs/ha) from gross income. Benefit: cost ratio was worked out as follows:

$$\text{B: C ratio} = \frac{\text{Net returns (Rs/ha)}}{\text{Cost of cultivation (Rs/ha)}}$$

The data recorded was analysed by using MS-Excel and OPSTAT. The mean value of data was subjected to analysis of variance as described by Panse and Sukhatme (2000) using Randomized Block Design (RBD) Factorial.

RESULTS AND DISCUSSION

It is clear from the data presented in Table 1 and 2 that there was a significant effect of different planting methods, mulches and training systems on various growth, yield and yield contributing factors, yield, quality and diseases.

Planting methods: Number of flower clusters per plant (11.24), number of fruits per cluster (5.78), fruit weight (77.98 g), pericarp thickness (4.71 mm), TSS (4.79 degree Brix) and lycopene content (5.96 mg/100 g), were found maximum for the plants grown on raised bed and lower (3.85 %) incidence of buckeye rot and severity of *Alternaria* leaf blight (3.35 %). Similar plots observed increased fruit yield per plot (127.57 kg) and per hectare (899.96 q).

Mulching Levels: The plants grown on raised beds along with black polythene mulch produced maximum (11.60) number of flower clusters per plant, number of fruits per cluster (5.88), fruit weight (78.52 g), pericarp thickness (4.76 mm), TSS (4.93 degree Brix), and lycopene content (6.09 mg per 100 g). The incidence of buckeye rot (3.76 %) and severity of *Alternaria* leaf blight (3.28 %) was also minimum for the black polythene mulched plots. Similar plots observed increased fruit yield per plot (129.42 kg) and per hectare (913.05 q).

Training systems: As regards the training systems two stem trained plants were best for producing the greater number (10.83) of flower clusters per plant, maximum (5.59) number of fruits per cluster, greater fruit weight (77.64 %), maximum pericarp thickness (4.65 mm), TSS

(4.75 degree Brix), and lycopene content (5.84 mg/100 g). The incidence of buckeye rot and severity of *Alternaria* leaf blight was also minimum i.e. 3.94 % and 3.48 % for the plants trained to two stem training system. Similar plots observed increased fruit yield per plot (125.12 kg) and per hectare (882.66 q).

Consortium effect: The interaction effect of P, M and T was found to be significant for all the growth, yield and yield contributing characters, quality as well as for disease parameters (Table 3, 4). The plants grown on raised beds along with black polythene mulch and trained to two stem training system produced maximum (12.64) number of flower clusters per plant, number of fruits per cluster (6.51), fruit weight (80.47 g), pericarp thickness (4.99 mm), TSS (5.10 degree brix), and lycopene content (6.42 mg per 100 g). The minimum severity of *Alternaria* leaf blight (2.80 %) and lower incidence of buckeye rot (3.46 %) was recorded in T_1.

Raised bed planting + silver/black polythene mulch + two stem training system produced excellent yield (140.71 kg/ plot) and (992.64 q/hectare), whereas, lower yield per plot (105.26 kg) and per hectare (742.58 q) was produced by $P_2M_3T_2$ (Table 3).

ECONOMICS OF TOMATO (BENEFIT: COST RATIO)

The adoption of technology in modern agriculture can only be feasible and acceptable to the farmers if it is economically viable. The relevant treatment-wise cost of cultivation, gross returns, net returns and benefit: cost ratio (B: C ratio) of tomato cv. Solan Lalima has been worked out and depicted in Table 5. A perusal of the data revealed that highest cost of cultivation (Rs. 3,23,991.31 /ha) was incurred in $P_IM_2T_2$ i.e. raised bed, silver/black mulch and three stem training system which was followed by $P_1M_1T_2$ i.e. raised bed, black mulch and three stem training system (Rs. 3,15,991.31 /ha), whereas lowest cost of cultivation (Rs. 2,46,404.64 /ha) was observed in $P_2M_3T_1$ i.e. flat bed, no mulch and two stem training system. The economic analysis showed that the highest net return of Rs. 1,18,1364.19 /ha by incurring Rs. 3,07,591.31/- towards cost of cultivation per hectare was obtained from treatment combination $P_1M_1T_1$ (raised bed + black mulch + two stem training system) on account of highest yield (992.64 q/ha) with a highest benefit: cost ratio of 3.84. However, the second highest benefit: cost ratio was 3.78 obtained in treatment combination $P_1M_3T_1$ (raised bed + no mulch + two stem training system) which otherwise recorded comparatively low yield (811.91 q/ha) as well as net returns (Rs.

9,63,060.36/-) as compared to the former treatment combination i.e. $P_1M_1T_1$. This was 'in fact' on account of additional cost incurred on intercultural operations like weeding, hoeing and fertilizer application in raised bed planting method and two stem training system in $P_1M_3T_1$ which in a non mulched treatments. The economic analysis also revealed the lowest benefit: cost ratio (2.91) which was obtained from the treatment combination $P_2M_2T_2$ (flat bed + silver/black mulch + three stem training system) on account of net returns of Rs. 9,18,284.69/ha by incurring Rs. 3,15,591.31/- towards cost of cultivation per hectare from total yield of 822.58 q/ha. This was due to the additional cost of silver/black mulch and three stem training system as compared to the above mentioned treatments. Statistically, $P_1M_1T_1$ is significantly superior from $P_1M_3T_1$ and all other treatment combinations w.r.t. net returns and benefit: cost ratio.

Discussion

Raised bed causes a significant difference in the root zone temperature during day time thus hastens the metabolic activities inside the plant cells and thereby approaches the reproductive phase more rapidly rather than vegetative phase consequently more fruits per cluster which ultimately increases the yield of tomato. (Locher *et al.,* 2003). Bahadur *et al.* (2013) also narrated that better soil aeration and light interception in raised bed planting have contributed to improved plant growth and yield. . Arvidsson *et al.* (1999) linked increase in fruit size and other related characters to easy assimilation of macro and micronutrients, more developed root system caused by tillage and greater nutrients availability. The prevention of soil compaction and reduced trafficking also responsible for the increased fruit size of tomato crop. Moreover, the improvement of soil characteristics in raised bed such as better porosity due to reduced soil compaction, improvement of soil temperature and conservation of soil moisture could be the other reasons for increased fruit weight (Beecher *et al.* 2003). The increased yield of tomato fruits on raised beds may be due to higher soil organic matter content along with higher phosphorus and potassium levels. This may be because of increased enzymatic activity of microorganisms which consequently facilitated the mineralization of organic matter (Daza *et al.*, 2016), whereas, Aykas *et al.* (2005) were of the opinion that soil compaction in the flat beds decreased nutrients which were mineralized from the soil organic matter. The best possible reason for the high total soluble solids in the raised bed planting method is the more exposed surface area which allows more absorbance of radiations and greater photosynthetic activities within the plant cells. Therefore, the photosynthates are better partitioned resulting into high TSS of tomato fruits (Locher *et al.,* 2003). Zhang *et al.* (2012) were of the opinion that that raised bed planting system achieved higher vitamin C content in vegetables due to increased soil microorganism's activity which enhances nitrogen fixation, mineralization and enzyme activity and ultimately increased quality and yield. In the present case, better drainage conditions coupled with quick warming of the upper layer as well as beneath of the soil might have created conditions which are not suitable for the development of various disease causing organisms. This might have resulted into less growth of the germinating spores and insufficient disease causing inoculum. Similar are the findings of Sharma *et al.* (2016) who observed the reduced disease incidence in the bell pepper plants grown on raised beds. The reduced buckeye rot incidence with black polythene mulch may be due to the fact that mulches mitigate the harmful effect of soil borne fungi and create a barrier to the pathogen which causes the disease. The results are in conformity with the findings of Mehta *et al*. (2010) in tomato. The minimum incidence of early blight was observed in black polythene mulch and it might be due to the reason that plastic mulching acts as a barrier between soil and plant and keeps away the foliage and fruits from soil contact. Mulch also prevents soil splash on lower canopy as soil often consist disease causing conidial spores (Bhujbal *et al.,* 2015). Less number of branches will provides more passage of air and sunlight towards the soil and less suffocative conditions might have resulted into less disease spread. Similar findings on various diseases have also been reported by Mehta *et al.* (2010) in tomato crop. In two stem training system, incidence of the disease was low because the plants were more erect as compared to three stem training system and foliage and fruits up to a height of 15-20 cm were removed which could avoid the moist and stagnant air conditions for the pathogen to perpetuate. This might be the suitable reason for less buckeye rot incidence in two stem trained plants. According to Moursi (2003) the improvement in the lycopene content of the fruits is due to the enhanced metabolic processes of the plant (increasing chemical composition of the fruits) in mulched plots. Abhivyakti and Kumari (2015) also reported that mulches also affect the lycopene content of tomato fruits. According to Wien (1997), carotenoids production such as lycopene, is influenced by light exposure. The increase in lycopene content in the fruits of two stem trained plants could be due to effective utilization of sunlight because of wider spacing. Total soluble solid is a desired quality character and a high total soluble solid is valuable for processed products like juice, ketchup, sauce and puree. Alam *et al.* (2016) reported that maximum (4.44 %) and the minimum (4.24 %) total soluble solid were obtained in the fruits harvested from plants with two stems and no pruning, respectively. The highest total soluble solids obtained from black mulched plots with increased photosynthesis might be due to the plastic reflective properties, which increased light reception on the leaves and fruits of tomatoes. The reflection of more light on the tomato shoots by black plastic is known to increase transpiration rate, amount of photosynthesis available to fruits and sugar: acid ratio and hence the higher brix value of tomato fruits as reported by Dorais *et al.* (2001) in tomato. Therefore, the relative elevated carbon dioxide concentration might have accounted for increased total soluble solids. Increased yield in two stem training system might be attributed to availability of more space for individual plant growth, more leaf area for better photosynthesis, ample sunlight and aeration. These findings are in conformity with the work of Bhattarai *et al.* (2015) and Singh and Kumar (2005) in cherry tomato. Gao *et al.* (2001) observed higher yield in mulched plots which promoted flower bud differentiation, enhanced yield and also improved fruit quality in tomato as compared to plastic mulch and no mulching. Vander Zaag *et al.* (1986) attributed increased yield and profits due to better weed management, reduced weed growth and clean crop. They were of the opinion that mulches provides a physical barrier which reduces the germination and nourishment of many weeds by suppressing their germination and growth. The present results are in line with the findings of Kosterna (2014) in tomato, Abhivyakti *et al.* (2016) in tomato, Helaley *et al.* (2017) in tomato, Angmo *et al*. (2018) in tomato, Kumari *et al.* (2018) in tomato and Sowinska and Turczuk (2018) also in tomato crop. The possible reason for increased fruit weight could be fewer branches per plant because the fruits contained higher levels of carbohydrates and other soluble compounds (Mantur and Patil, 2008 and De Pinho *et al.*, 2011). Candian *et al.* (2017) presented similar results during their study on tomato regarding the average fruit weight. As mulch films are nearly impervious to carbon dioxide which is necessary for photosynthesis, 'Chimney effect' might have been created resulting in abundant CO_2 for the plants which might have added higher plant growth, fruit weight and fruit yield grown under different plastic mulches (Singh and Kamal, 2012 and Gornat *et al.* 1973). The maintenance of soil temperature under black polythene mulch which could possibly be responsible for increased fruit size and yield in tomato (Bhella and Kwolek, 1984 and Taber, 1983). Kamboj and Sharma (2015) in bell pepper stated that two stem training system significantly increased the fruit size. This could be due to higher source to sink ratio. The possible reason in two stem trained plants may be that exposing plants to more sunlight resulted in more fruits due to increased cell division and cell elongation. Yadav *et al.* (2017) also recorded maximum number of fruits per plant (86.59) and number of fruits per clusters (5.50) in T_2 (double stem). Ravinder *et al.* (1997) also reported that mulching significantly improved the number of fruits per cluster and per plant. According to them, mulching reduced the percentage of fruit abortion thereby leads to increased fruit yield per plant also. In case of two stem training system, there would be maximum sunlight penetration and enhanced photosynthetic activity making more assimilates available for flower cluster setting (early shift from vegetative to reproductive phase) as compared to three stem training system, early and higher rate of morphogenesis (cell division, cell differentiation, cell elongation and cell maturation) and also good aeration through the canopy which might be a valid reason to increase the number of flower clusters per plant and ultimately increased fruit set (Ara *et al.,* 2007; Mbonihankuye *et al.,* 2013 and Ansari *et al.*, 2017). The possible reason could be the modification of light environment sufficiently to enhance photosynthetic rate and/or light stimulus of morphogenic development with the use of black plastic mulches; and its effects on crop growth and development.

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Table 1. Effect of planting methods, mulches and training systems on number of flower cluster per plant, number of fruits per cluster, fruit weight (g), yield per plot (kg) and yield per hectare (q) in tomato

Treatment	**Number of flowers clusters per plant**	**Number of fruits per cluster**	**Fruit weight (g)**	**Yield per plot (kg)**	**Yield per hectare (q)**
Planting methods (P)					
P_1	11.24	5.78	77.98	127.57	899.96
P_2	10.05	5.09	75.90	116.61	822.62
$CD_{0.05}$	**0.39**	**0.17**	**0.50**	**1.14**	**8.03**
Mulches (M)					
M_1	11.60	5.88	78.52	129.42	913.05

M_2	11.29	5.72	77.83	126.64	893.37
M_3	9.04	4.71	74.48	110.20	777.45
$CD_{0.05}$	**0.16**	**0.20**	**0.61**	**1.39**	**9.84**
Training systems (T)					
T_1	10.83	5.59	77.64	125.12	882.66
T_2	10.46	5.28	76.24	119.06	839.91
$CD_{0.05}$	**0.19**	**0.17**	**0.50**	**1.14**	**8.03**

P: Planting methods, **M:** Mulching treatments, **T:** Training systems; **P_1:** Raised bed planting method, **P_2:** Flat bed planting method, **M_1:** Black polythene mulch, **M_2:** Silver polythene mulch, **M_3:** No mulch, **T_1:** Two stem training system, **T_2:** Three stem training system

Table 2. Effect of planting methods, mulches and training systems on pericarp thickness (mm), TSS (degree brix), lycopene content (mg per 100 g of fresh fruit weight), incidence of buckeye rot (%) and severity of *Alternaria* leaf blight (%) in tomato

Treatment	**Pericarp thickness (mm)**	**TSS (degree Brix)**	**Lycopene content (mg per 100 gm of fresh fruit weight)**	**Incidence of buckeye rot (%)**	**Severity of *Alternaria* leaf blight (%)**
Planting methods (P)					
P_1	4.71	4.79	5.96	14.91 (3.85)	11.40 (3.35)
P_2	4.47	4.62	5.50	17.64 (4.19)	14.48 (3.80)
$CD_{0.05}$	**0.04**	**0.06**	**0.20**	**0.02**	**0.03**
Mulches (M)					
M_1	4.76	4.93	6.09	14.15 (3.76)	10.90 (3.28)
M_2	4.69	4.88	5.95	14.87 (3.85)	11.83 (3.43)
M_3	4.31	4.31	5.15	19.80 (4.45)	16.09 (4.01)
$CD_{0.05}$	**0.05**	**0.07**	**0.25**	**0.03**	**0.04**
Training systems (T)					
T_1	4.65	4.75	5.84	15.68 (3.94)	12.33 (3.48)
T_2	4.52	4.66	5.62	16.87 (4.09)	13.55 (3.67)
$CD_{0.05}$	**0.04**	**0.06**	**0.20**	**0.02**	**0.03**

P: Planting methods, **M:** Mulching treatments, **T:** Training systems; **P_1:** Raised bed planting method, **P_2:** Flat bed planting method, **M_1:** Black polythene mulch, **M_2:** Silver polythene mulch, **M_3:** No mulch, **T_1:** Two stem training system, **T_2:** Three stem training system

Table 3. Consortium/interaction effect on number of fruits per cluster, number of fruits per cluster, fruit weight (g), yield per plot (kg) and yield per hectare (q) in tomato

Treatment	**Number of flowers per cluster**	**Number of fruits per cluster**	**Fruit weight (g)**	**Yield per plot (kg)**	**Yield per hectare (q)**
T_1 ($P_1M_1T_1$)	12.64	6.51	80.47	140.71	992.64
T_2($P_1M_1T_2$)	11.97	6.04	78.92	132.20	932.64
T_3($P_1M_2T_1$)	12.07	6.23	79.47	136.16	960.58
T_4 ($P_1M_2T_2$)	11.69	5.88	78.35	130.25	918.84
T_5($P_1M_3T_1$)	9.58	5.10	76.00	115.09	811.91
T_6($P_1M_3T_2$)	9.50	4.94	74.69	111.01	783.12

T_7($P_2M_1T_1$)	11.12	5.69	77.99	125.76	887.21
T_8($P_2M_1T_2$)	10.69	5.29	76.68	119.03	839.69
T_9($P_2M_2T_1$)	10.97	5.52	77.25	123.53	871.46
T_{10}($P_2M_2T_2$)	10.97	5.52	77.25	123.53	871.46
T_{11}($P_2M_3T_1$)	10.44	5.24	76.23	116.60	822.58
T_{12}($P_2M_3T_2$)	8.47	4.29	72.54	105.26	742.58
$CD_{0.05}$	**0.42**	**0.26**	**3.49**	**10.42**	**26.47**

*Figures in parenthesis represent square root transformation

P: Planting methods, **M:** Mulching treatments, **T:** Training systems; **P_1:** Raised bed planting method, **P_2:** Flat bed planting method, **M_1:** Black polythene mulch, **M_2:** Silver polythene mulch, **M_3:** No mulch, **T_1:** Two stem training system, **T_2:** Three stem training system

Table 4. Consortium/interaction effect on pericarp thickness (mm), TSS (degree brix), lycopene content (mg per 100 g of fresh fruit weight), incidence of buckeye rot (%) and severity of *Alternaria* leaf blight (%) in tomato

Treatment	Pericarp thickness (mm)	TSS (degree Brix)	Lycopene content (mg per 100 gm of fresh fruit weight)	Incidence of buckeye rot (%)	Severity of *Alternaria* leaf blight (%)
T_1 ($P_1M_1T_1$)	4.99	5.10	6.42	11.99 (3.46)	7.84 (2.80)
T_2($P_1M_1T_2$)	4.85	4.96	6.21	13.71 (3.70)	9.74 (3.12)
T_3($P_1M_2T_1$)	4.90	5.03	6.38	12.87 (3.59)	8.81 (2.97)
T_4 ($P_1M_2T_2$)	4.80	4.94	6.14	13.89 (3.73)	11.58 (3.40)
T_5($P_1M_3T_1$)	4.40	4.39	5.39	18.12 (4.26)	15.09 (3.88)
T_6($P_1M_3T_2$)	4.31	4.32	5.25	18.88 (4.35)	15.37 (3.92)
T_7($P_2M_1T_1$)	4.71	4.86	5.98	14.54 (3.81)	12.47 (3.53)
T_8($P_2M_1T_2$)	4.49	4.79	5.74	16.38 (4.05)	13.55 (3.68)
T_9($P_2M_2T_1$)	4.61	4.83	5.80	15.50 (3.94)	12.83 (3.58)
T_{10}($P_2M_2T_2$)	4.61	4.83	5.80	15.50 (4.15)	12.83 (3.58)
T_{11}($P_2M_3T_1$)	4.46	4.73	5.49	17.21 (4.15)	14.10 (3.75)
T_{12}($P_2M_3T_2$)	4.21	4.23	4.91	21.13 (4.60)	16.97 (4.12)
$CD_{0.05}$	**0.04**	**0.42**	**1.20**	**0.06**	**0.04**

*Figures in parenthesis represent square root transformation

P: Planting methods, **M:** Mulching treatments, **T:** Training systems; **P_1:** Raised bed planting method, **P_2:** Flat bed planting method, **M_1:** Black polythene mulch, **M_2:** Silver polythene mulch, **M_3:** No mulch, **T_1:** Two stem training system, **T_2:** Three stem training system

Table 5. Effect of different treatment modules on economics of tomato production

Treatment code	Treatments Details	Yield (q/ha)	*Gross returns (Rs/ha)	Cost of cultivation (Rs/ha)	Net return (Rs/ha)	B: C ratio
$P_I M_1 T_I$	Raised bed + Black mulch + Two stem training	992.637	1488955.50	307591.31	1181364.19	3.84
$P_I M_1 T_2$	Raised bed + Black mulch + Three stem training	932.640	1398960.00	315991.31	1082968.69	3.43
$P_I M_2 T_1$	Raised bed + Silver/black mulch + Two stem training	960.585	1440877.50	315591.31	1125286.19	3.57
$P_I M_2 T_2$	Raised bed + Silver/black mulch + Three stem training	918.836	1378254.00	323991.31	1054262.69	3.25
$P_I M_3 T_1$	Raised bed + No mulch + Two stem training	811.910	1217865.00	254804.64	963060.36	3.78
$P_I M_3 T_2$	Raised bed + No mulch + Three stem training	783.121	1174681.50	263204.64	911476.86	3.46
$P_2 M_1 T_I$	Flat bed + Black mulch + Two stem training	887.214	1330821.00	299191.31	1031629.69	3.45

$P_2 M_1 T_2$	Flat bed + Black mulch + Three stem training	839.693	1259539.50	307591.31	951948.19	3.09
$P_2 M_2 T_1$	Flat bed + Silver/black mulch + Two stem training	871.458	1307187.00	307191.31	999995.69	3.26
$P_2 M_2 T_2$	Flat bed + Silver/black mulch + Three stem training	822.584	1233876.00	315591.31	918284.69	2.91
$P_2 M_3 T_1$	Flat bed + No mulch + Two stem training	772.173	1158259.50	246404.64	911854.86	3.70
$P_2 M_3 T_2$	Flat bed + No mulch + Three stem training	742.584	1113876.00	254804.64	859071.36	3.37
CD $_{(0.05)}$						0.10

* The gross returns were worked out on the basis of sale price of tomato @ Rs. 15/- kg fixed by the University