RESEARCH ARTICLE Agricultural Science Digest, Volume 45 Issue 1: 17-23 (February 2025)

Effect of Planting Methods, Plastic Mulches, Training Systems, Soil Temperature and Soil Moisture on Tomato Yield

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10.18805/ag.D-5408

ABSTRACT

Background: Tomato is an important vegetable crop of Himachal Pradesh grown during summer and rainy seasons. Although the produce of the tomato fetches lucrative rates in the plains of Northern India, yet, the production is threatened by plethora of factors *viz*., diseases, insect-pests and weeds which ultimately affects yield and quality of fruits. The planting methods, mulches and training systems played enormous role in maintaining the soil temperature and moisture.

Methods: The present investigation was carried out to study the performance of tomato (var. Solan Lalima) crop under open field conditions with two different planting methods, three types of mulch treatments and two types of training systems. This experiment was conducted at Vegetable Research Farm of DR YSP, UHF, Nauni, Solan during the period from March to September, 2017-18 and similarly for the period from March to September, 2018-19.

Result: The maximum soil temperature was recorded under blackmulch followed by silver/black polythene mulch and control during the standard meteorological week (March to September, 2017-18 and 2019). Soil moisture was found to be maximum those treatments where silver or black mulch was used as compared to black mulch plot under the open field conditions. The maximum fruit yield (140.71 kg/plot) was obtained under the raised bed planting system, black mulch and two stem training system and the corresponding value being 136.16 kg/plot for raised bed planting method, silver/black mulch and two stem training system.

Key words: Plastic mulch, Soil moisture, Soil temperature, Tomato, Yields.

INTRODUCTION

Improving soil moisture conservation is an ongoing goal in agricultural production system, especially in India, where the water resources are scanty and regulated. One reason that there is a push to use less water in agriculture is because of increasing demand generated by the increasing population in India. To feed that much population it becomes necessary to use less water resources and more emphasis should be given to save those natural resources. The water demands of urban populations are essentially fixed and increase, so water availability for agricultural producers is constantly reduced. To address and therefore to encompass both of these issues, farmers are searching for new ways or the techniques to improve rather than soil moisture but overall hydrothermal properties of the soil. Mulching is one cultural practice which can be used to addresses or overcome this problem. Covering the ground with mulch saves water by preventing surface evaporation and therefore maintains the soil temperature. Using certain agricultural byproducts as mulch is a sustainable practice which can reduce water use and provide other benefits as well (Ghosh *et al*., 2006). Tomato is one of the most important commercial vegetable crops grown in India and throughout the world. The requirement of irrigation waterto tomato crop is moderately high in Indo-Gangetic plains. It is generally about 550-600 mm, while the crop evapo-transpiration demand is about 250-270 mm. The scarcity of the water resources and competition for water in many sectors also reducesthe availability of water for agricultural usage. Considering the water scarcity for more intense in future, the planning and management of this resource for its optimal, economic and judicious use has become very important aspect for making the agriculture a sustainable approach.

The advantages of the raised bed-planting system includes water savings (up to 30% along with the furrow irrigation) combined with enhanced water use efûciency, improvement in soil physiochemicalstatus and better nitrogen use efûciency, greater and better utilization of sunlight, less crop-weed competition and increment in yield (Zhang *et al.,* 2007 and Kumar *et al*., 2015). Polythene mulches or synthetic mulches are widely used in so many

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How to cite this article: Shilpa, Bijalwan, P. and Shukla, Y.R. (2025). Effect of Planting Methods, Plastic Mulches, Training Systems, Soil Temperature and Soil Moisture on Tomato Yield. Agricultural Science Digest. 45(1): 17-23. doi: 10.18805/ag.D-5408.

Submitted: 05-06-2021 **Accepted:** 10-09-2021 **Online:** 16-10-2021

horticultural crops to promote the growth of main plants and also suppress the weed growth and to reduce their population, to conserve the soil moisture and to alter temperature in the rhizosphere. One of the main benefits associated with plastic mulching is the modification of the microclimate around the plant. Synthetic mulches (plastic of different colors) are widely used invegetable production due to their highefficacy to maintain the soil hydrothermal regime by altering the water distribution between soil evaporation and plant transpiration, and thus modifying the soil temperature and moisture parameters (Bahadur *et al*., 2013). Plastic mulches increased the soil temperature generally by about 6-7°C at a depth of 5 cm and by 4°C at 10 cm depth. The present investigation aimed to study the effect of various planting systems used for vegetable production and mulch materials on hydrothermal regime of soil and plant training system on yield in tomato.

MATERIALS AND METHODS

An experiment was conducted for the consecutive two years during *Kharif* season (2017-2018 and 2018-2019) at two different sites of the Research Farm of Vegetable Science. This experiment was laid out under factorial randomized block design with three replications comprising of twelve treatment combinations of planting methods *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. The experimental field was ploughed thoroughly with the help of a tractor followed by planking well in advance before transplanting. Tomato variety 'Solan Lalima' was grown during the present study. It's fruit having medium sized, round shaped deep red in colour with TSS 4-5 °Brix. It is a self pollinated indeterminate variety developed by selection. Healthy seedlings were transplanted on 12th April, 2017 and April, 2018 at a spacing of 90 cm × 30 cm. Black polyethylene mulch and silver/black mulch of 50 µ (200 gauge thickness) were applied according to the treatment combinations. Black mulch and grey or black mulch used in the experiment were procured from the open market. The observations were recorded on the parameters regarding the yield per plot (kg), soil moisture content (%) and soil temperature (°C).The data pertaining to the present investigation were statistical analyzed using the standard procedures of the factorial randomized block design (RBD).

RESULTS AND DISCUSSION

Soil temperature (°C)

Soil temperature was measured throughout the plant growth period using mercuryin-glass soil thermometers in each plot of each treatment and also replication wise. Soil thermometers were installed at 5 cm depth in eachplot within the rows of tomato plants.Soil temperature at 5 cm depth by soil thermometer was recorded daily outside the open field conditions (an open environment) at local standard time and then averaged. The soil temperature was observed at weekly interval from May-August at 7:30 hours and 14:30 hours (local standard time) at 0-5 cm soil depth during the year 2017-2018 and 2018-2019. The observed data enumerated that the mulches played enormous role in maintaining the soil temperature. The data indicated that application of black mulch in raised bed planting method ($P_1M_1T_1$) along with two stem training system increased the soil temperature by 3.46°C, 4.07°C, 4.06°C and 1.97°C during (Fig 1, 2, 3 and 4) the 4th week of May, June, July and August, 2017-18 and 3.12°C, 1.73°C, 2.77°C and 2.08°C, during the 4th week of May, June, July and August, 2017-18 respectively over no mulch application in flat beds along with three stem training system ($P_2M_3T_2$) as recorded during the morning and afternoon hours. The soil temperature was also increased

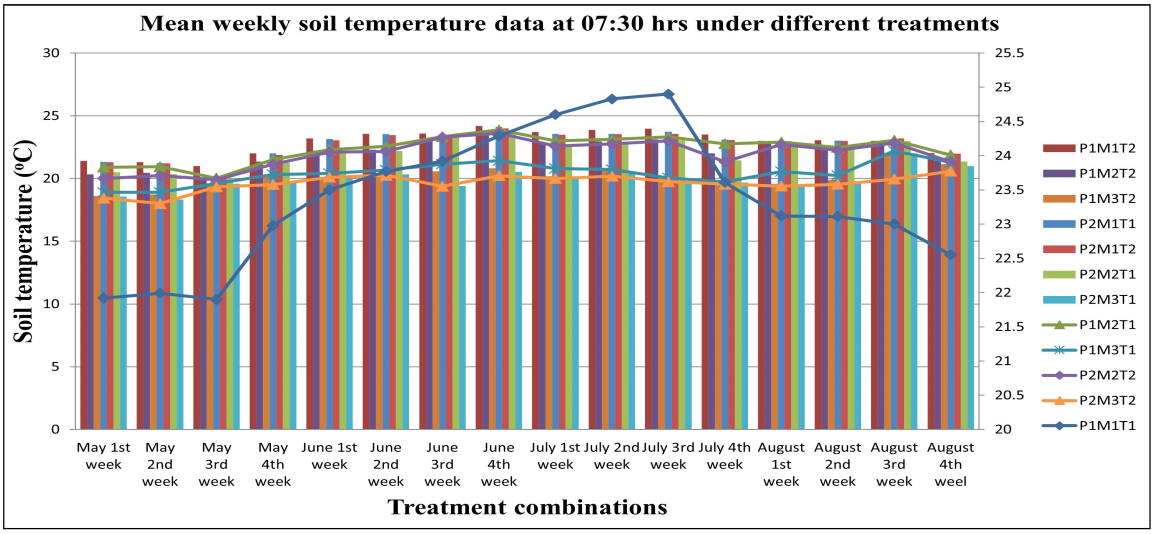


Fig 1: Mean weekly soil temperature (° C at 07:30 hrs) at 0-5 cm soil depth under different treatments during 2017-2018.

by 3.22°C, 5.78°C, 3.44°C and 6.11°C during the 4th week of May, June, July and August, 2018-19 and 3.10°C, 2.95°C, 1.91°C and 2.52°C during the 4th week of May, June, July and August, 2018-19 with the application of black polythene mulch placed on raised beds ($P_1M_1T_1$) along with three stem training system, respectively, during morning and afternoon hours over no mulch application in flat beds along with three stem training system ($P_2M_3T_2$). The same trend was observed during all the weeks of different months during both the years of experimentation. In general, the effect of mulching on the temperature regime of the soil varied depending on capacity of the mulch materials to reflect and transmit solar energy (Lamont, 2005). Black mulch materials have specific optical properties due to which mulches control soil temperature, which can augment or reduce crop yield (Kader *et al.,* 2017). According to Kumar and Lal (2012), Kosterna *et al.* (2014) and Angmo *et al.* (2018) in tomato mulching reduces soil temperature in summer and raises it in winter.

Soil moisture (%)

The data pertaining to soil moisture content under different treatment combinations, recorded during the growth and development of tomato for both the cropping periods 2017-

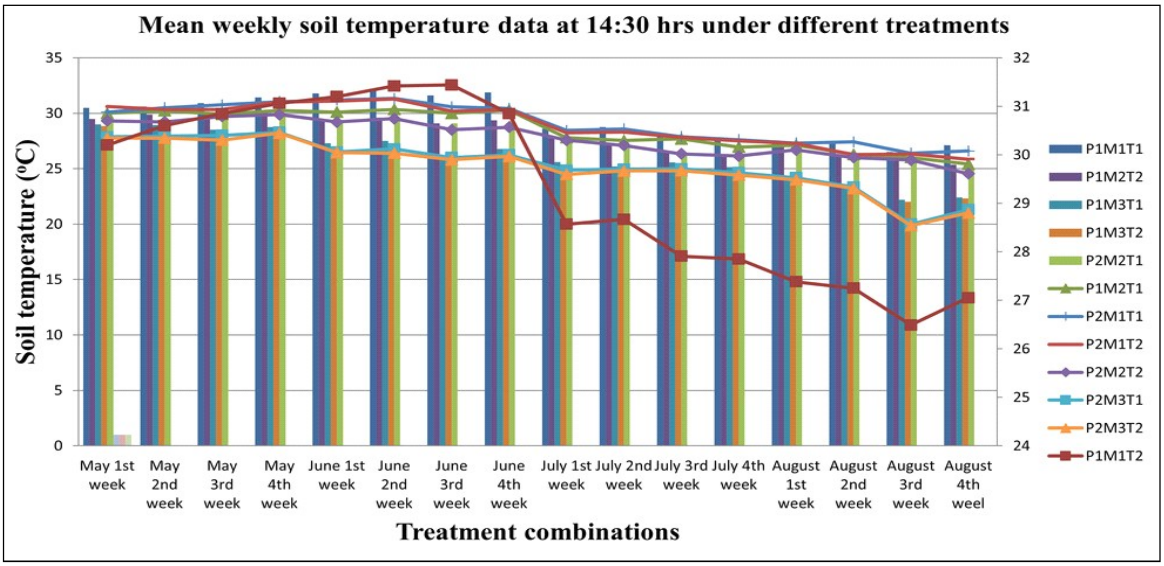


Fig 2: Mean weekly soil temperature (°C at 14:30 hrs) at 0-5 cm soil depth under different treatments during 2017-2018.

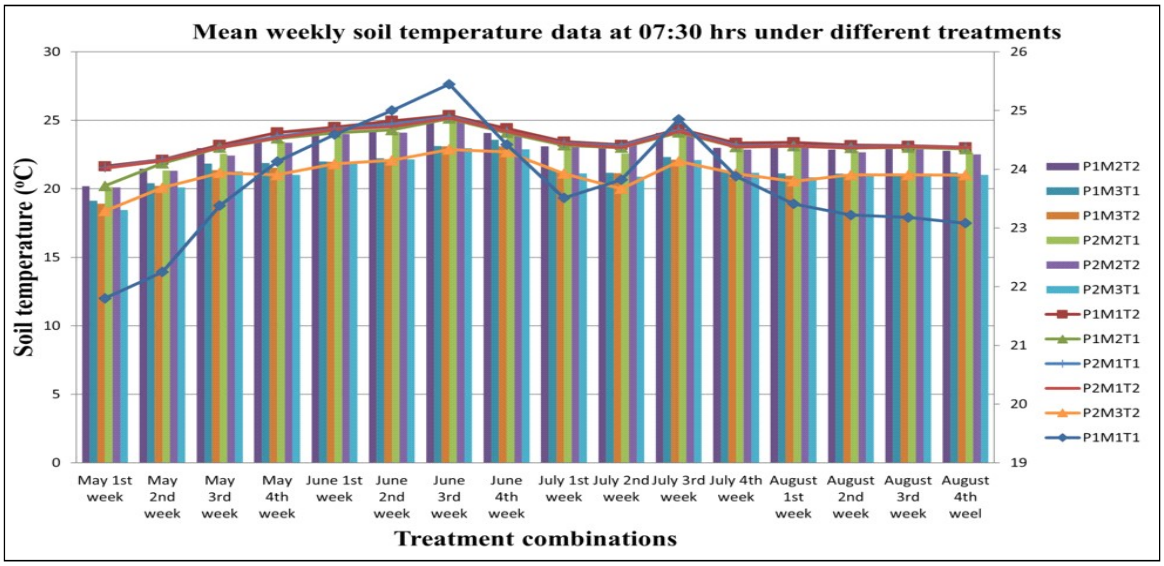


Fig 3: Mean weekly soil temperature (°C at 07:30 hrs) at 0-5 cm soil depth under different treatments during 2018-2019.

18 and 2018-19 at 0-15 cm soil depth at fortnightly interval. Both the mulches (black mulch and silver/black mulch) were found effective in conserving the soil moisturecontent. Maximum soil moisture conservation was observed under silver/black mulch followed by black polyethylene mulch placed on flat beds. The per cent increase in soil moisture content during the cropping period of 2017-18 during the fortnight interval of May, June, July and August was calculated as 20.10, 20.15, 21.26, 25.40, 19.90, 21.15, 26.78 and 29.86 per cent, respectively in the treatment combination $P_2M_2T_1$ as compared to the $P_1M_3T_2$ (Fig 5 and 6). Similarly, during the year 2018-19, the per cent increase in soil moisture content during the fortnight interval of May, June, July and August was 44.52, 38.99, 17.32, 24.13, 21.16, 16.08, 30.00 and 21.98 per cent, respectively in the treatment combination $P_2M_2T_1$ as compared to the $P_1M_3T_2$. The soil moisture content was higher during the months of July and Augustdue to heavy rains. The higher moisture content in the flat beds was due to less drainage compared to the raised beds. Kumar *et al*. (2010) also reported low

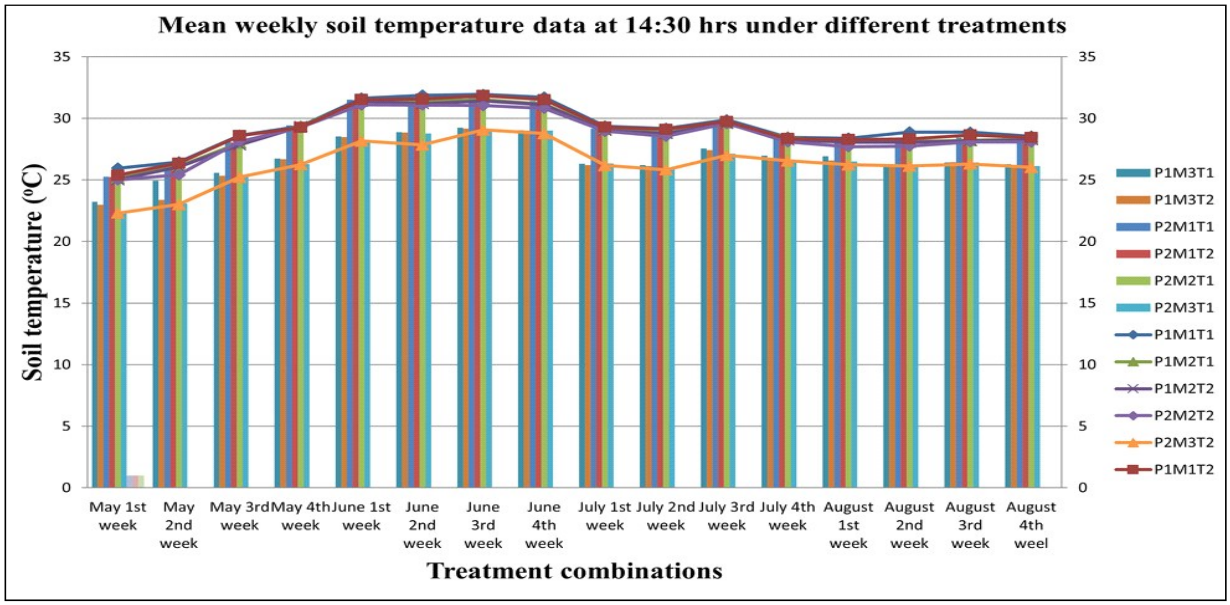


Fig 4: Mean weekly soil temperature (ºC at 14:30 hrs) at 0-5 cm soil depth under different treatments during 2018-2019.

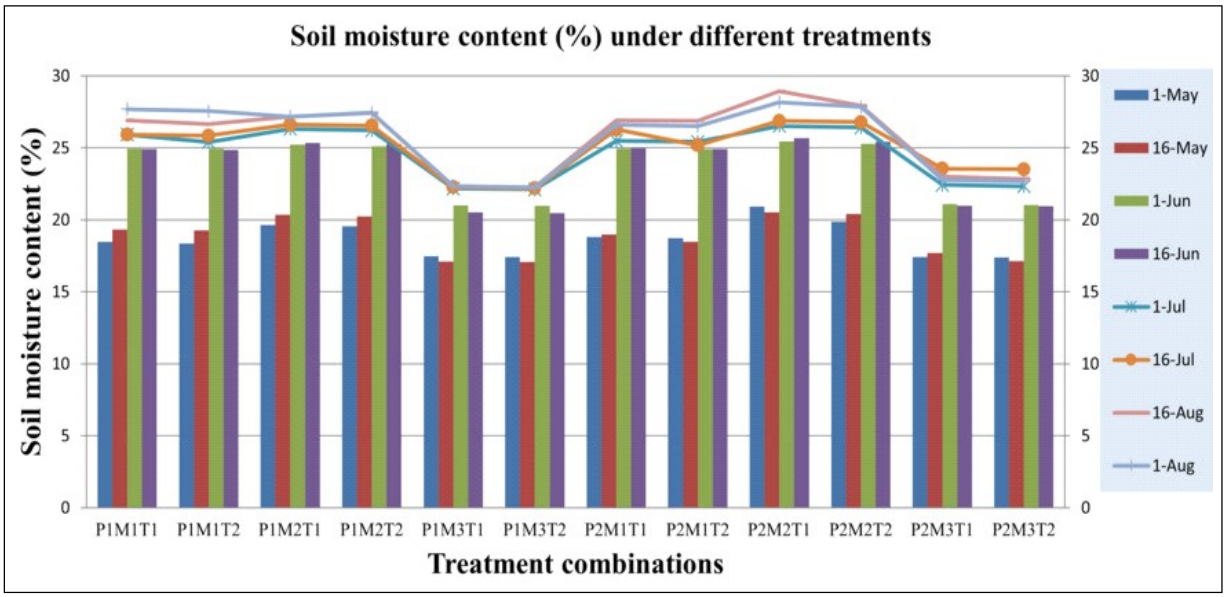


Fig 5: Soil moisture (%) at 0-15 cm soil depth under different treatments during cropping period of 2017-2018.

soil moisture under raised bed than flat bed planting method. They attributed that this might be due to the rapid drying of raised bed in comparison to flat bed which resulted into higher soil moisture content in flat beds. The higher moisture recorded in soil mulched with silver polythene sheet could be attributed to its ability to reflect high amount of sunlight, thereby reducing evapo-transpiration and enhancing moisture retention in the soil. As the moisture depletion was least under silver/grey mulch, the moisture recharging-ability was also least because water infiltration was prevented. None of the less, capillary movement of water molecules through the soil pores from the water table has strongly supplied water to the root zone of the crop grown under silver/grey plastic mulch in the present study. Similar results were represented by Awodoyin *et al.* (2007) in tomato, Diaz-Perez (2010) in bell pepper and Ashrafuzzaman *et al.* (2011) in chilli.

Fruit yield per plot (kg)

The data pertaining to the effect of different treatments on fruit yield per plot (Table 1) which revealed significant effects for all the interactions. The plants which were grown on raised bed (P_1) planting method produced maximum yield (127.57 kg/plot) and this treatment was significantly superior over flat bed planting method (P_2) producing 116.61 kg/plot (pooled data). Similar trend was observed during the years 2017-18 and 2018-19. The influence of different types of mulches on yield per plot was also significant (pooled data as well as during both the years). An examination of the pooled data revealed significant differences of different mulches and maximum value (129.42 kg/plot) was recorded in the plants grown on black mulch (M_1) followed by those (126.64 kg/plot) grown on silver/black mulch (M_2), while minimum (110.20 kg/plot) yield per plot was recorded in the plots where no mulch (M_3) was applied. Regarding the effect of training systems, maximum (125.12 kg/plot) yield was recorded in those plants which were trained to two stem (T_1) and minimum yield (119.06 kg/plot) was recorded from the plants trained to three stem (T_2). Similar results were followed during both the years of study. The influence of two way interactions on yield per plot was significant in P × M (planting methods and mulching treatments) interaction (pooled data). Maximum value was recorded in the plants grown on raised bed with black mulch (136.45 kg/plot).

Table 1: Effect of planting methods, plastic mulches and training systems on fruit yield per plot of tomato.

Treatments	Fruit yield per plot (kg)		
	2017-2018	2018-2019	Pooled
Planting Methods (P)			
P_1	127.15	127.99	127.57
P_2	117.74	115.47	116.61
$CD_{0.05}$	**1.59**	**1.63**	**1.14**
Mulches (M)			
M_1	128.93	129.93	129.42
M_2	126.45	126.82	126.64
M_3	111.97	108.44	110.20
$CD_{0.05}$	**1.94**	**2.00**	**1.39**
Training Systems (T)			
T_1	125.22	125.02	125.12
T_2	119.68	118.44	119.06
$CD_{0.05}$	**1.59**	**1.63**	**1.14**

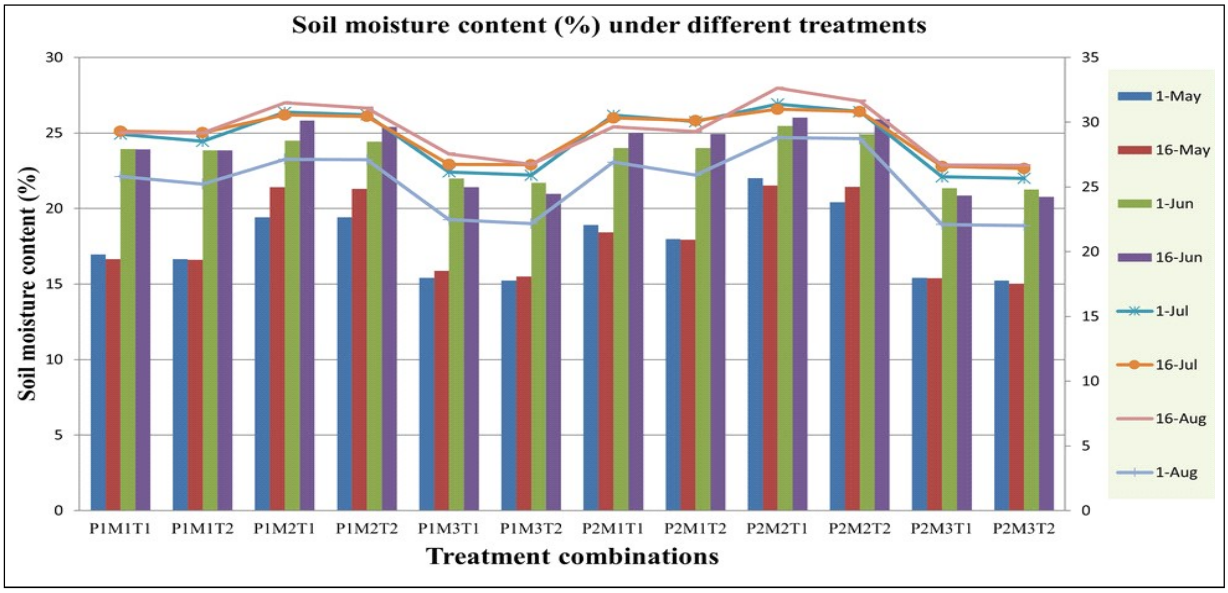


Fig 6: Soil moisture (%) at 0-15 cm soil depth under different treatments during cropping period year 2018-2019.

This treatment combination was significantly superior over P_1M_2 (raised bed with silver/black mulch) producing 133.20 kg/plot yield, P_2M_1 (122.40 kg/plot) and P_2M_2 (120.07 kg/plot). Minimum value of yield (107.36 kg/plot) was recorded in plants which were produced on flat beds without mulch (P_2M_3). The effect of planting methods and mulches (M × T) was also significant for the year 2018-2019 as well as when the data were pooled data, but non significant during the experimentation year of 2017-2018. Maximum yield per plot (133.23 kg) was recorded in treatment combination M_1T_1 (black mulch with two stem training system). This treatment combination was significantly superior over M_2T_1 (raised bed with silver/black mulch) producing 129.85 kg/plot yield, M_1T_2 (125.61 kg/plot) and M_2T_2 (123.42 kg/plot). Minimum yield (108.13 kg/plot) was recorded in M_3T_2 (no mulch with three stem training system) treatment combination. Similarly P × T (planting methods and training systems) interaction showed non significant effects on yield per plot. Maximum value (130.65 kg) for yield per plot was recorded on those plants which were grown on raised bed and trained to two stem training system (P_1T_1) and minimum (113.63 kg/plot) in P_2T_2 (flat bed with three stem training system). Similar results were recorded for P × M, M × T and P × T interactions during both the years of study.The pooled data pertaining to the effect of three way interactions (P × M × T) have been presented in Table 2. The analysis of variance showed that there was also the significant effect of various interactions on yield per plot during both the years as well as when the data was pooled, however, maximum value (140.71 kg/plot) was recorded in the plants grown on raised bed, black mulch with two stem training system ($P_1M_1T_1$) which was followed (136.16 kg/plot) by $P_1M_2T_1$ (raised bed, silver/black mulch with two stem training system) and minimum (105.26 kg/plot) was recorded in those plants grown on flat bed with no mulch and three stem training system ($P_2M_3T_2$). The pooled data pertaining to the effect of three way interactions (P × M × T) have been presented in Table 3. The analysis of variance showed that there was no effect of various interactions on yield per plot during both the years as well as when the data was pooled, however, maximum value (140.71 kg/plot) was recorded in the plants grown on raised bed, black mulch with two stem training system ($P_1M_1T_1$) which was followed (136.16 kg/plot) by $P_1M_2T_1$ (raised bed, silver/black mulch with two stem training system) and minimum (105.26 kg/plot) was recorded in those plants grown on flat bed with no mulch and three stem training system ($P_2M_3T_2$).

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 (Aykas *et al.,* 2005). Alagoz and Ozer (2019) observed that soil compaction in flat planting system was higher values in raised bed planting system and compaction values increased through the soil profile. Other reasons for increased yield on raised beds could be longer growing period, warming up of the bed, improved drainage, better management of water, fertilizers, mulch and other soil amendments and reduced foot trafficing (Berle and Westerfield, 2013; Bahadur *et al.,* 2013).

According to Sarkar and Singh (2007), black mulching enhanced growth and yield of plants, while they also concluded that mulching especially black mulch reduced leaching of nutrients, reduced weed problem, reduced evapotranspiration of soil water and increased water use efficiency. Angmo *et al.* (2018) were also of opinion that reduced competition with weeds, higher soil temperature, reduced attack of soil pathogens and breakdown of phytotoxic substances are responsible for higher yield in the plants grown on black mulch.

Table 2: Effect of two way interactions P × M, M × T and P × T on fruit yield per plot of tomato.

Treatment combination	Fruit yield per plot (kg)		
	2017-2018	2018-2019	Pooled
P_1M_1	135.10	137.82	136.45
P_1M_2	131.73	134.69	133.20
P_1M_3	114.63	111.45	113.05
P_2M_1	122.75	122.03	122.40
P_2M_2	121.16	118.95	120.07
P_2M_3	109.30	105.43	107.36
$CD_{0.05}$	2.75	2.83	1.97
M_1T_1	132.30	134.17	133.23
M_1T_2	125.56	125.68	125.61
M_2T_1	128.77	130.92	129.85
M_2T_2	124.13	122.71	123.42
M_3T_1	114.59	109.96	112.27
M_3T_2	109.34	106.92	108.13
$CD_{0.05}$	NS	2.83	1.97
P_1T_1	130.06	131.24	130.65
P_1T_2	124.25	124.73	124.48
P_2T_1	120.38	118.79	119.58
P_2T_2	115.10	112.15	113.63
$CD_{0.05}$	NS	NS	NS

Table 3: Effect of P × M × T interaction on fruit yield per plot.

Treatment combination	Fruit yield per plot (kg)		
	2017-2018	2018-2019	Pooled
$P_1M_1T_1$	139.49	141.93	140.71
$P_1M_1T_2$	130.71	133.71	132.20
$P_1M_2T_1$	133.84	138.50	136.16
$P_1M_2T_2$	129.62	130.87	130.25
$P_1M_3T_1$	116.84	113.31	115.09
$P_1M_3T_2$	112.42	109.60	111.01
$P_2M_1T_1$	125.10	126.41	125.76
$P_2M_1T_2$	120.40	117.65	119.03
$P_2M_2T_1$	123.69	123.35	123.53
$P_2M_2T_2$	123.69	123.35	123.53
$P_2M_3T_1$	118.64	114.25	116.60
$P_2M_3T_2$	106.26	104.25	105.26
$CD_{0.05}$	NS	NS	NS

The two stem training system noticed significant and maximum fruit yield over other levels of training systems. 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. Ara *et al.* (2007) also recorded higher yield in two stem pruned plants as compared to single stem pruned.

Conflict of interest

All authors declared that there is no conflict of interest.

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