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Effect of planting methods, plastic mulches and training systems on soil temperature, soil moisture and tomato yield under open field conditions

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Abstract
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. The highest soil temperature was recorded under black mulch followed by silver/black polythene mulch and no mulch plot treatments during the standard meteorological week (March to September). It was found to be higher by about 1 to 10ºC as compared to no mulch plot. Soil moisture was found to be higher in those treatments where silver/black mulch was used as compared to black mulch plot under the open field conditions. But there was no definite pattern observed under mulched or no mulched conditions. Highest 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.

Keywords: 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 solve this problem. Covering the ground with mulch saves water by preventing surface evaporation and therefore maintains the soil temperature. The layer can also greatly reduce or eliminate weed propagation, which will also result in higher water use efficiency. Using certain agricultural byproducts as mulch is a sustainable practice which can reduce water use and provide other benefits as well. Wheat straw, grass clippings, and leaf debris are fairly abundant byproducts. Many producers already generate these mulching materials, and currently spend resources to dispose of them (Ghosh *et al*., 2006) [11].
Tomato is one of the most important commercial vegetable crops grown in India and throughout the world. Agriculture is by far the leading user of freshwater worldwide, accounting for almost 85 per cent of global consumption. Regarding the field irrigation requirement of tomato crop is moderately high in Indo-Gangetic plains generally about 550-600 mm, while the crop evapo-transpiration demand is about 250-270 mm. Because of the scarcity of the water resources and competition for water in many sectors also reduces the 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.
Raised bed planting (RBP) system, in which water is supplied in furrows and crops are raised on elevated beds, offers the better opportunity to the farmers' and researchers for managing the water resources more efficiently with the greater rate of efficacy. The advantages of the raised bed-planting system includes water savings (up to 30% along with the furrow irrigation)

combined with enhanced water use efficiency, improvement in soil physiochemical status and better nitrogen use efficiency, greater and better utilization of sunlight, less crop-weed competition and increament in yield (Zhang *et al.*, 2007 and Kumar *et al.*, 2015) [19, 14]. Polythene mulches/synthetic mulches are widely used in many horticultural crops to 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. It proves that mulching is most effective mean of microclimatic modifications, both under protected as well as open field conditions. Synthetic mulches (plastic of different colors) are widely used in vegetable production due to their high efficacy 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. Mulches by creating a physical barrier between the soil surface and adjacent atmosphere, minimizes or lessens the evapotranspiration losses from the soil and plant surface thus utilizes the conserved water by the use of mulches for higher transpiration by the plants and improves yield and WUE of the tomato crop (Bahadur *et al*., 2013) [7]. Ramakrishna and his coworkers during the year 2006 narrated that the 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 in groundnut. The principle of the double coloured mulch is that the colour of the mulch, type of the mulch material (reflectivity and absorbvity) affects the surface temperature of the mulch material and also the underlying temperature of the soil too due to which there will be the enhanced germination, flowering and finally increament in the yield per meter square, marketable yield. Vegetable production, profits are greatly dependent on the quantity and quality of the yield of the crop. Training maximizes the plant's ability to obtain the sunlight needed for growth and development. It is also important to maintain adequate air movement around the plant also to reduce risk of fungus and insect problems. A dense canopy of leaves shades the fruits, causing them to be pale. Relatively high perishability has made tomato plants to be more vulnerable to intensive crop management and unfavourable environmental conditions. Manipulation of canopy architecture through pruning and training together with appropriate arrangements has been identified as key management practices for getting maximum marketable yields. 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

The experiment was conducted for the consecutive two years during *Kharif* season at two different sites of the Research Farm of Vegetable Science. This experiment was laid out in a Randomized Block Design (Factorial) 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 cultivar 'Solan Lalima' was used for the present study. It bears medium sized and round shaped fruits of deep red colour having TSS 4-5 ^{0}Brix. It is a self pollinated indeterminate variety developed by selection. The crop is ready for first picking in 70-80 days after transplanting. Average fruit weight is 70-80 g and the average yield is 75-85 t/ha. Healthy seedlings were transplanted on 12th April, 2017 and April, 2018 at a spacing of 90 cm x 30 cm. All cultural operations and plant protection measures were adopted to maintain uniform plant population and ideal conditions for proper growth and development of plants. Black polyethylene mulch and silver/black mulch of 50µ (200 gauge thickness) were applied in different plots according to the treatment combinations. Black mulch and grey/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). Observations were recorded on 5 plants taken at random in each entry. The data pertaining to the present investigation were statistical analyzed using the standard procedures of the Factorial Randomized Block Design (RBD).

Land Preparation and planting: The experimental field was ploughed thoroughly with the help of a tractor followed by planking well in advance before the date of transplanting. Stones, pebbles and residues of previous crops were removed manually. Field was leveled for proper drainage of water. Beds were raised 15 cm above the ground level and separated by 45 cm distance to cover with plastic mulches as per the treatments. Eighteen raised and eighteen flat beds having size of 11.34 m^2 were prepared in accordance with the experimental design with appropriate provisions for drainage. The layout of the experiment was carried out with manual labour. Thereafter the transplanting of the seedlings was done.

Yield per plot (kg)

Yield per plot was calculated by pooling the weight of the all fruits harvested from every picking in a given plot and was expressed in kilogram.

Soil moisture content (%)

For estimation of soil moisture content, the data were recorded at fortnightly interval. Soil moisture content was measured for each treatment with the help of an augar from 0-15 cm soil depth. Gravimetric method was used for drying soil samples, drawn from each treatment in aluminium boxes. After taking fresh weight of samples these were dried in an electric oven at 105 °C till constant weight and soil moisture percentage was achieved on oven dry weight basis with the help of formula given below.

$$Mp = \frac{Fw - Dw}{Fw} \times 100$$

Where;
Mp = moisture percentage on oven dry weight basis
Fw = fresh weight of soil sample
Dw = dry weight of soil sample

Soil temperature (^{0}C)

Weekly soil temperature was recorded from three randomly selected plots, one each from black polyethylene mulch, silver/grey polyethylene mulch and un-mulched plots with the help of a thermometer put in the soil at a depth of 0-5 cm. The observations were recorded twice in a day at 7.30 A.M. and 2.30 P.M. starting from the date of sowing till the harvest of the crop. Mean temperature was worked out and expressed in ^{0}C.

Results and Discussion

Soil temperature (^{0}C)

Soil temperature influences the rate of chemical reactions, biological reactions, water content of plants and soil also, and transport of various nutrients in the soil, but it simultaneously affects the plant physiological aspects of ion uptake and their exchange too, root growth of the plant, and the composition of the soil microorganisms and function of those soil microbial communities to carry out the various processes in the soil. The extreme soil temperature influences the germination of seeds, functional activity of the root system and therefore the development of crop. As evident from the Figure 1 (a, b) the effect of various mulches on soil temperature were found more pronounced under open field conditions. In general, this effect was more pronounced during the early crop season when the tomato plants covered less soil surface. Temporal variation in soil temperatures showed that it was more under open field. The increase in soil temperature may be attributed to the passing of sun energy through mulch. This process heated both the air and soil as well. The higher soil temperature in the raised bed could be attributed to the wider and more exposed surface area compared to the flat beds.

Soil temperature was measured throughout the plant growth period using mercury in-glass soil thermometers in every plot of each treatment and also replication wise. Soil thermometers were installed at 5 cm depth in each plot within the rows of tomato plants. Daily soil temperature at 5 cm depth by soil thermometer was recorded 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 ^{0}C, 4.07 ^{0}C, 4.06 ^{0}C and 1.97 ^{0}C during the 4th week of May, June, July and August, 2017-18 and 3.12 ^{0}C, 1.73 ^{0}C, 2.77 ^{0}C and 2.08 ^{0}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 by 3.22 ^{0}C, 5.78 ^{0}C, 3.44 ^{0}C and 6.11 ^{0}C during the 4th week of May, June, July and August, 2018-19 and 3.10 ^{0}C, 2.95 ^{0}C, 1.91 ^{0}C and 2.52 ^{0}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. Black plastic mulch, an opaque blackbody absorber and radiator also absorbs most ultra-violet (UV), visible radiations, and infrared wavelengths (IR) of incoming solar radiations and re-radiates the absorbed energy in the form of thermal radiation or long-wavelength infrared radiations. Therefore, much of the solar energy absorbed by the black polythene mulch is lost to the atmosphere through radiations and the phenomena of forced convection. The efficiency with which black mulch increases the soil temperature can be improved by optimizing conditions for transferring the heat from the mulch to the soil. Because thermal conductivity of the soil is higher than the air, much of the energy absorbed by black plastic can be transferred to the soil by conduction with good contact between the plastic mulch and the soil surface.

Mulches have shown to lower soil temperatures in summer months. Extreme temperatures can kill fine plant roots which can cause stress and root rot. Mulches protect soils from extreme temperatures, either cold or hot. Coarse mulches are more temperature moderating and allow for better water and gas transfer than thick layers of finely textured mulches. There is an effect of mulch type on surface temperature. Some mulches heat the soil as a function of solar radiation absorption more than bare soils.

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) [16]. 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) [12]. The present results are in agreement with previous studies which have established that plastic film mulching absorbs solar radiations and reduces soil heat loss with a consequent increase in soil moisture and temperature, both of which augment plant growth and improve crop production as, the effects of soil temperature on crop growth are also related to the climatic conditions and locations, where the crop plants are grown. Colour of plastic mulch material determines the energy-radiating factors by influencing the surface temperature of the mulch and the underlying soil temperature. However, the effect of mulching materials on soil temperature is highly variable. The timing of soil temperature measurements and mulching thickness also cause variation in data pertaining to soil temperature. According to Kumar and Lal (2012) [15], mulching reduces soil temperature in summer and raises it in winter. Mulching also prevents extremes of temperature. The consistent high temperature under black plastic mulch is due to the green house effect that trap the little radiant energy and penetrates into the soil. Little energy is lost through evaporation, resulting in a net gain of soil heat during the day. Though the temperature on the bare plot was low, the poor crop performance obtained on the cultivated plot can be explained by the competition between crop and weeds. Similar are the findings of Kosterna *et al.* (2014) [13] and Angmo *et al.* (2018) [2] in tomato.

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 2017-18 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 moisture content. However, the magnitude of moisture conservation varied with the type of mulch material and planting methods. Maximum soil moisture conservation was observed under silver/black mulch followed by black polyethylene mulch placed on flat beds. Application of silver/black polyethylene mulch conserved higher soil moisture content as compared to the unmulched control. 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 $P_1M_3T_2$. 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 August due 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 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 evapotranspiration and enhancing moisture retention in the soil. Conversely, the significant decrease in the moisture content of soil mulched with black mulch could be linked to relative low abilities of the material to conserve moisture owing to their high transmissibility of solar radiations. Polythene mulching treatment (with hole) constantly stored soil moisture as compared to bare treatments, and therefore the current study recorded higher moisture content in the silver/black mulch treatments. Less moisture depletion under the mulches was a result of prevention of contact between the soil and dry air, which reduced water loss into the atmosphere through evaporation. Because of vapours, the water was further trapped within the mulches, resulting in fog which again dropped into the upper soil layer. Also mulches reduce impact of raindrops and splash, thereby, preventing soil compaction and disease infection, reducing surface run-off and increasing water infiltration. All these resulted into increase in the soil moisture content and reduced moisture depletion. 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 are the findings of Awodoyin *et al.* (2007) [5] in tomato, Diaz-Perez (2010) [10] in bell pepper and Ashrafuzzaman *et al.* (2011) [4] in chilli. The slightly higher water depletion under the bare treatment plots might be due to more water loss into the atmosphere through transpiration from the crop and weeds which was higher than combined water loss through evaporation from the soil surface and transpiration from the crop.

Fruit yield per plot (kg)

The data pertaining to the effect of different treatments on fruit yield per plot have been presented in 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). 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. This may be because of increased enzymatic activity of microorganisms which consequently facilitated the mineralization of organic matter, whereas, Aykas *et al.* (2005) [6] were of the opinion that soil compaction in the flat beds decreased nutrients which were mineralized from the soil organic matter. Alagoz and Ozer (2019) [1] 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) [8]. The present results are in line with the findings of Bahadur *et al.* (2013) [7] in tomato.

According to Sarkar and Singh (2007) [17], 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. According to them, maintenance of optimum soil moisture was responsible for optimum crop growth throughout the growing season. It was also pointed out that increased growth and yield of tomato through modification of crop growing environment could be due to reduced weed infestation, soil moisture depletion and ameliorating soil temperature. Angmo *et al.* (2018) [2] 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.

Growth and yield are functions of a large number of metabolic processes, which are affected by environmental and genetic factors. A number of researchers also recommended training as a cultural practice that improves the yield and quality of tomato. Plant growth analysis is considered to be a standard approach to plant productivity. Tomato yield could be increased substantially through improved agronomic techniques like training. 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) [9] and Singh and Kumar (2005) [18] in cherry tomato. Ara *et al.* (2007) [3] also recorded higher yield in two stem pruned plants as compared to single stem pruned.

Table 1: Effect of planting methods, 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

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

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/black polythene mulch, M_3: No mulch, T_1: Two stem training system, T_2: Three stem training system

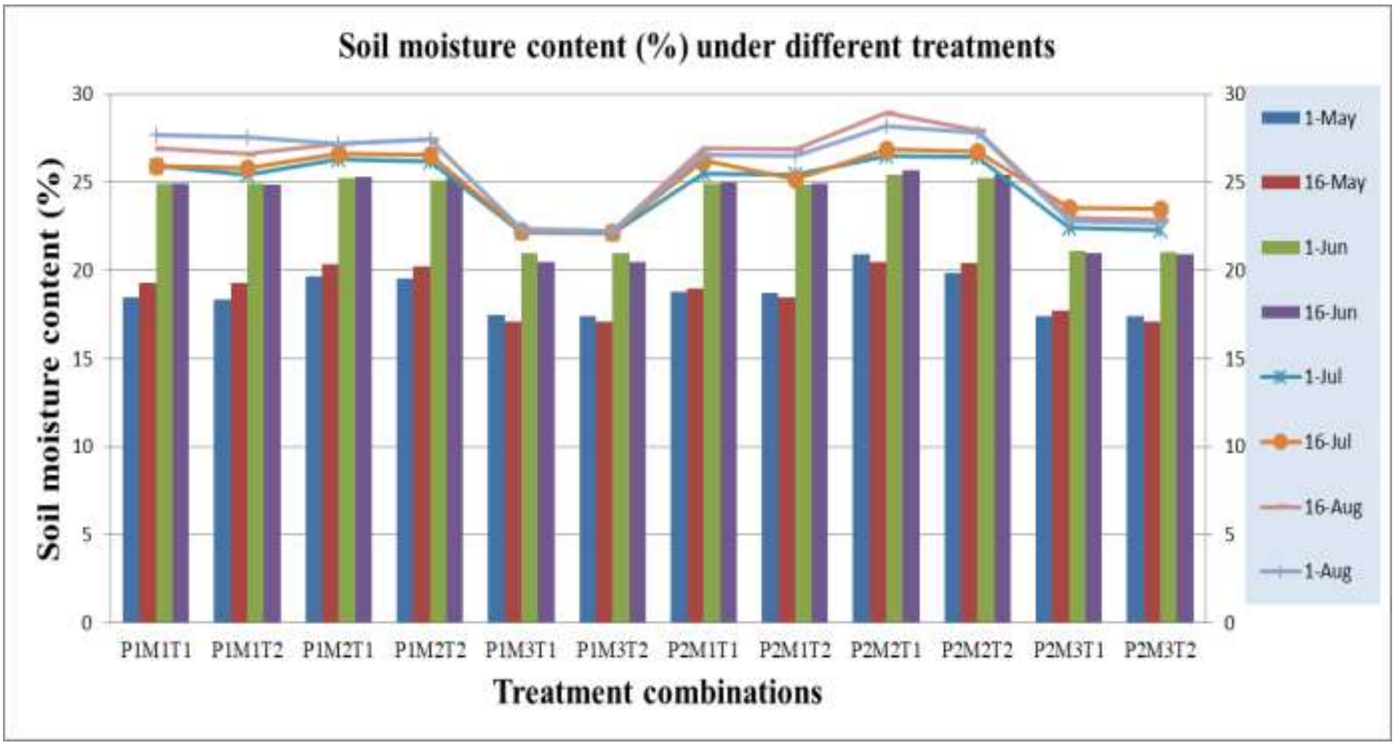

Fig. 1: Soil moisture content (%) at 0-15 cm soil depth under different treatments during cropping period of 2017-2018

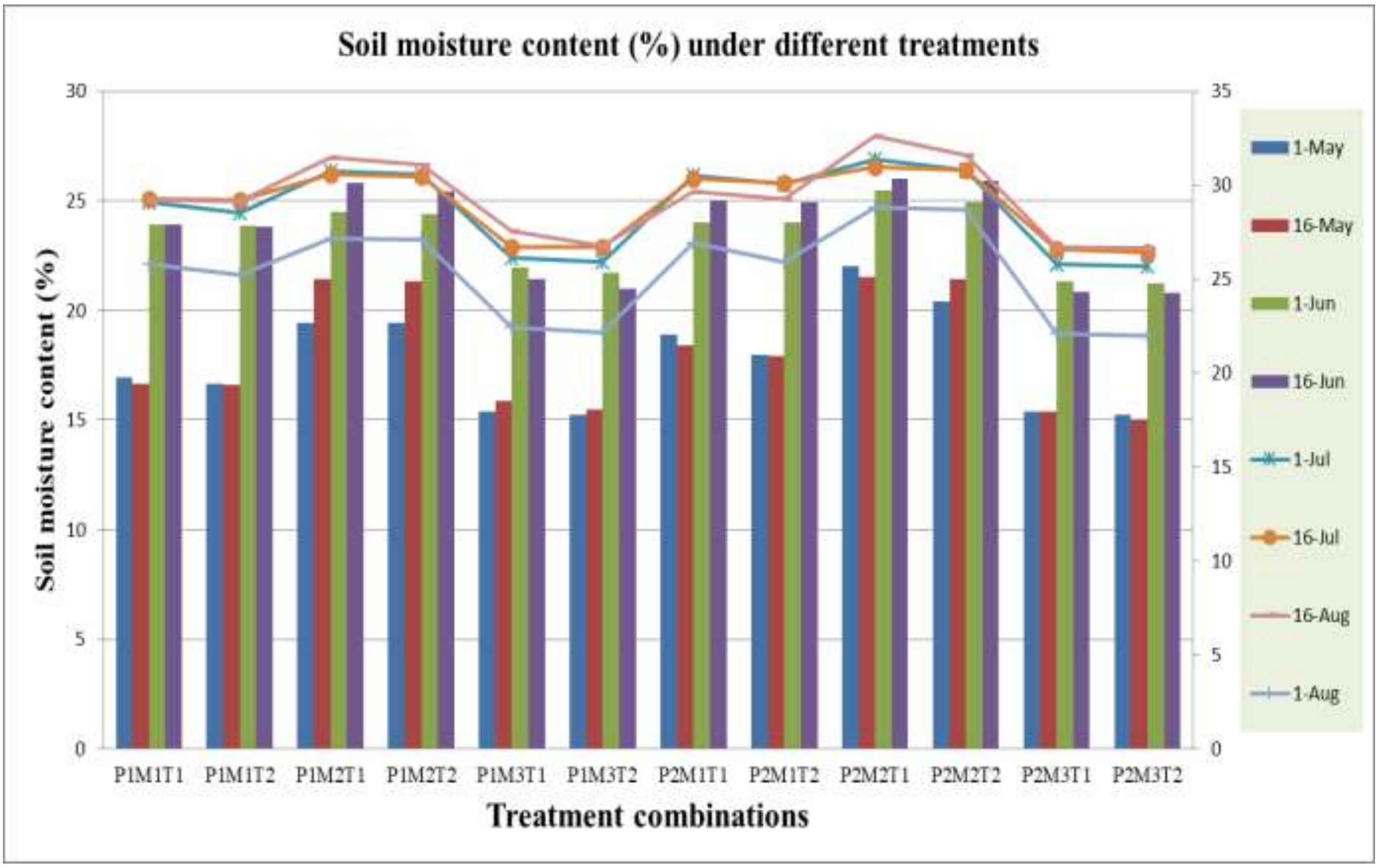

Fig. 2: Soil moisture content (%) at 0-15 cm soil depth under different treatments during cropping period year 2018-2019

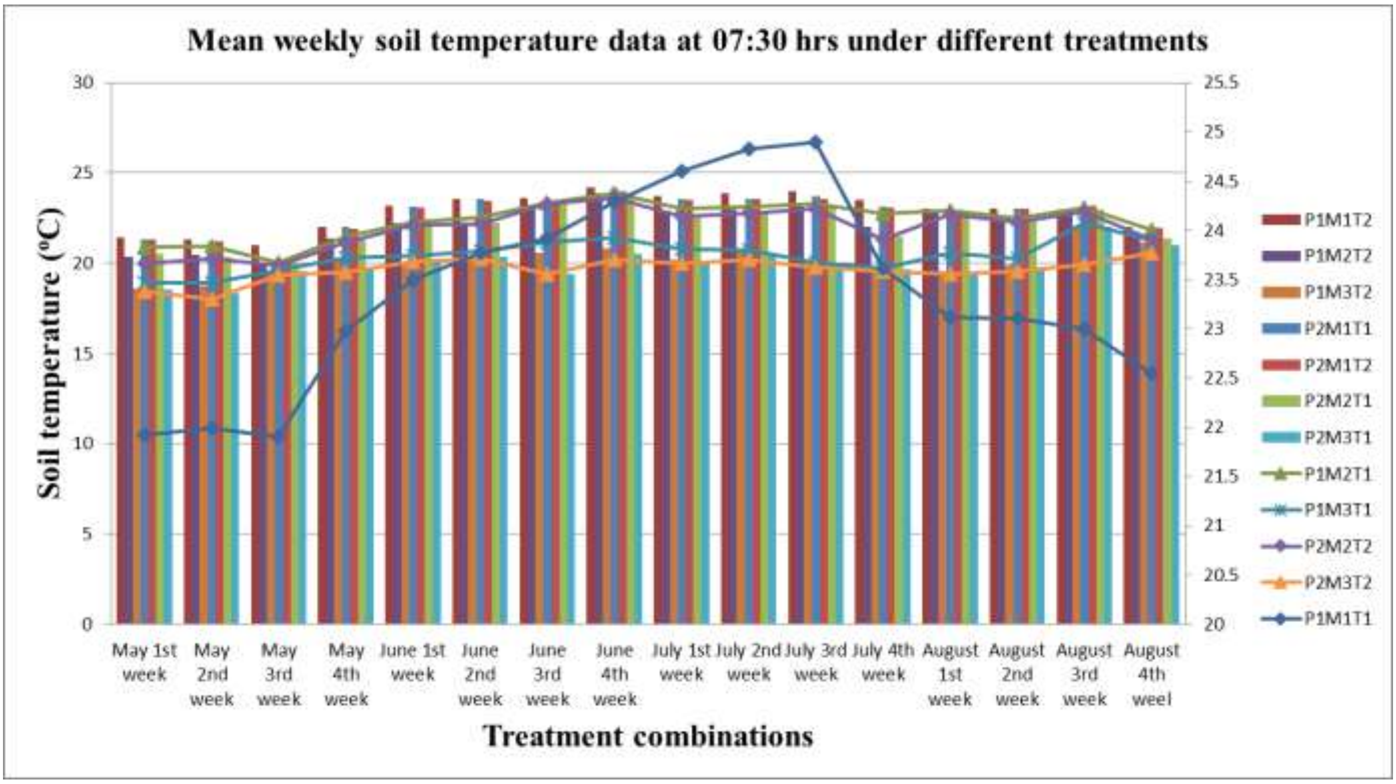

Fig. 3: Mean weekly soil temperature (° C at 07:30 hrs) at 0-5 cm soil depth under different treatments during 2017-2018

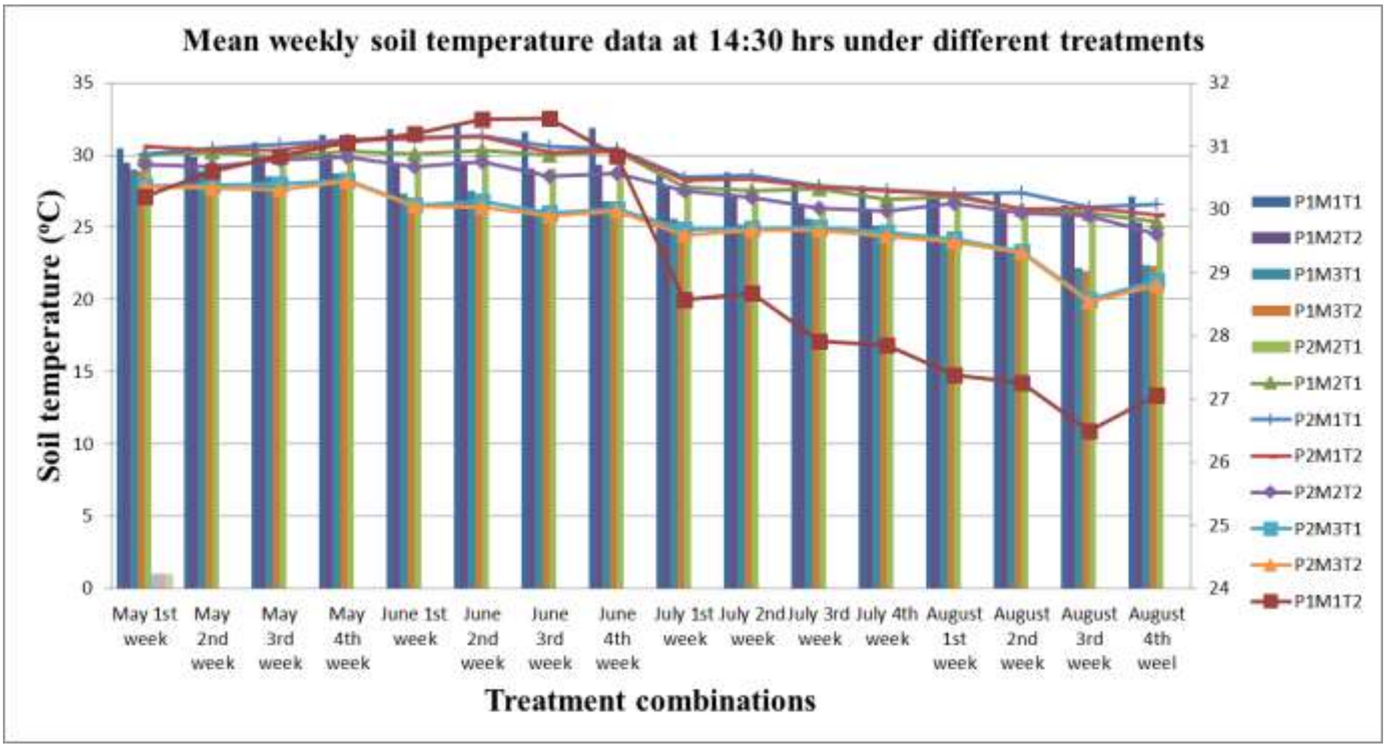

Fig 4: Mean weekly soil temperature (° C at 14:30 hrs) at 0-5 cm soil depth under different treatments during 2017-2018

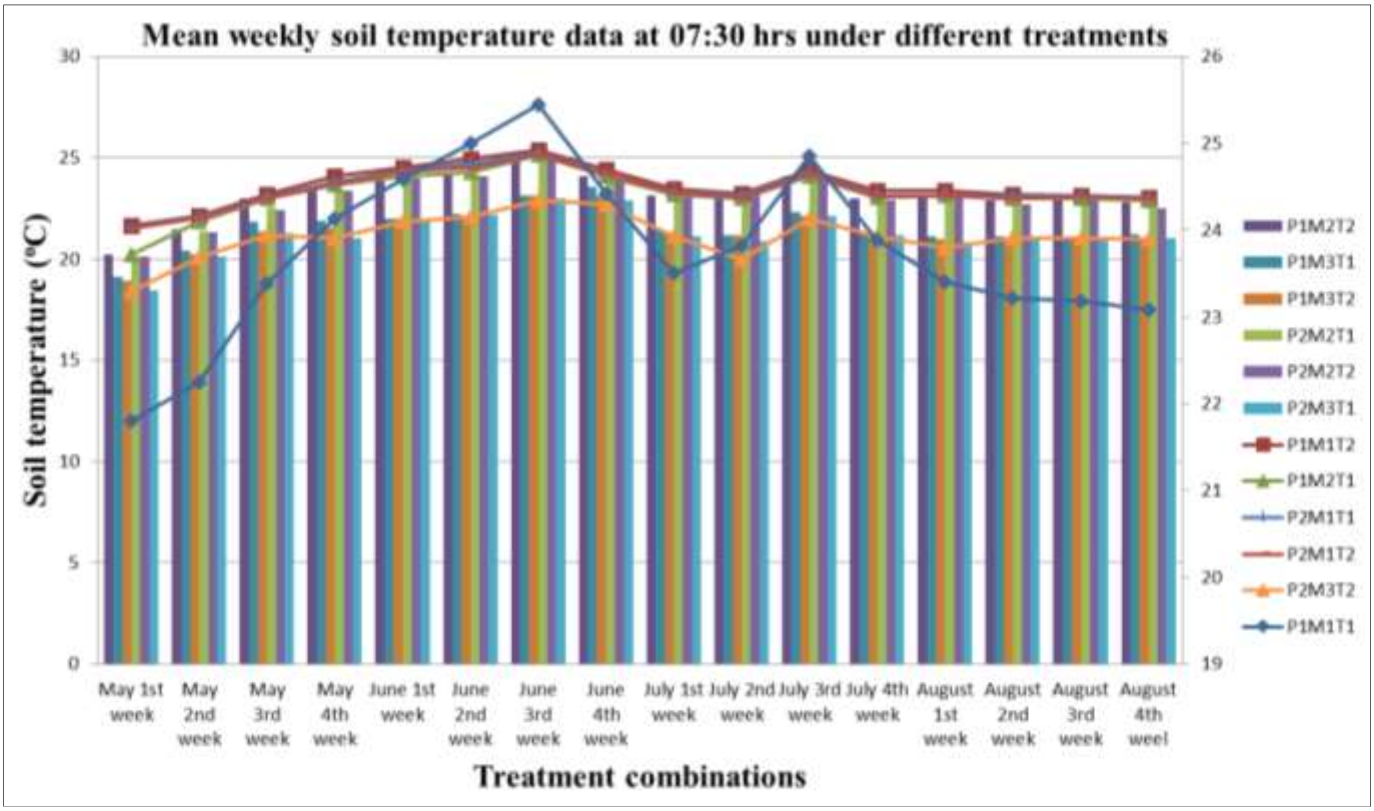

Fig. 5: Mean weekly soil temperature (° C at 07:30 hrs) at 0-5 cm soil depth under different treatments during 2018-2019

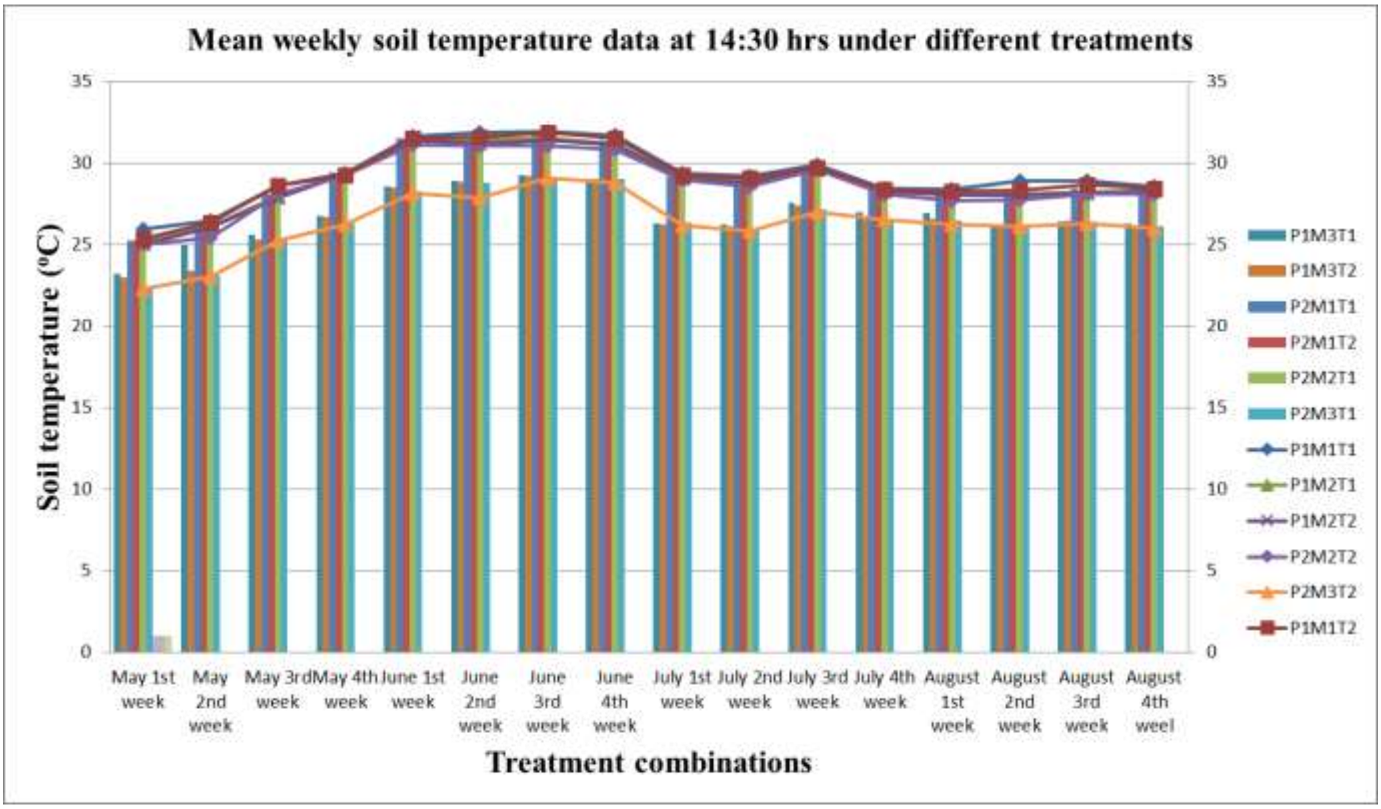

Fig. 6: Mean weekly soil temperature (° C at 14:30 hrs) at 0-5 cm soil depth under different treatments during 2018-2019

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