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Effect of Raised Bed, Mulching and Training System on Soil Temperature and Yield of Tomato (*Solanum lycopersicum* L.)

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ABSTRACT

Background: The use of crop improvement practices in vegetable cultivation has increased during the last years.

Methods: A field experiment was conducted on tomato (*Solanum lycopersicum* L.) at Research Farm of Vegetable Science, Dr YSP UHF Nauni, Solan in the year 2018-2019 in a randomized complete block design with three replications in order to evaluate the effects of planting methods, mulching and training system on soil temperature and yield of tomato. Treatments consisted of planting methods (raised bed, flat bed), mulching treatments (black mulch, silver/black mulch and no mulch) and training systems (two stem training and three stem training).

Result: Results of the study indicated highest values of plant height, fruit weight,yield and soil temperature were observed under raised bed planting methods, black mulch along with two stem trained plants. Also black coloured mulch had significantly higher values of marketable yield. The highest soil temperature was found to be higher by about 1 to 10°C as compared to no mulch plot. It can be concluded that use of black colour mulch significantly increased the growth, yield and yield contributing characters of tomato under the open field conditions.

Key words: Black mulch, Silver/black mulch, Soil temperature, Tomato, Training system, Yield.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the popularly grown and highly valuable vegetable crop worldwide ranking second followed by potato. Over the last century, tomato has attained a tremendous popularity because it can be grown in most places all over the world, like growing in open fields, greenhouses and net houses (Singh *et al*., 2017). It is one of the most highly praised vegetables consumed worldwide because is a rich source of vitamins A, C, potassium, minerals, fibre, antioxidants and essential amino acids therefore considered as protective food (Sainju *et al*., 2003). The tomato (*Solanum lycopersicum* L.), which is neither a vegetable nor a fruit but rather a berry, is now found all over the world and is an important component of most civilizations' cuisines. In India, value added has risen through the ranks of the agriculture policy agenda in order to support small family farms and producers in an era of economic liberalisation, commercialization and internationalization. Tomato is a fruit used as a vegetable mainly because of the low sugar content. It is consumed both in fresh as well as processed forms. Tomato varieties are now available with double the vitamin-C, 40 times more vitamin-A, high levels of anthocyanins and 2-4 times more lycopene compared to that in traditional varieties. Tomato contains over 80 nutrients beneficial to human. Tomato is a good source of vitamins, minerals and other useful substances like fiber which are necessary for good health. Tomato contains lycopene and beta-carotene pigment. Lycopene is one of the most important components in tomato as it has been found to have a vital role in protecting humans. Being a powerful antioxidant it has the ability to protect living cells and other structures in the body from oxygen damage and maintain DNA integrity in white blood cells.

During the last decade practice of raised bed planting has been emerge with a greater pace specially in high value vegetable crops. The major concern of this system is to enhance the productivity, maintain soil temperature and save the irrigation water. Raised bed planting system in which crops are sown on the beds. The height of the beds is maintained at about 12 to 15 cm and width of about 37 to 107 cm depending on the crops (Naresh *et al*., 2010; and Singh *et al*., 2010). The practice of mulching has been utilized to great advantage in the development of horticultural crops. Mulching is one of the important practices of covering the soil to make more favourable conditions for plant growth, development and efficient crop production. It also reduces the weed population, moderates soil temperature, improving

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soil structure and improves the microbial activity of the soil. It is important to maintain sufficient foliage on the plant for adequate rates of photosynthesis. Manipulation of canopy architecture through pruning and training together with appropriate spatial arrangements has been identified as key management practices for getting maximum marketable yields. Therefore, tomato yield could be increased substantially through improved agronomic techniques like training and pruning (removal of side shoots and lower shoots). 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 to reduce risk of fungus and insect problems (Herbert, 1998).

Raised bed combined with black plastic mulch nowadays gaining popularity, because of its profitability in the long term. The objectives of the present study were to measure effect of different agro-techniques on soil temperature and yield parameters of tomato.

MATERIALS AND METHODS

Two experiments were conducted during the year 2017-18 and 2018-19 at the Research Farm of Dr YSP UHF Nauni, Solan, HP. The variety used for the research work was Solan Lalima. The experimental design was both year a randomized block design with twelve treatments and 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 (Table 1). The observations were recorded on the parameters regarding plant height (cm), fruit weight (gm), yield per plot (kg) and soil temperature (°C). Soil temperature was measured throughout the plant growth period using mercury in-glass soil thermometers in each 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. 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 data pertaining to the present investigation were statistically analyzed using the standard procedures of the factorial randomized block design (RBD) using MS Excel and OP STAT online software.

RESULTS AND DISCUSSION

It is clear from the data presented in Table 2 that there was a significant effect of different planting methods, mulches and training systems on plant height, fruit weight and yield per plant of tomato. Treatment combination $P_1M_1T_1$ (raised bed, black mulch and two stem training system) recorded significantly maximum plant height (187.49 and 186.43 cm), fruit weight (139.49 and 141.93 g) and fruit yield per plant (3.32 and 3.38 kg). According to Locher *et al.* (2003), in raised bed treatment the average fruit weight was significantly higher than the flat bed. They were of the opinion that the

Table 1: Detail of treatments used in the studies.

Treatment code	Treatment details
$P_IM_1T_I$	Raised bed + Black mulch + Two stem training
$P_IM_1T_2$	Raised bed + Black mulch + Three stem training
$P_IM_2T_1$	Raised bed + Silver/black mulch + Two stem training
$P_IM_2T_2$	Raised bed + Silver/black mulch + Three stem training
$P_IM_3T_1$	Raised bed + No mulch + Two stem training
$P_IM_3T_2$	Raised bed + No mulch + Three stem training
$P_2M_1T_I$	Flat bed + Black mulch + Two stem training
$P_2M_1T_2$	Flat bed + Black mulch + Three stem training
$P_2M_2T_1$	Flat bed + Silver/black mulch + Two stem training
$P_2M_2T_2$	Flat bed + Silver/black mulch + Three stem training
$P_2M_3T_1$	Flat bed + No mulch + Two stem training
$P_2M_3T_2$	Flat bed + No mulch + Three stem training

Table 2: Effect of planting methods, mulching and training systems on number plant height (cm), fruit weight (g) and fruit yield per plant (kg) of tomato.

Treatment	Plant height (cm)		Fruit weight (g)		Fruit yield per plant (kg)	
combination	2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
$P_1M_1T_1$	187.49	186.43	139.49	141.93	3.32	3.38
$P_1M_1T_2$	165.87	167.58	130.71	133.71	3.11	3.18
$P_1M_2T_1$	176.71	176.08	133.84	138.50	3.19	3.30
$P_1M_2T_2$	164.95	163.93	129.62	130.87	3.09	3.12
$P_1M_3T_1$	174.97	172.59	116.84	113.31	2.78	2.70
$P_1M_3T_2$	163.69	165.09	112.42	109.60	2.68	2.61
$P_2M_1T_1$	173.25	174.93	125.10	126.41	2.98	3.01
$P_2M_1T_2$	165.92	164.99	120.40	117.65	2.87	2.80
$P_2M_2T_1$	171.99	169.85	123.69	123.35	2.95	2.94
$P_2M_2T_2$	171.99	169.85	123.69	123.35	2.95	2.94
$P_2M_3T_1$	166.92	166.57	118.64	114.25	2.83	2.73
$P_2M_3T_2$	157.18	154.95	106.26	104.25	2.53	2.48
$CD_{0.05}$	6.32	5.97	4.51	4.45	0.15	0.23

main reason behind significantly maximum fruit weight in the fruits produced by raised bed treatment was the more favorable root zone temperature and drainage than in the flat bed. According Helaley *et al.* (2017) main reason of significantly higher average fruit weight using black mulch treatment was due to more favorable root zone temperature conditions compared to unmulched plots. 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. 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) could be due to reduced fruit size and weight in three stem training system because of reduced assimilates availability in the source and increased demand in the sink. Mantur and Patil (2008) in tomato also found a larger number of fruits per plant with the increament in the number of pruned tomato branches per plant. Anand *et al.* (2018) in tomato crop who observed higher number of marketable fruits and total yield.

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 (Table 3, 4, 5 and 6). 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 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 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

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

	May				June				July				August			
TC	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
(7:30)	week	week	week	week	week	week	week	week	week	week	week	week	week	week	week	week
$P_1M_1T_1$	21.92	21.99	21.90	22.98	23.50	23.77	23.92	24.29	24.60	24.83	24.90	23.61	23.12	23.11	23.00	22.55
$P_1M_1T_2$	21.40	21.31	21.00	22.01	23.20	23.55	23.59	24.18	23.70	23.88	23.98	23.50	23.00	23.04	22.99	22.02
$P_1M_2T_1$	20.90	20.93	20.02	21.49	22.30	22.56	23.34	23.87	23.00	23.12	23.31	22.76	22.90	22.48	23.05	21.87
$P_1M_2T_2$	20.34	20.45	20.00	21.35	22.22	22.29	23.22	23.85	22.80	22.95	23.12	22.00	22.87	22.34	23.00	21.41
$P_1M_3T_1$	18.90	18.91	19.60	20.32	20.40	20.68	21.14	21.42	20.80	20.72	20.05	19.73	20.56	20.24	22.20	21.28
$P_1M_3T_2$	18.60	18.73	19.55	20.22	20.00	20.24	20.58	20.83	20.20	20.65	20.04	19.58	19.58	19.89	22.05	21.16
$P_2M_1T_1$	21.34	21.23	20.12	22.00	23.14	23.53	23.44	24.12	23.55	23.56	23.74	23.11	23.00	23.02	22.81	22.01
$P_2M_1T_2$	21.30	21.21	20.03	21.89	23.06	23.47	23.41	24.00	23.49	23.54	23.55	23.07	22.97	23.00	23.20	21.98
$P_2M_2T_1$	20.50	20.35	19.99	21.25	22.14	22.20	23.30	23.76	22.60	22.82	23.05	21.45	22.84	22.33	22.97	21.35
$P_2M_2T_2$	20.00	20.23	19.90	21.13	22.10	22.15	23.29	23.61	22.58	22.75	23.00	21.33	22.71	22.25	22.84	21.33
$P_2M_3T_1$	18.56	18.32	19.58	19.73	20.00	20.33	19.42	20.54	20.15	20.53	19.81	19.68	19.45	19.66	22.00	21.00
$P_2M_3T_2$	18.44	18.00	19.34	19.52	20.10	20.25	19.38	20.22	20.00	20.18	19.75	19.55	19.40	19.54	19.95	20.58

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

	May				June				July				August			
TC	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
(14:30)	week	week	week	week	week	week	week	week	week	week	week	week	week	week	week	week
$P_1M_1T_1$	30.50	30.62	30.90	31.42	31.80	32.04	31.60	31.89	28.61	28.77	28.00	27.86	27.45	27.32	26.51	27.11
$P_1M_1T_2$	30.20	30.60	30.85	31.06	31.20	31.42	31.44	30.85	28.57	28.67	27.91	27.85	27.38	27.25	26.49	27.05
$P_1M_2T_1$	30.00	30.23	29.90	30.25	30.10	30.34	30.00	30.29	27.80	27.54	27.69	26.95	27.12	26.29	26.00	25.41
$P_1M_2T_2$	29.50	29.89	30.00	30.14	29.40	29.61	29.10	29.36	27.74	27.29	26.54	26.24	27.00	26.20	25.90	25.35
$P_1M_3T_1$	29.00	28.95	28.52	28.75	27.30	27.52	26.25	26.78	25.60	25.19	25.58	25.13	24.35	23.31	22.20	22.41
$P_1M_3T_2$	28.85	28.45	28.20	28.47	26.80	27.06	26.20	26.44	24.91	24.98	25.28	25.00	24.21	23.18	22.00	22.33
$P_2M_1T_1$	30.10	30.49	30.75	31.04	31.19	31.33	30.58	30.43	28.44	28.58	27.88	27.61	27.31	27.42	26.40	26.59
$P_2M_1T_2$	30.60	30.33	30.34	31.00	31.11	31.27	30.20	30.33	28.25	28.31	27.82	27.52	27.27	26.26	26.33	25.85
$P_2M_2T_1$	29.44	29.33	29.90	29.91	29.24	29.57	29.08	29.33	27.81	27.15	26.45	26.22	26.98	26.10	25.80	25.00
$P_2M_2T_2$	29.31	29.22	29.70	29.87	29.21	29.51	28.50	28.73	27.56	27.09	26.33	26.14	26.69	26.00	25.78	24.54
$P_2M_3T_1$	27.87	27.94	28.00	28.28	26.50	26.78	26.00	26.24	24.87	24.95	24.99	24.64	24.18	23.35	19.99	21.30
$P_2M_3T_2$	27.77	27.76	27.58	28.20	26.45	26.40	25.80	26.11	24.49	24.80	24.82	24.42	24.00	23.23	19.87	21.00

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

	May				June				July				August			
TC (7:30)	1st week	2nd week	3rd week	4th week	1st week	2nd week	3rd week	4th week	1st week	2nd week	3rd week	4th week	1st week	2nd week	3rd week	4th week
$P_1M_1T_1$	21.80	22.25	23.38	24.13	24.59	25.00	25.45	24.42	23.51	23.82	24.85	23.88	23.41	23.22	23.18	23.08
$P_1M_1T_2$	21.64	22.12	23.20	24.11	24.50	24.96	25.37	24.41	23.45	23.21	24.36	23.35	23.39	23.19	23.14	23.03
$P_1M_2T_1$	20.21	21.86	23.00	23.67	24.09	24.29	25.13	24.09	23.18	23.00	24.11	23.04	23.11	22.98	23.01	22.90
$P_1M_2T_2$	20.20	21.47	22.97	23.55	24.08	24.22	25.10	24.08	23.11	22.98	24.09	23.00	23.08	22.87	23.00	22.78
$P_1M_3T_1$	19.13	20.42	21.84	21.88	22.00	22.23	23.13	23.58	21.43	21.18	22.32	21.23	21.13	21.11	21.13	21.20
$P_1M_3T_2$	18.92	20.21	21.36	21.54	21.97	22.13	23.11	23.11	21.17	21.16	22.12	21.19	20.96	21.09	21.08	21.10
$P_2M_1T_1$	21.55	22.09	23.04	23.82	24.36	24.72	25.25	24.20	23.33	23.13	24.28	23.15	23.14	23.06	23.11	23.02
$P_2M_1T_2$	21.49	22.04	23.01	23.72	24.33	24.53	25.16	24.18	23.27	23.02	24.18	23.07	23.13	23.00	23.08	23.00
$P_2M_2T_1$	20.13	21.35	22.56	23.45	24.05	24.17	25.08	24.07	23.10	22.59	24.08	22.96	23.04	22.78	23.00	22.68
$P_2M_2T_2$	20.11	21.32	22.43	23.37	24.00	24.10	25.00	24.00	23.05	23.49	24.01	22.87	23.00	22.68	22.89	22.52
$P_2M_3T_1$	18.45	20.11	21.28	21.03	21.96	22.16	22.98	22.88	21.13	20.89	22.11	21.18	20.84	21.11	21.03	21.02
$P_2M_3T_2$	18.38	20.08	21.16	21.01	21.82	22.08	22.87	22.69	21.11	20.00	22.00	21.11	20.55	21.01	21.01	21.00

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

	May				June				July				August			
TC (14:30)	1st week	2nd week	3rd week	4th week	1st week	2nd week	3rd week	4th week	1st week	2nd week	3rd week	4th week	1st week	2nd week	3rd week	4th week
$P_1M_1T_1$	25.96	26.46	28.62	29.35	31.63	31.87	31.94	31.72	29.36	29.18	29.88	28.46	28.38	28.89	28.88	28.54
$P_1M_1T_2$	25.38	26.36	28.60	29.26	31.53	31.57	31.85	31.52	29.28	29.11	29.74	28.36	28.28	28.33	28.65	28.45
$P_1M_2T_1$	25.13	26.11	28.00	29.38	31.40	31.38	31.53	31.15	29.11	28.83	29.63	28.42	28.10	28.12	28.22	28.33
$P_1M_2T_2$	25.02	26.05	27.84	29.34	31.38	31.19	31.42	31.10	29.02	28.77	29.58	28.24	28.06	28.05	28.18	28.25
$P_1M_3T_1$	23.22	24.93	25.58	26.75	28.53	28.88	29.24	29.05	26.31	26.22	27.56	26.99	26.92	26.23	26.43	26.30
$P_1M_3T_2$	22.98	23.38	25.33	26.68	28.49	28.86	29.18	29.00	26.22	26.13	27.42	26.65	26.58	26.22	26.44	26.14
$P_2M_1T_1$	25.26	26.34	28.19	29.43	31.52	31.63	31.83	31.42	29.18	28.88	29.77	28.35	28.19	28.21	28.44	28.25
$P_2M_1T_2$	25.23	26.12	28.03	29.40	31.43	31.42	31.74	31.36	29.24	29.01	29.68	28.34	28.16	28.13	28.33	28.14
$P_2M_2T_1$	25.01	26.01	28.52	29.30	31.18	31.10	31.11	30.98	29.00	28.68	29.63	28.22	28.00	28.00	28.14	28.15
$P_2M_2T_2$	25.00	25.41	28.12	29.27	31.09	31.08	31.04	30.82	28.95	28.55	29.59	28.10	27.70	27.75	28.09	28.08
$P_2M_3T_1$	22.34	23.10	25.32	26.30	28.24	28.78	29.13	29.00	26.33	26.00	27.14	26.60	26.49	26.20	26.41	26.12
$P_2M_3T_2$	22.30	23.01	25.23	26.25	28.16	27.85	29.06	28.77	26.18	25.82	27.00	26.55	26.23	26.12	26.30	26.02

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°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; Angmo *et al*. 2018 and Amare and Dasta, 2021).

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