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RESEARCH ARTICLE

Integration of raised beds, mulching and stem training for weed management in tomato under mid-hill conditions of Himachal Pradesh

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ABSTRACT

A field experiment was conducted at the Research Farm of Vegetable Science, DR YSPUHF, Nauni, Solan (HP), India to evaluate the effect of polythene mulches, planting methods and training systems on weed control and yield response of tomato crop. The experiment was laid out in factorial randomized block design with twelve treatments and replicated thrice. The consortium effect of raised bed (RB) + black polythene mulch (BPM) + two stem training have recorded less weed density (142.00/m^2), greater weed control efficiency (64.64%), less fresh (82.00 g/m^2) and dry weed biomass (13.00 g/m^2) and higher yield (100.12 t/ha). The dominance of *Cyperus rotundus*, *Echinochloa crus-galli* and *Galinsoga parviflora* weed species was also less with the integration of raised bed, black polythene mulch and two stem training system. This practice helps in the tomato production with better water conservation; weed management and improved tomato yield under mid-hill conditions of Himachal Pradesh.

Keywords: Black polythene mulch, Mulching, Raised bed system, Stem training, Tomato, Weed control efficiency

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is considered both as a vegetable and a fruit and has a number of uses. Weed management has always been an important component of tomato production (Bhullar *et al.* 2015). The negative implications of weeds in term of yield losses (45 to 60% in tomato) and the cost of its control are often ignored by farmers (Kaur *et al.* 2015). Weeds compete with crops for water, nutrients, space, light and oxygen resulting into a delay in maturity and low yield. The transplanted tomato's initial growth is slow and thus weeds pose a great problem during its initial slow growth stage of transplanted tomato and the weed competition during critical growth period could lead to tomato yield reduction up to 54.9% (Ved and Srivastava 2006)) and also reduces the quality and market value (Brown *et al.* 2019). Thus, weed control has always been an important constituent of tomato production (Bhullar *et al.* 2015).

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The manual weeding is becoming costly due to increasing cost of labour and reduced availability of labour. Controlling weeds with herbicides is possible but, overuse of herbicides causes environmental concerns because herbicides have negative effects on beneficial organisms also, may pollute the food and groundwater with their residue, and cause toxicity in mammalians (Sharma *et al.* 2019). Therefore, environment friendly, efficient and cost-effective weed management is essential. Growing of tomatoes on raised beds, black polythene mulch, along with a two stem has been identified as an alternative method that can increase not only the yield but also to manage weeds (Chaudhari *et al.* 2019, Hussain *et al.* 2016 and Alam *et al.* 2016). This study was conducted with an objective to evolve a cost-effective weed management method by integrating the cultural practices like planting bed systems, mulching and training systems for managing weeds in tomato.

MATERIALS AND METHODS

The field trial was conducted during *Kharif* (rainy) season of 2017-18 and 2018-19 at Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (Himachal Pradesh), Vegetable Experimental Farm [35^{0}5'N latitude and 77^{0}11'E longitude at an elevation of 1270 m (above MSL)]. Tomato cultivar '*Solan Lalima*' was taken as

experimental material. Treatments comprised of combinations of two different planting techniques: raised bed and flat-bed, three mulch treatments: black polythene, silver/black polythene, and no mulch, and two training systems; two stem and three stem training (**Table 1**). Two stem method was achieved by planting one seedling in a plot and allowing the sucker at the bottom to grow as the second main stem, which resulted in the growth of double leader stems. Three stem training method was achieved by planting one seedling and then allowing the two suckers at the bottom to grow as the three stem, which resulted in the growth of three stems trained plants.

The soil of experimental site was sandy loam, having pH 6.6, organic carbon 6.78 mg/L of soil, available nitrogen 312.56 kg/ha, phosphorus 22.15 kg/ha and potassium 154.5 kg/ha. Farm Yard Manure and fertilizers were applied as per package of practices for vegetable crops (RDF: 100 N: 75 P: 55 K kg/ha). The fertilizers were applied manually at the time of preparation of the experimental filed and nitrogen was given in three split doses. The experiment was laid out in randomized block design (factorial) with three replications, consisting of 12 treatments: raised bed + black mulch + two stem training, raised bed + black mulch + three stem training, raised bed + silver/black mulch + two stem training, raised bed + silver/black mulch + three stem training, raised bed + no mulch + two stem training, raised bed + no mulch + three stem training, flat bed + black mulch + two stem training, flat bed + black mulch + three stem training, flat bed + silver/black mulch + two stem training, flat bed + silver/black mulch + three stem training, flat bed + no mulch + two stem training, flat bed + no mulch + three stem training. The height of raised beds was 15 cm and each bed was separated at a 45 cm distance. Black polyethylene mulch and silver/black mulch of 50µ (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. Mulches of 50µ (200-gauge thickness) were applied in plots according to the treatment combinations. Mulches were applied one week prior of transplanting of the crop.

Weed density

Weed density was collected from each plot with the help of a quadrat of 1×1 m ($1m^2$) by placing the quadrat randomly in each plot. For this, the quadrate was placed randomly in each plot and the total number of weeds growing within the quadrate was counted.

Weed control efficiency

WCE was calculated at harvest as per the formula given below (Kondap and Upadhyay 1985). Lesser the weed index, better is the efficiency of the herbicide. It is expressed in percentage and was determined with the help of following formula: Where, WI = Weed index; X = Crop yield from weed free plot (hand weeding) and Y = Crop yield from the treated plot for which weed index is to be worked out.

$$WCE = \frac{DMC - DMT}{DMC} \times 100$$

Where,

WCE= Weed control efficiency (percent)

DMC= Dry matter production of weeds in control (weedy check) plots

DMT= Dry matter production of weeds in treatments.

Fresh and dry weight (biomass) of weeds

Observations on the fresh and dry weight (biomass) (g/m^2) of weeds were recorded from an area of 1×1 m in each plot. Fresh weight was recorded just after the collection of weeds from the field while dry weight was recorded after drying of weeds in an oven at 70°C and expressed as gram/m^2. Number of harvests varied within the treatment combinations. Yield per plot was calculated by pooling the weight of the all the tomato fruits harvested over all the pickings in a given plot/ treatment. On the basis of yield obtained from each plot in kilogram, yield per hectare was calculated in quintals. The results were similar during both the years. Hence, the data was pooled to show the results in a single table.

Statistical analysis

The data recorded was statistically analysed for interpretation (Panse and Sukhatme 2000). Yes pooled analysis of data for two years has been done. Statistical analysis of data was done manually on MS Excel sheet.

Post hoc test: Post hoc ("after this" in Latin) tests are used to uncover specific differences between three or more group means when an analysis of variance (ANOVA) F test is significant. The level of significance is 0.05. Probability is a branch of mathematics that deals with the occurrence of a random event.

RESULTS AND DISCUSSION

Effect of bed configuration, mulch and training systems on weeds and yield of tomato

Bidens Pilosa, *Commelina benghalensis*, *Echinochloa crus-galli*, *Galinsoga parviflora*, *Nicandra physalodes* and *Cyperus rotundus* were the predominant weeds in the experimental field.

The planting technique, mulch application and training had significant effect on weed density, weed control efficiency, fresh and dry biomass of weeds and tomato yield (t/ha) (**Table 2**). The raised bed planting method recorded less number of weeds (467.89/m^2), highest weed control efficiency (40.24%), least weeds fresh biomass (213.28 g/m^2), least weeds dry biomass (34.28 g/m^2) of weeds and produced more (90.29 t/ha) yield as compared to flat bed system. Regarding the effects of mulches, covering with black plastic mulch resulted in lesser weed density (207.42/m^2), greater weed control efficiency (52.62%), lower fresh weed biomass (113.25 g/m^2) and dry weed biomass (22.58 g/m^2) and higher tomato yield (916.58 g/ha) as compared to silver/black polythene mulched and non-mulched beds. In the case of training system, the two-stem training system had less weeds density (472.94/m^2), higher weed control efficiency (37.61%), least fresh weed biomass (245.11 g/m^2), least dry weed biomass (36.50 g/m^2) and higher yield (88.20 t/ha). The weed density and biomass were higher in the silver-coloured mulch as it allowed more solar radiation passed through it and was made available to weeds (Ramakrishna *et al.* 2006) in tomato.

Raised bed planting technique, black polythene mulch and plants trained to two stem training system recorded minimum weed density and greater weed control efficiency. In the raised beds, it could be due to less tillage and maintenance of the raised bed since, once the soil in a raised bed is stabilized, compaction is almost non-existent, so the need for tillage is minimal. Therefore, the weed population decreased over time in a raised bed which are well cared and managed. Black mulch prevented the weed seeds to germinate (Hussain *et al.* 2016) and created partially anaerobic conditions for the survival of weed species and thus resulted low weed density. Mulching enhances the soil moisture retention and improves the soil temperature which helps boost crop performance making the crop more competitive against the associated weeds. Reduced number of weeds under the two-stem training system might be due to unavailability of visible light spectrum resulting into reduced photosynthetic activity and therefore less number of weeds. Greater the competition for light lesser will be the absorbance of radiations resulting into reduced emergence of weeds along together with poor growth of germinated seeds (Brown *et al.* 2019). There was complete elimination of weeds under black polyethylene mulch. Similar findings were also reported by Ramakrishna *et al.* (2006) in tomato.

Consortium effect on weeds and yield of tomato

Interaction effect of planting technique + mulching + training (**Table 3**) caused less weeds density (142.0/m^2), higher weed control efficiency (62.24%), low fresh (82.00 g/m^2) and dry (13.00 g/m^2) biomass of weeds and higher tomato yield (100.12 t/ha) with raised bed + black polythene mulch + two stem training system.

Weed control efficiency (%) was positively correlated with tomato yield. The probable reason of

Table 1. Effect of planting methods, mulches and training systems on weed density, biomass and yield (pooled data for two years)

Treatment	Weed density (no./m^2)	Weed control efficiency (%)	Fresh weight of weeds (g/m^2)	Dry weight of weeds (g/m^2)	Yield (t/ha)
Planting method					
Raised bed	467.89	42.53 (40.24)	213.28	34.28	90.30
Flat bed	541.17	28.04 (28.68)	303.50	43.17	81.46
LSD (p=0.05)	41.43	2.20	9.79	1.77	1.15
Mulches					
Black polythene mulch	207.42	62.74 (52.62)	113.25	22.58	91.66
Silver polythene mulch	301.67	33.08 (34.92)	130.58	39.92	89.47
No mulch	1004.50	10.03 (15.84)	531.33	53.67	76.51
LSD (p=0.05)	50.74	2.69	11.99	2.17	1.41
Training system					
Two stem training systems	472.94	38.83 (37.61)	245.11	36.50	88.20
Three stem training system	536.11	31.74 (31.31)	271.67	40.94	83.55
LSD (p=0.05)	41.43	2.20	9.79	1.77	1.15

*Figures in parentheses represent angular transformation

maximum weed control efficiency using black polythene mulch could be due to conservation of moisture and reduction of temperature in the top soil which suppressed the weed growth. This is due to the fact that solar radiations transmittance is more in case of silver plastic mulch compared to black mulch as explained by Shylla *et al*. (2005). The present findings are in conformity with the report of Awodoyin *et al.* (2007) who reported that plastic mulches improve the performance of tomato due to less crop weed competition. Another reason could be less moisture depletion resulting into more water stress to the weeds vis-à-vis better availability of water to the economic part *i.e*. tomato plant. In the present studies, minimum fresh and dry weight of weeds was recorded in the plots mulched with black polythene. This may be due to lower weed density and short time of weed crop association to accumulate dry weight by weeds. Appearance of minimum number of the weeds through the holes and 100% (weed count) control of the weeds could be the reason for reduced fresh weight and consequently minimum dry weight of the weeds in okra (Muhammed *et al.* 2015), in tomato (Rajablariani *et al.* 2012) and in aonla (Iqbal *et al.* 2016). Raised beds with mulch cover gaining more and more importance in India, because tomato production in an open field can maintain its profitability in the long term just in case of using intensive production technology. It might be due to the reason that the soil in a raised bed is more stabilized and therefore compaction is almost non-existent so the need for seasonal tilling is minimal (Berle and Westerfield 2013). Another reason could be proper drainage facility which allows the plant roots to breathe properly as compared to the weeds, quick warming up of the soil, allowing the longer growing season and better growing conditions for the plants in the raised beds as compared to the flat beds (Locher *et al.* 2003).

Table 2. Interaction effect on weed density, weed biomass and yield of tomato

Consortium	Weed density (no./m^2)	Weed control efficiency (%)	Fresh biomass of weeds (g/m^2)	Dry biomass of weeds (g/m^2)	Yield (t/ha)
Raised bed + black polythene mulch+ two stem training system	142.00	78.26 (62.24)	82.00	13.00	100.12
Raised bed + black polythene mulch + three stem training system	209.33	64.68 (52.61)	89.33	21.00	94.31
Raised bed + silver/black polythene mulch + + two stem training system	265.33	41.93 (40.35)	98.33	34.67	97.71
Raised bed + silver/black colored polythene mulch + three stem training system	305.00	38.52 (38.35)	112.33	36.67	92.32
Raised bed + No mulch + + two stem training system	860.00	16.15 (23.64)	402.00	50.00	79.93
Raised bed + No mulch three stem training system	1025.67	15.62 (23.24)	495.67	50.33	77.32
Flat bed + Black polythene mulch + two stem training system	221.00	58.12 (49.68)	139.00	25.00	89.18
Flat bed + black polythene mulch + three stem training system	257.33	49.89 (44.94)	142.67	31.33	83.00
Flat bed + silver/black colored polythene mulch + two stem training system	310.00	30.14 (33.29)	152.67	41.67	87.02
Flat bed + silver/black colored polythene mulch + three stem training system	310.00	30.14 (33.29)	152.67	41.67	87.02
Flat bed + No mulch + two stem training system	326.33	21.71 (27.69)	159.00	46.67	80.81
Flat bed + No mulch + three stem training system	1093.00	1.00 (1.00)	631.00	59.67	73.54
LSD (p=0.05)	NS	5.39	23.97	3.88	NS

*Figures in parentheses represent angular transformation

Table 3. Effect of different treatments on economics of tomato

Treatment	Yield (t/ha)			*Gross return (`/ha)	Cost of cultivation (`/ha)	Net return (`/ha)	B: C ratio
	2017-18	2018-19	Pooled				
Raised bed + black mulch + two stem	99.27	99.84	100.12	1501875	307591	1194284	3.88
Raised bed + black mulch + three stem	91.95	94.90	94.31	1414605	315991	1098614	3.48
Raised bed + silver/black mulch + two stem	102.40	94.19	97.71	1465605	315591	1150014	3.64
Raised bed + silver/black mulch + three stem	96.66	91.23	92.32	1384875	323991	1060884	3.27
Raised bed + No mulch + two stem	79.71	80.81	79.93	1198995	254804	944190	3.71
Raised bed + No mulch + three stem	77.01	77.40	77.32	1159740	263204	896535	3.41
Flat bed + black mulch + two stem	90.78	88.78	89.18	1337715	299191	1038523	3.47
Flat bed + black mulch + three stem	82.75	83.19	83.00	1244955	307591	937363	3.05
Flat bed + silver/black mulch + two stem	87.39	88.13	87.02	1305285	307191	998093	3.25
Flat bed + silver/black mulch + three stem	88.32	86.04	87.02	1305285	315591	989693	3.14
Flat bed + No mulch + two stem	78.81	80.14	80.81	1212210	246404	965805	3.92
Flat bed + No mulch + three stem	72.99	73.36	73.54	1103175	254804	848370	3.33

Effect on economics

The highest cost of cultivation ₹ 323991/ha was with raised bed + silver/black mulch and three stem training system which was followed by raised bed + black mulch + three stem training system (₹ 315991/ ha), whereas lowest cost of cultivation (₹ 246404/ha) was observed in flat bed + no mulch + two stem training system (**Table 3**). The raised bed + black mulch + two stem training system recorded both highest net return of ₹ 1181364/ha and highest benefit: cost ratio of 3.88.

It was concluded that by integrating the raised bed planting with black polythene mulching and two stem training system, higher weed control efficiency, net returns and B:C ratio can be obtained in transplanted tomato crop cultivation under mid-hill conditions of Himachal Pradesh.

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