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INTEGRATION OF ROW SPACING, MULCHING AND HERBICIDES ON WEED MANAGEMENT IN TOMATO

TAMANA BAKHT[1*], IJAZ AHMAD KHAN[1], KHAN BAHADAR MARWAT[2] AND ZAHID HUSSAIN[1]

[1]*Department of Weed Science, The University of Agriculture Peshawar, 25130-Peshawar, Pakistan*
[2]*SBBU, Sheringal, Dir Upper, Pakistan*
[*]*Corresponding author's email: tamannabakht@yahoo.com*

Abstract

A field experiment was conducted at the Research Farm of The University of Agriculture, Peshawar during the year 2012 to determine the impact of row spacing and weed management strategies on tomato (*Lycopersicon esculentum* Mill.). The local variety 'Roma' was sown in a randomized complete block (RCB) design with split plot arrangements, having four replications. The main plots were row spacings while subplots of the experiment comprised of ten treatments including five mulches viz., white and black polyethylene, wheat straw, newspaper and saw dust, three herbicide treatments (fenoxaprop-p-ethyl, pendimethalin and s-metolachlor), hand weeding and a weedy check. The data were recorded on weed density m^{-2}, fresh and dry weed biomass, number of branches $plant^{-1}$, and fruit yield (kg ha^{-1}). All these parameters were significantly affected by row spacing and weed management treatments. Increase in weed population was observed with increasing in row spacing. The competitiveness of tomato with weeds can be enhanced by using black plastic as mulch. In light of the results, the row spacing of 60 cm is the optimum one for tomato plants, as the fruit yields decreased at 40 cm and 80 cm row spacing.

Introduction

Tomato (*Lycopersicon esculentum* L.) a member of family Solanaceae, is one of the most commonly grown vegetables in the world. It is reported to have been imported to Indo-Pak subcontinent by the Europeans in the second half of the nineteenth century. In the beginning, tomato was consumed here by the Europeans but later on it became popular amongst the rich classes of local population and now commonly used in one form or other in kitchen as well as fresh salad (Shahid, 1999; Marwat, *et. al*., 2002., Djordjevic *et al*., 2013). It is a rich source of vitamins A and C, potassium and fiber. Tomato is rich in lycopene (Dimascio *et al*., 1989) that is used in the fight against cancer, especially the prostate cancer (Giovannucci *et al*., 1995; Giovannucci, 1999 and Mills *et al*., 1989). A ripened tomato of 130 g contains 94% water, 25 calories of food energy, 28 mg of ascorbic acid, 0.07 mg thiamin, 0.05 mg riboflavin, 16 mg calcium, 33 mg phosphorus, 0.6 mg Iron, 3-4 mg sodium, 300 mg potassium (Hartmann *et al*., 1988). According to Anon., (2009), China is the world's leader in tomato production. The per-hectare production of tomato in our country is very low in comparison to other tomato producing countries. There are several reasons for the low yields but weeds play a bigger role, not only reducing yield, quality and value of the crops but also increase production and harvesting costs of the crop (Saleem *et al*., 2013a).

Weeds reduce crop yields by competing for light, space, water and nutrients that weaken the crops, while some weeds serve as alternate hosts for other pests, like, insects, diseases, viruses and or nematodes (Shah *et al.*, 2013). The critical period of weed competition is 4-6 weeks after sowing (Marana *et al*., 1986); therefore, weeds should be checked during this period. Weeds reduce fruit yield by 70%, depending on stage and duration of competition (Marana *et al*., 1986). The first four weeks are critical in many vegetable crops, theefore during this period weeds should be removed (Shadbolt and Holm, 1956) and 57% reduction in tomato yield may take place when compared with weed free conditions (Govindra *et al*., 1986). They further reiterated that one hand weeding in addition to herbicide application significantly increased crop yield. Unrestricted weed competition throughout the crop life cycle results in 92-95% reduction in tomato fruit yield (Adigun, 2000).

Herbicides work best if soil moisture is adequate for plant growth. Pre emergence herbicides will check germinating seeds but not the dry seeds. On the other hand, post emergence herbicides are best on plants that are not stressed for moisture. Non stressed plants translocate the herbicide from where it is absorbed (mostly leaves) to the site of action. Therefore, both the pre- and post emergence herbicides are tested in this experiment. Although herbicides can be effective in controlling weeds, they are also expensive and often beyond the budget of farmers in Pakistan. In addition, herbicide use requires special equipment and expertise to ensure proper herbicide rates are used and proper human health and safety precautions are employed (Saleem *et al*., 2013b).

Mulching is a recent and important non-chemical weed control method used in high value vegetable crops mainly. Mulching is employed to cover the soil surface with different materials to obtain high biological activity, retain soil moisture and to achieve a good control of weeds. The row spacing affects the light interception and also influences the space available for weeds and crops to grow. Row spacing can also influence the shape of tomato canopy and branching, thereby influencing flowering and fruiting as well as crop competitiveness with weeds. Row spacing is often determined by the type of planting and harvesting equipment available, and will result in different crop yields and can influence overall economic return.

Considering the importance of tomato, the costs of weeds in terms of yield reduction, expenditure on their control, and the different options available for weed control, farmers in Pakistan need more information about the effectiveness and economics of various methods for managing weeds. The present study was carried out to investigate the feasibility of using mulch materials in combination with herbicides and varying row spacing for controlling weeds and their impact on yield and yield components of tomato.

Materials and Methods

A field experiment was conducted at the Research Farm of The University of Agriculture, Peshawar, during 2012 to determine the impact of row spacing and weed management strategies on tomato yield. The experiment was laid out in a randomized complete block (RCB) design with split plot arrangements having three replications. Row spacing was allocated to main plots while herbicides and mulches were assigned to the sub plots. The soil structure of the experimental site was clay loam. Seeds of local variety of tomato "Roma" were planted at the Horticulture Research Farm of the University in a well prepared seed bed as nursery. Seedlings of uniform size were transplanted and then irrigated. All other agronomic practices, except treatments were kept constant.

Ploughing was done to prepare the soil and then ridges were made to accommodate different row spacing. Fifty-days-old seedlings were transplanted on March 22, 2012 and irrigation of the experimental plots was done immediately after transplanting; three days thereafter, mulch treatments were applied. Herbicides were applied using the rates as given below with the help of knapsack sprayer. The size of each sub plot (the experimental unit) was 4.8m x 3m. Tomato seedlings were planted on ridges with ten plants per row keeping a constant plant-to-plant distance of 30 cm.

The three different row spacing were assigned to main plots (40cm, 60cm and 80cm), whereas the 10 weed management treatments subjected to the subplots were, polyethylene (white), polyethylene (black), wheat straw @ 1 kg m^{-2}, saw dust @ 1 kg m^{-2}, paper mulch as required, fenoxaprop-p-ethyl @ 2.0 kg a.i ha^{-1}, s-metolachlor @ 1.5 kg a.i ha^{-1}, pendimethalin @1.44 kg a.i. ha^{-1}, a hand weeding and a weedy check. Data were recorded on weed density m^{-2}, fresh and dry weed biomass, no. of branches plant^{-1} and interpreted along with fruit yield, already reported (Bakht & Ijaz, 2014). All the parameters were subjected to analysis technique using LSD test (Steel & Torrie, 1980).

Results and Discussion

Weed density m^{-2}: Row spacing effect was not significant, while treatment effect and row spacing by treatment interaction was significant (Table 1). Though the row spacing had no significant effect, however, with increase in row spacing there was an increase in weed density. Among the treatments, highest number of 20.44 weeds m^{-2} was observed in weedy check and lowest of 7.91 weeds m^{-2} in hand weeding. Among other treatments, polyethylene (Black) was most effective reducing weed density to 9.49 weeds m^{-2}, second lowest to hand weed weeding. All herbicides were statistically similar in effecting weed density. Among the interaction polyethylene (Black) was equally effective across all the three row spacings. Similarly, the trend of all other treatments (excluding weedy check and no weeding) was similar. Our results are in line with those reported by Monks *et al*., (1997) who concluded that hand weeding and mulching provided satisfactory weed control.

Fresh weed biomass (kg ha^{-1}): Fresh biomass of weeds was significantly affected by row spacing as well as treatments, whereas row spacing by treatment interaction was not significant (Table 2). Highest fresh weed biomass of 648kg ha^{-1} was observed in 80cm row spacing followed by 60cm row spacing having biomass of 508 kg ha^{-1} and lowest of 413 kg ha^{-1} was observed in 40cm row spacing. In narrow row spacing, higher competition did not allow more resources to be utilized; therefore weeds in narrow spacing were less healthy compared to those in wide row spacing. In hand weeding, the average biomass was less (74kg ha^{-1}), as most of the weeds were removed. Surprisingly all other treatments were statistically at par, thereby meaning that at the end of season, the treatment effect was diluted and did not control the weeds. Similarly the mulches were also cut into pieces and were not effective at the end of the season, as were also displaced by irrigation water or blow by air at the end of the season.

Table 1. Weed density m^{-2} as affected by different treatments in tomato.

Treatments	Row spacing (cm)			Treatments Means
	40	60	80	
Polyethylene (white)	9.97efgh	9.80efgh	12.60defg	10.70
Polyethylene (black)	8.10fgh	8.30fgh	12.07defg	9.49
Wheat straw	11.17defg	13.07	10.17efgh	11.47
Saw dust	11.63fgh	15.07cde	11.63defg	12.78
Paper mulch	9.53defg	9.20fgh	12.50defg	10.41
fenoxaprop-p-ethyl	11.77defgh	19.10bc	11.63defg	14.17b
s-metolachlor	10.83efgh	10.53efgh	15.97bcd	12.44bc
Pendimethalin	10.40gh	12.50defg	14.97cde	12.62bc
Hand weeding	7.33def	5.73h	10.67defgh	7.91 d
Weedy check	13.07def	21.00b	27.27a	20.44 a
Row spacing Means	10.38	12.43	13.95	

$LSD_{0.05}$ (Row spacing) = ns, $LSD_{0.05}$ (Treatments) = 4.155, Interaction effect = 5.404

Table 2. Fresh weed biomass (cm) as affected by different treatments in tomato crop

Treatments	Row spacing (cm)			Treatments Means
	40	60	80	
Polyethylene (white)	296	393	536	408 de
Polyethylene (black)	251	300	407	319 e
Wheat straw	576	590	710	625 bc
Saw dust	538	612	758	636 bc
Paper mulch	257	415	486	386 de
fenoxaprop-p-ethyl	577	674	771	674 ab
s-metolachlor	326	473	658	486 cde
Pendimethalin	435	505	704	548 bcd
Hand weeding	218	326	419	321 e
Weedy check	652	806	1028	828 a
Row spacing Means	413 b	509 ab	648 a	

$LSD_{0.05}$ (Row spacing) = 219.2, $LSD_{0.05}$ (Treatments) = 176.8, Interaction effect = ns

Table 3. Dry Weed Biomass (cm) as affected by different treatments in tomato crop.

Treatments	Row spacing (cm)			Treatments Means
	40	60	80	
Polyethylene (white)	99	89	140	109 bc
Polyethylene (black)	89	11	165	122 ab
Wheat straw	105	150	166	140 ab
Saw dust	112	146	159	139 ab
Paper mulch	95	113	128	112 abc
fenoxaprop-p-ethyl	120	152	194	155 a
s-metolachlor	110	124	139	124 ab
Pendimethalin	107	133	151	130 ab
Hand weeding	73	70	79	74 c
Weedy check	143	165	166	157 a
Row spacing Means	106 b	125 ab	149 a	

$LSD_{0.05}$ (Row spacing) = 40.1, $LSD_{0.05}$ (Treatments) = 45.4, Interaction effect = ns

Dry weed biomass: Dry weight of weeds was significantly affected by row spacing as well as treatments. However, their interaction was not significant (Table 3). Dry weed biomass in 40cm row spacing (106 kg ha^{-1}) increased to 125 kg and 149 kg ha^{-1} in 60cm and 80cm row spacing, respectively. Among the treatments, weedy check produced a dry biomass of 157 kg ha^{-1} at par with fanoxaprop treatments (155 kg ha^{-1}), thereby meaning that weed control due to this herbicide at later stage was negligible and not effective enough to bring about measurable change in weed biomass. As whole the impact of herbicide, was statistically not different from one another. Similarly, neither of the mulches was significantly different from herbicides. Hand weeding reduced the dry weight of weeds to 74 kg ha^{-1}, the lowest among the treatments (Table 3). Since wider row spacing gave enough space to weeds to develop their canopies, therefore higher dry biomass in wide rows is understanble. Among the treatments, hand weeding continued till late as per farmers practice, therefore weed biomass was reduced resultantly. The impact of herbicide at later stage was diminished, therefore had little or no impact on biomass. Similarly, at later stages of the crop, the mulches were either taken away by wind/water or cut into prices (in case of polyethylene) with the passage of time.

Number of branches plant^{-1}: The number of branches plant^{-1} was significantly affected by increase in the row spacing. Similarly, the treatment effect was also highly significant. The row spacing by treatment interaction was not significant (Table 4). Among treatments, highest number of branches (19.59) was observed in hand weeding; followed by black polyethylene (9.53), paper mulch (8.97), white polyethylene (8.61), saw dust (6.18) and wheat straw (5.94) among the mulches. While among the herbicides, highest number of branches was observed in s-metolachlor (7.31) followed by pendimetalene (6.37) and fenoxaprop (8.82), respectively. Compared to other treatments, in the weedy check the number of branches was lowest (5.40) (Table 4). In weedy check little space was available to tomato crop to produce more branches. Similarly those herbicides which were not effective in controlling weeds also could not produce space for tomato to produce branches. Similarly, black polyethylene was more effective in controlling weeds, therefore enabled tomato to produce more branches per plant.

Table 4. Number of branches plant^{-1} (cm) as affected by different treatments in tomato crop.

Treatments	Row spacing (cm)			Treatments Means
	40	60	80	
Polyethylene (white)	7.80	8.27	9.77	8.61 ab
Polyethylene (black)	8.70	9.40	11.13	9.53 ab
Wheat straw	5.27	5.40	7.17	8.61 abc
Saw dust	5.67	5.93	6.93	9.53 ab
Paper mulch	7.87	8.93	10.10	5.94 de
fenoxaprop-p-ethyl	4.80	5.93	6.73	6.18 anc
s-metolachlor	6.27	7.20	8.47	8.97 ab
Pendimethalin	5.40	6.40	7.33	5.28 e
Hand weeding	9.40	11.40	11.27	7.31 bcde
Weedy check	4.80	5.13	6.27	10.69 a
Row spacing Means	6.53	7.40	8.52	5.40 e

$LSD_{0.05}$ (Row spacing) = ns, $LSD_{0.05}$ (Treatments) = 2.322, Interaction effect = ns

Table 5. Fruit yield (t ha^{-1}) as affected by different treatments in tomato crop

Treatments	Row spacing (cm)			Treatments Means
	40	60	80	
Polyethylene (white)	2.88	2.64	1.97	2.49 bcd
Polyethylene (black)	3.88	3.95	4.30	4.04 a
Wheat straw	1.61	2.16	1.63	1.80 de
Saw dust	1.91	2.10	1.51	1.84 cde
Paper mulch	3.00	2.72	2.32	2.68 bc
fenoxaprop-p-ethyl	1.40	1.92	1.30	1.54 e
s-metolachlor	2.22	2.51	1.89	2.21 cde
Pendimethalin	1.92	2.29	1.77	1.99 cde
Hand weeding	3.69	2.94	3.33	3.32 ab
Weedy check	1.28	1.83	1.09	1.40 e
Row spacing Means	2.38 ab	2.51 a	2.11 b	

$LSD_{0.05}$ (Row spacing) = 0.323, $LSD_{0.05}$ (Treatments) = 0.8748, Interaction effect = NS

Fruit yield (t ha^{-1}): Row spacing and various weed management strategies had significant effect on fruit yield of tomato while their interactions were not significant. Among the main effects i.e. varying row spaces, highest fruit yield of 2.51 t ha^{-1} was recorded at row spacing of 60 cm which was however statistically at par with row spacing of 40 cm and statistically different from 80 cm (Table 5). It indicated that 60 cm row spacing was the optimum one for tomato plants. The fruit yield was decreased at 40 cm and 80 cm row spacing which might be attributed to intra-specific competition at the lowest row spacing of 40 cm and inter-specific competition at highest row spacing of 80 cm. Increasing the row spacing definitely provides enough room for weeds to invade the empty niches and start competing with the tomato plants for the resources i.e., space water, nutrients and light. However, decreasing the row spacing from the recommended spacing will although do not provide enough room for the emerging weeds but there will be an intra specific competition among tomato plants themselves. Crop yield is always decreased at higher plant densities (Marwat, 2002, Mudarres *et al*., 1998). Limited availability of soil resources contribute to lower fruit yield inspite of decreasing the row spacing in crops (Sobkowicz & Tendziagolska, 2005).

Among weed management treatments, the application of polyethylene black plastic resulted in significantly highest fruit yield (4.04 t ha^{-1}) which was however statistically at par with the treatment of hand weeding (3.32 t ha^{-1}) as given in Table 5. The best treatment was followed by paper mulch (2.68 t ha^{-1}) and polyethylene white (2.49 t ha^{-1}), while the lowest fruit yield (1.4 t ha^{-1}) was recorded in weedy check, which was though statistically similar to that of fenoxaprop-p-ethyl treatments with fruit yield of 1.54 t ha^{-1}. The competitiveness of tomato with weeds can be enhanced by using black plastic as mulch. It is a general concept that one kilogram weed biomass in one's field will correspond to a loss of one kilogram of crop yield (Rao, 2000). The interaction effect of row spacing and the various weed control techniques was non-significant. Table 3 also revealed that the fruit yield of tomato crop was highest (4.30 t ha^{-1}) in 80 cm pacings where polyethylene black (plastic) was used as mulch. This was followed by the treatment of black plastic with 60 cm (3.95 t ha^{-1}) 40 cm spacing (3.88 t ha^{-1}), respectively. This shows that black plastic was more effective in increasing crop yield, indicating that the weeds were effectively controlled through the shadowing of the covered weeds disabling them to perform photosynthesis that reduced their competitiveness. The hand weeded treatments gave lower yields than the black plastic mulch which may be actually because of the fact that hand weeding cannot eliminate the hidden underground propagules of the perennial weeds which later in the season re-grew and inflicted certain yield losses; whereas the black plastic not only physically burried the perennial weeds from emerging and growing but also the underground propagules were suffocated because of increased temperature and reduced light availability. Yield losses in crops occur due to accumulation of weed biomass and weeds density (Mamolos & Kalburtji, 2001; Aman & Rab, 2013).

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