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WEED CONTROL IN TOMATO (*LYCOPERSICON ESCULENTUM* Mill.) THROUGH MULCHING AND HERBICIDES

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Abstract

Experiments were conducted at the Agricultural Research Farm of the University of Agriculture, Peshawar during 2012 and 2013 to determine the impact of row spacing and weed management strategies on tomato (*Lycopersicon esculantum* Mill.). Variety 'Roma' was planted on a plot size of 4.8m x 3m using a randomized complete block (RCB) design in split plot arrangements, having four replications. The experiment comprised of row spacing in main plots and ten treatments in the subplots that included five mulches viz., white polyethylene, black polyethylene, wheat straw, newspaper and saw dust; three herbicide treatments i.e. fenoxaprop-p-ethyl, pendimethalin, s-metolachlor along with a hand weeding treatment and a weedy check. The data were recorded on weed density m^{-2} at 20 days after treatments, plant height, fruit yield (kg ha^{-1}). All the studied parameters were significantly affected by the row spacing (factor A) and weed management treatments (factor B); however, the interaction effects were non-significant. An increase in weed density was observed with increase in row spacing, having weed density of 3.39, 4.19 and 4.53 weeds m^{-2} for 40, 60 and 80 row spacing, respectively. The overall weed density m^{-2} ranged between 3.24 to 4.30 m^{-2}. A maximum plant height of 62.44cm was recorded in weedy check and minimum 53.31cm plant height was observed in hand weeding treatments. As regards the fruit yield, a highest yield of 2.51 t ha^{-1} was recorded at row spacing of 60 cm (factor A) and the application of poly ethylene black plastic resulted in significantly highest fruit yield (4.04 t ha^{-1}) among factor B treatments.

Introduction

Tomato is a popular and nutritive vegetable crop ranking next to potato in world's vegetable production. Tomato is an important source of minerals and antioxidants such as carotenoids, lycopene, vitamins C, E and phenolic compounds, which have a key role in human nutrition to prevent certain cancer and cardiovascular diseases (Adalid *et al*., 2004). Tomatoes are consumed in a number of ways including sun-dried tomatoes, tomato sauce, tomato juice, tomato soup, tomato ketchup and fresh as salad (Frusciante *et al.*, 2007). In Pakistan, during 2008-09 tomato was grown on 53.40 thousand hectares with a production of 561.9 thousand tons and in the province of Khyber Pakhtunkhwa the figures were 16.50 thousand ha and 161.8 thousand t, respectively with an average yield of 9.8 tons ha^{-1} (Anon., 2010).

According to Anonymous (2009), China is the world's leading tomato producing country (45,365,543 tons), followed by USA (14,141,900 tons), India (11,148,800 tons), Turkey (10,260,600 tons) and Italy (6,877,400 tons), while Pakistan ranks at the 35th with production of 561,900 tons annually. The per-hectare production of tomato in our country is very low as compared to the other tomato producing countries. Several reasons are responsible for the low yields among which weeds have a big role that not only reduce yield, quality and value of the crops but also increase production and harvesting costs at the same time.

Weeds reduce yields by competing for space, light, water and nutrients, weakening crop stand and reduce harvest efficiency (Abbasi *et al.*, 2013). Some weeds can also increase other pest problems by serving as alternate hosts for insects, diseases, or nematodes. Although weed control has always been an important component of tomato production, its importance has increased with the introduction of the sweet potato whitefly and development of the associated irregular ripening problem. Increased incidence of several viral disorders of tomatoes also reinforces the need for good control of weeds which may act as alternate hosts. Marana *et al*., (1986) estimated the critical period of weed competition to be 30-40 days after sowing; therefore, they recommended that weeds should be removed for 40-50 days after sowing. They further noted that the presence of weeds reduced fruit yield by 70% depending on stage and duration of competition. Shadbolt & Holm (1956) also concluded from their studies that the first four weeks were critical in many vegetable crops, during which time weeds should be removed. Govindra *et al*., (1986) found that weeds resulted in a 57% reduction in tomato yield when compared with weed free conditions. They further reported that one hand weeding in addition to herbicide application significantly increased yield. Adigun (2000) reported that unrestricted weed growth throughout the crop life cycle resulted in 92 to 95% reduction in tomato fruit yield.

Herbicides work best if soil moisture is adequate for plant growth. Pre emergence herbicides will kill germinating seeds but not dry seeds. However, these materials should not be applied to wet soils because application equipments can cause soil compaction, particularly where power driven rotary tillers are used for soil incorporation. Post emergence herbicides work 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 (George *et al.*, 2013; Shamim *et al.*, 2013). 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 particular equipment and expertise to be sure that proper rates are used and that human health and safety are protected. Mulching is a recent and important non-chemical weed control method. It is necessary to cover the soil surface with different materials to obtain high biological activity, retain soil moisture and to achieve a good control of weeds.

Row spacing affects light interception and also influences the space available for weeds to grow. Row spacing can also affect the plant canopy (tomato) shape 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 many options available for weed control, farmers in Pakistan need more information about the effectiveness and economics of methods for managing weeds in tomatoes. The present study was designed to investigate the feasibility of using mulch materials and herbicides as a weed control approach and varying row spacing for controlling weeds in tomato in Peshawar with the objectives to evaluate effects of different mulches and herbicides on yield and yield components of tomato, to evaluate the effectiveness and economics of different types of mulches for weed control in tomato crop, to evaluate the effect of various row spacing on tomato yield and weeds, and to evaluate possible interactions between row spacing, herbicides and mulches.

Materials and Methods

Field experiments were conducted at New Developmental Farm, the University of Agriculture, Peshawar, during 2012 and 2013 to determine the impact of row spacing and weed management strategies on tomato. The experiment was laid out in a Randomized Complete Block (RCB) design with a split plot arrangement replicated four times. 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 "Roma" were planted at the Horticulture Research Farm in a well prepared seed bed in the month of March. Seedlings of uniform size were transplanted and then irrigated. All other agronomic practices were kept constant.

Ploughing was done to prepare the soil and then ridges were made to accommodate different row spacing. Fifty-day-old seedlings were transplanted on March 22nd 2012. Immediately after transplanting, irrigation of the experimental plots was done, and 3 days thereafter, mulch treatments were applied. Herbicides were applied using the rates as given below with the help of knapsack sprayers. The size of each sub plot 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 treatments in the main plots were 40cm, 60cm and 80cm, whereas the ten weed management treatments in the subplots were

polyethylene (white), polyethylene (black), wheat straw @ 1.0 kg m^{-2}, saw dust @ 1.0 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}, hand weeding and weedy check. During the course of studies the data were recorded on weed density m^{-2} at 20 days after treatment, plant height and fruit yield (kg ha-1). The data for each parameter were subjected to analysis of variance technique and the means were separated by LSD test (Steel & Torrie, 1980).

Results and Discussion

Weed density m^{-2} at 20 DAT: As depicted in Table 1, the effect of row spacing and treatments was significant ($p<0.05$) and highly significant ($p<0.01$), respectively; however, the interaction effect of row spacing and treatments was not significant. After subjecting the means to LSD test for effect of row spacing on weed density, there was an increase in weed density with increase in row spacing, with weed density of 3.39, 4.19 and 4.53 weeds m^{-2} for 40, 60 and 80 row spacing respectively. A high average weed density of 6.18 m^{-2} was found in weedy check, followed by other treatments (Table 1). Though the differences from one another were not substantial, the range of minimum and maximum was 3.24 to 4.30. Among the subplot treatments, the effect of mulches and herbicides was statistically similar. However, the hand weeding slots had the minimum weed density of 2.47, significantly lower than all other treatments. Our results are in line with those reported by Monks *et al.,* (1997) who concluded that hand weeding and some mulches provided satisfactory weed control.

Table 1. Weed density m^{-2} at 20 days after application of different treatments in tomato.

Treatments	Row spacing (cm)			Treatments means
	40	60	80	
Polyethylene (white)	3.17	3.93	4.13	3.74 bc
Polyethylene (black)	2.77	3.80	3.17	3.24 bc
Wheat straw	3.70	4.13	4.83	4.22 b
Saw dust	3.97	4.27	4.33	4.19 b
Paper mulch	2.87	4.13	4.9	3.97 b
Fenoxaprop-p-ethyl	3.90	3.77	4.37	3.97 b
s-metolachlor	3.53	4.60	4.77	4.30 b
Pendimethalin	3.63	4.00	4.80	4.14 b
Hand weeding	1.77	2.93	2.70	2.47 c
Weedy check	4.77	6.5	7.36	6.18 a
Row spacing means	3.39 b	4.19 ab	4.53 a	

$LSD_{0.05}$ (Row spacing) = 1.124, $LSD_{0.01}$ (Treatments) = 1.270, Interaction effect = NS

Plant height: The row spacing and weed management treatments affected the height of tomato significantly. However, the interaction of row spacing with treatments was not significant (Table 2). With increase in row spacing, the height decreased from a maximum of 62.39 in 40cm row spacing to a minimum of 51.04 in 80cm row spacing. Among the subplot treatments maximum average plant height of 66.44cm was recorded in weedy check whereas minimum height of 53.31 was observed in hand weeding. Statistically, the mulches and herbicide treatments were at par with one another (Table 2). In small rows, interaction competition including quest for reaching sun light is high. This is established in high populations, the plant height is always large compared to thin population, as in dense population the plants are trying to reach and harvest maximum of the sunlight, therefore became taller (Saccol & Estefanel, 1995; Mishra, 2000). Similarly in weedy check inter-specific competition is high, therefore again plant became taller in such competitive environments. The data in Table 2 also indicated that maximum plant height of 62.44cm was recorded in weedy check. However, it was statistically similar with paper mulch and sawdust (59.80cm), followed by fenoxaprop-p-ethyl (60.57cm). A minimum plant height of 53.1 was observed in hand weeding. Polyethylene white (56.30) and poly ethylene black (54.82) were also in same range. In the interaction effect, weedy check had highest plants i.e. 56.2, 64.0 and 67.13cm in 80, 60 and 40cm row spacing, respectively.

Table 2. Plant height (cm) as affected by different treatments in tomato crop.

Treatments	Row spacing (cm)			Treatments means
	40	60	80	
Polyethylene (white)	62.47	55.20	51.23	56.30 bcd
Polyethylene (black)	61.47	54.93	48.07	54.82 cd
Wheat straw	60.07	60.67	51.73	57.48 abcd
Saw dust	64.53	61.93	52.93	59.80 abc
Paper mulch	61.20	54.67	47.80	54.56 cd
Fenoxaprop-p-ethyl	65.13	63.00	53.57	60.57 ab
s-metolachlor	60.40	58.53	51.27	56.73 abcd
Pendimethalin	61.60	55.87	50.20	55.88 bcd
Hand weeding	59.93	52.53	47.47	53.31 d
Weedy check	67.13	64.00	56.20	62.44 a
Row spacing means	62.39 a	58.13 ab	51.04 b	

$LSD_{0.01}$ (Row spacing) = 9.744, $LSD_{0.05}$ (Treatments) = 5.725, Interaction effect = NS

Fruit yield (t ha^{-1}): The analysis of the data showed that the effect of the row spacing was significant ($p<0.05$), weed control treatments was highly significant ($p<0.01$) and interaction effect was non significant on the fruit yield of tomato crop. 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 3). It indicated that 60 cm row spacing is the optimum one for tomato pants. The fruit yields were decreased at 40 cm and 80 cm row spacing which may 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 limited resources of land, water, nutrients and light. However, decreasing the row spacing from the recommended spacing will though do not provide enough room for the emerging weeds but there will be an intra specific competition among tomato plants themselves. Single plant yield is always decreased at higher plant densities (Mudarres *et al*., 1998). Limited availability of soil resources contributes to lower fruit yields in spite of decreasing the row spacing in crops (Sobkowicz & Tendziagolska, 2005).

Among weed management treatments in subplots, the application of poly ethylene 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 3. The best treatment was followed by paper mulch (2.68 t ha^{-1}) and poly ethylene white (2.49 t ha^{-1}), while the lowest fruit yield (1.4 t ha^{-1}) was recorded in weedy check treatments, 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 statistically. However, Table 3 showed that the fruit yield of tomato crop was highest (4.30 t ha^{-1}) in spacing of 80 cm where polyethylene black (plastic) was used as mulch. This was followed by the treatment of black plastic where the row spacing was kept as 60 cm (3.95 t ha^{-1}) and where the spacing was of 40 cm (3.88 t ha^{-1}). This shows that black plastic has performed best in the enhancement of the subsequent yield, indicating that the weeds were effectively control 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 barred 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 biomass and density of weeds (Mamolos & Kalburtji, 2001).

Table 3. 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, $LSD_{0.01}$ (Treatments) = 0.8748, Interaction effect = NS

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