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EFFECT OF SOWING DIRECTION, PLANT SPACING AND WEED CONTROL TREATMENTS ON TOMATO YIELD AND ITS WEEDS

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ABSTRACT

A field trial was conducted at the Research Farm of the University of Agriculture Peshawar, Pakistan in 2014 in order to assess the effect of sowing direction, plant spacing and weed control treatments on tomato yield and its associated weeds at. The experiment was laid out in a three factorial RCB Design with three replications. Sowing direction (factor A) had two levels i.e. North-South and East-West row sowing, factor B included three varying plant spaces (20, 30 and 40 cm) while factor C included the treatments of Rumex crispus as mulch, Sisymbrium irio as mulch, a hand weeded treatment and a weedy control. Results showed that E-W sowing direction significantly increased weed density m^{-2} (132.92), fresh weed biomass (1616 kg ha^{-1}) and plant height (73.96 cm), whereas N-S direction resulted in increase in number of branches (11.96 $plant^{-1}$), number of fruits (11.11 $plant^{-1}$), individual fruit weight (87.17 g) and yield (20.46 tons ha^{-1}). Plant spacing of 40 cm significantly increased the weed density (152.67 m^{-2}), fresh weed biomass (1984 kg ha^{-1}), number of branches (12.52 $plant^{-1}$), number of fruits (11.79 $plant^{-1}$) and individual fruit weight (90.40 g); while plant spacing of 20 cm resulted in increased plant height (74.96 cm) and tomato fruit yield (22.07 tons ha^{-1}); whereas minimum weed density (89.75 m^{-2}), fresh weed biomass (987 kg ha^{-1}), number of branches (9.61 $plant^{-1}$), number of fruits (6.65 $plant^{-1}$) and individual fruit weight (72.24 g) were noted at planting space of 20 cm. Among the treatments of weed control, weedy check resulted in highest weed density (184 m^{-2}), weed biomass ha^{-1} (2243.7 kg) and plant height (80.94 cm) while hand weeding resulted in maximum number of branches $plant^{-1}$ (13.37), number of fruits $plant^{-1}$(12.25), individual fruit weight (91.35 g) and yield ha^{-1} (23.69 tons) while minimum number of branches $plant^{-1}$ (7.91), number of fruits $plant^{-1}$(6.53), individual fruit weight (70.25 g) and yield ha^{-1} (14.21tons)

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were recorded in weed check. In light of the results it can be concluded that north-south sowing direction, plant to plant spacing of 20 cm along with mulching of biomass of R. crispus can prove the best for environment friendly weed management in tomato at Peshawar (a lower elevated area), Khyber Pakhtunkhwa, Pakistan..

Key words: Epistasis Lower elevation, mulches, plant spacing, sowing orientation, tomato, weeds.

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INTRODUCTION

Tomato is the second most important vegetable crop of Pakistan after potato. All types of soils are suitable for tomato production including sandy and heavy clay with soil pH of 5.5 to 7.5 best one. However sandy loam soil1 is considered best for early crop (Baloch, 1994). Highest yield can be obtained by growing tomato in loam, clay loam and silty loam having enough organic matter.

Manipulating crop row orientation and row spacing is a significant determinant of crop productivity and controlling weeds (Karanja *et al*., 2014 Rousseaux *et al*., 1996). Theoretically, planting crops in narrow rows improves yield for a given area, since it allows the crop to capture more of the available light, water and nutrients. More importantly, narrow rows provide maximum crop competition with neighboring weeds (Maboko *et al.*, 2011; Heider, 2002). Use of increased plant populations, narrower rows and row directions perpendicular to the path of the sun all perfectly work in suppressing associated weeds and increasing crop yields from the point of view of many authors. Many noxious weeds (*e.g.* ryegrass, littleseed canarygrass, wild oat, common vetch and black nightshade) gave response to crop row orientation and row spacing as reported by Hozayn *et al*. (2012) and Shrestha and Fidelibus (2005). Recently, Borger *et al*. (2010) reported that crop rows oriented at a right angle to sunlight (east-west direction) suppress weed growth through greater shading of weeds in the interrow spaces (a study conducted on wheat, barley canola, lupines and field pea cops).

Different types of mulch play an important role in conserving soil moisture (Dalorima *et al*., 2014; Nwokwu and Aniekwe, 2014). Mulch regulates soil temperature, creates suitable condition for germination, improves soil moisture, suppresses weed growth, saves labour cost and improves soil physical conditions by enhancing biological activity of soil fauna and thus increases soil fertility which ultimately increases the yield of tomato. In addition, mulching has the unique character of reducing the maximum soil temperature and increasing the minimum temperature (Sanni and Eleduma, 2014; Abubaker, 2013; Singh, 1995).

Keeping in view the recognized importance of mulching, sowing direction and planting density for weed management, a field trial was conducted under the agro-climatic conditions of Peshawar with the objectives to figure out the efficacy of sowing direction on growth and yield of tomato, to determine the effect of mulching on weed control and yield of tomato, to recommend the better plant spacing for the maximum yield of tomato, and to recommend a best environment friendly weed management package for tomato crop in the target area.

MATERIALS AND METHODS

This field experiment was conducted at the Research Farm of the University of Agriculture Peshawar, Pakistan during 2014. The design of the experiment kept a three factorial Randomized Complete Block Design (RCBD) with the experiment replicated thrice. Seedling of the available tomato cultivar Rio Grand were selected from the Agriculture Research Institute (Tarnab) Peshawar. The size of each unit was kept as 2.4m×3m. Planting was done on raised beds of about 45 cm high using transplanting of the available tomato cultivar Rio Grand. The basal dozes of N @ 150 kg ha^{-1}, P @ 100 kg ha^{-1} and K 60 kg ha^{-1} were applied by using urea, Triple Super Phosphate (TSP) and potassium sulphate sources. P, K and half N was mixed with soil before transplantation, while the remaining N was applied after two weeks of transplantation. During the research all other cultural activities like weeding, hoeing, irrigation were carried out at proper time. Data were recorded on weed density and fresh weed biomass, plant height, number of branches plant^{-1}, number of fruit plant^{-1}, individual fruit weight, and fruit yield (tons ha^{-1}). Data for fruit yield (t ha^{-1}) was recorded with the following formula,

$$\text{Yield (kg ha}^{-1}\text{)} = \frac{\text{Yield in subplot (kg) x 10000 m}^2}{\text{Area of subplot (m}^2\text{)}}$$

The obtained yield in kg ha^{-1} was divided by 1000 to calculate the yield in tons ha^{-1}.

Statistical analysis

The recorded data of the two field experiments was individually subjected to the ANOVA procedure using MSTATC and Statistix 8.1 computer softwares and the significant means were separated by using LSD test (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Weed density m^{-2}

The analysis of the data showed that weed density was significantly affected by the sowing orientation, plant spacing, weed control treatments and their interactions (Table-1). The weed density was significantly lower (112.58 weeds m^{-2} in plots with tomato plants sown in north-south direction as compared to sowing in the east-west direction (132.92 m^{-2}). The sowing orientation of north south receives the solar radiation more conveniently as compared to the east west sowing because of the higher line to line distance than the plant to plant distance. In addition, the plant canopy of individual plants touches the canopy of the adjacent plants due to which the situation becomes favorable in north south sowing. Karanja *et al*. (2014) reported higher yields for sorghum crop in north south row orientation due to reduced number of weeds per unit area. However, Hozayn *et al*. (2012) reported best results for inhibition of weeds growth in wheat crop under East-West crop row direction with 48.5% reduction in weeds. This means that the effect of row orientation on weeds is different in different crops. The number of weeds per unit area was significantly lowest (89.75 m^{-2}) in plant spacing of 20 cm, followed by plots in which tomato plants were sown at a distance of 30 cm with weed density of 125.83 m^{-2} and highest weed population (152.67 m^{-2}) was found in tomato palnt to plant distance of 40 cm. Narrow spacing of 20 cm in tomato plants suffocated weeds number per unit area whereas wider spacing (30 and 40 cm) gave room to the growing weeds with which the number and composition of weeds increased (Ara *et al*., 2007). For the factor C, the weed density was significantly lowest (81.22 m^{-2}) in hand weeded plots followed by *Rumex crispus* plant biomass used as mulch (110.33 m^{-2}) and plots with *Sisymbrium irio* plant biomass applied as mulch (115.44 m^{-2}) as compared to the significantly highest weed density (184 m^{-2}) in the weed check plots. Mulching enhances the soil moisture retention and improves soil temperature (Dalorima *et al*., 2014), which helps boost crop performance making the crop more competitive against the associated weeds. The interaction effect of all factors was non-significant except that for interaction of plant spacing and weed control treatments (P x T). This showed that the P x T interaction significantly reduced the weed density in tomato crop in the Peshawar region, a lower elevated area.

Fresh weed biomass (kg ha^{-1})

The yield and yield related components of crop have been significantly affected by weed biomass. It is clear from the analyzed data that weed biomass (kg ha^{-1}) was significantly affected by the sowing orientation, plant spacing, weed control treatments and their interactions (Table-1). The weed biomass was significantly lower i.e.

1371 kg ha^{-1} in plots with tomato plants sown in north-south direction as compared to sowing in the east-west direction (1616 kg ha^{-1}). Karanja *et al*. (2014) achieved higher yields for sorghum crop in north south row orientation because of significant decrease in the weed density per unit area. It is thus inferred from the situation that the effect of row orientation on weeds is different in different crops and different localities. Weed biomass kg ha^{-1} was significantly lowest (987 kg ha^{-1}) in plant spacing of 20 cm, followed by plots in which tomato plants were sown at a distance of 30 cm with weed biomass of 1510 kg ha^{-1} and highest weed biomass (1984 kg ha^{-1}) was found in tomato palnt to plant distance of 40 cm. Narrow spacing of 20 cm in tomato plants suffocated weeds number per unit area whereas wider spacing (30 and 40 cm) gave room to the growing weeds with which the number and composition of weeds increased (Ara *et al*., 2007). Among the weed control treatments, the weed biomass was significantly lowest (992.2 kg ha^{-1}) in hand weeded plots followed by *Rumex crispus* plant biomass used as mulch (1337.1 kg ha^{-1}) and plots with *Sisymbrium irio* plant biomass applied as mulch (1402.9 kg ha^{-1}) as compared to the significantly highest weed biomass (2243.7 kg ha^{-1}) in the weed check plots. Mulching of the soil causes a decrease in the weed density in the beginning of the growing period of vegetables like tomato, potato and onion (Kosterna, 2014). In this experiment, the mulching of *Rumex crispus* performed well in reducing weed density because of its higher canopy and shading of the emerging weeds as compared to the mulching of *Sisymbrium irio*. Though hand weeding resulted best in reducing the number of weeds per unit area, it is not feasible in conditions of labour scarcity, or at large scale. The interaction effect of all factors was significant except that for interaction of sowing orientation, plant spacing and treatments (S x P x T). This indicated that all the factors are important in reducing the weed density in tomato.

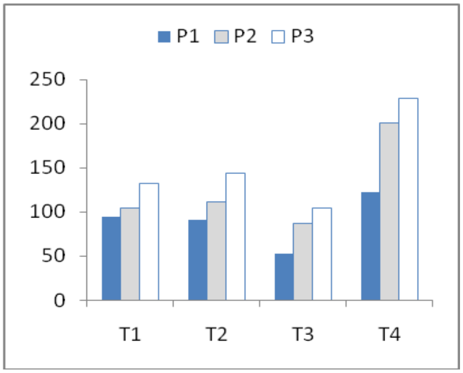
Plant height of tomato (cm)

The analysis of the data showed that plant height was significantly affected by the sowing orientation, plant spacing, weed control treatments and their interactions (Table-1). Plant height was significantly lower i.e. 69.29 cm in plots with tomato plants sown in north-south direction as compared to sowing in the east-west direction (73.96 cm). The plant canopy of individual plants touches the canopy of the adjacent plants due to which the situation becomes favorable in north south sowing. Plant height was significantly lowest (68.65 cm) in plant spacing of 40 cm, followed by plots in which tomato plants were sown at a distance of 30 cm with plant height of 71.25 cm and highest plant height (74.96 cm) was found in tomato palnt to plant distance of 20 cm. Close spacing of 20 cm in tomato plants increased plant height whereas wider spacing (30 and 40 cm) resulted in decrease plant height. The results are in hormany with that of (Athanasios et al. 1991) who recorded increase in plant height of tomato with close spacing. For the factor C, the plant height was significantly lowest (71.25) in hand weeded plots followed by *Rumex crispus* plant biomass used as mulch (75.58 cm) and plots with *Sisymbrium irio* plant biomass applied as mulch (77.38 cm) as compared to the significantly highest plant height (80.94 cm) in the weed check plots. Mulching of the soil causes increase in plant height of pepper (Mochiah *et al*., 2012). The interaction effect of all factors was significant except that for interaction of sowing orientation, plant spacing and treatments (SxPxT). This indicated that all the factors are important in increasing the height of tomato.

Table-1. Effect of sowing orientation, plant spacings and weed control treatments on weed desnsity m^{-2}, weed biomass (kg ha^{-1}) and plant height of tomato in 2014 at lower elevation of Peshawar, KP Pakistan

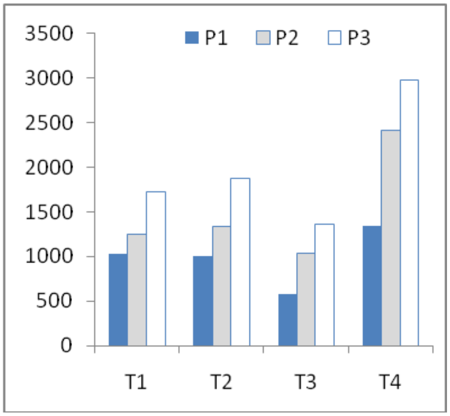
Treatments	Parameters		
	Weed density m^{-2}	Weed biomass (kg ha^{-1})	Plant height (cm)
Sowing orientation (S)			
East west sowing	132.92 a	1616 a	73.96 a
North south sowing	112.58 b	1371 b	69.29 b
Significance level	*	*	*
Plant spacing (P)			
20 cm	089.75 c	0987 c	74.96 a
30 cm	125.83 b	1510 b	71.25 b
40 cm	152.67 a	1984 a	68.65 c
LSD (0.05)	15.33	195.26	1.17
Treatments (T)			
Rumex crispus as mulch	110.33 b	1337.1 b	75.58 c
Sisymbrium irio as mulch	115.44 b	1402.9 b	77.38 b
Hand weeding	081.22 c	992.2 c	71.25 d
Weedy check	184.00 a	2243.7 a	80.94 a
LSD (0.05)	17.70	225.46	1.35
Interactions	Significance level		
S x P	NS	NS	*
S x T	NS	NS	*
P x T	*	*	*
S x P x T	NS	NS	*

Means followed by different letters are significantly different at 5% level of probability after LSD test; * = Significant, NS = Non-significant



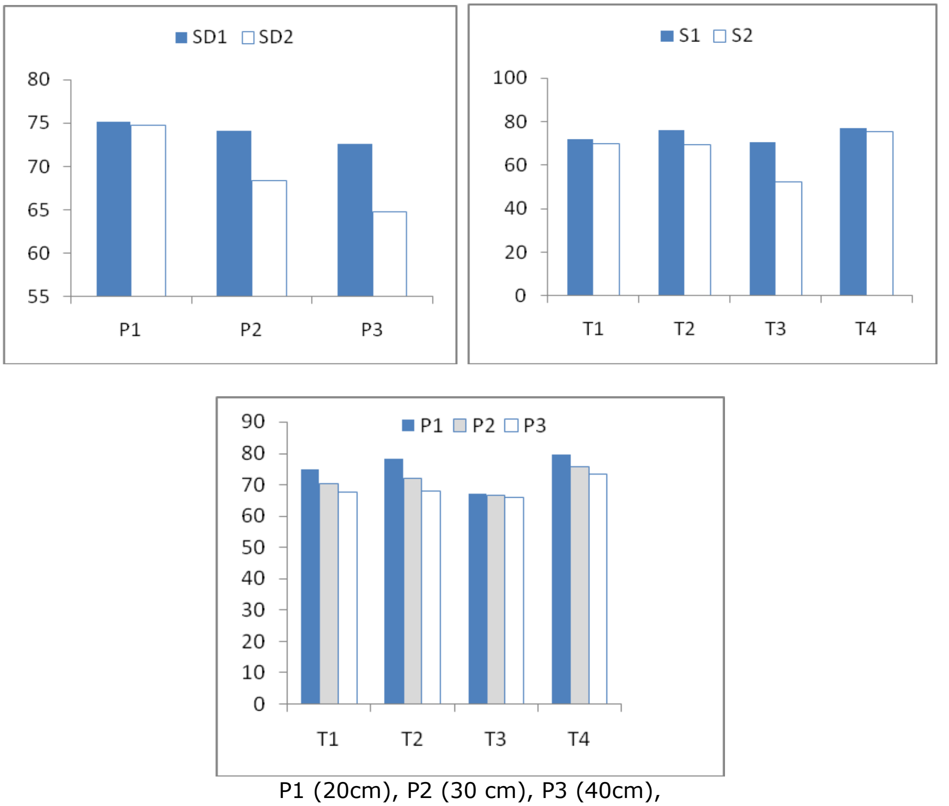
P1 (20cm), P2 (30 cm), P3 (40cm),
T1 (*R. crispus* as mulch), T2 (*S. irio* as mulch), T3 (hand weeding), T4 (weedy check)

Figure 1. Interaction effect of plant spacing and weed control treatments (P x T) for weed density (m^{-2}) in tomato crop at lower elevation of Peshawar during 2014



P1 (20cm), P2 (30 cm), P3 (40cm),
T1 (*R. crispus* as mulch), T2 (*S. irio* as mulch), T3 (hand weeding), T4 (weedy check)

Figure 2. Interaction effect of plant spacing and weed control treatments (PxT) for weed biomass kg ha^{-1} in tomato crop at lower elevation of Peshawar during 2014.



P1 (20cm), P2 (30 cm), P3 (40cm),
T1 (*R. crispus* as mulch), T2 (*S. irio* as mulch), T3 (hand weeding), T4 (weedy check)

Figure-3. Interaction effect of (a) sowing orientations and plant spacing (S x P), (b) sowing orientations and weed control treatments (S x T) and (c) plant spacing and weed control treatments (P x T) for plant height (cm) in tomato crop at lower elevation of Peshawar during 2014.

Number of branches plant^{-1} of tomato

The number of branches plant^{-1} was significantly affected by the sowing orientation, plant spacing, and weed control treatments (Table-2). Less number of branches plant^{-1} (10.61) was recorded in plots with tomato plants sown in east-west direction as compared to sowing in the north-south direction (11.96). The plant canopy of individual plants touches the canopy of the adjacent plants due to which the situation becomes favorable in north south sowing. Karanja *et al*. (2014) reported higher yields for sorghum crop in north south row orientation due to reduced number of weeds per unit area. The number of branches plant^{-1} were significantly lowest (9.61) in plant spacing of 20 cm, followed by plots in which tomato plants were sown at a distance of 30 cm with number of branches plant^{-1} of 11.71 and highest number of branches plant^{-1} (12.52) was found in tomato plant to plant distance of 40 cm. Increase in number of branches plant^{-1} with wider space may be due to the availability of more area for proper growth and spreading of plant. Similar results were also obtained by Zaag *et al*. (1990) who reported that wider space increase in braching potato. For the factor C, the number of branches plant^{-1} was significantly lowest (7.91) in weedy check plots followed by *Sisymbrium irio* plant biomass used as mulch (11.62) and plots with *Rumex crispus* plant biomass applied as mulch (12.23) as compared to the significantly highest number of branches plant^{-1} (13.37) in the weed check plots. Mulching helped increase the number of branches plant^{-1} (Gudugi *et al*., 2012). The interaction effect of all factors was non significant except that for interaction of sowing plant spacing and treatments (P x T). This indicated that all the factors are important in reducing the weed density in tomato crop.

Number of fruit plant^{-1} of tomato

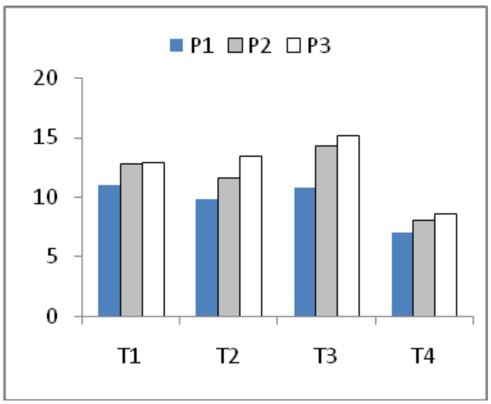
The number of fruits plant^{-1} was significantly affected by the sowing orientation, plant spacing, weed control treatments and their interactions (Table-2). The number of fruits was significantly lower i.e. 8.29 in plots with tomato plants sown in east-west direction as compared to sowing in the north-south direction (11.11). The number of fruits plant^{-1} were lowest (6.65) in plant spacing of 20 cm, followed by plots in which tomato plants were sown at a distance of 30 cm with number of fruits plant^{-1} 10.66 and highest number of fruits plant^{-1} (11.79) was found in tomato plant to plant distance of 40 cm. Narrow spacing of 20 cm in tomato plants suffocated weeds number per unit area whereas wider spacing (30 and 40 cm) gave room to the growing weeds with which the number and composition of weeds increased (Ara *et al*., 2007). The number of fruits plant^{-1} were significantly lowest (6.53) in weedy check plots followed by *Sisymbrium irio* plant biomass used as mulch (9.52) and plots with *Rumex crispus* plant biomass applied as mulch (10.52) as compared to the significantly highest number of fruits plant^{-1} (12.25) in the hand weeded plots. The mulching of *Rumex crispus* performed well in enhancing no. of fruit plant^{-1}. Though hand weeding resulted best in improving the number of weeds per unit area, it is not feasible in conditions of labour scarcity, or at large scale. The interaction effect of all factors was non-significant except interaction of sowing, plant spacing and treatments.

Fruit yield (t ha^{-1})

Sowing orientation, plant spacing, weed control treatments all significantly affected the fruit yield of tomato. Table-2 indicates the mean values and ANOVA for tomato fruit yield, respectively. The fruit yield was significantly higher (20.46 t ha^{-1}) in plots of north-south row sowing as compared to row orientation of east-west sowing (18.29 t ha^{-1}). The effect of row orientation varies with latitude and with the seasonal tilt of the earth in relation to the sun. Near the equator, north–south (as opposed to east–west) orientation gives crops higher levels of light absorption for most of the year. At higher latitudes (up to 55u), absorption is highest in north–south crops in summer and east–west crops for the rest of the year. From 65u upwards, east–west orientation gives greatest light absorption all year (although the difference between orientations is minor) (Agele *et al*., 1999). Pakistan also appears to be at higher latitude. Moreover, the canopy of individual crop plants overlap with the adjacent plants, consequently rendering the situation favorable for photosynthetic process in plots of north south row sowing. In case of the plant spacing, the fruit yield was significantly highest (22.07 t ha^{-1}) in plots of 20 cm spacing between tomato plants. The highest fruit yield was followed by 18.99 t ha^{-1} where there was 30 cm spacing between tomato plants; while the lowest fruit yield (17.06 t ha^{-1}) was achieved in plant spacing of 40 cm. Increasing the plant spacing from 20 cm to 40 cm decreased the per plant yield because of intra specific competition among the crop plants but the gross yield was highest in the same plant spacing. The per hectare yield however decreased with increasing the plant spacing from 20 to 40 cm. the results are in harmony with that of (Ahmad and Singh, 2005) who reported that even though the fruit size and the weight was higher in wider spaced rows, the total yield obtained was higher in the close spaced rows. The fruit yield was also significantly highest (23.69 t ha^{-1}) in treatments of hand weeding which was followed by the mulching of *Rumex crispus* plants (20.41 t ha^{-1}) and mulching of *Sisymbrium irio* whole plants (19.18 m^{-2}) as compared to the significantly lowest fruit yield of 14.21 t ha^{-1} in the control plots. Hand weeding resulted in the best fruit yield as a result of efficient weed control. Hand weeding was followed by the mulches of the selected weeds. The mulching factor enhanced the moisture retention capacity of the soil which optimized the soil temperature (Dalorima *et al*., 2014). The mulching of plant biomass of *Rumex crispus* enhanced the yield of tomato because of shading of the emerging weeds. The mulching of *Sisymbrium irio* was also better than the weedy check in significantly improving the tomato fruit yield per hectare.

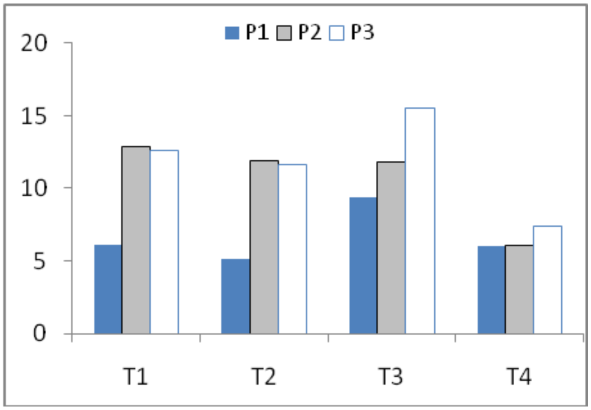
Table-2. Effect of sowing orientation, plant spacings and weed control treatments on no. of branches plant^{-1}, no. of fruits plant^{-1}, fruit weight plant^{-1} (kg)and fruit yield (t ha^{-1}) of tomato during 2014 at lower elevation of Peshawar, Khyber Pakhtunkhwa, Pakistan

Treatments	Parameters		
	No. of branches plant^{-1}	No. of fruits Plant^{-1}	Fruit yield (t ha^{-1})
Sowing orientation (S)			
East west sowing	10.61 b	08.29 b	18.29 b
North south sowing	11.96 a	11.11 a	20.46 a
Significance level	*	*	*
Plant spacing (P)			
20 cm	09.61 c	6.65 c	22.07 a
30 cm	11.71 b	10.66 b	18.99 b
40 cm	12.52 a	11.79 a	17.06 c
LSD (0.05)	0.61	0.62	1.43
Treatments (T)			
Rumex crispus as mulch	12.23 b	10.52 b	20.41 b
Sisymbrium irio as mulch	11.62 b	09.52 c	19.18 c
Hand weeding	13.37 a	12.25 a	23.69 a
Weedy check	07.91 c	06.53 d	14.21 d
LSD (0.05)	0.70	0.72	0.99
Interactions		Significance level	
S x P	NS	NS	NS
S x T	NS	NS	NS
P x T	*	*	NS
S x P x T	NS	NS	NS



P1 (20cm), P2 (30 cm), P3 (40cm),
T1 (*R. crispus* as mulch), T2 (*S. irio* as mulch), T3 (hand weeding), T4 (weedy check)

Figure 4. Interaction effect of (a) plant spacing and weed control treatments (P x T) for number of branches plant^{-1} in tomato crop at lower elevation of Peshawar during 2014



P1 (20cm), P2 (30 cm), P3 (40cm),
T1 (*R. crispus* as mulch), T2 (*S. irio* as mulch), T3 (hand weeding), T4 (weedy check)

Figure 5. Interaction effect of (a) plant spacing and weed control treatments (P x T) for number of fruit plant^{-1} in tomato crop at lower elevation of Peshawar during 2014

CONCLUSION

All the experimental treatments had almost the same effect at both the locations i.e. the altitudinal variation has minimum or no effect on the performance of row orientation, plant spacing and mulching practices. Row orientation of north south is better than east west in the agroecological conditions of both Mansehra and Peshawar regarding tomato crop growth. Plant spacing of 20 cm among tomato seedlings is an optimum distance and proved to be better than 30 and 40 cm, the former is too small while the latter is too large. Hand weeding resulted in highest yields both at Mansehra and Peshawar as compared to the mulching treatments. Using *Rumex crispus* and *Sisymbrium irio* plant biomass as mulch produced better results as compared to control plots. However, mulching of *Rumex crispus* was better than *Sisymbrium irio* in terms of weed reduction and higher crop yield.

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