ECO FRIENDLY WEED MANGEMENT IN TOMATO AT HIGHER ELEVATION

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ABSTRACT

A field trial was carried out at Agriculture Research Station Chitral during 2020-21 to investigate the effect of plant spacing and weed mulches on weeds and yield of tomato (*Lycopersicon esculentum* L.) using RCBD experimental design. Factor A was spacing of 20, 30 and 40 cm among tomato plants, while Factor B comprised of the treatments of *Rumex crispus* and *Sisymbrium irio* as mulch, a hand weeded treatment and a weedy control for comparison. Results showed that plant spacing, weed mulches and their interaction significantly affected the crop and weed parameters. Among the different levels of plant spacing, the 40 cm plant to plant spacing showed significant increase in weed density and fresh weed biomass, number of fruits, and individual fruit weight; while plant spacing of 20 cm resulted in increased plant height and final fruit yield (t ha^{-1}). On the other hand, minimum weed density m^{-2}, weed biomass, number of fruits and individual fruit weight (g $fruit^{-1}$) were noted at planting space of 20 cm. Among the treatments of weed control, weedy check resulted in highest weed density (m^{-2}), fresh weed biomass (kg ha^{-1}) and plant height (cm) while hand weeding resulted in maximum number of fruits ($plant^{-1}$), individual fruit weight (g $fruit^{-1}$) and fruit yield (t ha^{-1}); while minimum number of fruits ($plant^{-1}$), fruit weight (g per single fruit) and fruit yield (t ha^{-1}) were recorded in weed check. In conclusion, plant spacing of 20 cm and mulching of *R. crispus* as weed control method could be a best combination for the weed management strategy and yield enhancement of tomato crop in higher elevation area of Chitral, Pakistan region in an environment friendly way.

Key words: Higher elevation, mulching, plant spacing, tomato, weeds, yield.

INTRODUCTION

Tomato (Lycopersicon esculentum L.) belonging to solanaceae family is a well known vegetable grown all over the world and is the second important vegetable crop after potato. As it is a self pollinated crop, it is susceptible to high temperatures, especially the large fruited fresh varieties. All types of soil are suitable for tomato production including sandy and heavy clay with soil pH of 5.5 to 7.5 best one. However, sandy loam soil 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. Tomato is very much vulnerable to weed competition. Since long the herbicides are considered as the sole effective method for weed management. The aim of this instant project was to devise non chemical methods to tackle the menace of weed infestation through an environment friendly strategy. There were many non chemical strategies to manage with the weed problems however only a few of them could be addressed because of the scarce funding. Some of the non chemical methods including mulching of the weed biomass, spacing among crop plants, crop rows orientation and intercropping were the matter of our concern here in this study. Different types of mulch play an important role in conserving soil moisture (Dalorima et al., 2014; Nwokwu and Aniekwe, 2014). Mulching process regulates the 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, 2005). Row spacing is also playing key role in affecting the crop performance and weed suppression. 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) recorded

response where crop row orientation and row spacing were implicated (Hozayn et al., 2012; 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).

Therefore, keeping in view the above mentioned eco-friendly weed management techniques in potato, a field experiment was planned to assess the various non-chemical weed control strategies for improvement in tomato production and reduction in weeds infestation through environment friendly means.

MATERIALS AND METHODS

Experimental Sites and Agronomic Practices

The experiment was conducted in an open field at the Agriculture Research Station Chitral during sowing season of tomato 2020-21. The design of the experiment was a two factorial design with three replications of the experiment. Seedling of the available tomato cultivar Rio Grand were selected from the Shinkyari Research Station. The size of each experimental unit was kept 2.4 m × 3 m. Planting was done on raised beds of about 45 cm high using transplanting of the available tomato cultivar 'Rio Grand'. The basal doses 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 were mixed with soil before transplantation, while the remaining N was applied after two weeks of transplantation. The soil texture was sandy clay type with pH slightly acidic. The first irrigation was carried out after one day of transplanting then regular irrigations was carried out at seven days interval.

Statistical Analysis

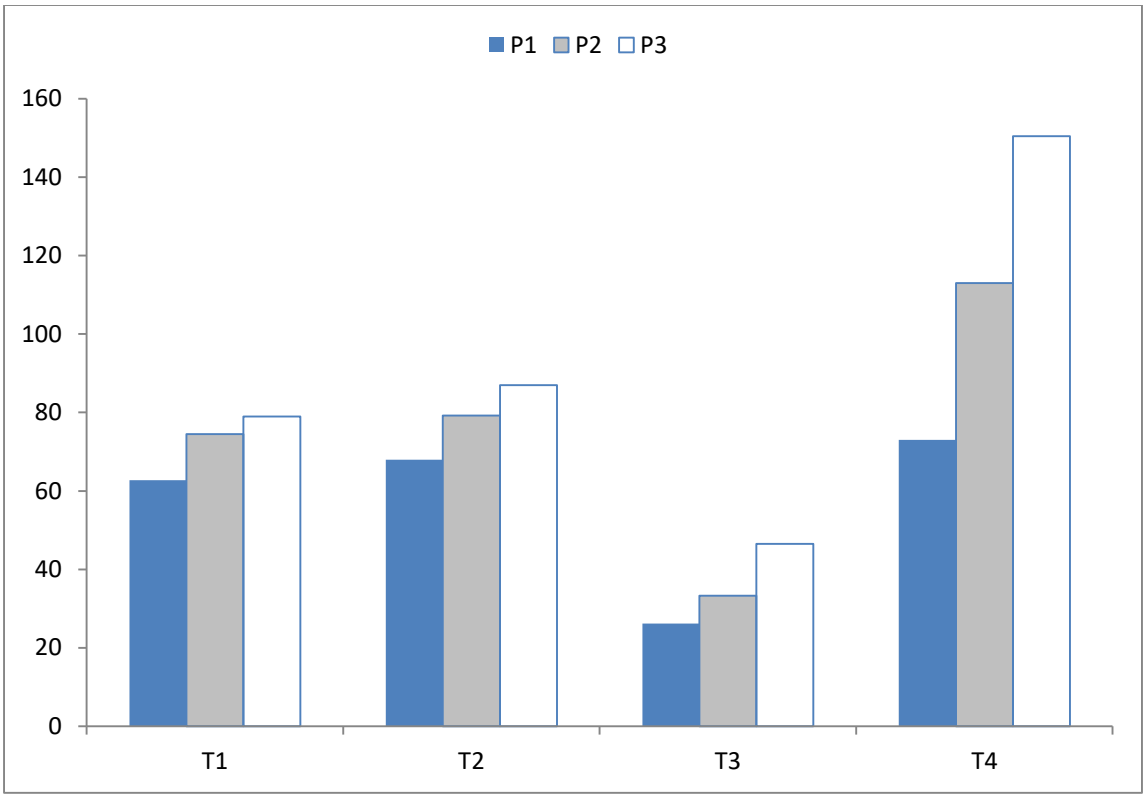
The recorded data of the four field experiments on tomato crop were individually subjected to the ANOVA procedures using the statistical software Statistix 8.1 version and the significant means were separated by using LSD test (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Weed density m-2

The density of the infesting weeds plays an important role in the yield and yield related parameters of the crop facing the competition from the weeds. The analysis of the data showed that weed density was significantly affected by plant spacing, weed control (mulching) treatments and their interactions. The number of weeds per unit area was significantly lowest (86.33 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 97.58 m-2 and highest weed population (113.42 m-2) was found in tomato plant to plant distance of 40 cm. For the factor B, the weed density was significantly lowest (55.89 m-2) in hand weeded plots followed by plant biomass of Rumex crispus used as mulch (92.11 m-2) and plots with Sisymbrium irio plant biomass applied as mulch (98.22 m-2) as compared to the significantly highest weed density (150.22 m-2) in the weed check plots. The significant interactions are given in Figure 1.1 below.

The spaces between the tomato plants significantly affected the weed density. 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 soil moisture retention is enhanced and soil temperature is improved by the mulching practice (Dalorima et al., 2014), which helped boost crop performance making the crop more competitive against the associated weeds. In addition, regardless of what kind of mulch is used, 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, as it provides weed free conditions in which the crop faces no competition for resources. However, it is not feasible in conditions of labour scarcity, or at large scale.



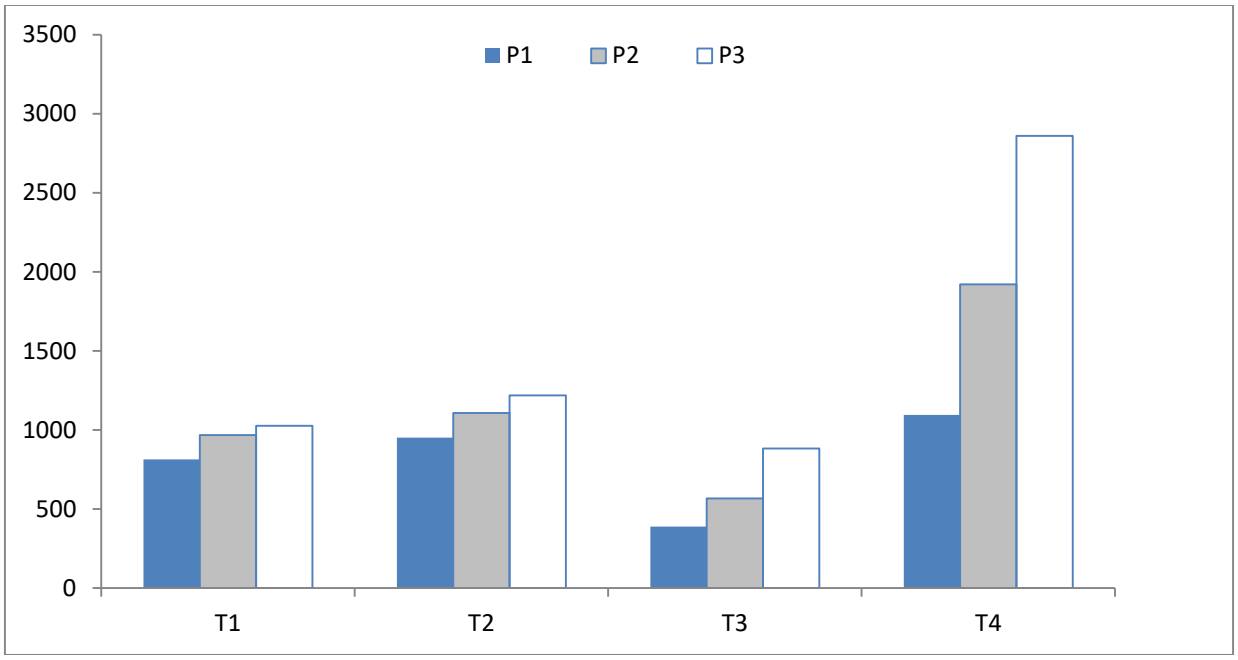
P1 (20cm), P2 (30 cm), P3 (40cm),
T1 (*R. crispus* as mulch), T2 (*S. irio* as mulch), T3 (hand weeding), T4 (weedy check)

Figure 1.1. Interaction effect of plant spacing and weed control treatments for weed density m^{-2} in tomato crop at higher elevation of Chitral during 2020-21.

Weed fresh biomass (kg ha^{-1})

Like the weed density, the weed biomass also has an important role in the ultimate yield and yield related parameters of the crops. The analysis of the data revealed that plant spacing, weed control treatments and their interactions had a significant effect on weed biomass Regarding plant spacing, the spacing of 20 cm resulted in the lowest weed fresh biomass (1090.92 kg ha-1), followed by plots of 30 cm (1208.17 kg ha-1); while highest weed biomass (1248.08 kg ha-1) was obtained in tomato plant to plant distance of 40 cm. For the factor B, the weed biomass was significantly lowest (565.44 kg ha-1) in hand weeded plots which was followed by plots in which the Rumex crispus plant biomass was used as mulch (1034.89 kg ha-1) and plots with Sisymbrium irio plant biomass applied as mulch (1157.22 kg ha-1) as compared to the significantly highest weed biomass (1972.00 kg ha-1) in the weed check plots. The interactions were also significant which are expressed graphically in the given Figure 1.2.

The spaces between tomato plants significantly affected the weed biomass. 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 biomass of weeds increased (Ara et al., 2007). Hand weeding resulted in the best reduction in the weeds biomass in this experiment. However, it is not generally feasible in conditions of labour scarcity, or at large scale. It was followed by the treatments of weeds mulches. Dalorima et al. (2014) are of the view that mulching enhances the soil moisture retention and improves soil temperature, which helps boost crop performance making the crop more competitive against the associated weeds. Using the biomass of those weeds that have higher infestations in the crop fields will not only reduce their general infestation but also their biomass will be utilized for mulching which has two huge benefits. The first is that the emerging weeds are shaded which may not efficiently carry out photosynthetic process. The second is that the biomass used as mulch increases the soil fertility by adding organic matter to the soil (Kosterna, 2014). Rumex crispus was growing proliferately in the fields of Chitral which was thus selected for use as a mulch treatment in this experiment. Similar was the situation of Sisymbrium irio. This way not only the infestation of these weeds was reduced through manual weeding but also their biomasses were utilized for mulching process which further has dual benefits i.e. shading the emerging weeds and providing organic material to the soil. Thus it meant killing two birds in one attempt.



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

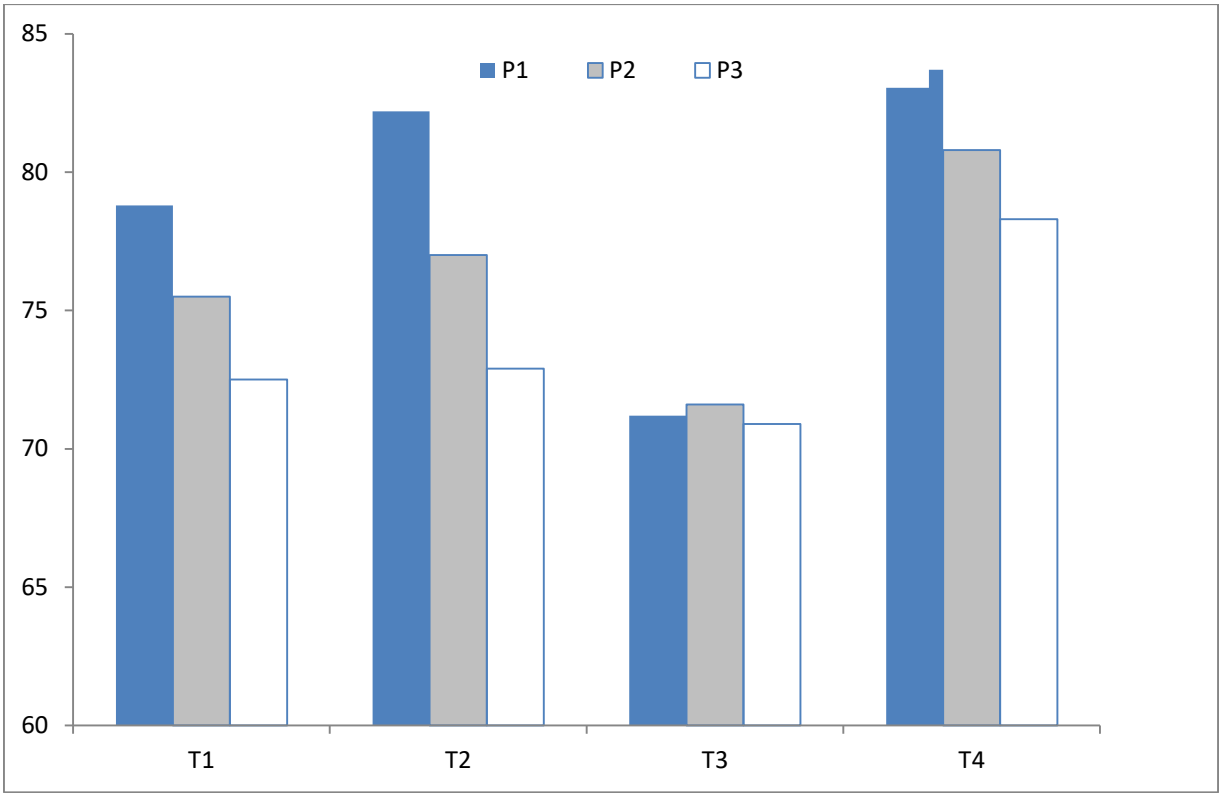
Figure 1.2. Interaction effect of plant spacing and weed control treatments (P x T) for weed biomass (kg ha^{-1}) in tomato crop at higher elevation of Chitral during 2020-21.

Plant height of tomato (cm)

The analysis of the data showed that plant height was significantly affected by plant spacing, weed control (mulching) treatments and their interactions (Table 1.1, Appendix A1.3). Regarding plant spacing, spacing of 40 cm resulted in lower plant height (75.05 cm), followed by plots in which tomato plants were sown at a distance of 30 cm with plant height of 76.04 cm and highest plant height (79.52 cm) was found in tomato palnt to plant distance of 20 cm. For the factor B, the plant height was lowest (70.65 cm) in hand weeded plots followed by Rumex crispus plant biomass used as mulch (76.06 cm) and plots with Sisymbrium irio plant biomass applied as mulch (79.83 cm) as compared to the highest plant height (80.92 cm) in the weed check plots. The significant interaction effect is given in Figures 1.3.

Generally the crop plant height increases with increase in competition for resources among the crop and weed plants. This happens in crop plants mostly in conditions of competition for light. Increase in height does not necessarily mean increase in yield because height is a vegetative character while yield is a reproductive character (Mochiah et al., 2012). The spaces between the tomato plants significantly affected the plant height. Close spacing of 20 cm in

tomato plants increased plant height whereas wider spacing (30 and 40 cm) resulted in decreased plant height. The results are in hormany with that of Papadopoulos and Ormrod (1991) who recorded increase in plant height of tomato with closer spacing. Mulching of the soil causes an increase in plant height of vegetables (Mochiah et al., 2012).



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

Figure 1.3. Interaction effect of plant spacing and weed control treatments (P x T) for plant height (cm) of tomato crop at higher elevation of Chitral during 2020-21.

Table 1.1. Effect of plant spacings and weed control (mulching) treatments on weed desnsity m^{-2}, weed biomass (kg ha^{-1}) and plant height of tomato during 2020-21 at higher elevation of Chitral, Khyber Pakhtunkhwa, Pakistan

Treatments	**Parameters**		
	Weed density m^{-2}	**Weed biomass (kg ha^{-1})**	**Plant height (cm)**
Plant spacing (P)			
20 cm	86.33 c	1090.92 c	79.52 a
30 cm	97.58 b	1208.17 b	76.04 b
40 cm	113.42 a	1248.08 a	75.05 c
LSD (0.05)	3.81	27.04	1.25
Treatments (T)			
Rumex crispus as mulch	92.11 c	1034.89 c	79.83 c
Sisymbrium irio as mulch	98.22 b	1157.22 b	76.07 b
Hand weeding	55.89 d	565.44 d	70.65 d
Weedy check	150.22 a	1972.00 a	80.92 a
LSD (0.05)	4.40	31.22	
Interactions	**Significance level**		
P x T	*	*	*

Means followed by different letters are significantly different at 5% level of probability after LSD test

LSD value or * = Significant, NS = Non-significant

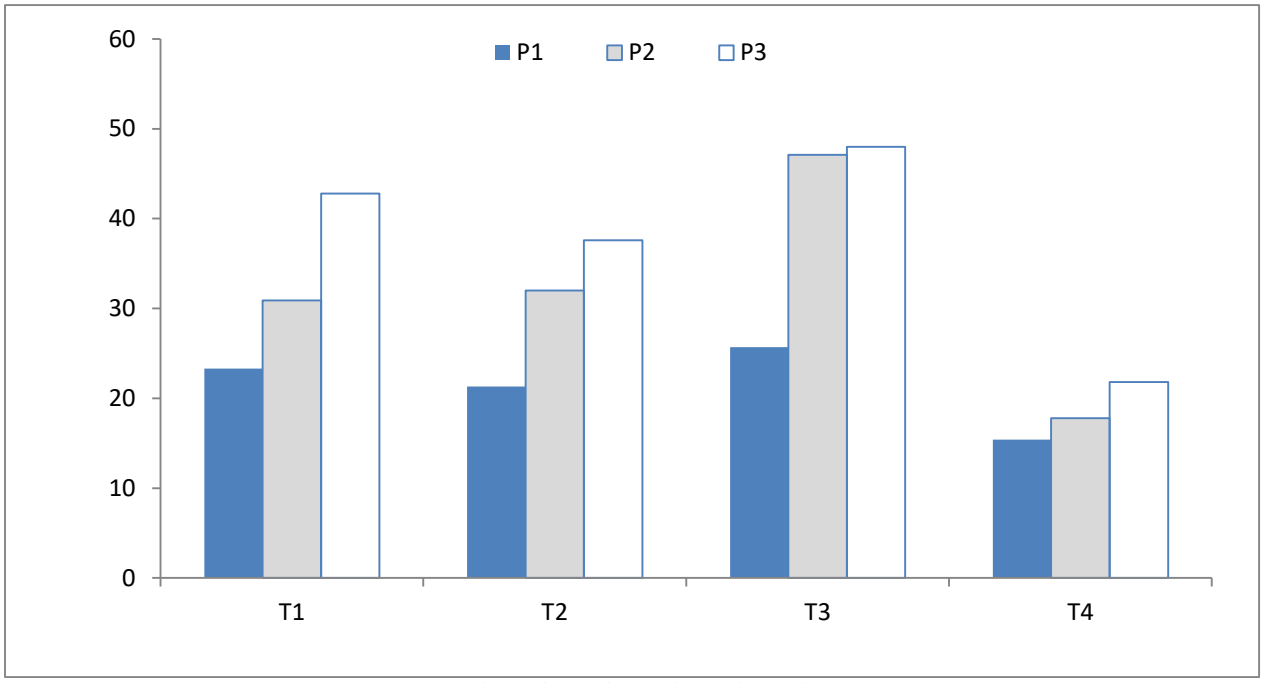
Note: Original replicated data for all the parameters can be observed in Appendices B1.1 to B1.3 for all the studied parameters of this experiment.

1.4. Number of tomato fruits plant^{-1}

The analysis of the data showed that number of fruits plant-1 was significantly affected by the plant spacing, weed control treatments and their interactions (Table 1.2). The number of fruits plant-1 were lowest (6.15) 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 10.22 and highest number of fruits plant-1 (12.58) was found in tomato palnt to plant distance of 40 cm. For the factor B, the number of fruits plant-1 were significantly lowest (6.78) in weedy check plots followed by Sisymbrium irio plant biomass used as mulch (9.38) and plots with Rumex crispus plant biomass applied as mulch (10.38) as compared to the significantly highest number of fruits plant-1 (12.06) in the hand weeded plots. The interaction effect is given in Figure 1.4.

The spaces between the tomato plants significantly affected the number of fruits plant-1. Narrow spacing of 20 cm in tomato plants resulted in less number of fruits plant-1 whereas wider spacing (30 and 40 cm) resulted in increased number of fruits plant-1 (Zaag et al., 1990).

Berihun (2011) reported an increase in number of fruits plant-1 in tomato plants with mulching treatments as compared to plants witout mulching. In this experiment, the mulching of Rumex crispus performed well in improving the no. of fruits plant-1. The interaction effect of plant spacing and treatments (P x T) was also significant regarding the no. of tomato fruits plant-1.



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

Figure 1.4. Interaction effect of plant spacing and weed control (mulching) treatments (P x T) for the number of fruit plant^{-1} in tomato crop at higher elevation of Chitral during 2020-21.

1.5. Single fruit weight (g fruit^{-1})

With improvement in the individual fruit weight the ultimate yield is enhanced. The analysis of the data showed that single fruit weight was significantly affected by the plant spacing, and weed control treatments (Table 1.2; Appendix A1.6). The single fruit weight was significantly highest (86.76 g) in plant spacing of 40 cm, followed by plots in which tomato plants were sown at a distance of 30 cm (83.15 g) and lowest fruit weight (80.41 g) was found in tomato palnt to plant distance of 20 cm. The fruit weight was significantly highest (89.70 g) in hand weeded plots followed by Rumex crispus plant biomass used as mulch (87.26 g) and plots with Sisymbrium irio plant biomass applied as mulch (82.47 g) as compared to the significantly

lowest fruit weight (74.32 g) in the weed check plots. The significant interaction effect is expressed in Figure 1.5.

Close spacing of (20 cm) in tomato plants resulted decrease in weight of the individual tomato fruits. Mulching enhanced the crop performance making the crop more competent with the weeds. Mulching of the soil caused an increase in individual fruit weight as compared to non mulched plants as reported by Kayum et al. (2008). In this experiment, the mulching of Rumex crispus performed well in increasing the fruit weight because of its higher canopy and shading of the emerging weeds as compared to the mulching of Sisymbrium irio. The interactions of plant spacing and weed control treatments (P x T) significantly affected the individual fruit yield.

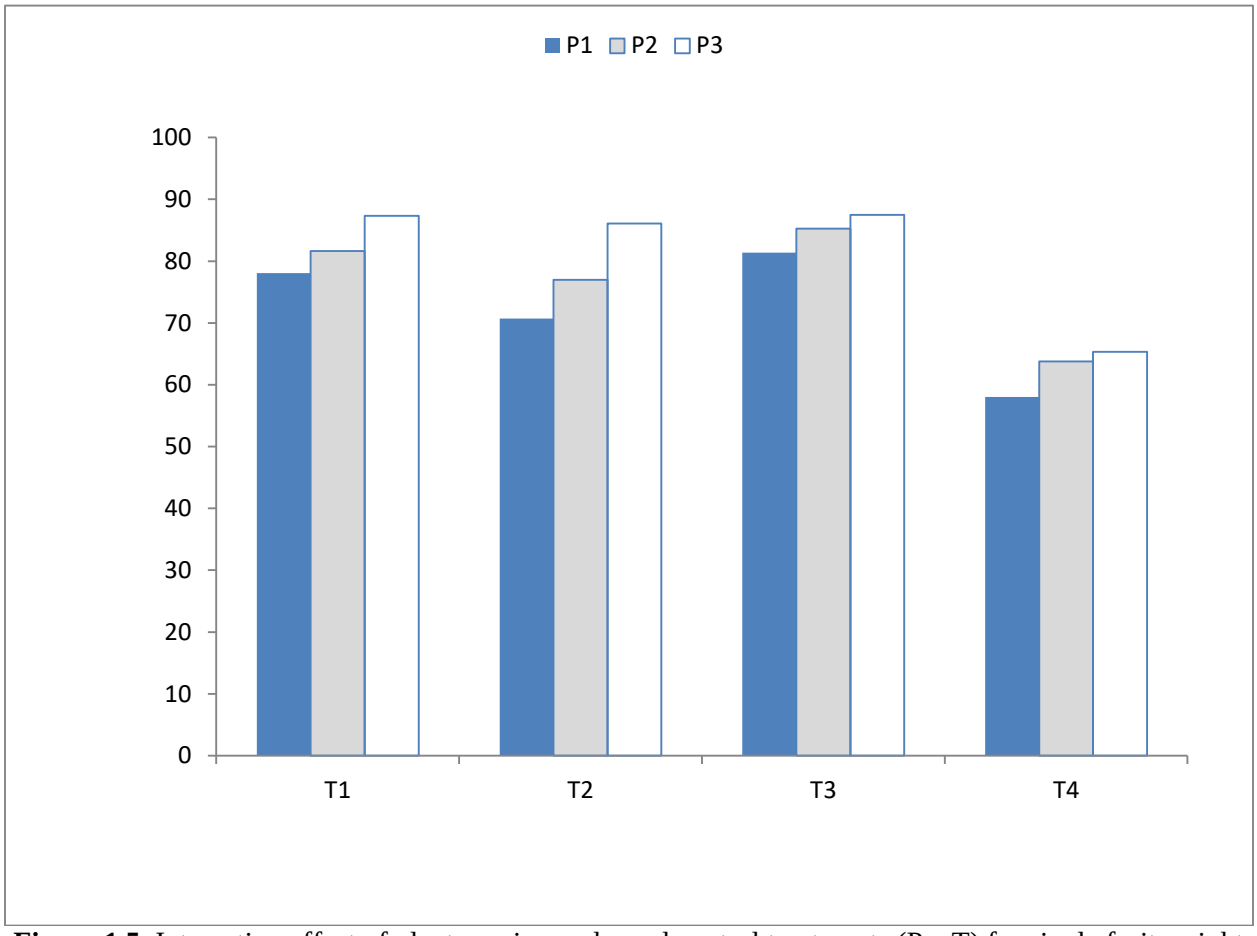
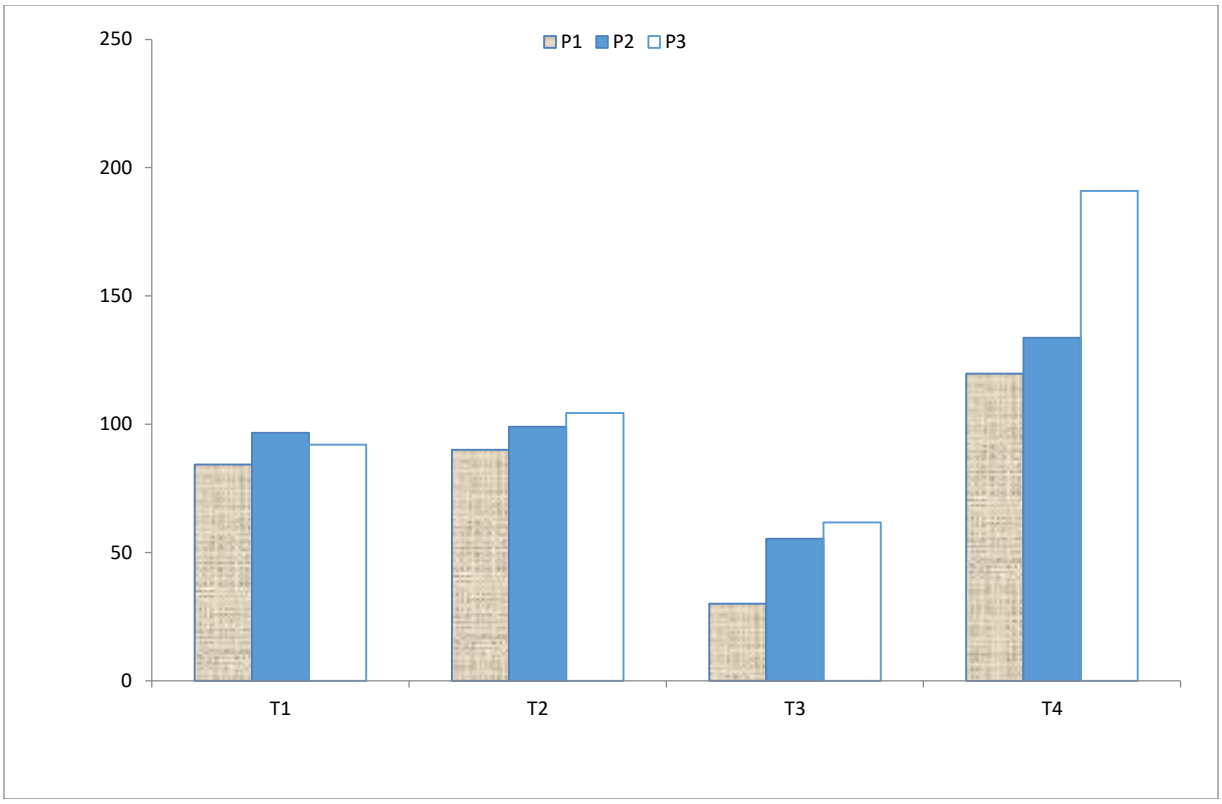


Figure 1.5. Interaction effect of plant spacing and weed control treatments (P x T) for single fruit weight (g) of tomato crop at higher elevation of Chitral during 2020-21.

1.6. Fruit yield (t ha^{-1})

Fruit yield of tomato is the only parameter on which all the experiment is dependent upon. After analyzing the data, it was found that the plant spacing, weed control treatments all significantly affected the fruit yield of tomato. Table 1.2 and Appendix A1.7 indicate the mean values and ANOVA for tomato fruit yield, respectively. In case of the plant spacing, the fruit yield was significantly highest (25.34 t ha-1) in plots of 20 cm spacing between tomato plants. The highest fruit yield was followed by 21.92 t ha-1 where there was 30 cm spacing between tomato plants; while the lowest fruit yield (20.47 t ha-1) was achieved in plant spacing of 40 cm. The fruit yield was also significantly highest (27.08 t ha-1) in treatments of hand weeding which was followed by the mulching of Rumex crispus plants (24.39 t ha-1) and mulching of Sisymbrium irio whole plants (24.03 m-2) as compared to the significantly lowest fruit yield of 14.81 t ha-1 in the control plots. The interaction of P x T was found significant which is given in the Figure 1.7.

The plant spacing in the tomato plants had a significant effect on the fruit yield of tomato. 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 hormany 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 Among the weed control treatments 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 significsntly improving the tomato fruit yield per hectare.



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

Figure 1.6. Interaction effect of plant spacing and weed control treatments (P x T) for fruit yield (t ha^{-1}) in tomato crop at higher elevation of Chitral during 2020-21.

Table 1.2. Effect of plant spacing and weed control treatments on no. of fruits plant^{-1}, fruit weight plant^{-1} (kg) and fruit yield (t ha^{-1}) of tomato during 2020-21 at higher elevation of Chitral, Khyber Pakhtunkhwa, Pakistan

Treatments	**Parameters**		
	No. of fruits Plant^{-1}	**Single fruit weight (g)**	**Fruit yield (t ha^{-1})**
Plant spacing (P)			
20 cm	6.15 c	80.41 c	25.34 a
30 cm	10.22 b	83.15 b	21.92 b
40 cm	12.58 a	86.76 a	20.47 c
LSD (0.05)	0.43	1.73	0.83
Treatments (T)			
Rumex crispus as mulch	10.38 b	87.26 b	24.39 b
Sisymbrium irio as mulch	9.38 b	82.47 c	24.03 b
Hand weeding	12.06 a	89.70 a	27.08 a
Weedy check	6.78 c	74.32 d	14.81 c
LSD (0.05)	0.49	2.00	0.96
Interactions	**Significance level**		
P x T	*	*	NS

Means followed by different letters are significantly different at 5% level of probability after LSD test

LSD values or * = Significant, NS = Non-significant

Note: Original replicated data for all the parameters can be observed in Appendices B1.4 to B1.6 for all the studied parameters of this experiment.

Cost Benefit Ratio (CBR)

For plant spacing/population density of tomato seedlings, the lowest population bearing lowest cost was considered as the control treatment. The CBR for the plant spacing of 20 cm between tomato seedlings was 3.51 which was higher than that for 30 cm (1.57). The CBR of 3.51 will mean that the farmer will earn Rs. 3.51 for spending Rs. 1 on the treatment applied. Among the mulching treatments, the CBR was highest (19.16) for the Rumex crispus applied as mulch followed by 18.44 in Sisymbrium irio applied as mulch. The CBR in hand weeding treatments was lowest i.e. 10.52.

Table 1.3. The cost-benefit-ratio (CBR) ha^{-1} for tomato crop as influenced by various plant spacings (planting density) and mulching treatments of tomato during 2020-21 at higher elevation of Chitral, Khyber Pakhtunkhwa, Pakistan

Factor A (plant spacing)	Added Cost ha^{-1}	Yield increase over control (kg ha^{-1})	Added Income ha^{-1}	CBR
20 cm	83333	4870	292200	3.51
30 cm	55555	1450	87000	1.57
40 cm (control)	41666	---	---	---
Factor B (Treatments)				
Rumex crispus as mulch	30000	9580	574800	19.16
Sisymbrium irio as mulch	30000	9220	553200	18.44
Hand weeding	70000	12270	736200	10.52
Weedy check (control)	---	---	---	---

P1= 83333 plants ha^{-1}, P2= 55555, P3= 41666 plants ha^{-1}
Price of tomato seedling @ Rs. 1/seedling and tomato fruit @ Rs. 60 kg^{-1}
Cost of 5 labors for weeds collection for 3 days = 1000/day = 1000 x 5 x 3 = Rs. 15000 ha^{-1}
Cost of 5 labors for mulch application for 3 days = 1000/day = 1000 x 5 x 3 = Rs. 15000 ha^{-1}
Total added cost for mulching treatments = Rs. 30,000
Cost of 7 labors for weeds manual removing for 10 different days (5 times) = 1000/day = 1000 x 7 x 10
Total added cost for hand weeding treatment = Rs. 70000 ha^{-1}

CONCLUSION

The plant spacing of 20 cm among tomato seedlings proved to be an effective and optimum distance as compared to keeping a distance of 30 or 40 cm among tomato seedlings.The treatment of hand weeding showed best results in terms of yields and yield components because of weed free conditions both at Chitral 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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