Pak. J. Weed Sci. Res., 22(3): 395-406, 2016

INFLUENCE OF SOWING ORIENTATION AND INTERCROPPING OF CHILI ON TOMATO YIELD AND ITS WEEDS

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ABSTRACT

A field trial was conducted at Agriculture Research Station Chitral during summer 2015 to observe the impact of sowing direction and intercropping of chili on tomato yield and the associated weeds. A two factor experiment with three replications was arranged in randomized complete block design. Factor A included sowing directions (viz. north-south and east-west), factor B was termed as intercropping treatments (sole tomato, sole chili, tomato 1 row: chili 1 row (1:1), tomato 1 row: chili 2 rows (1:2), tomato 2 rows: chili 1 row (2:1), and tomato 2 rows: chili 2 rows (2:2). Data were taken on weed density (m^{-2}), fresh weed biomass (kg ha^{-1}), tomato plant height (cm), number of tomato fruits $plant^{-1}$, fruit yield (t ha^{-1}), chili yield (t ha^{-1}) and land equivalent ratio (LER). Results revealed that sowing orientation, intercropping and their interaction significantly increased the yield and yield components of tomato crop. East-west wise sowing direction showed substantial increase in weed density (112.8 m^{-2}), fresh weed biomass (1134.7 kg ha^{-1}) and plant height (78 cm); whereas north-south-wise sowing had increased number of tomato fruits $plant^{-1}$(6.5), tomato fruit yield (18.37 t ha^{-1}) and chili yield (6.65 t ha^{-1}). The weed biomass was reduced by sowing tomato seedlings in north-south direction as compared to east-west. As far as the intercropping effect is concerned, highest weed density (148.3 m^{-2}) and biomass (1964 kg ha^{-1}) was recorded in the sole tomato plots as compared to the plots where intercropping was done. Plant height was higher (84.86 cm) in intercropping with a ratio of 2 rows of both tomato and chili. In addition, fruits $plant^{-1}$(9.02)and fruit yield of tomato (21.92 t ha^{-1}) were higher in sole tomato plots followed by intercropping with a ratio of 1 row of both tomato and chili (18.5 t ha^{-1}). Regarding the intercrop (chili), maximum yield of (8.1 t ha^{-1}) was recorded in sole chili plots as compared to the yields in intercropping. It is thus concluded that sowing tomato seedlings in north south direction and intercropping with a ratio of 1-tomato-row: 1-chili-row showed an excellent combination of environment friendly weed management for an improved yield of tomato crop.

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Key words: Intercropping, higher elevation, sowing orientation, tomato, yield.

Citation: Hussain, Z., M. Ilyas, Luqman and I.A. Khan. 2016. Influence of sowing orientation and intercropping of chili on tomato yield and its weeds. Pak. J. Weed Sci. Res. 22(3): 395-406.

INTRODUCTION

Tomato (*Lycopersicon esculentum* L.) belonging to solanaceae family is a famous vegetable grown throughout the world and is considered as the second important vegetable crop after potato. It is a self pollinated crop vulnerable to elevated temperatures, particularly the large fruited fresh varieties. Tomato can be grown on variety of soils, however sandy and heavy clay with soil pH of 5.5 to 7.5 are suitable one. For early crop, sandy loam soil is measured (Baloch, 1994). Growing tomato in loam, clay loam and silty loam with sufficient organic matter resulted in maximum yield.

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 cope 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.

Manipulating crop row orientation is a significant determinant of crop productivity and controlling weeds (Karanja *et al*., 2014; Rousseaux *et al*., 1996). Sunlight falls on the crop plants in different angles at lower and upper altitudes and also in the north and south latitudes.

Intercropping can also influence the crop weed interaction scenario in tomatoes. The main reason for using a multiple cropping system is the fact that it involves integrating crops using space and labor more efficiently (Baldy and Stigter, 1997). Biophysical reasons include better utilization of environmental factors, greater yield stability in variable environments and soil conservation practices. Best utilization of growth resources and modified microclimate by component crops of intercropping for their better yield performance are practical only when the right planting pattern of component crops is followed. Increased productivity of intercropping over sole cropping has been attributed to better use of solar radiation, nutrients and water and fewer incidences of insect pest and disease (Willey, 1990). Planting pattern of intercrops is an important management practice that can improve better use of these resources and opportunities (Reddy *et al*., 1989).

Keeping in view the recognized importance of sowing direction and intercropping for weed management, field experiments were conducted under the higher elevation (Chitral) of Khyber Pakhtunkhwa Pakistan with the objectives to figure out the efficacy of sowing orientation/direction on growth and yield of tomato, to assess the effect of intercropping on weeds and tomato yield, to observe the efficacy of all the applied treatments at higher elevations, and to recommend a best environment friendly weed management package for tomato crop in the target region.

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 2015. The design of the experiment was a two factorial design with three replications of the experiment. The size of each experimental unit was kept 2.4 m × 3 m. Seedlings of the available cultivar 'Rio Grand' were transplanted on raised beds of about 45 cm high. 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 irrigation was carried out at seven days interval. Data were recorded on weed density (m^{-2}), weed biomass (kg ha^{-1}), plant height at maturity (cm), number of fruits $plant^{-1}$, individual fruit weight (g), fruit yield (t ha^{-1}), and LER.

For both the experiments, the weed density in each treatment was recorded by placing a quadrate of size 50cm x 50cm, three times randomly, counting the number of weeds occurring in each quadrate. The mean of three quadrates were subsequently converted to the density m^{-2}. The weed density m^{-2} data was collected both before and after the treatments application. Weed biomass parameter was recorded in the middle three rows of each of the treatments in both the experiments. The weeds were uprooted, then collected in paper bags and then their fresh weight was taken with the help of a digital balance. The values were averaged and converted to kg ha^{-1}.Data on plant height were recorded at the time of maturity. Ten representative plants in each treatment were selected randomly and their heights were measured from ground to the tip of the plant with the help of a graduated scale and then means were taken for each treatment separately. The data for number of fruits plant^{-1} was recorded by counting the fruits of the randomly selected ten plants in each treatment and then their means were calculated. Fruit weight data was recorded by calculating the weight of individual fruits picked from the randomly selected ten plants in and then their means were calculated. Data for fruit yield (t ha^{-1}) of the two field trials was recorded with the following formula. The obtained yield in kg ha^{-1} was divided by 1000 to calculate the yield in tons ha^{-1}.

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

For LER, the tomato partial LER (LER_{Tomato}) and partial LER of the intercrop Chili (LER_{Chili}) was calculated by using the formula presented by Willey (1990).

$$LER_{(TC)} = LERT + LERC = YIT/YST + YIC/YSC$$

where T stands for tomato, C for Chili, YIT = yield of intercropped tomato crop, YIC = yield of intercropped chili crop, YST = yield of sole tomato crop, and YSC = yield of sole chili crop.

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 for two factorial RCB design and the significant means were separated by using LSD test (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

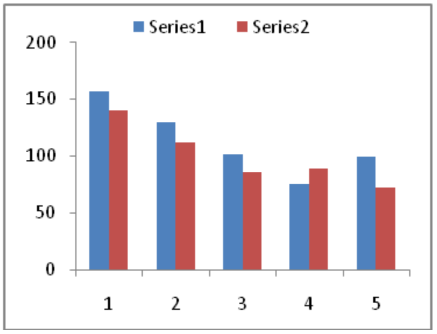
Weed density m^{-2}

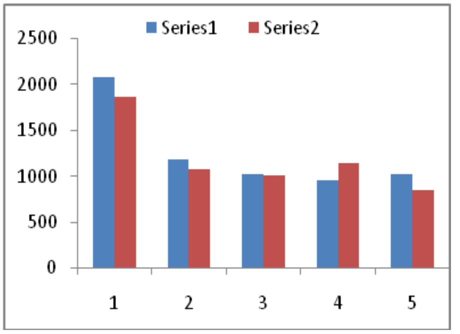
Analysis of the data revealed that sowing orientation, intercropping treatments and their interactions has significant effect density of weeds was significantly affected by sowing orientation and, intercropping treatments and their interactions (Table-1). Significant lower weed density i.e. 99.87 weeds m^{-2}was recorded in tomato plots sown in north-south orientation in comparison to east-west sowing direction (112.80 m^{-2}). Regarding the intercropping effect, the minimum weed density of 94 m^{-2} was noted in the intercropping of T3 = Tomato 1 row: Chili 2 row (1:2) and highest (148.33 m^{-2}) in sole tomato. It clearly indicated that intercropping factor reduced the weed biomass. Solar radiation falls more effectively on north south direction 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 touched the canopy of the adjacent plants due to which the situation became 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 sole tomato had the highest weed biomass because of sufficient space availability for weeds to germinate and grow higher. The intercropping provided less room to the emerging weeds and the weeds could not establish stronger in between the intercropped rows. Altier and Liebman (1986) pointed out that intercropping has a potential to suppress weeds and it offers the possibility of capturing a greater share of available resources than mono-crop. The interaction affect was also significant (Figure 1). Maximum weed density of m^{-2} was recorded in (156.67 m^{-2}) was recorded in plots of sole tomato plants sown in east –west direction, whereas less weed density (72.33 m^{-2}) was recorded in intercropped plots sown in north-south direction.

Weed biomass (kg ha^{-1})

It is evident from the statistical analysis that fresh weed biomass in different cropping geometries was highly significantly affected (Table-1). Significant lower weed biomass (1181.27 kg ha^{-1}) was recorded in tomato plots grown in north-south orientation as compared to the sowing of tomato seedlings in the east-west direction where the weed biomass was 1248.60 kg ha^{-}1. Maximum weed biomass (1964 kg ha^{-1}) was recorded in treatment having sole tomato followed by 1 row of sole tomato + 2 rows Chili (1122.33 kg ha^{-1}). Minimum fresh weed biomass was noted in 2 rows sole tomato + 2 row chili (932.83 kg ha^{-1}). Apparently the sowing of tomato crop plants in the north south received higher solar radiation than the east west sowing because the distance between lines is greater than the distance between plants. This made the crop more competitive which indirectly resulted in the lower weed biomass in the plots of north south direction (Monem*et al.*, 2012). Karanja *et al*. (2014) reported higher yields for sorghum crop because of reduced weed biomass in north south row orientation. The weed biomass is thus affected by the orientation of rows. It was observed that all the intercropping treatments decreased the fresh weed biomass probably due to the effective utilization of resources and severe inter-specific competition. As higher plant population of crop plants decrease the fresh and dry weed biomass (Khan et al., 2009) therefore it could be concluded that the concept of Chilli in tomato should be popularized in the area under discussion. Less weed biomass production and weed density under intercropping system is due to higher inter-specific competition combined with complementarily between intercrop species that improve the crop stand competitive ability towards weeds (Hauggaard-Nielson *et al*., 2003).

The interaction effect was also significant as shown in Fig. 2. Maximum weed biomass of 2069.33 kg ha^{-1} was recorded in sole tomato plants grown in east-west direction, while minimum weed biomass (843.kg ha^{-1}) was noted in plots grown in north south direction with intercropping.





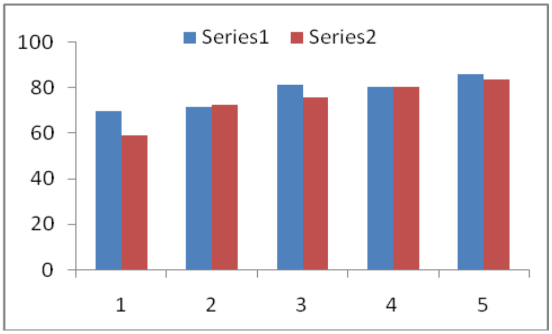
Series 1 (East west orientation), Series 2 (North south orientation)
1 (sole tomato), 2 (Tomato 1 row : Chili 1 row), 3 (Tomato 1 row : Chili 2 rows), 4 (Tomato 2 rows : Chili 1 row), 5 (Tomato 2 rows : Chili 2 rows)

Figure 1. Interaction of sowing orientations and intercropping for weed density m^{-2} at Chitral

Figure 2. Interaction of sowing orientations and intercropping for weed biomass (kg ha^{-1}) Chitral

Plant height at maturity (cm)

The analysis of the data revealed that sowing orientation, intercropping treatments and their interactions has significant effect on plant height (Table-1). The plant height was lower i.e. 74.31 cm in tomato plots of north-south direction as compared to sowing in the east-west direction (78.00 cm). As regards the effect of intercropping on tomato plant height,significant effect (P<0.05) was recorded in tomato plant height between mono and intercropping plots; plant height was higher in intercropping (84.86 cm) and lower in mono-cropping (64.59 cm). This might be due to more competition for capturing light in the plots where no. of individuals was higher. Therefore, in intercropping plots there were higher tomato plants as compared to the plants in monocropping plots. 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 interaction effect was also found significant as given in Fig. 2.3 below. Maximum plant height (86.22 cm) was recorded in intercropped with a ratio of 2 rows of tomato with 2 rows of chili sown in east-west direction, while minimum plant height (59.20 cm) was noted in sole onion plots grown in north south direction.



Series 1 (East west orientation), Series (North south orientation)
1 (sole tomato), 2 (Tomato 1 row: Chili 1 row), 3 (Tomato 1 row: Chili 2 rows), 4 (Tomato 2 rows: Chili 1 row), 5 (Tomato 2 rows: Chili 2 rows)

Figure 3. Interaction of sowing orientations and intercropping for Plant height (cm) at Chitral

Table-1. Effect of sowing orientation and intercropping on weed density m^{-2}, weed biomass (kg ha^{-1}) and plant height of tomato at Chitral, Pakistan during 2015

Treatments	Parameters		
	Weed density m^{-2}	Weed biomass (kg ha^{-1})	Plant height (cm)
Sowing orientation (SO)			
East west sowing	109.47 a	1248.60 a	78.00 a
North south sowing	103.20 b	1181.27 b	74.31 b
Significance level	*	*	*
Intercropping (IC)			
Sole tomato	148.33 a	1964 a	64.59 d
Tomato 1 row: Chili 1 row (1:1)	116.83 b	1122.33 b	72.09 c
Tomato 1 row:Chili two rows (1:2)	94 c	1014.33 bc	78.79 b
Tomato 2 rows: Chili 1 row (2:1)	82.17 c	1041.17 cd	80.45 b
Tomato 2 rows: Chili 2 rows (2:2)	90.33 c	932.83 d	84.86 a
LSD (0.05)	14.47	86.35	2.97
Interactions	Significance level (LSD Values)		
SO x IC	20.46	122.12	4.20

Means followed by different letters are significantly different at α = 0.05 after LSD test
LSD Values or * = Significant, NS = Non-significant

Number of fruits plant^{-1}

It is evident that sowing orientation and intercropping treatments has significant effect on number of fruit plant^{-1}while their interactions were found non-significant (Table-2). The number of fruit plant^{-1} was significantly lower i.e. 5.68 in plots with tomato plants sown in east-west direction as compared to sowing in the north-south direction (6.51). As far as the intercropping treatments were concerned, maximum number of fruit $plant^{-1}$(9.02) was recorded in plots of sole tomato while number of fruit $plant^{-1}$ were reduced (4.20) in intercropping with two rows of chili to one row of tomato. The increase in chili density enhanced plant competition for nutrients, water, light resulting in weak growth, which ultimately resulted in less production. In the work of Mallanagouda *et al.* (1995), a significant decrease occurred in the number of fruits of pea when it was intercropped with garlic as two crops there was an active competition between two crops for attaining essential nutrients for their growth. Similar results were recorded when chilies were intercropped in tomato here in this experiment. The interaction effect was observed non significant (Fig. 2.4) for the number of fruits $plant^{-1}$ of tomato crop.

Fruit yield (t ha^{-1})

It is clear from the analyses of data that the sowing orientation and intercropping significantly affected the fruit yield of tomato, where as their interaction was found non-significant. Table 2 showed the mean values and ANOVA for tomato fruit yield, respectively. The fruit yield was significantly higher (18.37 t ha^{-1}) in plots of north-south row sowing as compared to row orientation of east-west sowing (17.44t ha^{-1}). Regarding intercropping maximum fruit yield (21.92 t ha^{-1}) was recorded in rows with sole crop of tomato, while minimum (12.76 t ha^{-1}) was recorded with intercropping of two rows of chili with one row of tomato. The maximum fruit yield recorded in tomato when grown as single crop was due to maximum fruit diameter and weight. Light being important factor for photosynthesis plays an important role in growth and yield of plant. As in north south row orientation the crop plants receive more solar radiation than the east west row orientation which is apparently because of the higher distance between rows than the spacing between the crop plants so there will be more photosynthesis and more yield will be there. In this regard, Karanja *et al*. (2014) reported higher yields for his target sorghum crop in north south row orientation but lower yields for his cowpea crop as compared to the row orientation in east west. The interaction effect of sowing orientation vs intercropping was found non-significant for fruit yield of tomato at the upper elevation of Chitral during 2015.

Chili yield (t ha^{-1})

The analysis of variance showed that intercropping significantly affected the fruit yield of chili, used as intercrop, where as sowing orientation and their interaction was found non-significant (Table-2). Maximum chili yield (8.11 t ha^{-1}) was recorded in sole chili plants as compared to (4.52 t ha^{-1}) in plots of intercropping with a ratio of 2 rows of tomato to one row of chili. Light being an important factor for photosynthesis, and maximum solar radiation falls on south-west direction as compared to east west so maximum photosynthesis will result in maximum yield. Fruit yield decreased significantly in intercropping (chili with onion) might be due to less number of fruit, size and weight in this intercropping treatment as intercrop crops compete with each other for getting nutrients for proper growth. Similar results were concluded when chilies intercropped in garlic (Mallanagouda *et al*., 1995).The interaction effect of sowing orientation vs intercropping was found non-significant for fruit yield of Chili at the upper elevation of Chitral during 2015.

Table-2. Efficacy of sowing direction and intercropping on number of fruits plant^{-1}, fruit yield of tomato (t ha^{-1}) and chili yield (t ha^{-1}) at higher elevation (Chitral) of Pakistan

Treatments	Parameters		
	No. of fruits plant^{-1}	Fruit Yield (t ha^{-1})	Chili Yield (t ha^{-1})
Sowing orientation (SO)			
East west sowing	5.68 b	17.44 b	5.93
North south sowing	6.51 a	18.37 a	6.65
Significance level	*	*	NS
Intercropping (IC)			
Sole tomato	9.02 a	21.92 a	8.11 a
Tomato 1 row: Chili 1 row (1:1)	6.11 b	18.50 b	6.08 c
Tomato 1 row: Chili two rows (1:2)	4.20 d	12.76 d	6.95 b
Tomato 2 rows: Chili 1 row (2:1)	5.82 b	19.01 b	4.52 e
Tomato 2 rows: Chili 2 rows (2:2)	5.32 c	17.33 c	5.79 d
$LSD_{0.05}$	0.49	0.85	0.21
Interactions	Significance level		
SO x IC	NS	NS	NS

Means followed by different letters are significantly different at ɑ = 0.05 after LSD test
LSD Values or * = Significant, NS = Non-significant

Land equivalent ratio (LER)

The LER is an important parameter in the intercropping practices which calculates the net benefit from the same piece of land by sowing more than one crop at a time. It is to note that if the LER accedes to one will indicate a better result of the intercropping. Thus, the results indicated that the LER was good in all the intercropping treatments. All the yields obtained from the four different crops in their sole treatments as well as in intercropping with chili have been presented in Table 3. The LER values which were larger than one in the intercropping treatments of tomato, chili showed the yield benefit of intercropping over sole tomato crop. The largest LER value of 1.59 was calculated for the treatment of 1-row tomato intercropped with 1-row chili which was followed by 1.50 in the treatment of Tomato 2 rows: Chili 2 rows (2:2). On the other hand, the smallest LER value of 1.43 was noted in the treatments of Tomato 2 rows: Chili 1 row (2:1). The LER values thus ranged from 1.4065 to 1.4940 in all the intercropping treatments during 2012. In conclusion, all the intercropping systems have the potential to give substantially higher net income over mono-cropping.

Table-3. The effect of tomato and chili sownas monoculture (sole) or intercrops (IC) on their respective (LER) at Chitral, Pakistan

Treatments	Partial LER		Total LER
	To	Ch	
Tomato 1 row: Chili 1 row (1:1)	0.84	0.75	1.59
Tomato 1 row: Chili two rows (1:2)	0.58	0.86	1.44
Tomato 2 rows: Chili 1 row (2:1)	0.87	0.56	1.43
Tomato 2 rows: Chili 2 rows	0.79	0.71	1.50

CONCLUSION

The orientation of north south sowing produced better results as compared to east west sowing. The intercropping of chili crop in ration of 2 rows of tomato and one row of chili proved to be a best combination in terms of weed management, crops yield and LER. In case there is no problem of land slope or terrace, the sowing of tomato seedlings be made in north south direction for a better crop performance. Chili crop is good option for intercropping it with tomato crop so that the weeds are left least room for competition with crop, and also for having a diverse production from the same piece of land which has minimum risk of crop failure due to natural hazards or mishaps. Therefore, farmers having large land holdings should undergo an integrated weed management strategy that includes sowing orientation, and intercropping is the most profitable option. Such experiments should also be conducted in tunnel and the effect of such factors i.e. sowing orientation, and intercropping should also be tested accordingly in off-season tomato production.

ACKNOWLEDGMENT

The manuscript has been published under the HEC funded research project “Environment friendly weed management in vegetables” (grant no. 2332).

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