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INFLUENCE OF SOWING ORIENTATION AND INTERCROPPING OF CHILIES ON ONION YIELD AND ITS ASSOCIATED WEEDS IN PESHAWAR, PAKISTAN

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Abstract

A field trial was carried out at the Agronomy Research Farm of the The University of Agriculture Peshawar during the onion sowing season of 2015 to find out the effect of sowing orientation and intercropping chilies (*Capsicum annum* L.) on onion (*Allium cepa* L.) yield and the associated weeds. A two factorial experimental design was used for the experiment data analysis, with the experiment replicated three times. The sowing orientation was termed as Factor A with two levels i.e. North-South and East-West wards sowing, and Factor B was the intercropping treatments with five levels viz. sole onion, onion 1 row + chili 1 row (1:1), onion 1 row + chili 2 rows (1:2), onion 2 rows + chili 1 row (2:1), and onion 2 rows + chili 2 rows (2:2). Data were taken on weed density m^{-2}, weed fresh biomass (kg ha^{-1}), plant height (cm) of onion, biological yield (t ha^{-1}), bulbs yield of onion (t ha^{-1}), chili yield (t ha^{-1}) and Land equivalent ratio (LER). The results indicated that sowing orientation, intercropping and their interaction significantly affected the studied parameters of onion crop, intercrop and weeds. Regarding the sowing orientation, E-W sowing showed significant increase in weed density (94.27 m^{-2}), weed biomass (1323 kg ha^{-1}) and onion plant height (35.69 cm) as compared to the lower weed density (84 m^{-2}) and biomass (1240.67 kg ha^{-1}) in north-south sowing. On the other hand, the N-S sowing resulted in increased biological yield (3848.73 kg ha^{-1}) and bulb yield (20.73 tons ha^{-1}). The yield of chili was higher (6.98 t ha^{-1}) in North-South sowing than in east-west plots (6.20 t ha^{-1}). As far as the intercropping effect is concerned, maximum weed density (119.17 m^{-2}) and biomass (2118.5 kg) were recorded in the monocrop treatments as compared to the intercropping ones. In addition, biological (4625.84 kg) and bulb yields (23.21 kg ha^{-1}) were highest in sole onion plots, while intercropping with a ratio of one row of onion and two rows of the intercrop resulted in minimum weed density (48.5 m^{-2}), weed biomass (853.17 kg), biological yield (2430 kg ha^{-1}) and bulb yield (13.39 t ha^{-1}). The onion plant height was maximum (40.62 cm) in plots with intercropping in ratio of onion 2 rows + chili 2 rows. The chili yield was maximum (8.58 t ha^{-1}) in sole chili plots while minimum in the intercropping treatment of onion 2 rows + chili 2 rows (4.50 t ha^{-1}). It is thus inferred that sowing in the north south direction, with intercropping chili with onion in ratio of 1:1 could be a best environment friendly addition in the weed management program for yield enhancement of onion crop.

Key words: Chillies, Intercropping, Onion, Peshawar, Sowing orientation.

Introduction

Economy of Pakistan is mainly based on agriculture sector. The environmental conditions of Pakistan are conducive to grow a wide range of crops. However, production of most of the crops in Pakistan is lower as compared to the world's average (Khan, 2004). Various weeds infestation is one of the most important reasons for the lower yields of crops in the country. According to Anon., (2004), onion (*Allium cepa* L.) is the world's one of the most important vegetable crop having about 61 m t total production in the world. Pathak (2000) is of the view that out of the 15 vegetables at FAO list, the total production of onion comes second after the tomato (which is at first rank). It is grown in almost all the districts of the Khyber Pakhtunkhwa, Pakistan covering irrigated and un-irrigated areas of 10157 and 823 ha, with total production of 170629 and 10624 tons, respectively (Anon., 2011).

Baloch (1994) mentions that any well-drained and fertile soil is good for successful growth of onion. The best soil types for onion cultivation are clay, sandy loam and manure soils. The soil pH of 6-7 is best suitable for onion crop production. Out of the many factors weed infestation is a very important factor for onion yield reduction. Onions face strong competition from weeds for nutrients, space, light, and soil moisture (Singh *et al*., 2006) which considerably diminish the onion yield, quality and crop value through increased cost of production and harvesting (Kizilkaya *et al*., 2001). Onions cannot effectively compete with weeds due to its smaller size of leaves (Smith *et al*., 2008; Qasem, 2006; Carlson & Kirby, 2005; Ghosheh, 2004). The weed-crop competition begins at very early growth stages. In addition, weeds give refuge to insect pests and disease causing agents as well (Singh *et al*., 2006). The weed based losses in yields have been reported to be much higher than the insect and disease based losses. Generally weeds infestation reduces the crop yield by 30-60% (Hussain, 1983). Hand weeding is one of the key weed control method for marketable bulbs. Generally, the farmers do not apply weed control methods at the early stages of the crop to prevent major weed related damages. Furthermore, Melander & Rasmussen (2001) described that manual weeding was a time-consuming, laborious and expensive method of weed control, and even it might also damage the crop.

Many scientists regarded onion plants as the poor competitors (Ozer *et al*., 1997; Dunan *et al*., 1996; Menges & Tamez, 1981). Wicks *et al*., (1973) opined that the poor competitive capability of onion plants along with their lack of adequate foliage and initial slow growth made them weaker against weeds. The slow growth in addition to shallow roots and thin canopy render onion seedlings poor weed competitors. Moreover, the cylindrical upright leaves have less shading capacity of the soil to block the weed

emergence and growth (Bell & Boutwell, 2001). Several factors like present weed species, crop variety, growth stage of the crop, weed species, labor costs and availability etc. all play role together.

The lower yields are attributed to limited availability of good quality seeds and improved varieties (Ali *et al*., 2007). Improved seed varieties would contribute to crop yield up to 30% (Shaikh *et al*., 2002). The yield gap of 50–60% between potential and actual yield is also attributed to several agronomic constraints of which improper sowing methods and poor weed control practices are considered to be important ones (Ahmad, 1992). Soil moisture is also one of the most important factors that influences onion yield. Onion requires frequent irrigation as the crop extract very little water from depths below 5 cm; most of the water is within the depth of 30 cm of the soil (Ali *et al*., 2007). Thus, to stimulate the root growth and also provide adequate water to the plant, upper soil areas should be kept moist. Using plant residues and synthetic materials as mulch is a well-established practice for soil moisture conservation and plant growth and development (Kashi *et al*., 2004; Rhu *et al*., 1990). There is another scope of manipulating the sowing directions in relation to sunlight that falls on the crop canopy. No proper research has yet been reported on this aspect. Therefore, it could make us discover the impact of sowing directions on the weeds and yield of the crop.

The experiment was conducted with the objectives to determine the effectiveness of sowing directions on weed management and improving onion yields, to evaluate the effect of intercropping on onion yield and associated weeds, and to generate a best environment friendly weed management package for the farming community of the locality.

Materials and Methods

Experimental site: The experiment was conducted at the Research Farm of the University of Agriculture Peshawar during growing season of onion 2015. The experiment was arranged in a randomized complete block design with three replications. The variety used for onion was Swai-1 and that for chili was B-9, respectively. Disease free well developed seedlings of onion were transplanted in furrows. Seedlings of chili were transplanted in between the rows of onion, spaced at 30 cm x 15 cm. The observations on growth and yield and quality characters of onion were recorded by tagging ten randomly selected plants leaving the border rows from each plot of different treatments and their average values were worked out. For the intercrop (chili) only the fruit yield was recorded.

A nursery was raised before the experiments. The cultivar used was SWAT-1 for onion and B-9 for chili. The experimental field was leveled and standard amount of FYM were applied before transplantation. Recommended dose of N:P:K i.e. (90:50:30 kg ha^{-1}) were applied just before transplantation and half nitrogen were applied after four weeks of transplantation. Irrigation was carried out at weekly interval. Mulching was applied in the different plots after one week of transplantation.

The intercropping treatments included (1)sole onion, (2) onion 1 row + chili 1 row (1:1),(3) onion 1 row + chili 2 rows (1:2), (4) onion 2 rows + chili 1 row (2:1), (5) onion 2 rows + chili 2 rows (2:2) and (6) sole chili. The data was recorded on the following parameters with two sowing orientation (i.e. Series 1; East-West and series 2; North-South).

Weed density in each treatment of the two experiments was recorded by placing quadrat of 50cm x 50cm size, three times randomly, counting the number of weeds occurring in each quadrat. The mean of three quadrates were subsequently converted to the density m^{-2}. Weed biomass parameter was recorded in the middle three rows of each of the treatments in both the trials. The weeds were uprooted, then collected in paper bags and then their weight was taken with the help of a digital balance. The data on plant height was recorded at the time of maturity. A total of 10 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. For recording bulbs yield, three central rows from each treatment were harvested and then bulbs were separated from plants and weighed. Finally the bulbs yield per hectare were computed by the formula,

$$\text{Bulb yield (kg ha}^{-1}) = \frac{\text{Bulb yield (kg) from treatments}}{\text{Area harvested (m}^{-2})} \times 1000 \text{ m}^2$$

For recording the chili yield, three central rows from each treatment were harvested and then fruits were separated from plants and weighed. Finally the chili fruit yield per hectare were computed by the formula,

$$\text{Chili yield (kg ha}^{-1}) = \frac{\text{Chili yield (kg) from treatments}}{\text{Area harvested (m}^{-2})} \times 1000 \text{ m}^2$$

Onion partial LER (LER $_{Onion}$) and intercrops partial LER (LER_{Chili}) was calculated by using the formula of Willey (1990).

$$LER_{(OC)} = LER\text{-}O + LER\text{-}C = YIO/YSO + YIC/YSC$$

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

Statistical analysis

The data collected was statistically analyzed through MS Excel and also by using the statistical software Statistix 8.1 for confirmation. The design used was three

factorial RCB design. Upon getting significant F-test results the least significant difference (LSD) test was applied in order to compare the means of the treatments at 5% probability level.

Results and Discussion

Weed density m^{-2}: Statistical analysis of the data collected on weed density (m^{-2}) revealed that density of weeds was significantly affected by sowing orientation and intercropping treatments (Table 1) and their interactions (Fig. 1). Significantly less weed density (84 weeds m^{-2}) was recorded in plots with onion plants sown in north-south direction as compared to sowing in the east-west direction (94.27 m^{-2}). In the intercropping treatments, the lowest weed density (48.5 m^{-2}) was noted in the intercropping of onion 1 row + chili 1 row (1:2) and highest (119.17 m^{-2}) in sole onion. It is obvious that intercropping factor reduced the weed biomass. 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. The sole onion 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. Intercropping is one option for reducing weed problems through nonchemical methods (Bibi *et al*., 2019; Vandermeer, 1989). Altier & Liebman (1986) pointed out that intercropping had a potential to suppress weeds and it offers the possibility of capturing a greater share of available resources than mono-crop.

Weed biomass (kg ha^{-1}): Statistical analysis of the data revealed that fresh weed biomass in different cropping geometries and intercropping treatments was significantly affected (Table 1), while the interaction effect was also significant (Fig. 2). Weed biomass was significantly lower (1240.67 kg ha^{-1}) in onion plots grown in north-south direction as compared to the sowing of onion seedlings in the east-west direction (1323 kg ha^{-1}). Maximum weed biomass (2118.5 kg ha^{-1}) was recorded in treatment having sole onion followed by onion 1 row + chili 1 row (1211.67 kg ha^{-1}), minimum fresh weed biomass was noted in onion 1 row + chilli 2 rows (853.17 kg ha^{-1}). It seemed that the sowing of onion 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. 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 Chili in onion 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).

Plant height at maturity (cm): The data presented in (Table 1) showed that plant height was significantly affected by the sowing orientation, intercropping treatments and their interactions (Fig. 3). The plant height was lower (74.95 cm) in plots with onion plants sown in north-south direction as compared to sowing in the east-west direction (77.62 cm). Regarding intercropping, significant difference in onion plant height (p<0.05) between mono and intercrops was observed which was higher in intercropping (22.97 cm) and lower in mono-cropping (15.88 cm). This might due to more light capturing by intercropping resulting more taller plant than mono-cropping. 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).

Table 1. Effect of sowing orientation and intercropping on weed density m^{-2}, weed biomass (kg ha^{-1}) and plant height (cm) of onion at lower elevation (Peshawar) Pakistan.

Treatments	Parameters		
	Weed density m^{-2}	Weed biomass (kg ha^{-1})	Plant height (cm)
Sowing orientation (SO)			
East west sowing	94.27 a	1323.00 a	34.04 b
North south sowing	84.00 b	1240.67 b	35.80 a
Significance level	*	*	*
Intercropping (IC)			
Sole onion	119.17 a	2118.5 a	26.27 d
Onion 1 row: chili 1 row (1:1)	98.17 b	1211.68 b	34.10 c
Onion 1 row: Chili 2 rows (1:2)	48.5 d	853.17 d	35.21 bc
Onion 2 rows: Chili 1 row (2:1)	92.5 bc	1164.5 b	38.43 ab
Onion 2 rows: Chili 2 rows (2:2)	87.33 c	1061.33 c	40.62 a
LSD (0.05)	7.69	68.39	4.04
Interaction	**Significance level (LSD values)**		
SO x IC	10.87	96.72	5.71

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

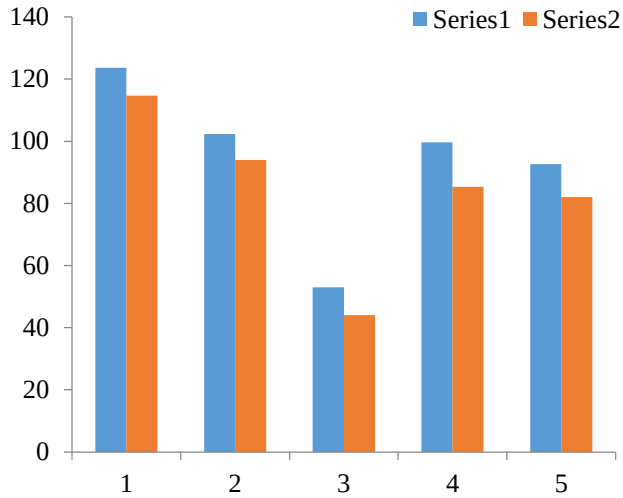

Fig. 1. Interaction effect of sowing orientation and intercropping treatments for weed density in onion crop at lower elevation of Peshawar Pakistan during 2015.

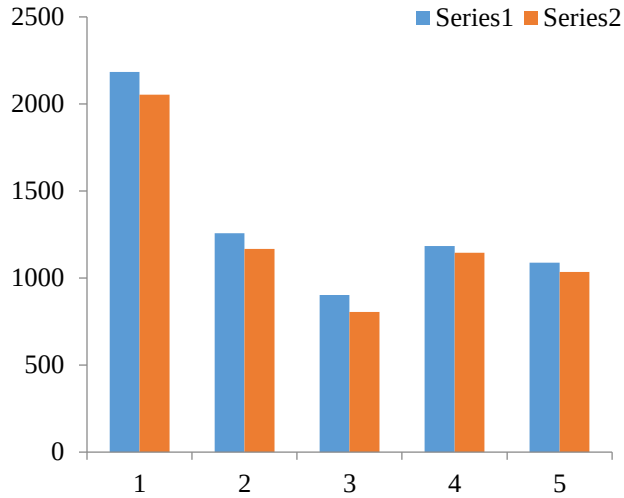

Fig. 2. Interaction effect of sowing orientation and intercropping treatments for weed biomass in onion crop at lower elevation of Peshawar Pakistan during 2015.

Series 1 (east west orientation), Series 2 (north south orientation), 1 (sole onion), 2 (Onion 1 row: Chili 1 row), 3 (Onion 1 row: Chili 2 rows), 4 (Onion 2 rows: Chili 1 row), 5 (Onion 2 rows: Chili 2 rows)

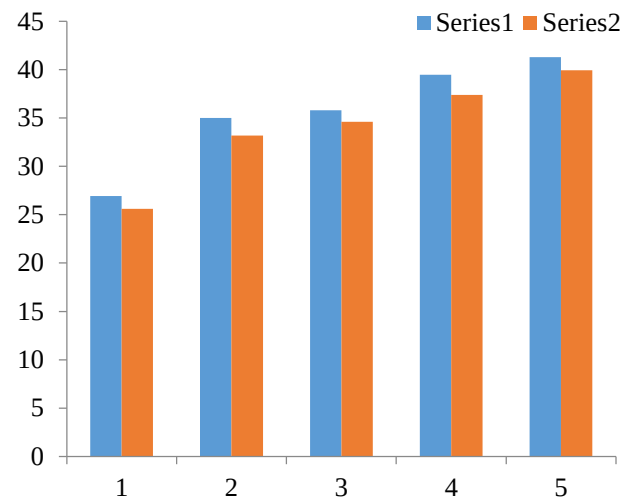

Fig. 3. Interaction effect of sowing orientation and intercropping treatments on plant height (cm) in onion crop at Peshawar during 2015.

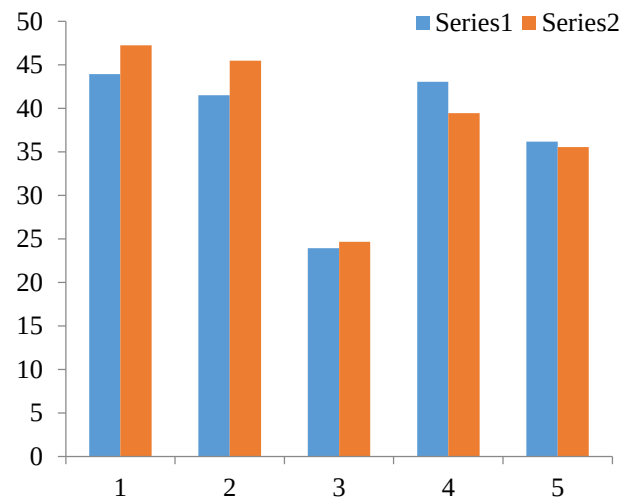

Fig. 4. Interaction effect of sowing orientation and intercropping treatments for biological yield of onion crop at Peshawar during 2015.

Series 1 (east west orientation), Series 2 (north south orientation), 1 (sole onion), 2 (Onion 1 row: Chili 1 row), 3 (Onion 1 row: Chili 2 rows), 4 (Onion 2 rows: Chili 1 row), 5 (Onion 2 rows: Chili 2 rows)

Biological yield (t ha^{-1}): Statistical analysis of the data revealed that biological yield was significantly affected by the sowing orientation, intercropping and their interactions (Table 2; Fig. 4). The biological yield was significantly lower (37.72 t ha^{-1}) of onion plants sown in east-west direction as compared to those sown in north-south direction (38.49 t ha^{-1}). On the other hand, the biological yield was significantly lowest (24.3 t ha^{-1}) in plots of intercropping of chili 2 rows + onion 1 row and highest biological yield (45.59 t ha^{-1}) was found in sole onion plots. Regarding the interaction effect, maximum biological yield (47.26 t ha^{-1}) was recorded in sole onion plants sown in north-south direction. Light is an important factor for growth and yield as well as photosynthesis of plants. The onion plants in north south direction might have received optimum light as compared to plants sown in east west direction, which resulted in more photosynthesis and better growth and yield. In intercropping, there is always a comparatively stronger competition for soil, nutrients, water and light among the plants of the main crop and the intercrop than in sole cropping, so there will be higher growth per plant in sole cropping as compared to intercropping. Similar results were reported by Frey (1973) who intercropped turnip with pea by Caetano *et al.* (1999) who intercropped lettuce with carrot.

Bulb yield (t ha^{-1}): Bulb yield of onion was significantly affected by sowing orientation and intercropping, while their interaction was found non-significant (Table 2). The bulb yield was higher (20.73 t ha^{-1}) in plots of north-south row sowing than east-west sowing (19.79 t ha^{-1}); while

the highest bulb yield (23.21 t ha^{-1}) was recorded in rows with sole crop of onion, while minimum (13.39 t ha^{-1}) was recorded with intercropping of two rows of chili with one row of onion. The maximum bulb yield recorded in onion when grown as single crop was due to maximum bulb diameter and weight. The role of light interception is important for the growth and yield of plants in the photosynthesis process. The onion plants that produced higher yield in north south direction might have captured optimum light interception as compared to the plants sown in east west direction, which underwent more photosynthesis that resulted in better yield. In intercropping conditions, there is a stronger interspecific competition for soil nutrients, space, water and light as compared to sole cropping, so the per plant yield in sole cropping is greater in sole cropping. Frey (1973) provided similar results who intercropped turnip with pea and Caetano *et al*., (1999) also gave analogous results who intercropped lettuce with carrot.

Chili yield (t ha^{-1}): Data regarding chili yield is presented in (Table 2). Analysis of variance showed that sowing orientation and intercropping treatments significantly affected chili yield while their interaction was found non-significant. Maximum chili yield (6.98t ha^{-1}) was recorded in plots sown in north-south direction as compared to (6.20 t ha^{-1}) in east-west direction. Regarding intercropping maximum chili yield (858 t ha^{-1}) was recorded in sole chili crop whereas it was less (4.50 t ha^{-1}) in plots intercropped with a ratio of two rows of onion and 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 results in maximum yield. A significant decrease occurred in fruit yield when chili was intercropped in onion probably due to decrease in fruit, number, size and weight in this intercropping treatment as there was an active competition between two crops for attaining essential nutrients for their growth. Similar results were obtained when chilies were intercropped with garlic (Mallanagouda *et al*., 1995).

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 onion, chili showed the yield benefit of intercropping over sole onion crop. The largest LER value of 1.68 was calculated for the treatment of onion 1 row intercropped with 1-row chili which was followed by 1.63 in the treatment of Onion 2 rows: Chili 2 rows (2:2). On the other hand, the smallest LER value of 1.48 was noted in the treatments of Onion 2 rows: Chili 1 row (2:1). In conclusion, all the intercropping systems have the potential to give substantially higher net income over mono-cropping.

Table 2. Effect of sowing orientation and intercropping on bulb size (cm), biological yield (t ha^{-1}), bulb yield (t ha^{-1}) and chili yield (t ha^{-1}) of onion at lower elevation (Peshawar) of Khyber Pakhtunkhwa.

Treatments	Parameters		
	Biological Yield (t ha^{-1})	Bulb Yield (t ha^{-1})	Chili Yield (t ha^{-1})
Sowing orientation (SO)			
East west sowing	37.72 b	19.79 b	6.20 b
North south sowing	38.49 a	20.73 a	6.98 a
Significance level	*	*	*
Intercropping (IC)			
Sole onion	45.60 a	23.21 a	8.58 a
Onion 1 row: Chili 1 row (1:1)	43.50 b	21.81 b	6.37 c
Onion 1 row: Chili two rows (1:2)	24.3 e	13.39 c	7.31 b
Onion 2 rows: Chili 1 row (2:1)	41.25 c	21.93 b	4.50 e
Onion 2 rows: Chili 2 rows (2:2)	35.88 d	20.97 b	6.19 d
LSD (0.05)	1.69	1.02	1.11
Interactions	**Significance level (LSD values)**		
SO x IC	2.39	NS	NS

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

Table 3. The effect of onion and chili grown in monoculture or intercrops on land equivalent ratio (LER) at Peshawar during 2015.

Treatments	Partial LER		Total LER
	Onion	Chili	
Onion 1 row: Chili 1 row (1:1)	0.94	0.75	1.68
Onion 1 row: Chili two rows (1:2)	0.58	0.85	1.43
Onion 2 rows: Chili 1 row (2:1)	0.95	0.53	1.48
Onion 2 rows: Chili 2 rows	0.90	0.73	1.63

Conclusion

Row sowing in north south direction produced promising results as compared to that in east west direction in the agroecological conditions of Peshawar in terms of onion bulb yield and weed control. Intercropping of Chili can be a good source for weed management and diverse production from the same piece of land. Therefore, the north south row sowing orientation should be adopted by the farmers for having good crop yield and weed control in a non-costly and environment friendly way. In addition, the diagonal orientations may also be tested for having a comprehensive understanding of the orientations. Intercropping should be adopted by the farmers because there is very less intercropping concept in the area.

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