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PLANT SPACING AND MULCHING EFFECT ON ONION YIELD AND WEEDS

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ABSTRACT

A field experiment was conducted at the Horticulture Research Farm of the University of Agriculture Peshawar Pakistan during summer 2015 to find out the effect of different plant spacings and weed control treatments on onion yield and its infesting weeds. A two factorial RCBD experimental design was used for the experiment replicated three times. Factor A was termed as plant spacing (10, 15 and 20 cm) while factor B included the treatments of Rumex crispus as mulch, Euphorbia helioscopia as mulch, a hand weeded treatment and a weedy control for comparison. Data were taken on weed density m^{-2}, fresh weed biomass (kg ha^{-1}), plant height (cm), bulb size (cm), biological yield (t ha^{-1}), bulb yield (t ha^{-1}) and the cost benefit ratio. Results of the experiment showed that plant spacing, weed mulches and some of their interactions showed significant effect on growth and yield parameters. Plant to plant spacing of 20 cm significantly increased the weed density, weed biomass and bulb size of onion; whereas minimum weed density and biomass were obtained at 10 cm plant spacing which resulted in increased plant height, biological and bulb yields. Among the treatments of weed control, weedy check resulted in highest weed density, biomass and onion plant height while hand weeding resulted in highest bulb size, biological and bulb yields as compared to the weedy check. The values in the mulches treatments were though lower than hand weeding but better than the weedy check. In conclusion, the 10 cm spacing among onion seedlings and the mulching of R. crispus and E. helioscopia can be recommended as a suitable environmentally friendly weed management method for the enhancement of onion yield.

Key words: Mulches, onion, Peshawar, planting density, weeds.

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INTRODUCTION

The environmental conditions of Pakistan are naturally conducive for growing a wide range of crops. However, the net production of most of the crops in the country is lower than the world's average production (Khan, 2004). There are many reasons for the lower production in which the weeds infestation is the most important factor and mostly neglected. According to Anon. (2013) onion (*Alium cepa* L.) is one of the most important vegetable crops in the world having about 68.45 m tons total global production.

It is grown in majority of the districts of Khyber Pakhtunkhwa province, with total production of 1740.2 thousand tons with an area of 143.9 thousand ha (Anonymous, 2015). The best soil for successful onion cultivation is deep, friable loam and alluvial soil with good drainage, moisture holding capacity and sufficient organic matter. Weed infestation is a very important factor causing reduction in onion yield, as there is always a strong competition for nutrients, space, light, and soil moisture posed by weeds (Singh *et al*., 2006) which considerably diminish the onion yield and quality through increased cost of production (Kizilkaya *et al*., 2001). However, onions cannot effectively compete with weeds due to its smaller leaves' size (Smith *et al*., 2008; Carlson and 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. The weed based losses in yields have been reported to be very higher than the insect and disease based losses (Singh *et al*., 2006). Generally weeds infestation reduces the crop yield by 30-60% (Hussain, 1983). Hand weeding is one of the key weed control method used by the farmers for marketable bulbs. However, the manual weeding is a time-consuming, laborious and expensive method of weed control, and even it may also damage the crop (Melander and Rasmussen, 2001).The poor competitive ability of onion plants is due to the lack of adequate foliage and initial slow growth (Dunan *et al*., 1996). The slower growth in addition to shallow roots and thin canopy render onion seedlings poor weed competitors (Qasem, 2006). Moreover, the cylindrical upright leaves have less shading capacity of the soil to block the weed emergence and growth (Bell and Boutwell, 2001).

The control of plant spacing is one of the cultural practices to control bulb size, shape and yield (Geremew *et al*., 2010). The higher yield and better control of over or under bulb size could be obtained if plants are grown at optimum density. Bulb neck diameter, mean bulb weight and plant height decreased as population density increased. Total bulb yield can be increased as population density increases (Kantona *et al*., 2003).

Soil moisture is 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). Consequently, to stimulate root growth and provide optimum water to the seedlings, the soil surface should be kept moist. Using the plant residues or synthetic materials as mulch is a well-established practice for soil moisture conservation and plant growth and development (Kashi *et al*., 2004). If the weeds seedlings biomass is removed manually before seeding and used as mulch will not only help reduce the weed seed bank but also increase the soil moisture conservation and soil fertility as well.

Keeping in view the significance of plant spacing and mulching for weed management strategy, a field experiment was conducted with the objectives to figure out the efficiency of plant to plant spacing and weed biomass as mulch on crop and weeds performance and to recommend a best environment friendly weed management method for onion crop in the target region.

MATERIALS AND METHODS

Experimental sites and Agronomic practices

The experiment under reference was carried out at the Horticultural Research Farm of the University of Agriculture, Peshawar, Pakistan in crop growing season 2015. The experiment was laid out in a two factorial Randomized Complete Block design keeping three replications. Factor A included plant spacing of three levels i.e. 10, 15 and 20 cm. The treatments in factor B were biological material of two weeds i.e. *Rumex crispus* and *Euphorbia helioscopia* as mulch used @ 5 tons ha^{-1}, along with a hand weeding treatment and a weedy check for comparison. The size of each individual treatment was 2m x 4m.

The data were recorded on weed density m^{-2}, weed biomass (kg ha^{-1}), plant height (cm), size of bulb plant^{-1} (cm) and bulbs yield (kg ha^{-1}). Weed density in each treatment was recorded by placing quadrate of 50cm x 50cm size, three times randomly, counting the number of weeds occurring in each quadrate. The means of three quadrates were subsequently converted to the density m^{-2}. Weed biomass parameter was recorded in the central three rows of each of the treatments. The weeds were uprooted before setting seeds then collected in paper bags and then their weight was taken with the help of a digital balance. Data on plant height was 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 size of bulb plant^{-1} was measured by selecting ten bulbs from each treatment randomly and was measured by the help of Vernier Caliper and means were taken out. 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 was computed by the formula,

$$\text{Bulb yield (kg ha}^{-1}\text{)} = \frac{\text{bulb yield (kg) from treatments}}{\text{Area harvested (m}^{-2}\text{)}} \times 10000 \text{ m}^2$$

Statistical analysis

The data collected were statistically analyzed through MS Excel and also by using the statistical software Statistix 8.1 for confirmation. The design used was 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 (Steel and Torrie, 1980)

RESULTS AND DISCUSSION

Weed density m^{-2}

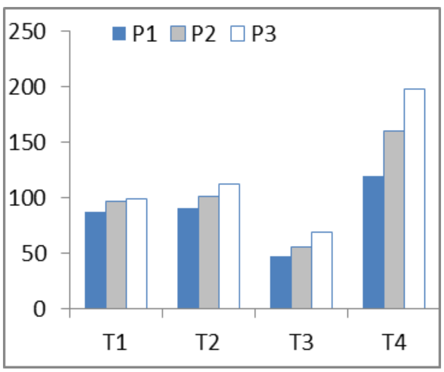
The analysis of the data showed that weed density was significantly affected by the plant spacing, weed control treatments and their interactions (Table-1). The density was significantly lowest (91.7 weeds m^{-2}) in plant spacing of 10 cm, followed by spacing of 15 cm (100.5 m^{-2}) and highest weed population (108.08 m^{-2}) was found in 20 cm spacing. In the weed control treatments, the weed density was significantly lowest (59.33 m^{-2}) in hand weeded plots followed by *Rumex crispus* plant biomass used as mulch (97.11 m^{-2}) and plots with *Euphorbia helioscopia* plant biomass applied as mulch (104 m^{-2}) as compared to the significantly highest weed density (153.22 m^{-2}) in the weedy check. Figure.1 shows the significant interaction for P x T regarding weed density.

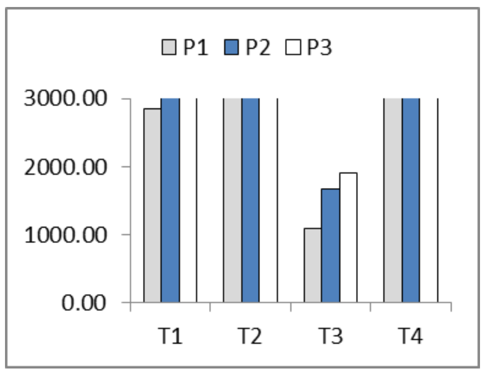
Narrow spacing of 10 cm in onion plants smothered weeds number per unit area whereas wider spacing of 15 and 20 cm gave room to the emerging weeds helped increase the density and composition of the infesting weeds (Ara *et al*., 2007). The weed biomasses as mulch enhanced the soil moisture retention and improvedthe soil temperature which boostedthe crop performance making it more competitive against the growing weeds (Dalorima *et al*., 2014). 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 onion (Kosterna, 2014). In this experiment, the mulching of *Rumexcrispus* performed well in reducing weed density because of its higher canopy and shading of the emerging weeds as compared to the mulching of *E helioscopia*. Though hand weeding resulted best in reducing the number of weeds per unit area, it is not feasible in conditions of labor scarcity, or at large scale.

Weed biomass (kg ha^{-1})

The analysis of the data showed that weed biomass was significantly affected by the plant spacing, weed control treatments and their interaction (Table-1). Weed biomass was significantly lowest (1085 kg) in plant spacing of 10 cm, followed by plots of 15 cm (1300 kg) and highest biomass (1327 kg ha^{-1}) was recorded in 20 cm spacing. On the other hand, the weed biomass was lowest (518 kg) in hand weeded treatments followed by mulching of *R. crispus* plant biomass (1104 kg) and *E. helioscopia* plant biomass (1219 kg) as compared to the significantly highest weed biomass (2110 kg ha^{-1}) in weedy check. The significant interaction is given in Fig. 2 for P x T.

The spaces between the onion plants significantly affected the weed biomass. As the weed density finally results in biomass thus the narrow spacing of 10 cm where weed density was lowest resulted in lowest biomass because of weeds suffocation due to higher crop population as compared to that of 15 and 20 cm (Ara *et al*., 2007). Using weed biomass as mulch also boosted crop performance making it more competitive against the associated weeds. Mulching of the soil decreased the weed biomass because of suffocation of the seedlings due to limited photosynthesis being under shade (Kosterna, 2014).





P1 (10 cm), P2 (15 cm), P3 (20 cm),
T1 (*R. crispus* as mulch), T2 (*E. helioscopia* as mulch), T3 (hand weeding), T4 (weedy check)

Figure 1. Interaction effect of plant spacing and weed control treatments for weed density m^{-2}

Figure 2. Interaction effect of plant spacing and weed control treatments for weed biomass (kg ha^{-1})

Plant height of onion (cm)

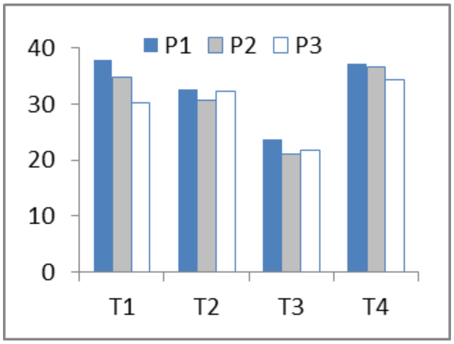
The analysis of the data revealed that plant height was significantly affected by the plant spacing and weed control treatments (Table-1). Similarly plant height under wider spacing (20 cm) resulted in lower heights (31.51 cm), followed by plots in which onion plants were sown at a distance of 15 cm with plant height of 33.11 cm and highest plant height (34.3 cm) was found in plant distance of 10 cm. The plant height under the factor B was significantly lowest (24.69 cm) in hand weeded plots followed by *Euphorbia helioscopia*plant biomass used as mulch (33.50 cm) and plots with *Rumex crispus* biomass applied as mulch (36.41cm) as compared to the significantly highest plant height (37.35 cm) in the weed check plots.

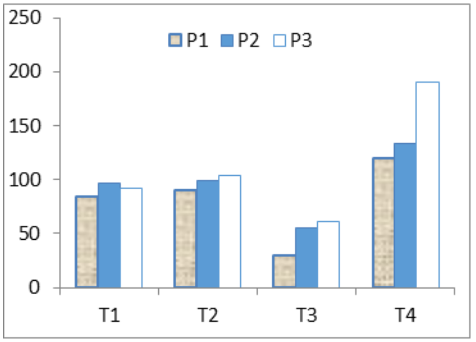
Close spacing of 10 cm in onion plants increased plant height whereas wider spacing (15 and 20 cm) resulted in decreased plant height. The reason could be that plants grow higher under competition regimes for capturing photosynthetic light. Papadopoulos and Ormrod (1991) recorded increased plant height with close spacing among crop plants. However, Sikder*et al*. (2010) got longest plant heights in onion under wider spacing for which the reason is not known. The soil moisture retention is enhanced under mulching due to which the crop performance is boosted and thus height is improved.Mochiah *et al*. (2012) obtained increased plant height of pepper under mulching treatment of the soil.

Bulb size/diameter (cm)

Bulb size plays a significant role in yield and yield related components of the crop under weed competition stress. It is evident from the analysis of the data that plant spacing significantly affected the onion bulb size (Table-2). Similarly, close spacing (10 cm) resulted in lowest (5.7 cm), followed by plots of 15 cm (6.35 cm) and bulb size (7.13 cm) was found in 20 cm spacing. For the factor B, the bulb sizewas significantly lowest (5.27 cm) in weedy check plots followed by *Euphorbia helioscopia* plant biomass used as mulch (6.45 cm) and plots with *Rumex crispus* plant biomass applied as mulch (6.74 cm) as compared to the significantly highest bulb size (7.16 cm) in the hand weeded plots.

Sikder *et al*. (2010) got maximum bulb diameter and fresh weight under wider spacing. The logic is quite obvious that under higher competition the bulb size or diameter will get reduced because of higher utilization of resources for vegetative growth. As far as mulching is concerned, Dalorima *et al*. (2014) observed higher soil moisture retention under mulching that improved the crop competitive ability against the associated weeds, increased soil fertility and had a significant effect bulb size, a yield component. Though hand weeding resulted best in getting the highest bulb size, it becomes impracticable at large scale or under the labor scarcity.





P1 (10 cm), P2 (15 cm), P3 (20 cm),
T1 (*R.crispus* as mulch), T2 (*E. helioscopua* as mulch), T3 (hand weeding), T4 (weedy check)

Figure 3. Interaction effect of plant spacing and weed control treatments on plant height (cm)

Figure 4 Interaction effect of plant spacing and weed control treatments on bulb size (cm)

Biological yield (t ha^{-1})

It is evident from the analysis of the data that biological yield was significantly affected by the plant spacing, weed control treatments and their interactions (Table-2). Similarly, wider plant spacing (20 cm) resulted in minimum biological yield (29.57 t ha^{-1}), followed by plots of 15 cm (31.01 t ha^{-1}) and highest biological yield (33.9 t ha^{-1}) was recorded under 10 cm. Regarding factor B, the biological yield was significantly lowest (21.60 t ha^{-1}) in weedy check followed by *Euphorbia helioscopia* biomass mulch (33.54 t ha^{-1}) and *Rumex crispus* biomass mulch (34.09 t ha^{-1}) as compared to the significantly highest biological yield t ha^{-1} (36.72t ha^{-1}) in the hand weeded plots. The significant interaction for P x T is given in Fig.5.

The spaces between the onion plants significantly affected the biological yield of onion. Kahsay *et al*. (2013) recorded highest yieldsof onion at the closest intra-row spacing (5 cm) followed by 7.5 cm. Ramalingam *et al*. (2013) achieved lowest yields in un-weeded control plots which in turn reflected through higher weed index of 60.6% due to heavy competition of weeds for nutrients, space and light.Regardless of what kind of mulch was used, mulching of the soil decreased the weed density in the beginning and also improved the soil structure and fertility that resulted in improved yield of onion (Kosterna, 2014). Hand weeding though resulted best in achieving highest yield, however its application on large scale is impracticable and also not feasible in conditions of labor scarcity. As for as interaction is concerned, the interaction effect of P x T is important in increasing the biological yield of onion grown in the test area.

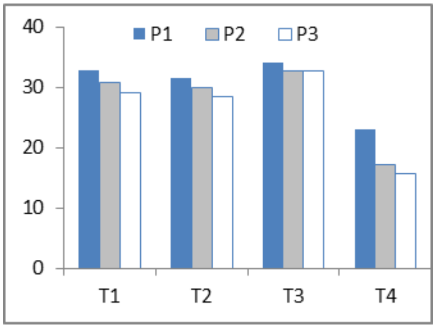
Bulb yield (t ha^{-1})

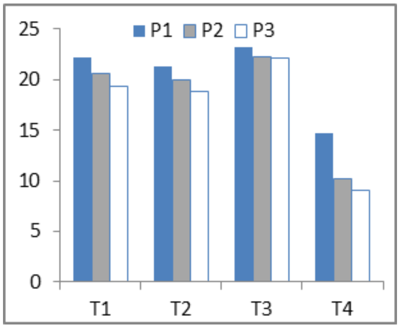
From analyzing the data, it became obvious that the plant spacing, weed control treatments and their interactions all significantly affected the bulb yield of onion. Table-2 indicates the mean values for onion bulb yield. Regarding plant spacing, the bulb yield was significantly highest (22.9 t ha^{-1}) in plots of 10 cm spacing, followed by 20.84 t ha^{-1}(15 cm spacing)and the lowest bulb yield (19.88 t ha^{-1}) was achieved in plant spacing of 20 cm. The bulb yield was also significantly highest (25.12 t ha^{-1}) in treatments of hand weeding which was followed by the mulching of *Rumex crispus* plants biomass (23.47 t ha^{-1}) and mulching of *Euphorbia helioscopia* plants biomass (22.70 t ha^{-1}) as compared to the significantly lowest bulb yield (13.60 t ha^{-1}) in control plots.

Decreasing the plant spacing from 20 cm to 10 cm decreased the per plant yield because of intra specific competition among the crop plants but the gross yield was highest in the close plant spacing. The per hectare yield however decreased with increasing the plant spacing from 10 to 20 cm. Kahsay *et al*. (2013) got highest bulb yield under the row spacing of 5 cm followed by 7.5 cm. Among the weed control treatments, hand weeding resulted in highest bulb yield, followed by mulching treatments of the selected weeds. The mulching factor enhanced the moisture retention capacity of the soil which optimized the soil temperature (Dalorima *et al*., 2014). Ramalingam*et al*. (2013) observed lowest bulb yield in weedy check due to heavy weed competition for nutrients, space and light. The mulching of plant biomass of *Rumex crispus* increased the yield of onion because of suppression of the emerging weeds through shading. The mulching of *Euphorbia helioscopia* was also better than the weedy check in significantly improving the onion bulb yield ha^{-1}.

Cost Benefit Ratio (CBR)

The CBR for the plant spacing of 10 cm was highest (1.51) followed by plant spacing of 15 cm (0.72). The spacing of 20 cm was considered as the control treatment. For weed control treatments, the highest CBR (16.45) was computed for the mulch treatment of *Rumex crispus* which was followed by 14.47 in the treatment of *E. helioscopia* applied as mulch. The lowest CBR was calculated for the hand weeding treatments. The straw technology continues to dominate in terms of economic returns. The results revealed that for every kilogram of onion produced, the grass straw technology yielded GHc 0.74 as gross margin (Inusah *et al.*, 2013)





P1 (10 cm), P2 (15 cm), P3 (20 cm),
T1 (*R.crispus* as mulch), T2 (*E. helioscopua* as mulch), T3 (hand weeding), T4 (weedy check)

Figure 5. Interaction effect of plant spacing and weed control treatments on biological yield (t ha^{-1})

Figure 6. Interaction effect of plant spacing and weed control treatments on bulb yield (t ha^{-1})

Table-1. Effect of plant spacing and weed control treatments on weed density m^{-2}, weed biomass (kg ha^{-1}) and plant height (cm) of onion crop during 2015 at Peshawar Pakistan

Treatments	Parameters		
	Weed density (m^{-2})	Weed biomass (kg ha^{-1})	Plant height (cm) of onion
Plant spacing (P)			
10 cm	91.70 c	1085 c	34.30 a
15 cm	100.50 b	1301 b	33.11 b
20 cm	118.08 a	1328 a	31.51 b
LSD (0.05)	9.02	23.9	1.46
Treatments (T)			
R. crispus (mulch)	97.11 c	1104 c	36.41 b
E. helioscopia (mulch)	104 b	1219 b	33.50 c
Hand weeding	59.33 d	518 d	24.69 d
Weedy check	153.22 a	2110 a	37.35 a
LSD (0.05)	10.41	27.6	1.69
Interactions	Significance level		
P x T	*	*	*

Means in the same column with different letters are significantly different at α = 0.05 using LSD test
LSD value or * = Significant

Table-2. Effect of plant spacing and weed control treatments on onion bulb size plant^{-1} (cm), biological yield (t ha^{-1}) and bulb yield (t ha^{-1}) during 2015 at Peshawar, Pakistan

Treatments	Parameters		
	Bulbs size (cm) plant^{-1}	Biological yield (t ha^{-1})	Bulb yield (t ha^{-1})
Plant spacing (P)			
10 cm	5.7 c	33.9 a	22.9 a
15 cm	6.35 b	31.01 b	20.84 b
20 cm	7.13 a	29.57 c	19.88 c
LSD (0.05)	0.15	0.45	0.32
Treatments (T)			
R. crispus (mulch)	6.74 b	34.09 b	23.47 b
E. helioscopia (mulch)	6.45 c	33.54 c	22.70 c
Hand weeding	7.16 a	36.72 a	25.12 a
Weedy check	5.27 d	21.60 d	13.60 d
LSD (0.05)	0.16	0.52	0.37
Interactions	Significance level		
P x T	*	*	*

Means in the same column with different letters are significantly different at α = 0.05 using LSD test
LSD value or * = Significant

Table-3. The cost-benefit-ratio ha^{-1} for onion crop as influenced by plant spacings and mulching treatments during 2015 at Peshawar, Pakistan

Plant spacing	Added Cost ha^{-1}	Yield increase over control (kg ha^{-1})	Added Income ha^{-1}	CBR
10 cm	99999	3020	151000	1.51
15 cm	66666	960	48000	0.72
20 cm (control)	49999			
Factor C (Treatments)				
R. crispus (mulch)	30000	9870	493500	16.45
E. helioscopia (mulch)	30000	9100	455000	14.47
Hand weeding	70000	11520	576000	8.23
Weedy check (control)	---	---	---	---

P1= 333333, P2= 222222, P3= 166666 seedlings ha^{-1}
Onion seedling price (2015) Rs. 0.3/seedling and onion bulbs @ Rs. 50 kg^{-1}
Cost of 5 labor for weeds collection for 3 days **=** 1000/day = 1000 x 5 x 3 = Rs. 15000 ha^{-1}
5 labor 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
7 labors for weeds manual removing (10 days) (5 times) = 1000/day = 1000 x 7 x 10
Total added cost for hand weeding treatment = Rs. 70000 ha^{-1}

CONCLUSION

Keeping a distance of 10 cm among the onion seedlings generated best results in terms of weed control and bulb yield per hectare as compared to plant spacing of 15 and 20 cm. Hand weeding as usual was the best treatment for weed control and best bulb yield. However, the plant biomass of *Rumex crispus* and *Euphorbia helioscopia* as mulch also gave better results than control plots. Mulching of *R. crispus* was however better than *E. helioscopia* in all the determined parameters particularly the cost benefit ratio.

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