ESTIMATION OF ECONOMIC THRESHOLD OF *Convolvulus arvensis* L. WEED IN WHEAT (*Triticum aestivum* L.)

Muhammad Ehsan Safdar[1*], Muhammad Sikander Hayyat, Muhammad Zeshan Maajid, Mubashar Nadeem and Amjed Ali

https://doi.org/10.28941/25-1(2019)-2

ABSTRACT

Weed economic threshold in a specific crop serves as a tool for employing its cost-effective management. Studies were carried out to find out competitive effect of field bindweed (Convolvulus arvensis L.) on wheat at research area of College of Agriculture, University of Sargodha, Pakistan during winter season 2014-15. Experimental treatments included varying densities (0, 4, 8, 12, 16 and 20 plant m^{-2}) of Convolvulus arvensis. The weed densities were maintained by thinning the excess weed seedlings one week after crop emergence. Wheat variety Galaxy was sown as a test crop. Results exhibited that increasing densities of C. arvensis increased its dry weight m^{-2} but reduced its plant height. A significant reduction in wheat growth and yield was recorded by increasing C. arvensis density. Wheat plant height, number of productive tillers, spike length and grain yield showed a significant decline at and beyond C. arvensis density of 8 plants per m^2. Whereas number of grain $spike^{-1}$ and 1000-grain weight of wheat were prone to substantial reduction at and above 4 and 12 C. arvensis plants m^{-2}, respectively. Losses of grain yield of wheat ranged between 10 to 28% under the influence of C. arvensis density between 8 to 20 plants per m^2. Economic threshold of C. arvensis as estimated by prediction model was 5.6 plants per m^2 indicating that field bindweed weed in wheat should be controlled at this density.

Keywords: Density, economic threshold level, field bindweed weed, yield losses.

Citation: Safdar, M. E., M.S. Hayyat, M. Z. Maajid, M. Nadeem and A. Ali. 2019. Estimation of economic threshold of Convolvulus arvensis L.. weed in wheat (Triticum aestivum L.). Pak. J. Weed Sci. Res., 25 (1):17-26.

[1]Department of Agronomy, University College of Agriculture, University of Sargodha, Sargodha, Punjab, Pakistan.
*Corresponding author's email: mehsan.safdar@uos.edu.pk,

INTRODUCTION

Wheat (Triticum aestivum L.) is the utmost imperative cereal crop in Pakistan and bears key position in economy of the country constituting 10% to the value addition in agriculture and 2.1% to gross domestic product. Approximately, wheat is grown on an area of 8734 thousand hectares area in Pakistan that gives 25.5 MT grain productions (Economic Survey of Pakistan, 2017-18). Besides other production constraints, main reason of low field crop production in Pakistan is high weed infestation. Globally, losses due to weeds have been increased from 100 billion dollars (Buruchara, 2007). The average weed losses of up to 34% have been reported in various crops which are more than those caused by pathogens and animal pests (Oerke, 2006). Initial studies have proved that antagonism between cereals and weeds for environmental capitals can be recognized primarily to physiological and morphological characters of plants (Didon, 2002). Imperative characters are photosynthetically active radiation interruption, early vigor, tillering capacity, plant height, seed size, and initial root and shoot growth rates (Bertholdsson, 2004). Weed economic threshold is a term defined as the density of weed at which price of its control just become equivalent to the yield of crop profit derived from its control (Coble and Mortensen, 1992). In a specific crop, its value for a specific weed varies with prevalent agro-ecological conditions, management practices and tillage systems.

During the previous few years, field bindweed (Convolvulus arvensis L.) is the main weed in different growing area of Pakistan especially in wheat crop. Field bindweed is a perennial weed native to Mediterranean area of Europe and Asia. It was initially found in the United States in 1739 (Jacobs, 2007). Field bindweed belongs to the family Convolvulaceae. The genus Convolvulus comprises of almost 250 species (Kaur and Kalia, 2012). Field bindweed is a common weed of almost 54 countries and it is the problematic weed of the 32 different crops. Now-a-days, it is counted in 10 noxious weeds of the world (Holm et al., 1991). This plant is also planted for medicinal and ornamental purposes (Mitich, 1991). Field bindweed is a perennial vine and spread through seed and rhizome. Its stem is 1.5 m or longer and rhizomes can be between 5 cm to 2.6 m long. The deep penetrating and extensive roots can be 6.6 m long or more (Wiese and Phillips, 1976). Fully developed leaves are usually 2-6 cm long. The flower of field bindweed has 5 petals which are fused to form corolla which is between 2-2.5 cm in length. The sepals are 5 mm long and distinct. Flower has compound pistil which has two stigmas (Weaver and Riley, 1982). Fruit is 8 mm wide, rounded in shape and color is light brown. Fruit usually has two seeds. Seeds are 0.5-1.2 cm long, rough and dark brown in color (Brown and Porter, 1942).

Worldwide, a number of studies have been carried out to estimate the losses of yield in different crops due to existence of field bindweed. It has been observed that increasing density of this weed decreased crops' yields linearly. Critical densities of field bindweed in different crops have been found different like 140 plants per m^2 in wheat, 65 plants per m^2 in barley and 100 plants per m^2 in peas that caused 56, 92 and 74% yield reduction in these crops, respectively (Black et al., 1994). The yield reduction by its density greater than 14 plants per m^2 was 33-64% in wheat field and 17-19% in sunflower crop (Jurado et al., 2004). However, in Pakistan there is no report about the economic threshold level of field bindweed in wheat and its probable yield reduction due to its infestation in wheat. The current study was therefore proposed to determine the effect of increasing field bindweed densities on growth pattern of this weed and wheat yield under agro-ecological and crop management system of Sargodha, and to evaluate economic threshold of field bindweed in wheat.

MATERIALS AND METHODS

The field study was planned at the Agronomic Research Area, College of Agriculture, University of Sargodha, Sargodha, Punjab, Pakistan (Latitude

31.32°N, Longitude 73.18°E and Altitude 190 m) during winter season 2014-15. At the commencement of research, the soil analysis of experimental location was done and soil was found to be loamy in texture have pH 8.0 and 1.1% organic matter contents Throughout the growing season, mean's monthly temperature ranged from 15.7 to 30.7°C. The maximum temperature was 30.7°C while minimum temperature was 6.4°C, and total precipitation during the entire wheat growing season was 1142.5 mm.

A field found to be heavily infested with field bindweed in the previous growing season was selected for experiment. The seed bed preparation was done by cultivating the soil 2-3 times followed by planking. The wheat variety Galaxy was sown on 4th of December, 2014 by using single row hand drill maintaining line to line distance of 25 cm with seed rate of 125 kg per ha. The treatments including six field bindweed densities viz. 0, 4, 8, 12, 16 and 20 plants per m^2 were maintained by thinning the excess seedlings one week after crop emergence. The experiment was laid out in randomized complete block design that comprised of four replications. The net plot size was 3 m × 1.5 m. There were six rows of wheat, each 3 meter long in each plot. Nitrogen, phosphorous and potassium were applied at the rate of 125, 85 and 62 kg per hectare in the form of urea, di-ammonium phosphate and muriate of potash, respectively. Whole of the phosphorous, potassium and half of the nitrogen were applied at sowing time. The residual nitrogen was applied 60 days after sowing. Recommended agronomic practices were uniformly applied to whole experiment. The all other weeds which emerge naturally in the field were uprooted through hand pulling. At physiological maturity, the wheat crop was harvested manually on 21st April, 2015.

Field bindweed growth traits including plant height and dry weight were recorded with their standard procedures. At time of wheat crop harvesting, data of field bindweed growth (plant height and dry biomass) and wheat crop (plant height, spike length, number of productive tillers, 1000-grain weight, number of grains per spike and grain yield) were recorded as per their prescribed procedures.

Data collected were statistically analyzed according to principle described by Fisher's analysis of variance and means' comparison was made using Tukey's honestly significant difference test at 5% probability (Steel et al., 1997). To identify linear, quadratic and cubic responses, trend analysis was done using Statistix 8.1 (Analytical Software, 2005) computer software. To investigate the association between wheat grain yield (Y) and density of field bindweed weed (X), a model proposed by Moon et al. (2012) as an adaptation from non-linear hyperbolic regression model of Cousens (1985) (Equation 1) was used:

$$Y = {y_o}/{1+\beta} \qquad \text{(Equation 1)}$$

Where

Y= expected wheat yield (t ha^{-1}) at a specific density

y_o = wheat yield (t ha^{-1}) zero weed

β = degree of weed competitiveness (a weed density of 1/β reduces the wheat yield by 50%)

X = density of field bindweed weed

Economic threshold (ET) of C. arvensis was predicted by using the following equating used by Moon et al. (2012) adapted from Cousens (1987):

$$E \;= (C_h + C_a)/(Y_o\, P \quad) \qquad \text{(Equation 2)}$$

Where

ET = Economic threshold

C_h = cost of herbicide (Rs. ha^{-1})

C_a = cost of application (Rs. ha^{-1})

Y_o = wheat yield (t ha^{-1}) zero weed

P = value per unit of crop (Rs. t^{-1})

L = comparative loss per unit weed density

H = Herbicide efficiency (a relative decline in density of weed or weed biomass by the application of herbicide).

RESULTS AND DICUSSIONS

Growth characteristic of field bindweed

Plant height (cm)

Plant height is the indicator of vegetative growth of a plant. Greater the plant height, more will be the vegetative growth and vice versa. Data displaying the influence of different field bindweed densities on its plant height are given in Table-1. The perusal of data showed that field bindweed plant height was significantly decreased with incline in its density. The maximum plant heights (95.1 and 97.6 cm) of field bindweed were recorded at its density of 4 to 8 plants per m^2. By increasing its density at and beyond 16 plants per m^2 in wheat, its plant height was significantly decreased reaching the lowest value of 81.75 cm. Trend analysis revealed that this parameter followed a cubic response to increasing densities (Table-1). Decline in plant height of field bindweed in wheat in response to increase in its density was probably the consequence of increasing intra-specific competition among plants of this weed. Our results are similar with the judgments of Nassab and Lalelo (2012) who established that increasing wild oat densities imparted significant effect and decreased its plant height. Higher number of plants of wild oat weed as well as wheat caused significant reduction in vegetative growth of both species (Armin and Asghripour, 2011).

Dry weight (m^{-2})

Data concerning the field bindweed dry weight as influenced by its differing densities are represented in Table-1. The data showed that dry weight per m^2 of field bindweed increased significantly by raising its density from 4 to 20 plants per m^2 in a linear fashion. The lowest dry weight (2.48 g m^{-2}) of field bindweed was observed with its 4 plants per m^2. An increase in density at and beyond its density of 8 plants per m^2 caused significant enhancement in its dry weight. The maximum dry weight (9.1 g m^{-2}) of field bindweed was observed at its peak density (20 plants m^{-2}). The increasing trend in weed dry weight by enhancing its density from 4 to 20 plants per m^2 seems to be due to accumulation of biomass of 4 field bindweed plants at each successive density level. Izquierdo et al. (2003) conducted a series of experiments at various locations of Mediterranean dry lands of Spain and Western Australia in order to see the consistency of the weed-crop competitiveness in different environmental and management conditions. They found that in all experiments, biomass of Lolium rigidum, a weed of barley always followed linear increasing pattern in response of its increasing density in variable plant populations of barley.

Relative competitive index (%)

Relative competitive index (RCI) of weed expressed its oppressive effect on crop in terms of percent yield reduction over zero weed density. The effect of increasing field bindweed densities on its relative competitive index has been depicted in Table-1. The results of study revealed that RCI increased significantly by increasing field bindweed density. The significant increase in this parameter from its lowest value (6.1%) started to arise from field bindweed density of 12 plants per m^2 that attained its highest value (26.4%) at 20 plants per m^2. Trend analysis indicated the linear trend to be significant showing possibility of further increase in percent crop yield reduction at further higher density levels of this weed in wheat crop. The incline in RCI of field bindweed with enhancing its density in wheat crop might be the result of increasing severity in inter-specific competition between weed and crop.

Growth and yield parameters of wheat

Plant height (cm)

Effect of field bindweed density on wheat plant height (cm) was shown by data presented in Table-2. Data revealed that increase in number of field bindweed plants from 4 to 20 per m^2 gradually reduced the wheat plant height. The highest plant height (102.4 cm) of wheat was observed in zero weed density control. However, field bindweed density at and beyond 8 plants m^{-2} caused significant reduction in wheat plant height compared to control. Consequently, the smallest plant height (80.19 cm) of wheat was recorded with the highest (20 plants m^{-2}) field bindweed density. Trend analysis revealed that plant height displayed a linear response to increasing field bindweed densities (4 to 20 plants m^{-2})

(Table-2). The decrease in plant height of wheat by increasing weed density was probably the result of reduced vegetative growth of wheat on account of increased severity in weed competition stress. These conclusions are reinforced by the conclusions of Hassan and Khan (2007) who described that increase in wild oat densities from 0 to 20 plants per m^2 in wheat crop reduced plant height of wheat. They observed the highest wheat plant height in 0 wild oat density while lowest plant height in 20 plants per m^2. Sarwar et al. (2013) reported that varying (0 to 8 plants m^{-2}) densities of Phalaris minor and Avena fatua exerted significant depressive effect on wheat plant height.

Number of productive tillers (m^{-2})

Data showing the effect of field bindweed densities on number of productive tillers per m^2 of wheat are depicted in Table-2. Analysis of data indicated that as field bindweed density progressed from 0 to 20 plants per m^2, the number of productive tillers per m^2 of wheat decreased significantly. The maximum numbers of productive tillers per m^2 (373.3) of wheat was counted in weed free control, that did not decrease significantly by increasing its density up to 4 plants per m^2. However, a significant decline in number of productive tillers of wheat was noticed at and beyond C. arvensis weed density of 8 plants per m^2. Ultimately, the lowest number of productive tillers per m^2 (335) of wheat was recorded in the highest weed density (20 plants m^{-2}). This parameter responded linearly to increasing field bind density as shown by trend comparison (Table-2). The decreased number of productive tillers of wheat in response to increasing weed density was attributed to enhanced weed competition stress imposed on wheat at its tillering stage. Our findings are similar to the conclusions of Chaudhary et al. (2008) and Sarwar et al. (2013) who described that increase in wild oat densities caused significant reduction in productive tillers of wheat.

Spike length (cm)

It is a varietal character that is also influenced by various resource deficiencies and environmental stresses. Data showing the effect of field bindweed densities on spike length of wheat are presented in Table-2. Statistical analysis of data shows that spike length of wheat was significantly reduced by the increase in field bindweed density. Maximum spike length (12.25 cm) was recorded in control treatment which was kept weed free. However, a significant decreased in this parameter occurred at and beyond field bindweed density of 4 plants per m^2. Minimum wheat spike length (7.4 cm) was measured with field bindweed density of 20 plants per m^2. Trend comparison of this parameter showed quadratic trend to be significant in response to increasing field bindweed densities in wheat (Table-2). Decrease in spike length of wheat by increasing field bindweed densities might be attributed to increase in severity of weed-crop competition during spike emergence that reduced its size. These outcomes are in close conformity to the conclusions of Khan et al. (2012) who described that wild oat densities impart great influence on the wheat spike length. They predict 10% decrease in spike length of wheat by increasing wild oat density up to 2.6 plants per m^2. Hassan and Khan (2007) concluded that increase in density of wild oat had substantial effect on wheat spike length which may lead to decrease in number of grains per spike and cause reduction in wheat yield.

Number of grains spike^{-1}

Data pertaining to number of grains per spike of wheat under the influence of different field bindweed densities have been shown in Table-2. The highest number of grains per spike (49.7) of wheat was counted in weed free control. As the weed density was increased, a successive decrease in number if grains per m^2 of wheat was noted. At and above field bindweed density of 4 plants per m^2, the number of grains per spike was significantly reduced. Subsequently, the lower number of grains per spike (32.2) was noted from wheat plants in treatment exposed to the highest field bindweed density (20 plants m^{-2}). The trend analysis showed that number of grains per spike of wheat was reduced in a linear fashion in response to increasing field bindweed density (Table-2). Decline in number of grains per spike of wheat in response to increasing field bindweed density was probably due to reduction in spike length. Previous findings showed that number of grains per spike of wheat was decreased with increase in weed density. Chaudhary et al. (2008) found that higher the number of plants per m^2 of weed, lower was the number of grains per spike. Noshadian et al. (2014) reported that if weeds remained in wheat field for whole of the season, they caused significantly effect on number of grains per spike while earlier eradication caused less effect on it because of the elimination of weed crop competition at earlier stages.

1000-grain weight

Effect of field bindweed density on 1000-grain weight of wheat can be viewed from Table-2. Analysis of data showed maximum 1000-grain weight (40.4 g) in control treatment which remained weed free. As the field bindweed density increased up to 12 plants per m^2, the 1000-grain weight of wheat started to reduce significantly compared to control treatment in linear fashion. The lowest 1000-grain weight (31.1 g) was recorded with field bindweed density of 20 plants per m^2. In this study, it seems that higher weed density resulted in increasing competition stress for wheat plants at grain development stage that was responsible for reduced grain weight. Our findings are in line with results of Khan and Hassan (2007) and Noshadian et al. (2014) who stated that increase in wild oat and canary grass density from 0 to 320 plants per m^2 caused significant reduction in 1000-grain weight of wheat.

Grain yield (t ha^{-1})

Grain yield is cumulative of numerous yield component of a crop. Crop yield is final goal and it bears a key position in crop production. Table-2 presented the effect of diverse field bindweed densities on grain yield of wheat. Statistical analysis of data showed that the increase in field bindweed densities imparted significant effect on wheat yield. Wheat grain yield decreased linearly with increase in field bindweed density. The maximum wheat yield (5.4 t ha^{-1}) was harvested from the treatment where no weed plant was permitted to grow. However, the wheat grain yield decreased significantly at and beyond field bindweed density of 8 plants per m^2. The minimum grain yield (3.9 t ha^{-1}) was recorded in treatment where field bindweed density was kept the highest (20 plants per m^2). The percent wheat grain yield reduction over control as shown by RCI (Table-1) was calculated to be 10-28% at field bindweed density of 8-20 plants per m^2. The decrease in the grain yield of wheat due to intensification in weed density was due to decrease in yield contributing traits such as number of productive tillers, number of grains per spike and 1000-grain weight. The current conclusions are reinforced by the findings of Hesammi (2011), Khan and Hassan (2006) and Sarwar et al. (2013) who described that grain yield of wheat was decreased with increase in wild oat density.

Estimation of wheat yield loss and economic threshold of field bindweed weed

By fitting the model to wheat grain yields at different field bindweed densities, the projected weed-free grain yield of wheat is 5.4 t per ha^1 (Figure 1). The competitivity of weed (β), whose reciprocal (1/β) is the density of weed that decreases crop yield by 50% was 0.027. There was good covenant between projected and observed yield as field bindweed density was augmented, displaying that competition between wheat and field bindweed was described well by the model. Keeping the herbicide cost Rs.1800, application cost Rs.741 and value per unit of crop Rs.32500; the economic threshold (ET) of C. arvensis was expected to be 5.6 during wheat season 2014-15 (Table-3). The herbicide efficiency was kept 0.95.

CONCLUSION

It can be concluded from present investigation that field bindweed is a serious weed of wheat crop that can cause up to 28% decline in yield of wheat grain at its density of 20 plants per m^2. Further, when field bindweed plant density in wheat crop reaches to 5.6 plants m^{-2}, it must be controlled in order to avoid significant wheat grain yield losses.

Plant Material

Table-1. Effect of C. arvensis density on its growth characteristics.

C. arvensis density (m^{-2})	Plant height (cm)	Dry weight ($g\ m^{-2}$)	Relative competitive Index (%)
0	-	-	-
4	95.1 ab	2.48 e	6.1 c
8	97.7 a	4.5 d	10.4 c
12	89.6 bc	6.3 c	17.3 b
16	81.7 d	7.8 b	23.2 ab
20	86.1 cd	9.1 a	27.7 a
HSD	5.61	0.83	6.23
Trend comparison			
Linear	**	**	**
Quadratic	**	Ns	Ns
Cubic	**	Ns	Ns

Values of means followed by same letter in a column did not differ significantly at 5% probability level, ns and ** showed non-significant and significant at 1% probability level, respectively.

Table- 2. Effect of C. arvensis density on grain yield and yield components of wheat.

C. arvensis density (m^{-2})	Plant height (cm)	Number of productive tillers (m^{-2})	Spike length (cm)	Number of grains $spike^{-1}$	1000 grain weight (g)	Grain yield ($t\ ha^{-1}$)
0	102.4 a	373.3 a	12.2 a	49.7 a	40.4 a	5.4 a
4	98.4 a	366.7 ab	10.2 b	46.5 b	39.6 ab	5.1 ab
8	94.3 b	363.0 b	9.4 bc	42.0 c	37.7 ab	4.8 b
12	88.2 c	358.3 b	8.5 cd	39.2 c	36.7 bc	4.5 c
16	82.1 d	245.7 c	7.7 de	35.2 d	33.8 cd	4.1 cd
20	80.2 d	335.0 d	7.4 e	32.2 d	31.1 d	3.9 d
HSD	4.06	10.18	0.97	3.2	3.18	0.37
Trend comparison						
Linear	**	**	**	**	**	**
Quadratic	ns	Ns	**	Ns	ns	ns
Cubic	ns	Ns	ns	Ns	ns	ns

Values of means followed by same letter in a column did not differ significantly at 5% probability level, ns and ** showed non-significant and significant at 1% probability level, respectively.

.

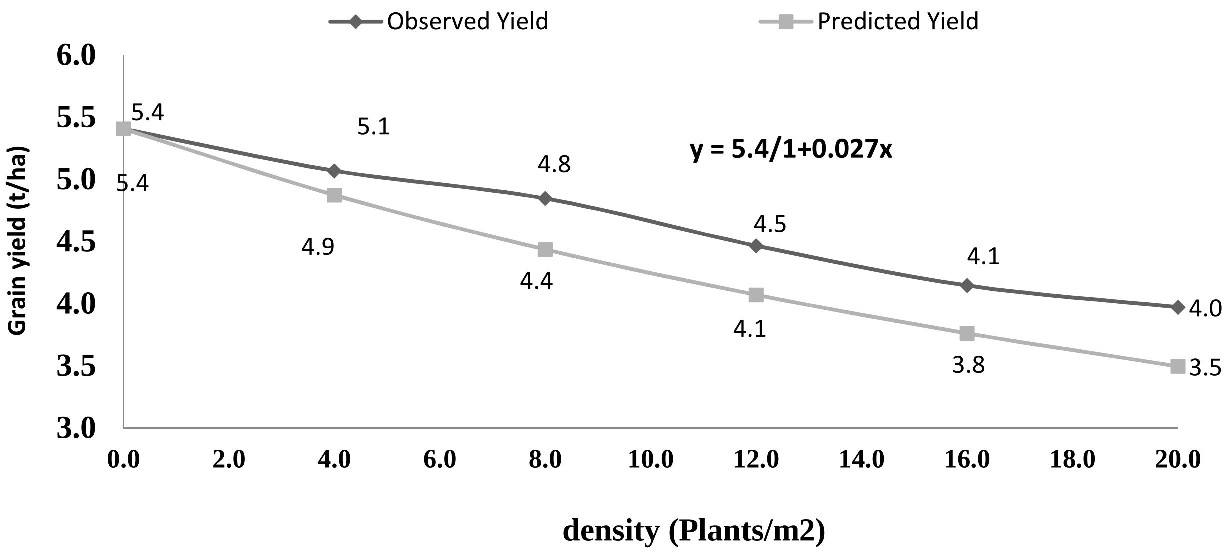

Figure 1 Estimated weed-free grain yield of wheat ($t\ ha^{-1}$).

Table-3. Parameters for estimating economic threshold of C. arvensis in wheat.

C_h+C_a (Rs.)	Y_o (t ha^{-1})	P (Rs. t^{-1})	L	H	ET (plants m^{-2})
1800 + 741	5.4	32500	0.027	0.95	5.6

C_h = cost of herbicide, Ca = cost of herbicide application, Y_o = wheat yield in weed free plots, P = value per unit of crop, H = herbicide efficacy, L = proportional loss per unit weed density, ET = economic threshold

REFERENCES CITED

Analytical Software. 2005. Statistix 8.1 for Windows. Analytical Software, Tallahassee, Florida.

Armin, M. and M. Asghripour. 2011. Effect of plant density on wild oat competition with competitive and non-competitive wheat cultivars. Agric. Sci. in China, 10: 1554-1561.

Asghari, T. C., S. Mahmoodi, M. H. R. Mohassel and G. R. Zamani. 2011. Effect of nitrogen on competition between wild oat (Avena fatua) and wheat (Triticum aestivum) at vegetative growth stage. Iranian J. Field Crop Res., 9: 15.

Bertholdsson, N.O. 2004. Variation in allelopathic activity over 100 years of barley selection and breeding. Weed Res., 44: 78-86.

Black, I., R. Matic and C. Dyson. 1994. Competitive effects of field bindweed (Convolvulus arvensis L.) in wheat, barley and field peas. Plant Prot. Quart.. 9: 12-14.

Brown, E.O. and R.H. Porter. 1942. The viability and germination of seeds of Convolvulus arvensis L. and other perennial weeds. Agricultural Exp. Station, Iowa State College, Research Bulletin, 294.

Buruchara, R. 2007. Background information on Common Beans (Phaseolus vulgaris L.) in Biotechnology, Breeding & Seed Systems for African Crops. Nairobi, Kenya: The Rockefeller Foundation.

Chaudhary, S.U., M. Hussain, M. A. Ali and J. Iqbal. 2008. Effect of weed competition period on yield and yield components of wheat. J. Agric. Res., 46: 47-54.

Coble, H.D., and D. A. Mortensen, 1992. The threshold concept and its application to weed science. Weed Technol., 6: 191-195.

Cousens, R. 1985. A simple model relating yield loss to weed density. Ann. Appl. Biol., 107: 239-252.

Cousens, R. 1987. Theory and reality of weed control thresholds. Plant Prot. Quart., 2: 13-20.

Didon, U. 2002. Variation between barley cultivars in early response to weed competition. J. Agron. Crop Sci., 188: 176-184.

Economic Survey of Pakistan. 2017-18. Economic Survey of Pakistan. Governmnet of Pakistan, Ministry of Finance, Islamabad. P.18.

Hassan, G. and H. Khan. 2007. Effect of wild oats (Avena fatua L.) density on wheat yield and its components under varying nitrogen regimes. Pak. J. Bot., 39: 2585-2594.

Hesammi, E. 2011. Different densities of weeds and wild oats (Avena ludoviciana) and canary grass (Phalaris minor) on yield and yield components of wheat cultivar Chamran. Adv. Environ.Biol.. 5: 2497-2500.

Holm, L.G., J.V. Pancho, J.P. Herberger and D.L. Plunknett. 1991. A Geographical Atlas of the Worlds Weeds. Krieger Publishing Co, Malabar, Florida.

Izquierdo, J., J. Recasens, C. Fernandez-Quintanilla and G. Gill. 2003. Effects of crop and weed densities on the interactions between barley and Lolium rigidum in several Mediterranean locations. Agronomie, EDP Sci., 23(7): 529-536.

Jacobs, J. 2007. Ecology and Management of field bindweed (Convolvulus arvensis L.). United States Department of Agriculture. Invasive Species Technol. Note No. MT: 9.

Jurado-Exposito, M, F. L. Granados, J.L.G. Andujar and L.G. Torres. 2004. Spatial and temporal analysis of Convolvulus arvensis L. populations over four growing seasons. Europ. J. Agron., 21: 287-296.

Kaur, M. and A. N. Kalia. 2012. Convolvulus arvensis – A useful weed. Int. J. Pharm. Pharmaceut. Sci., 1: 38-40.

Khan, I. A., G. Hassan, S.A. Khan and S. Shah. 2012. Wheat-wild oats interactions at varying densities and proportions. Pak. J. Bot., 44: 1053-1057.

Khan, I. and G. Hassan. 2006. Effect of wild oats (Avena fatua) densities and proportions on yield and yield components of wheat. Pak. J. Weed Sci. Res., 12: 69-77.

Mitich, L. W. 1991. Intriguing world of weeds: Field bindweed. Weed Technol., 5: 913-915.

Moon, B.C., J.G. Won, Y.L. Kim, S.W. Kim, I.Y. Lee, J.E. Park and K. Do-Soon. 2012. Prediction of rice yield loss from rice - A. indica (Aeschynomeme indica L.) competition in transplanted rice cultivation. Pak. J. Weed Sci. Res., 18: 823-827.

Nassab, A.D.M. and F.S. Lalelo. 2012. Effect of density and root-shoot interference on wheat (Triticum aestivum L.) and wild oat (Avena fatua L.) performance. Int. Res. J. Appl. Basic Sci., 3: 279-285.

Noshadian, H., N.R. Azizi, E. Yasari and A. Kakularimi. 2014. Effects of removal time and Canary grass density on wheat yield and yield components. Int. J. Farm. Allied Sci.. 3: 733-741.

Oerke, E.C. 2006. Crop losses to pests. J. Agric. Sci., 144: 31-43.

Sarwar, M., A. Ali, M.M. Maqbool, M. Ahmad, R. Mahmood and T.U. Haq. 2013. Suppressing Impact of Avena fatua and Phlaris minor on the growth and yield in wheat. Pak. J. Nutr., 12: 912-916.

Weaver, S. A. and W. R. Riley. 1982. The biology of Canadian weeds. 53, Convolvulus arvensis L. Can. J. Plant Sci., 62: 461-472.

Wiese, A.F. and W.M. Phillips. 1976. Field bindweed. Weeds Tod.,7:22-3.