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Article

COMPETITIVE INTERACTIONS OF WILD OAT (*Avena fatua* L.) WITH QUALITY AND YIELD OF WHEAT (*Triticum aestivum* L.)

*Interações Competitivas de Aveia Selvagem (**Avena fatua** L.) com Qualidade e Rendimento de Trigo (**Triticum aestivum** L.).*

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ABSTRACT - Crop-weed competition and interactions are the focus of many researchers to make the weed management decision accurate and economical. Therefore, field studies were conducted in two consecutive years (2012-13 and 2013-14) at two different locations viz Peshawar (34.0167° N, 71.5833° E) and Chitral (35°50'46" N, 71°47'9" E) of Khyber Pakhtunkhwa (KPK) province, Pakistan. The aim of the studies was to determine the competitive ability of wild oat (*Avena fatua* L.) with wheat (*Triticum aestivum* L.) at two ecologically different locations and the possible effects on quantity and quality of wheat grains. In field studies, the experiment were laid out in randomized complete block design (additive design) with three replications in which the seed rate of wheat (var. Ata-Habib) was 125 kg ha^{-1} while wild oat was planted at 0, 5, 10, 15, 20, 25, 30, 35, and 40 plants m^{-2}. Field data showed the effects of different wild oat densities during both the years were prominent by significantly decreasing the grain and biological yield-related variables of wheat. Wild oat density above 5 plants m^{-2} resulted in decreasing the wheat yield components. These results showed that wild oat started competition at initial stage of the wheat. All other yield related variables of wheat were decreased by the increasing density of wild oat, which is indicated that wild oat compete with wheat throughout the crop season. The grain yield losses in wheat ranged from 2-35% during year 1 and 1-21% during year 2 at wild oat density of 5-40 plants m^{-2}. The quality variables of wheat grains showed protein content in wheat grains were decreased at higher density of wild oat. During year 2, the gluten content in Chitral was decreased with increasing density of wild oat. In light of the present studies, it is suggested that presence of wild oat decrease all eco-biological yield related variables of wheat.

Keywords: weed-crop competition, wild oat, plant density, suppression, yield losses.

*RESUMO - A competição e as interações entre plantas daninhas são o foco de muitos pesquisadores para tornar a decisão de gerenciamento dessas plantas precisa e econômica. Portanto, foram realizados estudos de campo em dois anos consecutivos (2012-13 e 2013-14) em dois locais diferentes: Peshawar (34.0167° N, 71.5833° E) e Chitral (35°50'46" N, 71°47'9" E), da província de Khyber Pakhtunkhwa (KPK), Paquistão. O objetivo dos estudos foi determinar a capacidade competitiva da aveia selvagem (**Avena fatua** L.) com trigo (**Triticum aestivum** L.) em dois locais ecologicamente diferentes, bem como os possíveis efeitos na quantidade e qualidade dos grãos de trigo. Em estudos de campo, o experimento foi delineado em delineamento de blocos ao acaso (delineamento de*

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aditivos) com três repetições, nas quais a taxa de sementes de trigo (var. Ata-Habib) foi de 125 kg ha^{-1}, enquanto a aveia selvagem foi plantada a 0, 5, 10, 15, 20, 25, 30, 35 e 40 plantas m^{-2}. Dados de campo mostraram que os efeitos de diferentes densidades de aveia selvagem durante os dois anos foram proeminentes, visto que diminuíram significativamente as variáveis relacionadas ao rendimento de grãos e biológicas do trigo. A densidade de aveia selvagem acima de 5 plantas m^{-2} resultou na diminuição dos componentes da produção de trigo. Esses resultados mostraram que a aveia selvagem iniciou a competição no estágio inicial do trigo. Todas as outras variáveis relacionadas à produção de trigo foram diminuídas pela densidade crescente de aveia selvagem, o que indica que esta compete com o trigo durante toda a safra. As perdas de rendimento de grãos no trigo variaram de 2-35% durante o ano 1 e 1-21% durante o ano 2 na densidade de aveia selvagem de 5-40 plantas m^{-2}. As variáveis de qualidade dos grãos de trigo mostraram que o teor de proteína nesses grãos diminuiu com a maior densidade de aveia selvagem. Durante o ano 2, o teor de glúten em Chitral diminuiu com o aumento da densidade de aveia selvagem. À luz dos estudos atuais, sugere-se que a presença de aveia selvagem diminua todas as variáveis relacionadas ao rendimento ecobiológico do trigo.

Palavras-chave: competição de plantas daninhas, aveia selvagem, densidade de plantas, supressão, perda de produtividade.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is economically an important crop and is grown successfully in several continents under different environments (Rasheed et al., 2012). Wheat production is concentrated in Australia, Canada, China, Europe, India, Pakistan, Russia, Turkey, Ukraine and the United States by producing more than 80% of the world's total wheat production. Among various winter weeds, wild oat (*Avena fatua* L.) is a major weed of wheat in more than 50 countries of the world (Simpson, 1990). It is a highly competitive in wheat, having irregular germination, a close resemblance to wheat, a high degree of phenotypic variation, highly reproductive, and the seeds remain viable in the soil for a longer period of time (Travlos and Giannopolitis, 2010). It is one of problematic weeds of wheat in Pakistan (Khan et al., 2013) and decreasing the grain yield of wheat linearly (Khan et al., 2009). Wild oat and wheat are equally competitive and the competition effects of wild oat on wheat are mainly after the stem elongation (Cudney et al., 1989).

Several researchers have reported the importance of density-dependent studies of individual weeds based on their competitiveness (O'Donovan et al., 2013). However, apart from density, the time of weed germination and emergence in the field is influenced by light, soil temperature, soil moisture and soil atmosphere (Shaheen et al., 2016). Thus weed density, which can cause economic losses, depends on several environmental factors. Some have argued that damages are greater to crop when weeds remain in competition for a longer period of time (Khan and Marwat, 2006). While others (Khan et al., 2009) observed that higher densities of wild oat linearly decreased the grain yield of wheat. Similarly using higher crop densities could reduce the impact of weed on crop biomass and yield (Banisaeidi et al., 2014). In addition to crop density, application of nitrogen can improve wheat competitiveness against weed (Blackshaw et al., 2003) and decrease the grain yield loss, in addition to decreased seed production and biomass by wild oat (Banisaeidi et al., 2014). Wild oat populations at 100 plants m^{-2} resulted in grain yield losses up to 50 to 60% (Shehzad et al., 2012).

Apart from yield reduction, wild oat can decrease the protein content in wheat grain (Khan and Hassan, 2007). In addition, the gluten content in wheat grains are improved when the distance of rows and seed was increased (Bostrom et al., 2012) probably due to the availability of more nutrients for the crop plants. However, cereal crop species and varieties differed in competitive ability against weeds due to differences in canopy architecture (Olesen et al., 2004). Thus all improved cultural practices used in crop production can favour the crop plants and thus can be used as a mean of weed suppression. Siddiqui et al. (2010) observed that under field conditions, the competitive ability of winter weeds were species specific with wheat. While Singh et al. (2013) observed better performance of weed as compared to wheat at high nutrients level.

Various weed management options have been employed in the past that address weed management without calculating threshold level of individual weed species (Willenborg et al., 2005). Underlining reason is that weed flora in wheat and their competitive abilities differ with changes in the environment. The availability of herbicides has resulted in the reliance on herbicidal control of weeds without investigating the threshold level and time of weed removal. Due to herbicidal application, weed shift occurs which change the spectrum of weeds in an area. In order to control weeds in minimal time, farmers prefer to use herbicides (Tang et al., 2010). Tremendous research work has been conducted to manage weeds in wheat. But none of these has addressed the issue, especially under different ecological zones. Some work has been published that have reported the effect of various densities of wild oat on grain yield of wheat. However, competition index of wild oat at ecologically different locations are not reported from the areas under discussion. Due to the economic importance of wheat in Pakistan and the huge losses due to wild oat and cost of herbicides, trials were conducted to find out the effect of various densities of wild oat on yield-related traits and quality of wheat grains at ecologically different regions. Such studies are meaningful for researchers and farmers to decide the proper time, density and benefits of wild oat management in wheat.

The objectives of the present trials were to determine the yield losses due to *A. fatua* in wheat at different densities and investigate the interactions of wheat and *A. fatua* at two contrasting and ecologically different locations. Similarly, it was also conducted to determine the effect of *A. fatua* on the chemical composition of wheat grains.

MATERIALS AND METHODS

Field experiments were conducted in two different agro-ecological conditions in Khyber Pakhtunkhwa (KPK) Province, Pakistan" simultaneously at two locations viz. Peshawar (34.0167° N, 71.5833° E) and Chitral (35°50'46" N, 71°47'9" E) for two years (2012-2013 and 2013-2014). Wild oat is the most dominant weed in wheat crop at both of these locations. In addition, wheat is the major crop at these locations due to its good adoptability and need of the farmers for food and feed purposes. To help in the management options of wild oat in wheat, major crop (wheat) and major weed (wild oat) were selected for the present studies.

Experimental design and field methods

Wheat seeds (cv. Atta-habib) were obtained from the University of Agriculture Peshawar, Pakistan and the seeds of wild oat were collected during the previous years from the concerned experimental locations (Peshawar and Chitral). The seeds of wild oat were collected in the respective location and were stored till the next year. The experimental fields at both locations were irrigated and then ploughed at proper moisture conditions. During both growing seasons, the seedbeds were prepared by ploughing the field twice with a tractor-mounted cultivator, followed by manual planking and leveling at proper moisture conditions at each location. As per recommended cultural practices, nitrogen (N) and phosphorus (P) fertilizers in the form of urea, diammonium phosphate (DAP) and potassium (K) were broadcast applied and incorporated into the soil of all experimental plots at the rate of 120-90-60 NPK kg ha^{-1}. Half dose of N and full dose of P and potassium (K) were applied at sowing time of the wheat and the remaining N was applied at tillering stage of wheat at each location.

For both years, wheat variety (Ata-habib) was planted with a single-row hand drill at 30 cm row spacing; using a seed rate of 125 kg ha^{-1} at both locations (reflects the common practice in irrigated areas of Northwest Pakistan). Similarly, at each location, weed seeds were planted by mixing with wheat seeds in the experimental field during the month of November. To get uniform stand of the crop in each treatment and row, the number of wheat seeds was calculated for each row of wheat. While for getting the desired densities of wild oat, and to avoid the risk of germination failure, higher number of wild oat seeds was planted in each treatment and then thinned where needed.

The experiment was laid out in randomized complete block design (additive design) with three replications in which the wild oat was maintained at densities of 0, 5, 10, 15, 20, 25, 30,

35, and 40 m^{-2}. Thus there were nine treatments, each having plot size of 5 x 3 m, with ten rows of wheat in each treatment. Several weed species were germinated during the exs removed manually on weekly basis. The seedlings of wild oat were also thinned by hand to the desired densities as mentioned above. The wheat crop at each location was irrigated using flood irrigation method as per requirement. The density of wild oat was kept constant and all other weeds were manually removed at the initial stage of the wheat crop. However, keeping in view the laborious nature of this work and chances of damage to the wheat crop, the weeds were not removed 90 days after sowing the crop at Peshawar and 100 days after sowing the wheat at Chitral. However, weed removal plan was similar for all the treatments. Visual examination of the experimental fields indicated that there was no disease or aphids on wheat crop during both the years and both locations. Therefore no insecticides or fungicides were applied to the wheat.

Statistical Analyses

Recorded data were examined statistically by using Fisher's ANOVA analysis of variance technique and least significance difference test (LSD) at 0.05 was applied to think about the difference between treatment means (Steel et al., 1997).

RESULTS AND DISCUSSION

Grain yield of wheat (kg ha^{-1})

Data presented in Table 1 (year 1 and 2) showed that grain yield of wheat was statistically similar at both the locations (Peshawar and Chitral). Grain yield of wheat was 3375.4 kg ha^{-1} at Peshawar as compared to 2916.7 kg ha^{-1} at Chitral during year 1 (2012-13). While in year 2 (2013-14) the grain yield of wheat was 3551.2 kg ha^{-1} at Peshawar and 3480.5 kg ha^{-1} at Chitral. Although number of grains $spike^{-1}$ during year 1 and spike length in year 2 was higher at Peshawar however, the number of tillers and number of spikes compensated for this variations and thus similar grain yield was noted. It seems that the variety of wheat used in the present studies performed equally in term of grain yield and thus can be cultivated successfully at any of these two locations. However, the competitive ability of this variety with wild oat might be different. Because the competitive ability of the weed with wheat can be changed under changing environmental conditions (Cousens et al., 1991).

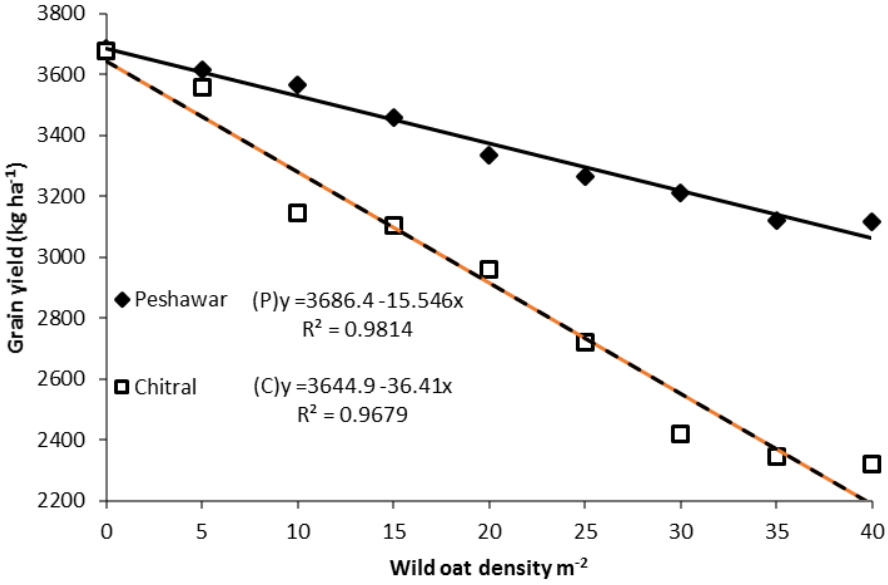
Table 1 - Competitive effects of wild oat densities on grain yield of wheat at different locations during 2012-13 and 2013-14

Location	Grain yield of wheat (kg ha^{-1}) 2012-13	Grain yield of wheat (kg ha^{-1}) 2013-14
Peshawar	3375.4	3551.2
Chitral	2916.7	3480.5
LSD(0.05)	NS	NS
Treatment (Wild oat density m^{-2})		
0	3683.3 a	3866.3 a
5	3587.2 a	3811.0 ab
10	3355.7 b	3751.3 b
15	3281.0 bc	3634.8 c
20	3147.8 cd	3531.3 d
25	2993.0 de	3381.2 e
30	2816.2 ef	3268.2 f
35	2732.7 f	3221.7 fg
40	2717.7 f	3177.0 g
LSD(0.05)	194.9	85.604
Interaction		
Location x Treatment	*** (Figure 1)	*(Figure 2)

The values followed by different letters are significantly different at 5% probability level. NS = Non-significant; ** P<0.01; *** P<0.001.

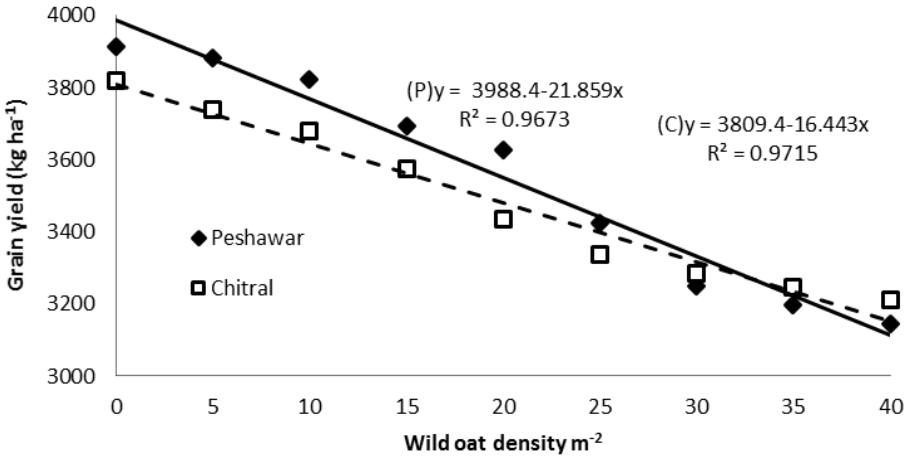
Means of the data showed that wild oat densities significantly (P≤0.05) decreased the grain yield of wheat. Wild oat density at 0 and 5 plants m^{-2} were statistically similar by producing grain yield of 3683.3 and 3587.2 kg ha^{-1} during year 1 and 3866.3 and 3811 kg ha^{-1} during year 2 (Table 1). Any further increase beyond 5 wild oat plants m^{-2} resulted in significantly lower grain yield during both the years. Wild oat-free plots produced 3683.3 and 3866.3 kg ha^{-1} of grain yield (Table 1). During year 1, maximum decrease in the grain yield of wheat was at wild oat density of 35 m^{-2} that produced grain yield of 2732.7 kg ha^{-1} however, this value was statistically at par with grain yield obtained from the plots where the wild oat density was 30 and 40 plants m^{-2}. During year 2, minimum grain yield (3177 kg ha^{-1}) was found at highest wild oat density (40 plants m^{-2}). These results showed that wild oat was more competitive at higher densities during year 2. As all the yield related variables of wheat were decreased due to increasing density of wild oat therefore, the grain yield of wheat was subsequently decreased.

Higher densities of wild oat can efficiently utilize the available resources. Therefore decrease in grain yield of wheat was higher. However, Bowden and Friesen (2006) noted that the effect of soil fertility status was important than moderate densities of wild oats in determining crop yield losses. Therefore in wheat-wild oat competition, all other factors need to be incorporated in economic threshold models because at higher density of weeds, the limited resources are shared by crop and weeds. Which ultimately affect the growth and development of crop plants. Previously, it was noted that higher population of weed in competition with wheat decreased grains $spike^{-1}$ and 1000-grain weight of wheat (Javaid et al., 2016). Because resources like nutrients and moisture become limited at higher population of plants. The interaction of location and treatments was also highly significant (P<0.001) during year 1 (Figure 1) and year 2 (Figure 2). Grain yield decreasing trend of wheat due to increasing density of wild oat was higher at Chitral as compared to Peshawar although, the decreasing trend was linear (R^2 = 98 for Peshawar and 96 for Chitral) as shown in Figure 1. While during year 2, the linear trend was observed with R^2 = 96 and 97 for Peshawar and Chitral, respectively. In light of the present studies, it is concluded that wild oat can drastically decrease the grain yield of wheat. However this decrease was wild oat density dependent and varied at different locations. Therefore all other wheat varieties under cultivation in the area need to be studied against wild oat. Apart from different varieties, different stages of the wild oat plants that emerge during the growing season of the crop are also important (Dai et al., 2012). Barroso et al. (2013) confirmed wild oat as highly competitive even at low densities that cause wheat yield losses up to 70 kg ha^{-1} per panicle m^{-2} and thus the threshold level of this weed ranged from 4-81 panicles m^{-2}.



In regression equations, C denotes Chitral and P denotes Peshawar.

Figure 1 - Effect of different wild oat densities on the grain yield of wheat at different locations during 2012-13.



In regression equations, C denotes Chitral and P denotes Peshawar.

Figure 2 - Effect of different wild oat densities on the grain yield of wheat at different locations during 2013-14.

There is a need of decreasing the losses due to wild oat in wheat by using all possible cultural practices in combination with herbicides because such approach decreased the number of seed of wild oat seed in the soil seed bank (O'Donovan et al., 2013). Javaid et al., (2016) observed that dry biomass of weed was constantly increased with every additional weed, which consequently resulted in substantial loss in grain yield of wheat due to reduction in yield related traits. Overall there is a lack of knowledge about the main factors involved in competitive interactions between crops and weeds (Weisany et al., 2016). Thus all possible weed suppression techniques may favour the crop in term of grain yield. Our results showed that wild oat density above 5 plants m^{-2} decrease the grain yield of wheat. Therefore it is suggested that the wild oat density at five or above 5 m^{-2} need to be controlled. However, the method of control, cultural practices, nutrients status of the soil and environmental factors can also affect the competitive ability of wheat and wild oat. As a general recommendation for the farmers in the studied area, it is suggested that wild oat be managed if the density of wild oat is 5 plants m^{-2} or above to avoid grain yield losses.

Dry biomass of wild oat (kg ha^{-1})

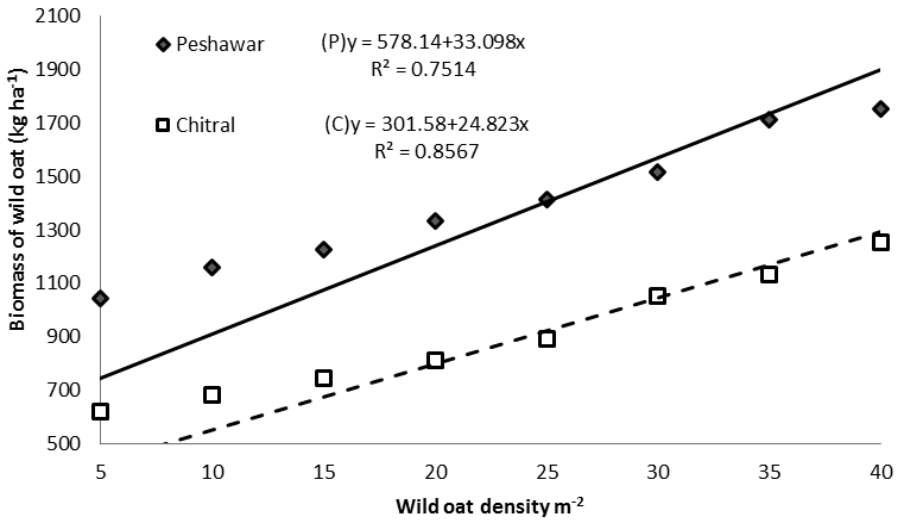
Weed biomass is always considered to be inversely proportional to grain yield of a crop. Data presented in Table 2 showed that dry biomass of wild oat were significantly ($P \leq 0.05$) higher at Peshawar (1240 kg ha^{-1}) than Chitral (798 kg ha^{-1}) during year 1. In year 2, the wild oat biomass was statistically similar at both the locations (Table 2); where Peshawar produced dry wild oat biomass of 1278. 2 kg ha^{-1} and Chitral produced 1186.1 kg ha^{-1}. These results indicated that wild oat can produce different biomass at different locations and thus can be more competitive (Figure 3). However, this increase in dry biomass of wild oat was climate and environment dependent because the climates at experimental locations during year 2 were different than year 1. By correlating the dry biomass of wild oat with the weather (temperature and total rainfall), it could be attributed that dry biomass was different under different weather conditions. Wild oat is considered as a cosmopolite weed that cause yield losses under temperate and semiarid climates (Blanco et al., 2014). Thus growth of plants could be different under different climates (Scott et al., 2016) and temperatures (Shaheen et al., 2016).

Means of the treatments showed that addition of each wild oat plant constantly increased its dry biomass. Minimum density of wild oat (5 plants m^{-2}) produced 830.5 kg ha^{-1} and increased with each additional density. However, maximum dry biomass (1504.3 kg ha^{-1}) was recorded in the plots where wild oat plants were 40 m^{-2} during year 1. This value was statistically at par with the dry biomass at 35 wild oat plants m^{-2}. The trend in the increase of wild oat dry biomass during year 2 was similar to year 1. But the magnitude of increase in dry biomass of wild oat was higher. Maximum biomass attained was 1706 and 1655.8 kg ha^{-1} at wild oat density of 40 and 35 plants m^{-2}. These values were statistically at par with each other. Wild oat produce tillers and thus biomass is increased with addition of density. Our results indicated that low density of wild oat cannot

Table 2 - Competitive effect of different weed densities on biomass of wild oat at different locations during 2012-13 and 2013-14

Location	Biomass of wild oat (kg ha^{-1}) 2012-13	Biomass of wild oat (kg ha^{-1}) 2013-14
Peshawar	1240.1 a	1278.2
Chitral	798.0 b	1186.1
LSD(0.05)	211.83	NS
Treatment (Wild oat density m^{-2})		
0	00.0 g	000.0 g
5	830.5 f	1000.2 f
10	921.5 ef	1133.8 e
15	984.3 de	1208.2 e
20	1071.3 cd	1325.2 d
25	1151.8 c	1487.7 c
30	1285.7 b	1572.7 b
35	1422.2 a	1655.8 a
40	1504.3 a	1706.0 a
LSD(0.05)	103.42	77.422
Interaction		
Location x Treatment	***(Figure 3)	NS

The values followed by different letters are significantly different at 5% probability level. NS = Non-significant.



In regression equations, C denotes Chitral and P denotes Peshawar.

Figure 3 - Effect of different weed densities on the biomass of wild oat at different locations during 2012-13.

compensate by producing more tillers and attain more biomass. Thus higher density was able to produce higher dry biomass and thus will result in more grain yield losses in wheat. As per previous work, it was noted that number of tillers of *P. minor* per plant was decreased when its density was increased (Hussain et al., 2015). Thus the lower density of wild oat compensates biomass by producing more tillers. However, it was noted that due to severe competition between wheat and wild oat, the older leaves become dry at early stage. Therefore the data given in tables may not reflect the exact biomass of wild oat in the field. As the earlier leaves have already consumed the nutrients and moisture and have caused competition therefore these components need to be explored to fully understand the crop-weed competition and biomass production.

In addition to other methods of weed suppression, the variety of wheat may differ in competitive ability against weeds (Siddiqui et al., 2010). While the tillage systems and depth can also affect the overall growth and persistence of weeds (Sans et al., 2011). Several researchers (Behdarvand et al., 2013) have reported that higher dose of nitrogen and higher density of wild oat produced

more seeds. Therefore the application of nitrogen to wheat may also benefit the wild oat and thus proved more competitive and produced more seeds. Like nitrogen, temperature and other environmental factors favour the growth of weeds (Scott et al., 2016) and thus the overall interaction of wild oat and wheat can be changed by making one species more competitive against other. Therefore in light of our findings and the previous research findings, it is suggested that all the possible measure may be adopted to favour the crop and suppress the wild oat. Although the success to control wild oat in wheat is difficult through cultural practices only but suppression of wild oat by using improved cultural practices may minimize the deleterious effects of wild oat on wheat. Overall data showed that wild oat dry biomass was increased with increasing its density. Therefore the focus of weed management should be to minimize the dry biomass of wild oat because there is a strong relationship between dry biomass of weeds and the grain yield of wheat. In a density dependent study, Khan and Hassan (2007) found that with the increasing density of wild oat, the biomass was increased. Because more number of plants produce more tillers and thus captured more resources which ultimately reflects in biomass accumulation.

Relationship between dry biomass of wild oat and grain yield of wheat

Wheat grain yield was plotted against the biomass of wild oat in the respective treatments. Overall the y-axis showed that the grain yield of wheat during year 1 was lower than year 2 (Figures 4 and 5). However the trend in decreasing the grain yield of wheat due to increasing density of wild oat was similar. Every addition of 5 wild oat plants m^{-2} decreased the grain yield of wheat. The decreasing trend of grain yield against dry biomass of wild oat during year 1was quadratic with R^2 = 99%. While during year 2, the wheat grain yield reduction due to increasing dry biomass of wild oat was linear with R^2 = 99%. These results showed that inter-specific and intra-specific competition was at peak at this stage of densities of wild oat and wheat during year 1. While during year 2, probably the climatic factors altered the competition and biomass production by both the species which ultimately changed the trend. Earlier reports (Singh et al., 2013) have shown that competitive ability of weed with wheat was density dependent probably due to biomass of weeds.

Thus it is suggested that the objective of all weed management approach should be to decrease the biomass of weed in competition with wheat. All cultural practices used for crop production in combination with other methods of weed control can significantly contribute in decreasing the wild oat biomass at different extent. While reporting the results of a study, it was previously reported that as weed density increased, wheat seed yield decreased hyperbolically (Gherekhloo et al., 2010). This reduction in grain yield of wheat is dependent on wheat and wild oat densities

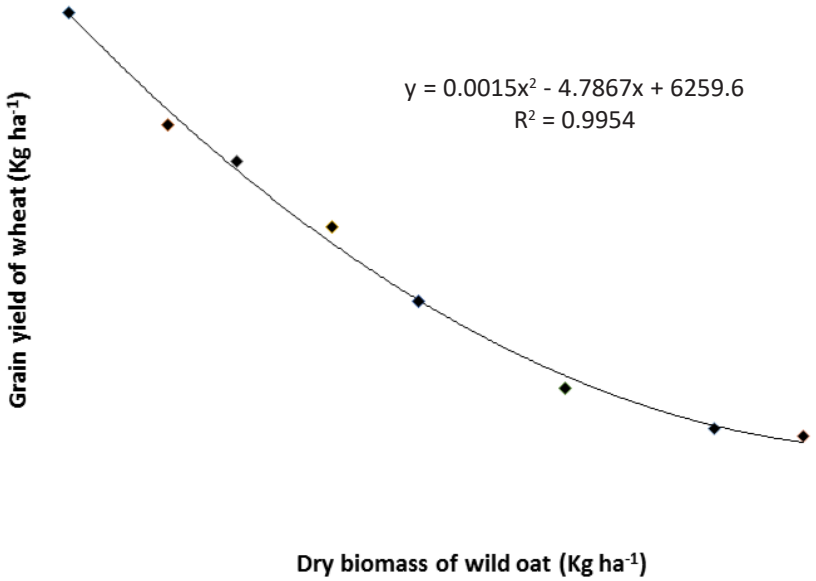


Figure 4 - Relationship between wild oat biomass and grain yield of wheat during year 1 (2012-13).

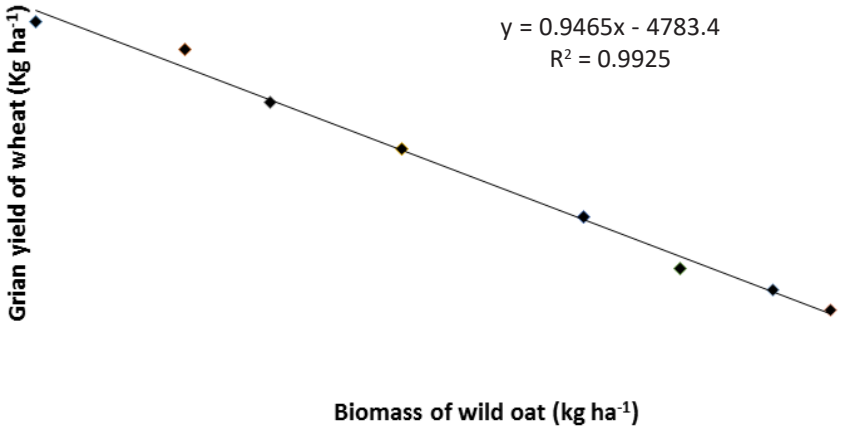


Figure 5 - Relationship between wild oat biomass and grain yield of wheat during year 2 (2013-14).

(Khan and Hassan, 2007) and nitrogen levels (Behdarvand et al., 2013). Peerzada et al. (2017) suggested that crop row orientation in relation to weed suppression is least studied. Therefore modified cultural practices may benefit the crop against weeds. They suggested that cultural practices in integration with all possible methods of weed management may prove more reliable and sustainable. It has been reported that one wild oat plant/square foot can decrease the grain yield of wheat by 12 % and the critical period for controlling wild oats in wheat is between 14-28 days after emergence (Sahota, 2016). Therefore any change in the density or time of emergence may provide different relationship between weed biomass and wheat yield. In light of our results and other published data it is concluded that wild oat at higher biomass was more harmful for the grain yield. Therefore decreasing biomass of weeds will increase the grain yield of wheat. Hence all cultural practices may be improved to suppress the growth of wild oat.

Grain yield losses (%) due to wild oat density

Percent yield losses of wheat grain yield was calculated by comparing the grain yield in plots having different wild aot densities with the pure stand of wheat. Overall the grain yield losses in wheat ranged from 2-35% during year 1 and 1-21% during year 2 at wild oat densities of 5-40 plants m^{-2}. Data (Figure 6) showed that quadratic equation was best fit for the data of percent yield losses of wheat with every addition of 5 wild aot plants m^{-2}. This trend of increasing wheat grain yield losses due to wild aot density was noted during both the years. The quadratic equations showed that at lower density of wild oat, the grian yield losses were linear and then decreased due to severe inter and intra-specific competition. Because at very high density both types of competition is started. During both the years the R^2 value was 98% in a quadratic

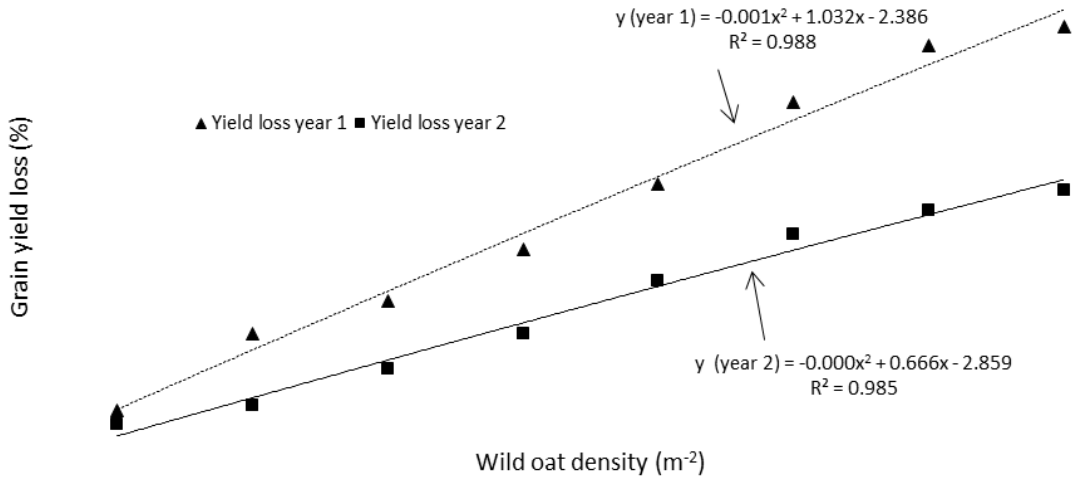


Figure 6 - Grain yield loss (%) due to different densities of wild oat.

fashion. As weeds share the available resources with crop plants therefore the reduction in grian yield of wheat is logical. Overall our results are in close conformity with other scientists that with the iuncreasing density of weeds, the biomass and gran yield of wheat was decreased (Noori et al., 2014). They added that apart from grain yield reduction, the quality parameters of wheat grains are also negatively affected due to presence of weeds. Such losses in total grain yield and quality variables of wheat cal be minimized by using all possible weed management options. However, the effect of losses in grian yield and quality of grians are dependent on biotic and abiotic factors. All these factors against all these variables are not studied.

Therefore it is suggested that individual weeds may be studied at different density and their effect on quality variables of grains. While in Pakistan, the grains are marketed without any quality check. Although flour mills check some quality parameters while purchasing the grains form the market. Therefore it is suggested that there is a very strong relationship between weed density, biomass and gran yield and quality of grians and thus needs to be addressed under different cliamtes. Such studies might be effective in increasing the grian yield and obtaining high quality grians from the market. It is suggested that by recommending a model form crop-weed competitions, several factors can alter the competitive ability of either species and thus should be adjusted accordingly.

Crude protein content (%)

Protein is an important quality variable (Souza et al., 1994) and is the cheapest source obtained from wheat in Pakistan because wheat is the staple food. Thus any change in the protein content due to weeds will reduce the quality and market price of the wheat grains. Data presented in Table 3 depicted that protein content in the grains of wheat were statistically at par across the locations (Peshawar and Chitral) during both the years (2012-13 and 2013-14). However, the presence of wild oat significantly ($P<0.05$) decreased the protein content in grains. Wild oat-free plots produced the grains with protein content of 12.87% as compared to the highest density of wild oat (40 m^{-2}) that produced grains with protein content of 10.77% during year 1. The protein content in grains under wild oat density up to 15 m^{-2} were statistically at par with the numerical value recorded in wild oat-free plots. However, increasing the density beyond 15 m^{-2}, the protein content was decreased during both the years. Thus the trend in the reduction of protein was similar during both the years. These results suggested that presence of wild oat can significantly decrease the protein content in the grain of wheat.

Table 3 - Competitive effects of wild oat densities on crude protein contentin grain of wheat at different locations during 2012-13 and 2013-14

Location	Crude protein content (%) 2012-13	Crude protein content (%) 2013-14
Peshawar	11.178	12.219
Chitral	12.037	12.241
LSD(0.05)	NS	NS
Treatment (Wild oat density m^{-2})		
0	12.867 a	13.458 a
5	12.783 a	13.267 a
10	12.400 a	12.983 ab
15	12.150 ab	12.767 ab
20	11.350 bc	12.167 bc
25	10.850 c	11.467 c
30	10.683 c	11.550 c
35	10.617 c	11.192 c
40	10.767 c	11.217 c
LSD(0.05)	0.5119	1.0094
Interaction		
Locations x Treatments	NS	NS

The values followed by different letters are significantly different at 5% probability level. NS = Non-significant.

As protein content is correlated with the gluten content (Anjum and Walker, 2000) therefore weed management in wheat can improve the grain yield and quality. Probably, the presence of wild oat shared the nitrogen at higher density and thus low protein content was observed in grains. Friesen et al. (1960) communicated that removal of weeds resulted in higher protein in grains because plant population and nitrogen are important factors that affect wheat yield and grain quality. At higher density of plants, the protein and gluten is decreased if no nitrogen was applied. However, application of nitrogen at 240 kg ha^{-1} increased protein content in wheat (Zhang et al., 2016). Nitrogen supply always affects the protein content in wheat (Lueck et al., 2006). Several factors like climate, moisture and presence of weeds also result in low protein content in wheat grains (Casagrande et al., 2009). Apart from sharing of nitrogen, temperature can also affect the protein content and gluten (Moldestad et al., 2014). Wheat is widely cultivated due to its unique properties of gluten and proteins that make the processing of wheat into a range of foods (Shewry, 2009). Beres et al. (2010) suggested that polymer-coated urea (PCU) may increase the wheat yield due to decreasing weed growth or by increasing grain yield and protein content.

The presence of wild oat shared the nutrients and moisture which ultimately affected the protein content in wheat. However, the wheat grains are marketed in Pakistan for human consumption without checking for the protein content. In light of the present studies, it is suggested that all other weeds may be explored for their effects on all wheat varieties. This might be a useful component in food security plans in the future. Grain and crude protein yields can also be affected by soil loading after deep ploughing (Gronle et al., 2015). Therefore all possible factors in combination with weed species are suggested to be studied to increase the protein content of wheat grains to a maximum level. Wheat flours with high protein content may catch high price in the market than flours of lower protein content. Therefore wild oat control in wheat may provide improved quality of wheat grains and thus will be suitable for export quality wheat grains because Pakistan has exported wheat for several years. Ibrahim et al. (2012) claimed that application of sulphur also increased the protein content in wheat grains. While Kent and Evers (1994) reported that protein content in wheat are affected by genetic as well as non-genetic factors. Thus it is concluded that presence of wild oat at higher density can decrease protein content in wheat grains. Because infestation of wild oat shares the available nutrients and moisture which can ultimately decreases the protein content. Therefore wild oat management in wheat is recommend for both the locations and other parts of the country. Because wheat is a staple food and wheat is the cheapest source of protein for the poor people of the country.

Gluten content (%)

Gluten is an important variable of the quality of wheat grains. Therefore any affect on the gluten content might be of interest for the farmers and nutritionists. We observed that gluten content was statistically higher at Chitral during year 2 (22.11% as compared to 21.35% at Peshawar). While in year 1, the gluten content was not affected by locations. It seems that there was variation in the environment which ultimately changed the chemical composition of wheat grains. As wheat is extensively used in making different food products due to higher amount of gluten content therefore, the decrease in gluten content due to weeds is of prime importance. Data revealed (Table 4) that gluten content was not affected by wild oat densities during year 1. But in year 2, the gluten content was decreased by increasing density of wild oat. However decrease in gluten was started at wild oat density at or above 25 plants m^{-2}. In light of the present results, it is suggested that higher densities of wild oat can decrease the gluten content in wheat. As mentioned earlier that the plants of wild oat were taller than wheat. Therefore the shading of wild oat on the spikes at grain filling stage of wheat might have affected the gluten content.

Gluten content determines the quality of bread. Therefore, more studies are suggested to explore the reasons of decreasing gluten in wheat due to weed infestation. In addition to weeds, temperatures may also change the gluten in wheat (Moldestad et al., 2014). While Johansson et al. (2005) reported that environmental factors can influence the gluten during grain development. Warmer growth seasons provided better wheat quality and stronger gluten compared to the cooler seasons (Uhlen et al., 2004). In a density related studies, it was noted that gluten content in

Table 4 - Competitive effects of wild oat densities on gluten content in grain of wheat at different locations during 2012-13, 2013-14

Location	Gluten content (%) 2013-14	Gluten content (%) 2013-14
Peshawar	21.356 b	28.619
Chitral	22.119 a	22.163
LSD(0.05)	0.4971	NS
Treatment (Wild oat density m^{-2})		
0	22.367 a	22.62
5	22.133 abc	22.63
10	22.250 ab	22.17
15	21.867 abc	22.27
20	21.683 abc	22.20
25	21.133 d	21.87
30	21.617 bcd	21.60
35	21.467 cd	21.40
40	21.117 d	21.32
LSD(0.05)	0.7128	NS
Interaction		
Locations x Treatments	NS	NS

The values followed by different letters are significantly different at 5% probability level. NS = Non-significant.

wheat grains is improved when the distance of rows and seed was increased (Bostrom et al., 2012) is probably due to availability of more nutrients for the crop. Water stress condition can also increase gluten content in wheat (Noorka and Silva, 2012). Conclusively, this study suggested that presence of wild oat decreases qualitative and quantitative traits of wheat. Apart from these, the quality variables of wheat; especially gluten content is decreased due to wild oat at higher density. Hence management of wild oat at any location needs to be implemented to get a higher yield of wheat grains with good protein content.

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