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Effect of Wild Oat (*Avena fatua* L.) Population and Nitrogen Levels on Some Agronomic Traits of Spring Wheat (*Triticum aestivum* L.)

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Abstract: A field experiment was conducted to determine the effect of wild oat (*Avena fatua*) densities on wheat (*Triticum aestivum*) yield, its components and protein content under varying nitrogen regimes, at the Agricultural Research Farm, North West Frontier Province Agricultural University, Peshawar, Pakistan, during winter 2004-5. The experiment comprised 3 nitrogen levels (75, 100, and 125 kg ha^{-1}) assigned to main plots and 5 wild oat densities (0, 10, 20, 30, and 40 plants m^{-2}) kept in sub-plots. The data were recorded on some agronomic and physiological parameters of wheat and wild oats. The statistical analyses of the data exhibited non-significant differences for nitrogen levels in all the parameters studied, while oat density and the interaction of density with nitrogen levels were significant for all the parameters studied. Less than 1 wild oat plant m^{-2} inflicted a 1% reduction in wheat yield, while a 30% reduction in yield was predicted with the infestation of 15, 17, and 16 plants m^{-2} under 75, 100, and 125 N kg ha^{-1} fertiliser regimes. We also discovered a wild oat density related reduction in grain protein content, which is a cause for further alarm. About 16 wild oat plants m^{-2} reduced protein content by 1%, which is alarming for countries with vegetable-based diets, like Pakistan.

Key Words: Competition, wild oat densities, nitrogen levels, yield, protein content

Introduction

Generally weeds are always considered harmful plants. Weeds are one of the biggest threats to agriculture (El-Khatib and Hegazy, 1999). They use the soil fertility, available nutrients, and moisture, and compete for space and sunlight with the crop plants. This not only results in yield reduction but also deteriorates the quality of the produce, hence reducing the market value of crops (Heyne, 1987). It has been estimated that crop losses due to weed competition throughout the world as a whole are greater than those resulting from the combined effects of insect pests and diseases. There are thus several reasons for entirely eliminating weeds from the crop environment. With the rising costs of labour and power, the use of herbicides will be the only acceptable method of weed control in the future (Norris, 1982; Young et al., 1996).

In North West Frontier Province (NWFP), Pakistan, the wild oat ranks as the most predominant weed distributed throughout the province (Hassan and Khan, 2003). It is the most competitive weed in agricultural crops, including wheat, in India and Pakistan (Rao, 2000).

Several researchers have assessed the effects of wild oats on both spring and winter wheat, and they reported that failure to remove wild oats reduced wheat yield by 28% and 39% where wild oat populations were at densities of 64 and 188 plants m^{-2}, respectively. Wheat yield was not reduced by wild oat densities of 64 or 118 plants m^{-2} until the 6- and 7-leaf stages, respectively. Removing wild oat at densities of 64 plants m^{-2} before the 7-leaf stage and at densities of 118 plants m^{-2} before the 5-leaf stage did not increase wheat culm or fresh weight (FW) production (Bhaskar and Vyas, 1988; Balyan et al., 1991). Likewise, in Western Canada, several studies have assessed the competition between spring wheat and wild oats; they reported that increasing the densities of wild oats decreased the competitiveness of wheat cultivars (Alex, 1970; Makowski, 1995).

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Several researchers studied weeds and wild oat was listed as a common weed threatening spring wheat production (Fay, 1990). Wild oat was described as a vigorously growing weed with a capability to attain greater height, and establish and develop extensive leaf area and horizontal branches when moisture and nutrients are not limiting. These morphological and physiological characteristics of wild oat allow it to shade and suppress the growth of its neighbours to a level that causes yield reduction. In spring wheat very few studies considered the effect of wild oat competition for light interception and canopy architecture perspectives (Cudney et al., 1991). Some studies (Alex, 1970) have attempted to quantify damage caused by wild oat through yield loss but they did not assess the impact of the wild oat on the growth of the crop.

In view of the importance of the wheat-wild oats competition, an experiment was conducted to investigate the impact of varying wild densities on wheat with the following objectives

a) to quantify the effect of competition between wheat and wild oats at varying densities,

b) to study the response of wheat and wild oat to different nitrogen levels, and

c) to decipher the interaction of wild oats and wheat at different nitrogen levels and wild oat densities.

Materials and Methods

An experiment on interspecific competition of wheat and wild oats as influenced by different nitrogen regimes was conducted at the Agricultural Research Farm, NWFP Agricultural University, Peshawar, Pakistan, during winter 2004-05. The experiment was laid out in a randomised complete block (RCB) design with a split-plot arrangement. Each sub-plot measured 5 x 1 m^2 . N was applied by broadcast with the first irrigation. P_2O_5 was used (90 kg ha^{-1}) as a basal dose at the time of planting. The seed of the Ghaznavi-98 wheat variety was sown at the rate of 120 kg ha^{-1}. The soil was silty clay loam in texture, calcareous in nature and alkaline in reaction. The organic matter content of the soil was low (<1%) with a poor supply of available phosphorus and total nitrogen. The physico-chemical properties and meteorological data of the experimental site are given in Table 1 below.

Table 1. Soil physico-chemical properties and meteorological data of the experimental site.

Months	Temperature		Precipitation (mm)
	Max (mean)	Min (mean)	
November	23.5	8.3	22.9
December	21.2	6.0	9.5
January	18.0	4.2	55.1
February	23.1	6.3	39.4
March	28.6	10.7	00.0
April	31.0	16.5	36.7
Average	24.23	8.66	Total = 163.6

Property	Unit	Value
Clay	%	25.7
Slit	----	47.1
Sand	-----	27.1
Textural class		Silty clay loam
pH		8.35
EC (1:5)	d S m^{-1}	0.12
Organic matter	------	0.85
Lime ($CaCO_3$)	-------	21.0
Total nitrogen	----	0.07

Source: Department of Soil Science and Environmental Science, NWFP Agricultural University Peshawar, Pakistan.

During the course of studies data were recorded on the following:

Wheat tillers plant^{-1}

In each treatment, 10 representative wheat plants were selected randomly and the number of tillers plant^{-1} was counted and then the average was obtained.

Number of wheat spikes m^{-2}

The number of wheat spikes was counted from the 3 randomly selected places in each treatment with the help of quadrates of size 0.5 x 0.5 cm^2. The means were computed and subsequently the data was converted to m^{-2}.

Wheat plant height at maturity (cm)

For recording plant height (cm) at maturity, 10 representative plants (including awns) were selected randomly from each treatment and the height of these plants was measured from the ground surface to the growing point at physiological maturity and then the average was obtained.

Wild oat plant height at maturity (cm)

For recording wild oat height (cm) at maturity, 10 representative wild oat plants (including panicles) were selected randomly from each treatment. The height of these plants was measured from the ground surface to the growing point at physiological maturity and then the average was taken.

Grain yield (t ha^{-1})

The above harvested produce was dried and then threshed with the help of a wheat thresher and cleaned. The seed was then weighed with a sensitive electronic balance for recording grain yield data. The data were subsequently converted into t ha^{-1} with the following formula:

$$\text{Grain yield (t ha}^{-1}) = \frac{\text{Grain yield (kg) x 10,000}}{\text{Area harvested (m}^2\text{) x 1000}}$$

Protein content (%) in wheat grain

Two grams of dry ground sample was put in a Kjeldhal's flask and about 5 g of nitrogen free K_2SO_4, $CuSO_4$, ferrous sulphate and selenium (94:6.5:1:7.5) was added. Then 25 ml of concentrated H_2SO_4 was placed in a digestion flask and digested until a clear solution resulted (digestion for 2 h). Then, the flask was removed and cooled and the material was transferred to a 100 ml volumetric flask. The digestion flask was rinsed with a small amount of water into the volumetric flask and then the volume was made up to 100 ml with distilled water. From this solution 10 ml was taken and mixed with 10 ml of strong alkali (40%) to make the solution alkaline and then distilled in 25 ml of 4% boric acid solution using methyl red (2 or 3 drops) indicator and then titrated with 0.1 N H_2SO_4. A blank was run simultaneously through all the steps, so as to bring into account any amount of nitrogen being added from the chemical. Percent protein of the sample was calculated by the following formula:

$$\text{\% Nitrogen} = \frac{\text{(S-B) X N of acid x 0.014 x dilution x 100}}{\text{Sample weight x aliquot of digest taken for distillation}}$$

$$\text{\% Nitrogen} = \frac{\text{(S-B) 0.1 X 0.014 X 100 X 100 X 5.7}}{\text{2.0 x 10}}$$

S = Sample titration reading

B = Blank titration reading (0.25)

0.014 = Milliequivalent of nitrogen

5.7 = Wheat factor

The data for each parameter were individually subjected to analysis of variance and the significant means were separated by the LSD test. Regression analysis was also run for each parameter against wild oat densities across the different nitrogen levels (Steel and Torrie, 1980).

Results and Discussion

Wheat tillers plant^{-1}

Tillers have the potential to develop grain-bearing heads that are the major component of yield. Secondary tillers may arise from the primary tillers. Tillering increases with light intensity and low plant populations and declines with high plant populations of weeds (Almeida et al., 2004). Statistical analysis of the data showed that wild oat densities and the interaction of densities with nitrogen levels had a significant effect while nitrogen levels had a non-significant effect on wheat tillers plant^{-1}. The data (Table 2) show that, among the nitrogen levels, the maximum (5.04) wheat tillers plant^{-1} was recorded in 75 N kg ha^{-1} while the minimum (4.81) wheat tillers plant^{-1} was recorded in 125 N kg ha^{-1} nitrogen level treated plots. Among the wild oat densities, the maximum (8.65) wheat tillers plant^{-1} was recorded in wheat monoculture (0 wild oats), while the minimum (3.46) wheat tillers plant^{-1} was recorded in 40 wild oat plants m^{-2}, which, however, was statistically comparable with 20 and 30 wild oat plants m^{-2} (Table 2). For the interaction of nitrogen with the wild oat densities, the maximum (8.77) wheat tillers plant^{-1} was recorded in 100 N kg ha^{-1} x wheat monoculture (0 wild oats). However, all the interactions involving the wheat monoculture had a statistically comparable number of tillers with the top ranking treatment. The minimum wheat tillers plant^{-1} (3.00) was recorded in 100 N kg ha^{-1} x 40 wild oats m^{-2}. The interactions across all fertiliser regimes planted with 40 or 30 wild oats m^{-2} were

Table 2. Wheat tillers plant^{-1} as affected by different nitrogen levels and wild oat densities.

N kg ha^{-1}	Wild oat (*Avena fatua*) densities m^{-2}					N means
	0	10	20	30	40	
75	8.75a	5.70b	3.45e	3.62de	3.70de	5.04a
100	8.77a	4.92bc	4.55bcd	3.92cde	3.00e	5.03a
125	8.45a	4.85bc	3.40e	3.65de	3.70de	4.81a
Density means	8.65a	5.15b	3.80c	3.73c	3.46c	
$LSD_{0.05}$ for densities	0.61					
$LSD_{0.05}$ for interaction	1.05					

statistically at par with the lowest ranking treatment (Table 2). As we increased the density level of wild oats, wheat tillers plant^{-1} decreased accordingly due to inter-specific competition. These findings are supported by the earlier work by Martin et al. (1987), who confirmed a similar wild oat density response on tillers plant^{-1}. Donald and Khan (1996) observed analogous results that increasing Canada thistle density decreased wheat stand. Karim et al. (1998) showed that dry matter of wheat plant^{-1} decreased progressively with the increase in weed density. Thus from previous work, as in this study, it is evident that competition of wild oats starts during the early stage of crop growth and hence this weed should be controlled before the tillering stage of wheat.

Regression equations show that the trend lines for wheat tiller plant^{-1} decrease quadratically at all wild oat densities m^{-2} (Figure 1). At higher wild oat densities, the wild oat proved to be more competitive as compared to lower densities. The R^2 values for nitrogen levels 75, 100, and 125 N kg ha^{-1} were 98%, 91%, and 97%, respectively. The present results confirm that there is inter-specific competition between wild oat and wheat crop at lower densities of wild oat. Increasing the densities of wild oat beyond 20 oats m^{-2} show no further reduction in tillers plant^{-1} because intraspecific competition started within the wild oats.

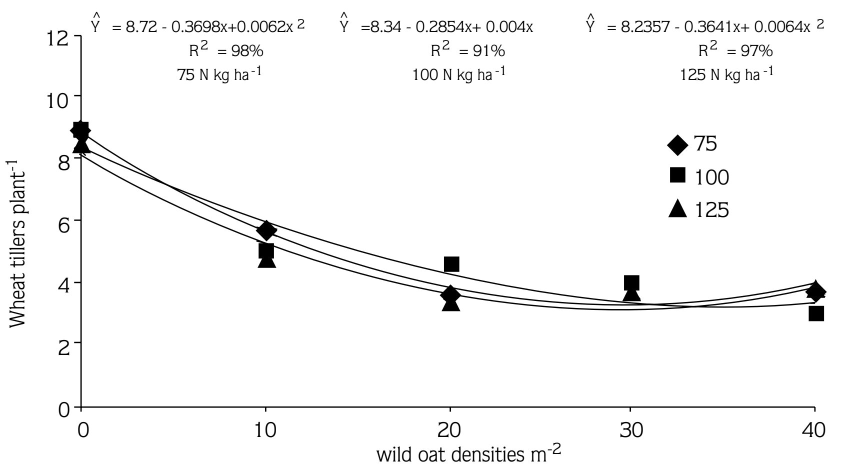

Figure 1. Wheat tillers plant^{-1} across wild oat densities at varying nitrogen levels.

Number of wheat spikes m^{-2}

Statistical analysis of the data showed that nitrogen levels had a non-significant effect on wheat spikes m^{-2} while wild oat densities and their interaction significantly affected wheat spikes m^{-2} (Table 3). The data indicate that, for the nitrogen levels, the maximum (165.4) wheat spikes m^{-2} was recorded in 100 N kg ha^{-1} while the minimum (155.48) wheat spikes m^{-2} was recorded in 125 kg N ha^{-1}. Among the wild oat densities, the maximum (260.48) wheat spikes m^{-2} was recorded in wheat monoculture (0 wild oats m^{-2}), while the minimum (118.32) wheat spikes m^{-2} was recorded in 40 wild oats m^{-2} treatment. For the interaction of nitrogen with the wild oat densities, the maximum (265.52) wheat spikes m^{-2} was recorded in 100 N kg ha^{-1} x 0 wild oat seed m^{-2}, which was, however, statistically comparable with the monocultures under the remaining 2 fertiliser regimes. The minimum wheat spikes m^{-2} (109) was recorded in 125 N kg ha^{-1} x 40 wild oat seed m^{-2}, which, however, shared statistical similarity with most of the interactions involving 30 and 40 oat density m^{-2}. These results are similar to those reported by other researchers, who found spikes m^{-2} to be a sensitive indicator of stress caused by weed competition (Flood and Halloran, 1984). Fischer (1985) and Fischer and Stockman (1980) reported a severe reduction in grains per spike of wheat due to reduced irradiance.

Regression equations (Figure 2) and trend lines show that wheat spike m^{-2} decreases linearly at all wild oat densities. Wheat spikes m^{-2} overall was negatively affected by wild oat densities. The coefficients of determination (R^2) at 75, 100, and 125 N kg ha^{-1} were 77%, 69%, and 77%. The reduction in wheat spikes m^{-2} may be due to severe competition and prevention of sunlight reaching the crop plants. These results are supported by the work by Abbate et al. (1997); they reported that intercepted light is the main factor determining both crop and spike growth during the spike growth period.

Table 3. Number of wheat spikes m^{-2} as affected by different nitrogen levels and wild oat densities.

N kg ha^{-1}	Wild oats (*Avena fatua*) densities m^{-2}					N means
	0	10	20	30	40	
75	260.52a	165b	144.52bc	128.2cd	122cd	164.04a
100	265.52a	156b	141.52bc	140bc	124cd	165.4a
125	255.52a	163b	123.52cd	126.52cd	109d	155.48a
Density means	260.48a	161.32b	136.48c	131.56cd	118.32d	
$LSD_{0.05}$ for densities	14.88					
$LSD_{0.05}$ for interaction	25.76					

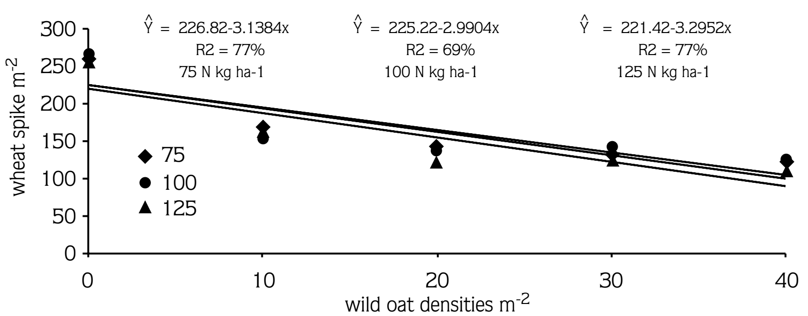

Figure 2. Regression of number of wheat spike m^{-2} vs. wild oat densities at varying nitrogen levels.

Wheat plant height at maturity (cm)

Statistical analysis of the data showed that wild oat densities and their interaction have a significant effect while nitrogen levels have a non-significant effect on wheat plant height. The data (Table 4) show that, for the nitrogen levels, the maximum (60.32) plant height was recorded in 75 N kg ha^{-1} while the minimum (58.71) wheat plant height was recorded in 100 N kg ha^{-1} nitrogen regime. Among the wild oat densities, the maximum (61.75) wheat plant height was recorded in 0 wild oats seeded m^{-2}. The minimum (57.23) wheat plant height was recorded in 30 wild oat planted seed m^{-2}, which, however, was at par statistically with the 20 and 40 wild oats m^{-2}. For interaction, the maximum (61.85) wheat plant height was recorded in 125 N kg ha^{-1} x monoculture wheat (0 wild oat seed m^{-2}), while the minimum wheat plant height (55.70) was recorded in 100 N kg ha^{-1} x 30 wild oat seed m^{-2} treatments. The plant height across 75 kg N ha^{-1} in all interactions shows that higher weed competition at a lower nutrition regime induced more photosynthate investment towards structural tissue, to keep the head above the wild oats as far as possible. The findings reported by Cheema (1991) support this idea. The check plant height was probably higher due to no competition with oat plants.

The regression equation shows that wheat plant height (cm) decrease linearly with wild oat competition (Figure 3). The regression line shows that the highest interspecific competitions for resources are at 20 to 40 wild oat densities m^{-2}. At 30 to 40 wild oat densities m^{-2} the wheat height will remain almost the same due to intraspecific competition of wild oats. The highest R^2 (87%) value was recorded at 75 N kg ha^{-1}.

Wild oat height at maturity (cm)

Statistical analysis of the data showed that wild oat densities and interaction have a significant effect while nitrogen levels have a non-significant effect on wild oat plant height (cm). The data (Table 5) show that, for the

Table 4. Wheat height at maturity (cm) as affected by different nitrogen levels and wild oat densities.

N kg ha^{-1}	Wild oats (*Avena fatua*) densities m^{-2}					N means
	0	10	20	30	40	
75	61.78a	61.57a	60.25ab	60.17ab	57.85abc	60.32a
100	61.65a	60.03ab	57.90abc	55.70c	58.30abc	58.71a
125	61.85a	59.92ab	60.25ab	55.83c	56.60bc	58.89a
Density means	61.75a	60.50a	59.46ab	57.23b	57.58b	
$LSD_{0.05}$ for densities	2.32					
$LSD_{0.05}$ for interaction	4.03					

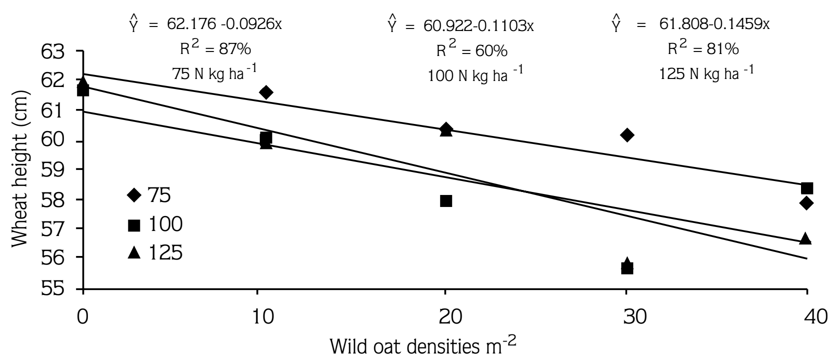

Figure 3. Wheat height (cm) across wild oat densities at varying nitrogen levels.

Table 5. Wild oat (Avena fatua) height (cm) as affected by different nitrogen levels and wild oat densities.

N kg ha^{-1}	Wild oats (*Avena fatua*) densities m^{-2}				N means
	10	20	30	40	
75	133.5bc	144.8a	123.5de	113.9f	103.15a
100	126.9cd	144.1a	117.7ef	120.0def	101.74a
125	131.9bc	139.9ab	123.1de	115.7ef	102.12a
Density means	130.78b	142.91a	121.45c	116.53d	
$LSD_{0.05}$ for densities	4.58				
$LSD_{0.05}$ for interaction	7.94				

nitrogen levels, the maximum (103.15) wild oat plant height was recorded in 75 N kg ha^{-1} while the minimum (102.12) wild oat plant height was recorded in 125 N kg ha^{-1}. Among the wild oat densities, the maximum (142.91) wild oat plant height was recorded in 20 wild oats planted seeded m^{-2}, while the minimum (116.53) wild oat plant height was recorded in 40 wild oats m^{-2}. For interaction, the maximum (144.8) wild oat plant height was recorded in 75 N kg ha^{-1} x 20 wild oats m^{-2} while the minimum wild oat plant height (113.9) was recorded in 75 N kg ha^{-1} x 40 wild oats seed m^{-2} treatments. The interactions involving the higher wild oat densities had a lower wild oat height due to interspecific competition with wheat. El-Khatib and Hegazy (1999) were of the opinion that during competition between wild oats and wheat for nutrients, water, space and light, the wheat plant is weakened, resulting in reduced yields.

When wild oat densities were subjected to regression analysis it was noted that plant height of wild oat (cm) increased quadratically (Figure 4). Regression lines show that there were very small numerical differences across the different densities of wild oats. The highest R^2 (82%) value was recorded at 125 N kg ha^{-1}.

Grain yield (t ha^{-1})

Statistical analysis of the data revealed that wild oat densities and interaction were significant statistically, while nitrogen levels were non-significant for grain yield (t ha^{-1}). The data in Table 6 show that, for the nitrogen levels, the maximum (1.01 t ha^{-1}) grain yield was observed in 100 N kg ha^{-1}; however, it was numerically comparable with the grain yield produced by 75 N kg ha^{-1} (0.92 t ha^{-1}). Among the wild oat densities the maximum (1.67 t ha^{-1}) grain yield was recorded in wheat monoculture (0 wild oats seeded m^{-2}). The minimum (0.51 t ha^{-1}) grain yield was recorded in 40 wild oats seed m^{-2} treatment, which, however, had the similar yield to

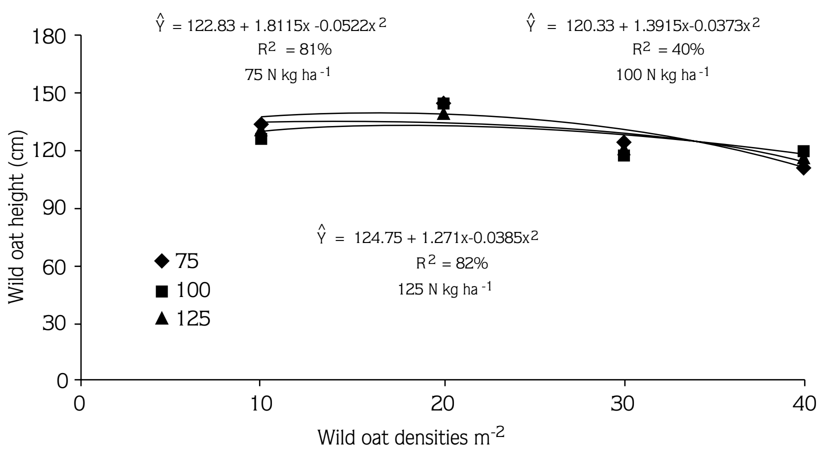

Figure 4. Wild oat height (cm) across wild oat densities at varying nitrogen levels.

Table 6. Grain yield (t ha^{-1}) as affected by different nitrogen levels and wild oat densities.

N kg ha^{-1}	Wild oats (*Avena fatua*) densities m^{-2}					N means
	0	10	20	30	40	
75	1.81a	1.11bc	0.66d	0.56d	0.46d	0.92a
100	1.83a	1.20b	0.65d	0.71cd	0.66d	1.01a
125	1.39b	1.23b	0.76cd	0.60d	0.41d	0.88a
Density means	1.67a	1.18b	0.69c	0.62c	0.51c	
$LSD_{0.05}$ for densities	0.23					
$LSD_{0.05}$ for interaction	0.41					

Table 6a. Parameter estimates for the simulation of wheat yield as affected by wild oat densities across different N levels.

N kg ha^{-1}	a (intercept) estimate	ß (regression coefficient)	R^2
75	1.572	-0.0324	0.86
100	1.575	-0.0282	0.76
125	1.400	-0.0259	0.96

Table 6b. Predicted wild oat densities to cause 1%, 10%, and 30% yield losses in wheat across different N levels.

N kg ha^{-1}	1%	10%	30%
75	0.62	4.85	14.55
100	0.71	5.67	16.67
125	0.56	5.41	16.22

20 and 30 oats m^{-2}. For the interaction of nitrogen with the wild oat densities, the highest yield (1.83 t ha^{-1}) was observed in 100 N kg ha^{-1} x 0 wild oats seed m^{-2}. It was, however, statistically at par with the interaction of monoculture with 75 N kg ha^{-1}. The minimum grain yield (0.41 t ha^{-1}) was observed in 125 N kg ha^{-1} x 40 wild oats seed m^{-2}. The lowest interaction, however, was statistically comparable with all the remaining interactions involving 40, 30, and 20 wild oats seed m^{-2}. Increasing sowing rates of wheat seeds and sowing in narrow rows competed with wild oats more effectively and increased yield by 8% (Sodhi and Dhaliwal, 1998). The findings reported by Pedreros (2001), Martin et al. (1987), and Cheema (1991) support our conclusions. Our results are strongly supported by Harrison et al. (2001); they stated that linear response range at low densities and a maximum yield loss of 90% at high weed densities were found. This indicates that wild oat attained its maximum growth earlier than wheat.

Regression equations show that response of grain yield to wild oat densities m^{-2} was linear and grain yield (t ha^{-1}) decreased with increases in the densities of wild oat. This shows that, at higher wild oat densities, the wheat plants are more vulnerable to interspecific competition (Figure 5). R^2 value decreased with increasing wild oat densities. The R^2 values were 85%, 76%, and 96% at 75, 100, and 125 N kg ha^{-1}, respectively. Thus, we conclude that wheat does not compete at higher levels of wild oat densities and there is a drastic decline with increased density of wild oats. Tables 6a and 6b depict 30% losses occurring with the predicted wild oat density of 14.55, 16.67, and 16.22 plants m^{-2} across 75, 100, and 125 N kg ha^{-1}, respectively. The declining trend of grain yield across the wild oat densities is shown in Figure 5.

Protein content in wheat grain (%)

High protein wheat fetches higher prices in the world markets. We have determined the wild density related

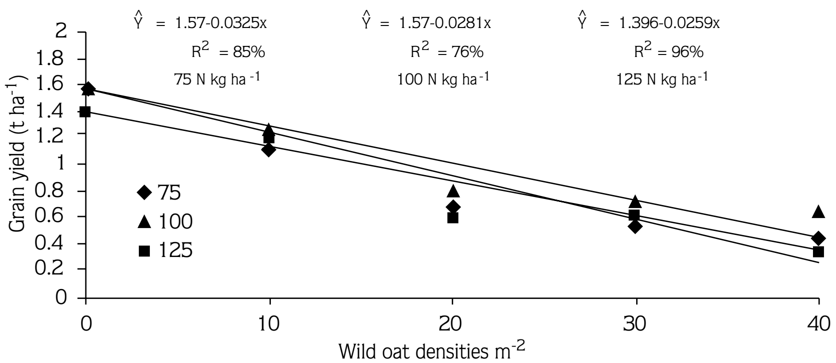

Figure 5. Wheat grain yield (t ha^{-1}) across wild oat densities at varying nitrogen levels.

protein content in wheat. Wheat grain, a major source of energy in the human diet, is higher in protein content than almost all other cereals. A major factor enhancing the competitive position of wheat in international markets is its high protein quantity and quality. Wild oat, a noxious weed, is a major production problem in wheat cultivation. Wild oat competes for light, water, and nutrients, and can cause lodging and problems with harvesting. The seeds of several weed species are almost impossible to remove from harvested wheat, e.g., wild oats, causing loss of quality and downgrading of the crop. Statistical analysis of our data also showed that when we increased the densities of wild oats, the protein content in wheat grain decreased. N levels have no effect on protein content in wheat grain. The highest (11.12%) protein content was recorded in 0 densities of wild oat while the lowest (8.29%) protein content was recorded in 40 density of wild oat. For the interaction of nitrogen with the wild oat densities, the highest numerical protein (11.17%) was observed in 75 N kg ha^{-1} x 0 wild oats seeded m^{-2} and 125 N kg ha^{-1} x 0 wild oats seeded m^{-2}, while the lowest (8.129%) protein content was recorded in 100 N kg ha^{-1} x 40 wild oats seeded m^{-2} (Table 7). Our results agree with the findings reported by Blackshaw (2004), who stated that protein content in winter wheat was similar ($P > 0.05$) among all nitrogen treatments.

The regression analysis run on protein content vs. density of wild oats reveals that wild oat density despite reducing grain yield also has a significant negative impact on protein content. Grain protein reached a maximum in the 0 wild oat seeded m^{-2} and minimum at 40 wild oat seed m^{-2} (Figure 6). Increases in wild oat density caused a significant reduction in protein content (%).

Conclusions

Wheat yield and yield components had a strong association with the wild oat densities, while the response of N was non-significant. Less than 1 wild oat plant m^{-2}

Table 7. Protein content (%) in wheat grain as affected by different nitrogen levels and wild oat densities.

N kg ha^{-1}	Wild oats (*Avena fatua*) densities m^{-2}					N means
	0	10	20	30	40	
75	11.17a	10.87ab	9.87bcd	9.675b-e	8.628efg	10.04a
100	11.02a	10.07abc	9.32c-f	8.329fg	8.129g	9.37a
125	11.17a	9.62b-e	9.22c-g	8.778d-g	8.130g	9.38a
Density means	11.12a	10.19b	9.47c	8.92cd	8.29d	
$LSD_{0.05}$ for densities	0.65					
$LSD_{0.05}$ for interaction	1.12					

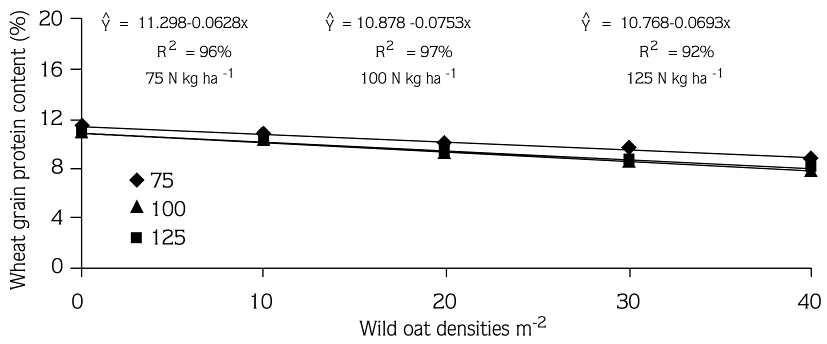

Figure 6. Protein content (%) in wheat grain across wild oat densities at varying nitrogen levels.

inflicted a 1% reduction in wheat yield. A 30% reduction in wheat yield was predicted with the infestation of 15, 17, and 16 plant m^{-2} under 75, 100, and 125 N kg ha^{-1} fertiliser regimes. We also discovered a wild density related reduction in grain protein content, which is a cause for further alarm. About 16 wild oats plant m^{-2} reduced protein content by 1%, which is alarming in countries with vegetable-based diets, like Pakistan. In order to achieve economic wheat yields, judicious management of wild oats is recommended.

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