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Effect of Nitrogen Fertilization Application on Simulating Wheat (*Triticum aestivum*) Yield Loss Caused by Wild Oat (*Avena fatua*) Interference

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Abstract: A field experiment was conducted to quantify the effect of nitrogen fertilizer on wheat yield loss due to wild oat interference and on crop-weed competition. The experiment was designed as a randomized complete block with a split plot arrangement with nitrogen fertilizer (N_0, unfertilized control; N_1, 150 N Kg ha^{-1} before wheat seeding and N_2, 50 N Kg ha^{-1} before wheat seeding + 100 N Kg ha^{-1} at late tillering stage of wheat) as main plot and wild oat density (D_0: weed- free control, D_1: 25, D_2: 50, D_3: 75 and D_4: 100 plants m^{-2}) as subplot with three replications. Initial slope (*i*) of the rectangular hyperbola model was significantly greater when nitrogen fertilizer was applied. Moreover, for the rectangular hyperbola model, there was significant effect of nitrogen application on estimated maximum wheat yield loss (*A*). Application of 150 N Kg ha^{-1} (N_1 treatment) before crop seeding resulted in a greater higher competitive ability of wild oat than other treatments. The slope (b) of the linear model representing the relationship between wild oat density and relative wild oat biomass significantly greater when nitrogen fertilizer applied. Information gained in this study will be utilized to develop a more integrated program for weed management in spring wheat.

Key words: Wild oat · Nitrogen fertilizer · Wheat · Interference · Competition

INTRODUCTION

Generally weeds are always considered harmful plants. Weeds are one of the biggest threats to agriculture [1-3]. 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 [4]. 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. 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 [3, 5, 6].

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 [7]. 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 [8].

Fertilization is an important agronomic strategy used extensively to increase crop yield. Nevertheless, although nutrients clearly promote crop growth, many studies have shown that, in some cases, fertilizers benefit weeds more than crops [9]. For example, Carlson and Hill [10] found that the addition of N fertilizer to wild oat-infested wheat increased the density of wild oat panicles without increasing crop yield. However, Satorre and Snaydon [11] showed that N fertilizer reduced the severity of competition experienced by wild oat from six spring cereals. The increase in weed competition at higher N rates has been suggested to be related to an increase in the efficiency of nutrient accumulation and use by weeds [9]. In addition, Brandt *et al*. [12] reported differences in weed response to soil fertility for wheat and canola (*Brassica napus* L.), suggesting that this may be exploited

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through the development of agronomic systems that stimulate crop growth over weed growth. Moreover, Knezevic *et al*. [13] noted that insufficient N can reduce corn (*Zea mays* L.) tolerance to weeds and can lengthen the critical period for weed control. Fertilizer application can have an influence on the composition of the weed community. In this sense, Jornsgard *et al*. [14] demonstrated an interaction between the growth of individual weed species and the level of N fertilizer in cereal crops. They found that common lambsquarters (*Chenopodium album* L.) in competition with spring barley has a lower N optimum than does the crop, whereas burning nettle (*Urtica urens* L.) has a higher N optimum than does the crop. Anderson *et al*. [15] found that in a spring wheat-winter wheat-sunflower (*Helianthus annuus* L.) rotation conducted under a no-till system, N application increased crop competitiveness and reduced weed density. Likewise, the increase in soil fertility as a result of the introduction of subterranean clover (*Trifolium subterraneum* L.) and the application of superphosphate has favored different species of thistles (*Cirsium* spp.) in Australia [16]. However anderson and Milberg [17], in longterm experiments, found that the effect of crop species on weed flora was more important than the effect of N application. Moreover, N application did not strongly influence the composition of the weed flora.

In small grain cropping systems of the south- western of Iran, wild oat (*Avena fatua* L.) is a weed species of primary concern. As expected, wild oat performance is affected by fertilizer and soil moisture levels. For example, Sexsmith and Pittman [6] and Blackshaw *et al*. [2] found that greater spring application rates of broadcast nitrogen increased the number of wild oats present in an oat (*Avena sativa* L.) field. Scursoni and Arnold [18] observed that when wild oat densities were high in wheat (*Triticum aestivum* L.), increasing nitrogen application rates resulted in greater wheat yield loss. Blackshaw *et al*. [2] found that the method and timing of nitrogen fertilizer application could affect the biomass of wild oat in spring wheat.

Although the effect of fertilizers are extensively investigated in wheat, there is little information to assess the effect of fertilizer application on wheat yield loss due to wild oat interference. The knowledge of the effect of N fertilization on weed population dynamics might be useful for recommending the most convenient method and stage of the crop cycle for fertilizer application to both increase the crop yield and reduce the growth rates of weed populations.

The objective of this was to investigate the effect of nitrogen fertilization application in simulating wheat (*Triticum aestivum)* yield loss caused by wild oat (*Avena fatua*) interference.

MATERIALS AND METHODS

Study Site, Experimental Design, Treatments and Crop Operations: A field experiment was conducted at agricultural research station of Islamic Azad University, Ramhormoz branch ((latitude 31.16°N, longitude 49.36°E and 151 m asl), south-western of Iran. Planting date was 6 December in 2008. The site has a silty clay soil with a mean annual precipitation 320 mm, mean solar radiation of 19.1 MJ m^{-2} d^{-1}, mean maximum temperature of 32.7°C and mean minimum temperature of 19.5°C. The climate is warm and dry. Some details about the experiment and weather conditions during the experiment are given in Tables 1.

The experiment was designed as a randomized complete block with a split plot arrangement with nitrogen fertilizer (N_0: unfertilized control, N_1: 150 N Kg ha^{-1} before wheat seeding and N_2: 50 N Kg ha^{-1} before wheat seeding + 100 N Kg ha^{-1} at late tillering stage of wheat) as main plot and wild oat density (D_0: weed- free control, D_1: 25, D_2: 50, D_3: 75 and D_4: 100 plants m^{-2}) as subplot with three replications. Seeding rates for wild oat were based on target stand densities, 1,000 seed weight and assumption of 10% recruitment. The wild oat seeds was sown at a depth of approximately 2 to 3 cm, between 2 planting row of wheat. After wild oat seed was sown (but before wheat seeding) granular urea fertilizer (46-0-0) was broadcast mechanically onto the main plot nitrogen treatments. Residual rate of nitrogen fertilizer (100 Kg ha^{-1}) which related to N_2 treatment was applied late tiller stage of wheat. An unfertilized control was also included. Subplot size was 6×1.25 m and all subplots were separately by a 2.5 m wide alley. Individual plots consisted of six rows,

Table 1: Summary of cultural practices and measurements in field experiments

Location	Ramhormoz
Growing season	2008-2009
Previous culture	Corn
soil	Silty clay
Initial condition	Electrical conductivity of 3.4 dS/m; pH of 7.4; organic carbon of 1.11%; total nitrogen of 0.57%; available *P* (Olsen method) of 8.1 mg/kg; available *K* (NH4AcO method) of 240 mg/kg
Fertilization	80 Kg p_2o_5 ha^{-1} and 50 Kg k_2o ha^{-1} + N treatments
Treatments	Nitrogen fertilizer + wild oat density

6 m long and spaced 25 cm apart. All subplots were sown by a seed drill at a wheat population density of 400 seed m^2. In general, weed control throughout the growing season was done by hand weeding. Insects were controlled by the appropriate chemicals. All the experiments were conducted under well-watered conditions. The plots were irrigated after 60-mm cumulative pan (Class A) evaporation and irrigation amount was based on soil moisture depletion. Therefore, there was no effect of flooding or water deficit stresses.

Measurements: In late January, when both crop and weeds had completed emergence, an area of 1 m^2 was marked in the centre of each plot. Weed seedling were counted and thinned as necessary to achieve desired densities. In the 2008-2009 growing season six more samples (by harvesting 0.25 m^2) were taken throughout growing season for determination of above ground dry weight(drying oven at 70°c for 48 h) of both wheat and wild oat. In late May wheat and wild oat plants from the previously marked areas were harvested by hand, then total dry matter and grain yield of wheat and total above ground weight of wild oat determined.

Statistical Analysis: Percent wheat yield loss was calculated using the following formula;

$$YL = [(Ywf - Yweedy)/Ywf] \bullet 100 \qquad (1)$$

Where YL is percent yield loss, *Y*wf is weed-free yield and *Y*weedy is yield in weed (wild oat)-infested plots. Percent relative wild oat biomass was calculated using the following formula [3]:

$$RelWb = [Wwo/(Wwo + Ww)] \bullet 100 \qquad (2)$$

Where RelW*b* is relative wild oat biomass, *W*wo is aboveground dry biomass of wild oat and *Ww* is aboveground dry biomass of wheat in the same plot. Data were subjected to ANOVA using the PROC GLM procedure in SAS [19].

For percent wheat yield loss and percent relative wild oat biomass, on the basis of the results obtained by an ANOVA, data sets were subjected to regression analysis using actual wild oat density as the independent variable. A rectangular hyperbola model was fitted where possible [20]:

$$YL = i\,d/[1 + (i\,d/A)] \qquad (3)$$

Where YL is percent wheat yield loss, *d* is wild oat density (plants. m^{-2}), *i* is the initial slope and *A* is the asymptote. The model was fitted to the data using the PROC NLIN procedure of SAS [19].

For percent relative wild oat biomass, A linear model was used as follows:

$$RrLW_b = b \times d \qquad (4)$$

Where *d* is wild oat density (plants. m^{-2}) and *b* is the slope of linear model. The data for each parameter were individually subjected to ANOVA and the significant means were separately by the LSD test.

RESULTS AND DISCUSSION

Application of nitrogen fertilizer increased the competitive effect of wild oat on spring wheat. The initial slope (*i*) of the rectangular hyperbola model was significantly greater when nitrogen fertilizer was applied (Table 2 and Fig. 1). Moreover, for the rectangular hyperbola model, there was significant effect of nitrogen application on estimated maximum wheat yield loss (*A*). Carlson and Hill [10] and Ross and Van Acker [3] also found that wheat yield loss due to wild oat interference was greater when nitrogen fertilizer was applied. However, The application of 150 N Kg ha^{-1} (N_1 treatment) before crop seeding resulted in a greater higher competitive ability of wild oat than other treatments (Table 2 and Fig. 1).

The comparison of initial slope (i) and estimated maximum wheat yield loss (A) between nitrogen treatments indicated that application of nitrogen than unfertilized control (N_0 treatment) increased the rates of these coefficients. However, the coefficient rates were greater in N_1 treatment (150 N Kg ha^{-1} before crop seeding) than N_2 (50 N Kg ha^{-1} before crop seeding + 100 N Kg ha_{-1} at late tillering stage of wheat). This result suggests more nitrogen application before crop seeding increased the wheat yield loss than that of treatments, which would be due to the more germinability of weed seeds [5]. Other studies, Blackshaw *et al*. [2] and Ross *et al*. [3] showed that nitrogen fertilizer can stimulate the weed seed dormancy, so because of more weed plant in area, wheat yield affected and reduced.

This result is of practical concern for farmers in this region because wild oat is a primary pest and extra use of nitrogen regardless of managed recommendations can benefit weed growth.

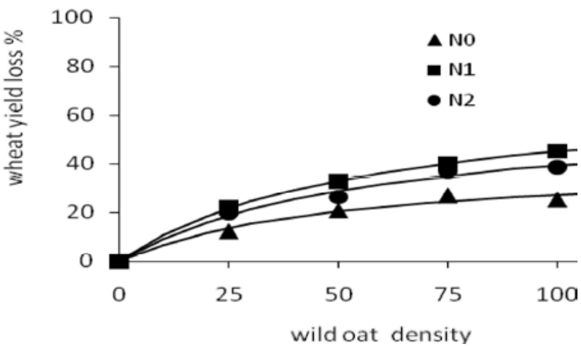

Fig. 1: Wheat yield loss due to the interference of wild oat in the different treatments of nitrogen fertilizer

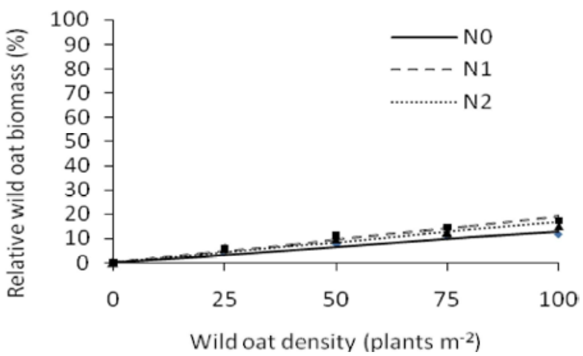

Fig. 2: Biomass of wild oat relative to total biomass (wild oat plus wheat) for wild oat grown in the different treatments of nitrogen fertilizer

Application of nitrogen fertilizer (N_1 and N_2 treatments) resulted in a greater wild oat biomass accumulation relative to wheat biomass than an unfertilized control treatment (Table 3 and Fig. 2). The slope (b) of the linear model representing the relationship between wild oat density and relative wild oat biomass significantly greater when nitrogen fertilizer applied. This result would help explain why the effect of wild oat on wheat yield increased when nitrogen fertilizer was applied. It also suggests that wild oat more effectively exploited surface-applied nitrogen fertilizer than did spring wheat. Di Tomaso [9] observed that broadcast nitrogen fertilizer applied under high weed densities tended to increase weed growth with little benefit to crops. Similarly, Blackshaw *et al*. [2, 21] and Ross and Van Acker [3] have shown that nitrogen fertilizer placement (relative to the crop) can make spring wheat more competitive against weeds. In this study, wild oat seedlings may have had preferential access to surface-applied nitrogen because the wild oat seed was broadcast and incorporated nearer the soil surface (2 to 3 cm deep) than the wheat (4-6 cm).

Table 2: Parameter estimates for rectangular hyperbola fitted to data of wheat yield loss as a function of wild oat density and as affected by nitrogen fertilizer

	i±se [a]	A±se	RMSE [b]	R^2
N_0	0.82±0.20	40.48±7.44	1.89	0.99
N1	1.27±0.03	69.57±1.33	0.30	0.99
N2	1.08±0.18	61.85±1.33	1.94	0.99

[a] Standard error of parameter estimates

[b] Root Mean Square Error

Table 3: Parameter estimates for linear models fitted to data of wild oat relative biomass as a function of wild oat density and affected by nitrogen fertilizer

	b±se [a]	RMSE [b]	R^2
N_0	0.13±0.01	1.57	0.97
N_1	0.19±0.02	2.54	0.96
N_2	0.17±0.01	2.00	0.97

[a] Standard error of parameter estimates

[b] Root Mean Square Error

Table 4: Analysis of variance of wheat grain yield and total dry matter of wild oat data as affected by different nitrogen levels and wild oat densities

		Mean square	
Source	DF	Wheat grain yield	Total dry matter of wild oat
Block	2	2.95 ^{NS}	45.26 ^{NS}
Nitrogen	2	30800.25 **	3366.86 **
Error	4	22.75	15.63
Wild oat density	4	24936.30 **	35564.85 *
Nitrogen×wild oat density	8	597.48 **	402.42 **
Error	24	20.24	8.64
CV%		1.79	2.88

*Difference significant ($p<0.05$); ** difference significant ($p<0.01$); NS, not significant

As well, Pavlychenko and Harrington [22] observed markedly reduced rooting systems in wheat vs. wild oat under competition. They found average total root length of wheat and wild oat to be 48.6 and 252.3 m, respectively, when the two species were grown together, while the average root length for wheat grown alone was 90 m. The more extensive root system of wild oat may allow it to continue to preferentially access and exploit soil nitrogen through the growing season. This may be true for other nutrients as well. For example, Callow *et al*. [23] found that when KCl fertilizer was applied to field plots, wild oat was more competitive with spring wheat. Blackshaw *et al*. [2] and Sexsmith and Pittman [6] found that nitrogen fertilizer significantly increased wild oat biomass in spring wheat and this translated into significantly greater wild oat seed return.

Table 5: The wheat grain yield (g m^{-2}) as affected by different nitrogen levels and wild oat densities

	Wild oat densities m^{-2}					
N	0	25	50	75	100	N means [aa]
N_0	281.3 d	238.0 f	200.0 h	190.0 h	193.3 de	220.5 c
N_1	316.6 b	246.6 e	212.3 g	190.0 h	173.3 i	227.8 b
N_2	400.3 a	320.6 b	294.3 c	251.6 e	245.0 e	302.4 a
Densities means [bb]	332.7 a	268.4 b	235.5 c	210.5 d	203.9 e	

[aa] LSD(0.05) for N means = 4.50

[bb] LSD(0.05) for densities means = 4.37

Table 6: Total dry matter (g m^{-2}) of wild oat as affected by different nitrogen levels and wild oat densities

	Wild oat densities m^{-2}				
N	25	50	75	100	N means [aa]
N_0	76.3 i	95.3 g	121.0 d	126.0 a	83.8 c
N_1	102.3 f	122.6 d	155.3 b	181.3 a	106.2 b
N_2	90.3 h	114.0 e	147.3 c	179.3 a	112.3 a
		110.6 c	141.4 b	162.2 a	
Densities means [bb]	89.6 d	110.6 c	141.4 b	162.2 a	

[aa] LSD(0.05) for N means = 2.40

[bb] LSD(0.05) for densities means = 2.83

Wheat grain yield was significantly affected by wild oat densities, nitrogen levels and by their interactions (Table 4). So, main effects of treatments and wild oat density × nitrogen interaction means are presented (table 5 and 6). The data in table 5 show that for the nitrogen levels, the maximum (302.4 g m^{-2}) grain yield was observed in N_2 treatment while lowest of that related to unfertilized control (N_0). Among the wild oat densities the highest (332.7 g m^{-2}) grain yield was recorded in weed-free treatment (D_0), while lowest (203.9 g m^{-2}) grain yield was recorded in 100 wild oat seed m^{-2} treatment (D_4).

For the interaction between nitrogen fertilizer and wild oat densities, the highest grain yield (400.3 g m^{-2}) was observed in N_2 (50 N Kg ha^{-1} before crop seeding + 100 N Kg ha^{-1} at late tillering stage of wheat) treatment × 0 wild oat seed. The minimum grain yield (173.3 g m^{-2}) was observed in N_1 (150 N Kg ha^{-1} before crop seeding) × 100 wild oat seed m^{-2}. The mean weed-free wheat yield at N_0 was lower than N_1 and N_2 treatments (Table 5). Weed-free wheat yields seem related to pre-seeding and post-seeding soil nitrogen levels, which were greatest for N_2 that nitrogen application in soil was applied at the two stages. The highest wild oat densities have had wheat yield loss than that of lower wild oat densities. Grain yield of wheat (with or without weed competition) was higher at N_2 treatment compared with N_1 treatment (Table 5).

Study results support previous findings indicating that many agricultural weed species are as responsive as or more responsive than crops to higher soil N levels [2, 24]. Thus, indiscriminate N fertilizer use has the potential to benefit weeds at the expense of crops [3]. Grower in south western of Iran sometimes apply N fertilizer in the previous fall before seeding spring wheat as a means of decreasing the workload at planting. Results indicate that this is not necessarily a bad practice in terms of wheat yield in absence of weeds. However, wheat infested with competitive weed species sometimes had lower yield with preplant (N_1) than with multistage-applied N (N_2). Multistage- applied N compared with preplant -applied N was never worse in terms of weed density, weed biomass (Table 6), wheat yield (Table 5), wheat yield loss (Table 2 and Fig. 1) and relative wild oat biomass loss (Table 3 and Fig. 2), indicating that it is a less-risky N application timing in terms of both weed management wheat yield response.

Nitrogen application (N_1 and N_2 treatments) compared with unfertilized control treatment (N_0) tended to have larger and more consistent effect on weed growth and crop weed competition. Although, the wheat yield loss was increased by N application, but a such reduction was more recorded at once N application than multistage- applied N. The findings reported by Pedreros [25] and Blackshaw *et al*. [2] support our conclusions.

Our results are strongly supported by Blackshaw *et al*. [2], Ross *et al*. [3] and Dhima *et al*. [5] who indicated application of nitrogen can be effective factor to effect the competitive ability weed and crop. In contrast, other studies found that N application method [26] or dose [27] had little effect on crop-weed competition. In additional, results may be crop and weed specific [2]. Commen Chickweed (*Stellaria media* L.) interference with potato (*Solanum teuberosum*) was reduced with higher N levels, but the opposite result occurred when it was competing with wheat [28]. Journsgard *et al* [14] report that weed biomass in barely (*Hordeum vulgar* L.) and winter wheat could be increased, unchanged or reduced with increased soil N, depending on the weed and crop.

CONCLUSIONS

The results of this study suggest that the application of nitrogen fertilizer to wild oat-infested wheat fields increases wild oat competitions. Although, the wheat yield loss was increased by N application, but a such reduction was more recorded at once N application than multistage- applied N. Greater knowledge of the effect of N on weeds and crop grown in competitive mixtures may b allow a better understanding of why differences occurred among previous studies and would aid development of fertilization strategies to reduce weed competition with crops. Manipulation of crop fertilization not only had potential to protect crop yield but also may contribute to long term reduction in weed populations. N fertilizer is known to break the dormancy of certain wed species [9, 29] and thus may directly affected weed infestation densities. Some weeds are luxury consumers of N and thus reduce the N available for crop growth [30]. Added N can be markedly the crop-weed alter competitive interactions.

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