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Influence of nitrogen and plant density on spring wheat (*Tritium aestivum* L.) and oat (*Avena ludoviciana* L.) competitiveness

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Abstract

The researches have shown increased plant density and nitrogen fertilizer may be an important component of integrated weed management programs. A field study was conducted to determine the effect of various plant densities and nitrogen fertilizer on spring wheat and wild oat competitiveness. The treatment were consisted of three levels of nitrogen (100, 150 and 190 kgNha^{-1}) and four crop sowing densities (400, 500, 600 and 700 plant m^{-2}) of spring wheat. The experimental design was factorial with three replications. Increased nitrogen rates up to 150 kg N/ha caused an increase in wheat grain yield in weedy plots. Nitrogen fertilization increased wild oat and spring wheat biomass. Increased plant densities caused significantly reducing spring wheat yield loss, wild biomass and seed production. The effects of nitrogen fertilizer on weed suppression were influenced by plant density. The result indicate that increased plant density and nitrogen fertilizer can improve spring wheat competitiveness and reduce grain yield loss, wild oat seed production and biomass.

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Introduction

Oat (*Avena ludoviciana* L.) is a one of the most problematic winter annual grass weed for winter wheat growers in much of Iran and it reduces winter wheat grain yield (Montazari *et al.,* 2005). Competitive effects of weeds compete with crops affected by factors such as variety, plant density, weed and have access to nutrients (Carlson and Hill, 1985). Cultural and mechanical control methods must be used to reduce the impact of weed in wheat fields (Kappler *et al.,* 2002). Increasing seeding rate the crop would reduce the competitive effects of weeds (O, Donovan, 1994).

Result from numerous studies showed that high crop densities could reduce the impact of weed on crop biomass and seed yield (Wille *et al.,* 1998; O, Donovan, J. 1994; Carlson and Hill, 1985; Armin *et al.,* 2011). Koscelny *et al.,* (1991) reported yield of winter wheat increased as the wheat seeding rate was increased. Lemerle *et al.,* (2004) showed that increasing the seedling rate of crop reduced the effects of rigid ryegrass (*Lolium rigidum L.*) on wheat biomass. Xue and Stougaard (2002) reported increasing spring wheat seeding rate from 175 to 280 plants m^{-2} reduced the number of panicles 10% and wild oat biomass and seed production 20%.

Nitrogen is the major nutrient added to increase crop yield (Camra *et al.,* 2003). Crops and weeds have the same basic needs so the competition between them will affect the amount of soil nitrogen. Iqbal and Wright (1997) showed that the relative competitive abilities of wheat and weeds were influenced by nitrogen supply. The crop-weed competitive interaction can be altered by amount (Blackshaw *et al.,* 2003) time and method of nitrogen application (Blackshaw *et al.*, 2004) and source (Blackshaw *et al.*, 2005). Crop and weed biomass could be increased, unchanged or reduced with increased soil nutrient depending on the weed and crop (Jornsgard *et al.*, 1996). Information on nitrogen and plant density effect on crop-weed competition may be effective in improving weed management. The objective of this study was initiated to determine the response of wild oat and spring wheat to various nitrogen rate and crop density.

Materials and methods

Design of Field Experiment

Field experiment was conducted in 2011-2012 at the Shoshtar Branch, Islamic Azad University, Iran (32 ^{O} 3´ N, 48^{O} 50´ E). The climate is arid and semi-arid with a mean annual rainfall of 321.4 mm and the average of annual minimum and maximum 9.5^{o}C and 46.3^{o}C, respectively. The soil was a clay loam texture, pH of 7.4 and 0.6 % organic matter content. Seedbed preparation included moldboard plough followed by disking and land leveling. Fertilizer application carried out in accordance with the soil test results. Plot size was 2 by 8 m, crop rows at 20-cm intervals. Treatment consisted of three nitrogen level 100, 150 and 190 kg N ha^{-1} and four spring wheat densities 400, 500, 600 and 700 plant m^{-2}. The type of design was based on a randomized complete block in a factorial arrangement with three replication. Spring Wheat was sown in November 9, 2011, and Wild oat, at a target density of 100 seeds/m^2 was seeded at right angles to the wheat in the plot by hand on the soil surface before the wheat seeded. All weed species except wild oat (*A. ludoviciana* L.) were removed by hand every week during the growing season. Pest and disease control were not necessary. Spring wheat and wild oat plants at maturity were harvested by hand in a single randomly placed 0.50 m^2 square in each plot by clipping plant to ground level. Harvested material was oven dried for 48 h at 75 ^{o}C to a constant mass.

Statistical Analyses.

Data collected were spring wheat grain yield and biomass, wild oat biomass and seed production. Percent spring wheat yield loss was calculated by using the following formula (Remy *et al.,* 1985).

$YL = [(Y\text{wf} - Y\text{weedy})/Y\text{wf}] * 100.$

Where YL is percent yield loss, *Y* wf is weed-free grain yield and *Y* weedy is grain yield in weed (wild oat)-infested plots. All data were analyzed using PROC GLM procedure in SAS software (SAS Institute, 2000).

Results and discussion

Wheat grain yield

Statistical analysis of nitrogen and plant density had a significant effect on grain yield and their interactions were not significant (Table1). Nitrogen fertilization greater increased grain yield of spring wheat grown absence wild oat compared with crop grown presence weed. In presence wild oat the maximum spring wheat grain were recorded in 190 kgNha^{-1} while the minimum grain yield was recorded with 100 kgNha^{-1}(Table2). Although in absence wild oat increasing N fertilizer up to 150 kgNha^{-1} were not increasing wheat grain yield. N fertilizer can affect weed competition with crops. Soil fertility can increase the competitive ability of the weeds more than that of the crop, many weeds are high N consumers and reduce for N available to crops. However, the increase for nitrogen can increase crop competitiveness. Cathcart and swanton (2003) reported that crop-weed competitive interactions can be altered by N dose as the addition of up to 200 kgNha^{-1} increased corn grain yield in weedy treatments, Also Pourreza *et al.* (2010) reported that N supply increased wheat yield when it compete to wild oat. Increased plant density in the presence and absence of wild oat cause increased seed yield. However, the increase in the slope of the regression line grain yield in the presence of weeds was higher than in the absence of wild oats (Fig. 1). This indicates that there was a decrease in wild oat competitive ability. O' Donovan *et al.* (2000) reported that increasing the seeding rate improved the competitiveness of different barley varieties. Paynter and Hills (2009) reported the increasing barley plant density in competition with rigid ryegrass, increased barley grain yield.

Table 1. Analysis of variance for spring wheat grain yield, wheat biomass, yield loss, oat biomass and oat seed production affected by spring wheat density and nitrogen application.

Source	df	Wheat grain yield		Wheat biomass		Yield loss	oat biomass	Oat seed production
		Weedy	Weed-free	Weedy	Weed-free			
				P value				
Nitrogen(N)	2	0.036	0.015	<0.001	<0.001	0.435	<0.001	<0.001
Plant density(D)	3	<0.001	0.160	<0.001	<0.001	<0.001	<0.001	<0.001
N*D	6	0.888	0.716	0.252	<0.001	0.1146	<0.001	<0.001

Spring wheat Biomass

Wheat biomass was significantly affected ($P<0.001$) by nitrogen and plant density levels, and in presence wild oat, their interactions were not significant (Table1). With increasing nitrogen in the absence or presence of weed, spring wheat shoot biomass increased in all three N fertilizer applications. Although in the presence of wild oat, spring wheat shoot biomass was lower compared to the absence of wild oat (Table2). Crop density had significant effect on wheat shoot biomass ($P< 0.001$) (Table1). The regression equations (Fig. 1) and trend lines show that wheat biomass increases linearly at all plant density. Increasing the density of plant per unit area can be increased crop competition with wild oat. Weed suppression by crops appears to be enhanced by size-asymmetric competition, in which the larger crop plants suppress the initially smaller weed plants (Kristensen *et al.,* 2008).

Wild oat biomass

Analysis of the data showed that nitrogen and plant density and their interaction had a significant ($P<0.001$) impact on weed biomass (Table 1). Wild oat shoot biomass increased with most fertilizer. The maximum wild oat biomass were recorded in 190 kgNha^{-1} (676 g/m^2) while the minimum was recorded with 100 kgNha^{-1} (472) (Table2), indicating that wild oat growth responded positively to increased level of soil fertility. Increase Plant density was reduced wild oat biomass. The maximum wild oat was recorded in 400 plant m^{-2} (870 g/m^2) while the minimum wild biomass was recorded with 700 plant m^{-2} (393g/m^2) (Fig. 2). At relatively low crop densities, crop cover early in growing season is low, leaving a larger amount of resources available for the weeds, thus enabling them to establish and grow quickly (Kristensen *et al.,* 2008). Olsen *et al.* (2012) showed increased crop density resulted in reduced weed biomass and increased crop biomass. Increasing nitrogen in low of plant density increased wild oat competitiveness. As the maximum of wild oat biomass was measured with 400 Plant m^{-2} and 190 kgNha^{-1} (Table3).

Table 2. Influence of N application on wheat seed yield, wheat biomass, yield loss, oat biomass and oat seed yield.

Nitrogen rate	Wheat grain yield		Yield loss	Wheat biomass		Oat seed production	Oat biomass
	weedy	Weed-free		weedy	Weed-free		
Kg N ha^{-1}	g/m^{-2}		%	g/m^{-2}		g/m^{-2}	g/m^{-2}
100	371	560	33	1265	1655	176	472
150	370	613	39	1497	1930	242	652
190	441	623	29	1597	2123	277	676
LSD(0.05)	64.9	58.1	6.9	116.2	64.9	17.2	66.2

Means within a Nitrogen rate followed by the same letter are not significantly different, according to Fisher's Protected LSD test at the 5% probability level.

Table 3. Influence of plant density and nitrogen application on oat biomass and oat seed yield.

	Wild Oat seed production					Wild oat biomass			
Nitrogen rate kgNha^{-1}	Wheat density(plant/m^2)				Nitrogen rate kgNha^{-1}	Wheat density(plant/m^2)			
	400	500	600	700		400	500	600	700
	g/m^2					g/m^2			
100	234bc	159d	155d	154d	100	771ab	452cd	358de	308e
150	265ab	273a	215c	212c	150	818ab	777f	497c	412cde
190	280a	279a	275a	273a	190	821a	653b	677b	459cd

Means within a nitrogen rate and plant density followed by the same letter are not significantly different, according to Fisher's Protected LSD test at the 5% probability level.

Oat seed production

Nitrogen rate, crop densities, and their interactions significantly ($P < 0.01$) affected wild oat seed production (Table 1).

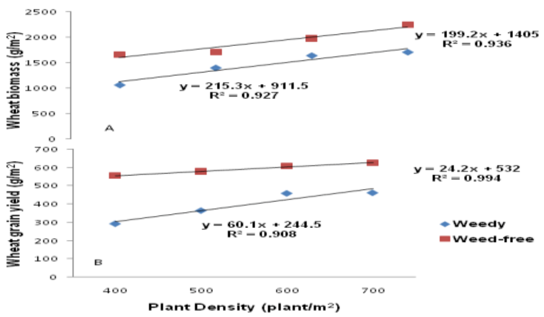

Fig. 1. The response of spring wheat grain yield per square meter (B) and biomass (A) to plant density.

Oat seed production increased with increasing nitrogen. As, the maximum of oat seed production was measured with application of 190 kg N ha (277 g/m^{-2}) (Table2). The results showed that higher nitrogen application was increased competition of wild oat with spring wheat. Increasing crop density reduced wild oat seed production, as the maximum of oat seed production was recorded with 400 plant m^{-2} (260 gm^{-2})(Fig. 2). Evans *et al.* (1991) reported increase in barley seeding rate reduced wild oat seed production by 70%. Interaction effect of nitrogen * plant density showed that the highest oat seed production (280 gm^{-2}) were obtained in density of 400 plant m^{-2} and application of 190 kgNha^{-1}

(Table3). Xue and Stougaard (2002) reported the combined effect of large seed and increased seeding rate reduced wild oat biomass and seed production 45%.

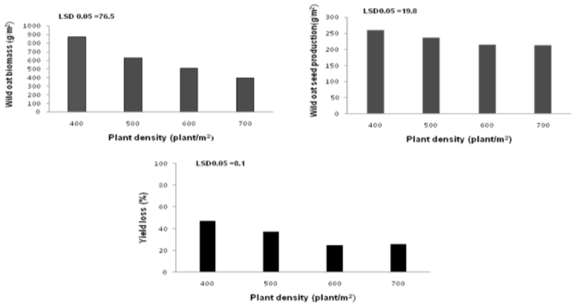

Fig. 2. Influence of plant density on yield loss, oat biomass and oat seed yield

Spring wheat yield loss

The main effect of nitrogen ($P < 0.05$) and plant density ($P < 0.01$) were significant but no interactions were detected (Table1). Reduction in wheat yield increased with increasing nitrogen, as the minimum of yield loss was measured with application of 190 kg N ha (29%) (Table2). Nitrogen level is often important for crop – weed competitive interaction (Kristensen *et al.,* 2008). Increased the amount of nitrogen were decreases the intensity of competition and increased tiller number, spike number, grain and biological yield and wheat yield loss (Armin *et al.,* 2011). Spring wheat Yield loss decreased by increased plant density. The highest (47 %) and lowest (26 %) yield loss were observed in 400 and 700 plant m^{-2}, respectively (Table 3). Kristensen *et al.,* (2008) reported increased crop density had strong and consistent negative effects on weed biomass and positive effects on crop biomass and yield. Kolb *et al.,* (2012) found that the increased seeding rates improved weed suppression. The results show that increasing plant density by increasing the suppresses weeds, helps prevent yield losses.

Conclusion

The overall results indicate that increased crop density strongly and consistently reduced weed biomass and seed production. Application of nitrogen can increased competitive ability in spring wheat, nitrogen fertilizer effects on crop yield were more important in the presence of competitive. Increased wheat density and nitrogen can play an important role in weed management. A strategy based on increased crop density and nitrogen fertilizer can reduce herbicide application in spring wheat production.

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