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Italian ryegrass (*Lolium multiflorum* Lam.) density and N fertilization on wheat (*Triticum aestivum* L.) yield in Argentina

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ABSTRACT

Italian ryegrass (*Lolium multiflorum* Lam.) is an important and troublesome weed in cereal crops in Argentina. It is present in 46% of the wheat fields of the most important cropped area and its control is mainly performed by selective grass herbicides that represent a significant percentage of total production cost. Designing weed management strategies is necessary to reduce the dependence on herbicides. This requires improving our knowledge of the effect of different management practices such as N fertilization on weed-crop interactions. Given the importance of achieving a sustainable and efficient use of herbicides, field experiments were carried out at wheat field crops in Argentina between 2004 and 2006. The main objective was to evaluate the competitive effect of ryegrass at different densities on wheat yield and its components with different nitrogen fertilization levels. In addition, the effect of N fertilization on weed emergence, growth and fecundity was also studied. N fertilization increased ryegrass competitiveness. Ryegrass densities of 100 plants m^{-2} reduced wheat yield by 30% and 20% with and without N fertilization, respectively. N fertilization did not modify seedling emergence dynamics but increased ryegrass growth and fecundity. Individual fecundity was 190 and 118 seeds per plant on the average of fertilized and non-fertilized plots, respectively.

1. Introduction

Italian ryegrass (*Lolium multiflorum* Lam.) is a troublesome annual grass weed influencing the productivity of wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.) crops worldwide (Holm et al., 1977; González-Andujar and Saavedra, 2003; Trusler et al., 2007; Paynter and Hills, 2009). In Argentina, wheat sown area in 2010–011 was 4,400,000 ha and 30% of this was carried out in the south-east of Buenos Aires Province (Minist. Agric., Ganad. y Pesca, Argentina, 2011), between 37°–39° S, and 58°–61° W. Scursoni et al. (2007) reported Italian ryegrass in 46% of wheat fields surveyed in that area.

In Argentina, ryegrass control is mainly achieved by applying herbicides such as diclofop methyl, clodinafop propargyl, pinoxaden and iodosulfurón plus metsulfuron methyl. The application of selective grass herbicides represents a significant proportion of total production costs. In addition, there are many studies showing resistance evolution of ryegrass species to these herbicides (Kuk et al., 2000; Ellis et al., 2010). *Lolium* spp. has evolved resistance to diclofop methyl and other ACCase inhibitors in 15 countries (Valverde and Heap, 2009). Currently there are 27 biotypes of Italian ryegrass resistant to ACCase inhibitors around the world (Heap, 2011).

While herbicides are a main component of weed management, other agronomic practices such as seeding rates, competitive crops, strategic fertilizer placement, narrow row spacing can also be used to suppress and manage weeds in an integrated weed management system, reducing dependence upon herbicides (Paynter and Hills, 2009). González-Andujar and Fernández-Quintanilla (2004), modeling the population dynamics of *Lolium rigidum* soil seed bank in different barley crop systems, found that keeping the prevailing crop rotation (continuous barley) and integrating the use of various chemical and cultural tactics (delayed seeding, crop competition, and preventing dispersal of seeds before harvest) resulted in better long-term results compared to a standard system based mainly on herbicide application.

The development of weed management strategies requires improving our knowledge of weed-crop interactions. Farmers are becoming increasingly interested in more comprehensive weed management programs which would lessen weed populations over time, thus reducing their dependence on herbicides (Liebman et al., 2001). Management practices that increase the competitive ability

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of crops with weeds can be important components of integrated weed management systems (Blackshaw and Brandt, 2008). Fertilization is an important agronomic strategy commonly used to increase crop yield. Although nutrients promote crop growth, many studies have shown that, in some cases, fertilizers benefit weeds more than crops (Di Tomaso, 1995).

Nitrogen is the major nutrient added to increase wheat yield, but it is not always known how N levels can affect weed demographic processes and crop–weed competitive interactions (Blackshaw et al., 2003). The knowledge of the relationship between wheat yield and ryegrass densities is a useful tool to evaluate the economic threshold and the benefit of herbicide application. However, there are few studies in Argentina focused on competitive effects of ryegrass or on the effect of nitrogen fertilization on wheat-ryegrass competition.

Given the importance of achieving a sustainable and efficient use of herbicides, this study was carried out with the main objective of evaluating the competitive effect of ryegrass populations at different densities ranged from 10 to 350 plants/m^2, on wheat yield and its components at different nitrogen fertilization levels. In addition the effect of N fertilization on ryegrass growth and fecundity was studied.

2. Materials and methods

2.1. Site descriptions and experimental design

Two field experiments were conducted during 2004–05 and 2005–06 on farmers' production fields infested with Italian ryegrass in Azul (36° 47′ S and 59° 51′ W) in Buenos Aires province and in Marcos Juarez (32° 42′ S, 62° 06′ W) in Cordoba province, respectively. An additional field experiment was carried out at the Experimental Station of the Faculty of Agronomy, Buenos Aires (34° 36′ S, 58° 22′ W) in 2005/06. Soils at experimental area were Typic argiudoll. In order to perform soil analysis, six soils samples (0–20 cm) were taken in each experimental area. Results were 2.3%–2.6% and 2.8% OM, 38–38.7 and 40 kg N ha^{-1} and pH 5.9–6.1 and 6.2, for Azul, Marcos Juarez and Buenos Aires, respectively. Annual rainfall in each experimental year was 824 mm, 760 mm and 1088 mm in Azul, Córdoba and Buenos Aires, respectively. Wheat was sown to achieve a density of 300 plants m^{-2} in a no-till system in rows 15-cm apart, at a depth of 3 cm on 13 July, 24 June and 28 July in Azul, Marcos Juarez and Buenos Aires, respectively. Crop density was checked at 12 Zadoks growth stage (Zadoks et al., 1974). At all experimental sites the entire area was fertilized before sowing with band-placed 21.6 kg N ha^{-1} and 55 kg P ha^{-1}.

Completely randomized design experiments were installed in Azul and Buenos Aires. Sixty two permanent quadrats (0.2 m^2) were established on a wheat cropped area of 0.5 ha. Forty eight quadrats were established with ryegrass densities ranging from 10 to 350 plants m^{-2}; eight quadrats with wheat without ryegrass and other six only with ryegrass at three densities, 100, 200 and 300 plants m^{-2}. Half of the total number of quadrats were fertilized by broadcasting 110 kg N ha^{-1} at the onset of crop tillering. Ryegrass emergence and density were assessed periodically and plants were thinned in order to achieve a constant ryegrass density in each plot. There were few other weeds in the experimental area so they were thinned by hand.

In Marcos Juarez, two different wheat cultivars (Buck Gaucho and Nidera Baguette 13) were sown with the objective of evaluating their competitiveness. These cultivars were selected because they are very representative of that area. The experimental design was a split plot with four replications for each treatment (cultivar × ryegrass density). Main plot was wheat cultivars and the subplots were different ryegrass densities: 0, 35, 70, 105, 140, 175, 210, 245 and 280 plants m^{-2}. In each plot of 6 m^2, quadrats of 0.5 m^2 were established, ryegrass seedling density was assessed periodically and individuals were thinned to keep ryegrass density constant. All the plots were fertilized with 125 kg N ha^{-1} at the beginning of crop tillering.

2.2. Data collection

Wheat and ryegrass emergence were determined in each quadrat. Ryegrass seedlings were identified during the crop cycle with color plastic cable rings in order to identify different seedling cohorts. At crop maturity, ryegrass plants were removed by hand, spikes were counted and fecundity was assessed from a sample of 50% of the spikes. After that, plants were dried for 48 h at 60 °C. Wheat plants were also removed from each quadrat at maturity. Then, spikes were counted and a sample of thirty percent of the whole spikes was threshed to attain the yield per quadrat. Then, one thousand grain weight was assessed and the total number of grains and grains per spike were calculated regarding the grain yield of each quadrat.

At Marcos Juarez experiment, on each 0.5 m^2 quadrat wheat and ryegrass biomass was evaluated four times during the crop cycle (tillering, Zadoks 15–23; stem elongation, Zadoks 3.3;, flowering, Zadoks 6.0; and maturity Zadoks 9). Above ground biomass was harvested by hand and dry weight was determined after drying plants at 65 °C for 48 h. At crop maturity wheat and ryegrass plants were processed such as in the other experiments to determine crop yield, components and ryegrass biomass, spikes and fecundity.

2.3. Measurement of competition

Aggressivity (Snaydon and Satorre, 1989) which takes into account the effect on competition of both crop and weeds was used for measuring competitive ability between species and was calculated as:

$$\text{Aggressivity} = (\text{Bcw}/\text{Bc}) - (\text{Bwc}/\text{Bw})$$

where Bcw and Bwc are the biomass per unit area at maturity of the crop and weed, respectively, when grown in mixtures and Bc and Bw are their biomass in monoculture (Puricelli et al., 2003).

Relative Yield Total (RYT) shows the intensity of competition and was calculated as:

$$\text{RYT} = \text{Bcw}/\text{Bc} + \text{Bwc}/\text{Bw}$$

RYT value of 1 means full competition between species, and a RYT value of 2 means no competition. Any value of RYT between 1 and 2 means that competition is partial, i.e., that there is some resource complementarity between species (Snaydon and Satorre, 1989; Satorre and Snaydon, 1992).

2.4. Statistical analyses

Data were analyzed by ANOVA and means were compared using LSD test ($P < 0.05$) corrected by Fisher. Previously Shapiro Wilks and Levene tests were carried out to test the assumptions of ANOVA.

Regression analyses were performed to determine the significance of the relationship between weed density and biomass and the relationship between crop yield, components and ryegrass abundance.