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Full Length Research Paper

Response of Italian ryegrass seed crop to spring nitrogen application in the first harvest year

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Italian ryegrass (*Lolium multiflorum* Lam.) cv. Tetraflorum was sown with different nitrogen application rates and it was tested under the agroecological conditions of Western Serbia. Four-year field experiments were carried out from 2002 to 2006 and the biometric characteristics of generative tillers, seed yield and shoot dry matter (herbage yield) were measured during the first production year. Italian ryegrass crop was established with four spring nitrogen application rates: 0, 50, 100 and 150 kg ha^{-1}. Tiller length was not affected by nitrogen application, while two other tiller parameters were much more affected by the treatments. The maximum seed yield in the first production year varied among treatments depending on season conditions. Harvest characteristics were impacted by nitrogen application; however, there was an opposite impact in arid and humid weather conditions. The N application of 50 kg ha^{-1} was found to be the optimal for seed production in those conditions. Higher rates of N application (100 to 150 kg ha^{-1}) had either no impact on seed yield, or decreased the yield of seed as a result of ryegrass lodging following seed shedding. Abundant shoot dry matter was obtained in some treatment variants, but there was no linear correlation between seed yield and yield components.

Key words: Harvest characteristics, Italian ryegrass, nitrogen application, seed yield.

INTRODUCTION

Italian ryegrass is an important short duration grass in Serbia. High palatability and digestibility make this species highly valued for forage/livestock systems from early spring to late summer. It is used in many environments where fast cover or quick feed is required. Italian ryegrass is well-adapted to high rainfall, but can be grown where a minimum of about 500 mm rainfall occurs during the growing season (Evers et al., 1997). Chastain (2000) suggested that rainfall events and short-term rainfall patterns appear to have much greater influence on seed yield than do temperature events or patterns. The Serbian production of forage and grass seed are often in areas characterized by seasonally very variable conditions.If all other elements are not limiting, nitrogen (N) is the main nutritional determinant of seed yield in grasses. Nitrogen fertilizers are now widely used in grass seed production. Applying N at early spring influences herbage N uptake and chlorophyll concentration in ryegrass grown for seed (Rowarth et al., 1999). Spring application of N nitrogen, as the most critical mineral element in ryegrass seed production (Youngberg, 1980), generally increases seed yield of ryegrass (Young et al., 1996). If the level or source and timing of nitrogen application is incorrectly managed, it may cause a reduction of grass seed yields. For example, applying excess nitrogen to ryegrass seed crops increases vegetative tiller production and reduces seed yield (Young, 1988). This occurs in part because the floral tiller sinks compete poorly with vegetative tillers for plant assimilates (Griffith, 1992). Intensive management of grass seed cropping systems could lead to a greater

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supply of N than demand and result in leaching of NO_3^- to surface and ground water (Davis et al., 2006). The recommended nitrogen application for ryegrass varies considerably (Acikgoz and Karagoz, 1989; Ahrens and Oliveira, 1997; Young et al., 2000; Choi et al., 2002, Kusvuran, 2011). Grass seed cropping systems in Western Oregon typically receive fertilizer applications in the range of 150 to 250 kg ha^{-1} N per year, which on average is 30% greater than extension service recommendations (Davis et al., 2006). Added N results in a significant increase in aboveground dry matter but without increasing of seed yield.

The production of grass seed has often been organized in areas characterized by seasonally very variable climates, such as the Western Serbia. Intensive fertilizer N management of these systems, high seasonal rainfall variability and an increasing awareness of the economic and environmental consequences of N loss have led to a growing interest in understanding how these systems process and retain N. Excess nitrogen can cause too much vegetative growth, leading to swathing difficulties. Lodging is ubiquitous in Italian ryegrass grown for seed, especially under high N fertilization (Griffith, 2000). The objective of this study was to determine the optimum rate for nitrogen (N) application in the spring with respect to seed yield in the first production year. Understanding the influence of N rates on seed yield components can be used to improve N use efficiencies and seed yield.

MATERIALS AND METHODS

Field experiments during 2002 to 2006 in Western Serbia (44°47′ N, 19°35′ E, 80 m a.s.l.) studied the effects of applied nitrogen in spring, on seed yield and yield components of Italian ryegrass, cv. Tetraflorum. Ryegrass was given different spring N fertilizer rates (0, 50, 100 and 150 kg ha^{-1}). The individual plot size was 10 m^2 (2.5 × 4 m), arranged in a randomized complete block design in four replications. Ryegrass was sown each autumn (first to third decade of October) with seeding rate of 20 kg ha^{-1} and 20 cm inter-row spacing. Seeds from the primary growth of Italian ryegrass cv. Tetraflorum were harvested in the first production year after the establishment. Phosphorus, potassium and a portion of nitrogen were applied in the fall before each seed production year (250 kg ha^{-1} of 8-16-24 fertilizer NPK).

Seed yield and shoot dry matter were analyzed per plot and their values per ha at each harvest and harvest index was calculated. Prior to the seed harvest, biometrical traits such as generative tillers length, spike length and the number of spikelets per spike were measured on 10 randomly sampled tillers from each plot. Italian ryegrass was harvested by hand in the third decade of June or in the first decade of July. The harvest was started in the stage of full seed ripening when a gentle hand rubbing of spike would result in evident seed shattering. After air-drying, the seed was threshed, cleaned and weighed with seed moisture of 140 to 150 g kg^{-1}. After seed threshing, the straw was collected and weighed as dry herbage yield. Harvest index was calculated by using the formula HI = [SY / (SY + SDM)] × 100, where HI is the harvest index (%), SY is the seed yield (kg ha^{-1}) and SDM is the shoot dry matter (straw yield) (kg ha^{-1}). Data were analyzed by analyses of variance (ANOVA) and with Statistical 8.0 software packages, and the treatment effect was determined according to Fischer's least significant difference procedure.

Experimental conditions

Meteorological data were collected at the Mitrovica Weather Station. The monthly precipitation and temperature during the 4 years of the experiment were very contrasting, and the use of growing degree days (GDD) is more acceptable to compare the rate of plant development among years instead of single or average monthly temperatures. Accumulated GDD was calculated by the formula $\{[(T_{max} - T_{min}) / 2] - T_{base}\}$, where T represents daily maximum and minimum temperatures. The T_{base} for ryegrass was 0°C, and values were summarized from January the 1st (Griffith and Chastain, 1997). Accumulated precipitation during the period implied by GDD was compared and presented (Figures 1 and 2). Soil in the experimental area was humofluvisol (2.54% humus), with rinsed limestone. The main characteristics of the soil (depth: 0 to 30 cm) were as follows: soil texture - clay; $CaCO_3$ - 0.36%; pH in KCl - 5.25 (slightly acid); K_2O - 15 mg kg^{-1} and P_2O_5 - 3 mg kg^{-1}.

RESULTS

Climatic conditions, temperature and precipitation played a major role in determining the influence level of nitrogen application in the Italian ryegrass seed yield during the four contrasting years. Accumulated precipitation during the spring of 2003 was deficient (Figure 1). Tiller characteristics were unaffected by spring applied nitrogen in 2003 and main characteristic of this year was dry conditions during vegetation season, which neutralized nitrogen effect (Table 1). N application did not affect tiller length in all years. However, the spike length was affected by nitrogen during 2004 to 2006 and maximum length was obtained by 50 and 100 kg N. Also, the number of spikelet per spike in 2005 and 2006 was the highest at 50 kg ha^{-1} N.

Higher precipitation during the 2 consecutive years resulted in abundant biomass accumulation (Table 2). In the spring of 2004 and 2005, lodging was extremely high and the percentage of crop lodging increased as N rates increased. Average seed yield was higher in 2005 than the other years. Differences among treatments existed among the different years. Seed yield was unaffected by N in 2003, but in 2004-2006 seed yield was higher with 50 kg ha^{-1} N. Generally, there were no seed yield increases with up to 100 kg ha^{-1} N. Profit increased with the first increment of N application (50 kg ha^{-1}), and tended to reach a peak with that rate. There was also some crop lodging in 2006, but it occurred late in the seed-filling period. A favourable effect of increased nitrogen rates on herbage yield was observed in dry conditions of 2003. The lowest average seed yield was observed in the first experimental year (785 kg ha^{-1}), while the highest was in the third experimental year (1559 kg ha^{-1}) (Table 2). The reduced seed yield and herbage production in 2003 were attributed to a spring rainfall shortage. Little lodging was observed in 2003, but all plots severely lodged by maturity in 2004-2006.The harvest index as an indicator of seed production efficiency was significantly influenced by the applied treatments; the highest harvest index was observed in

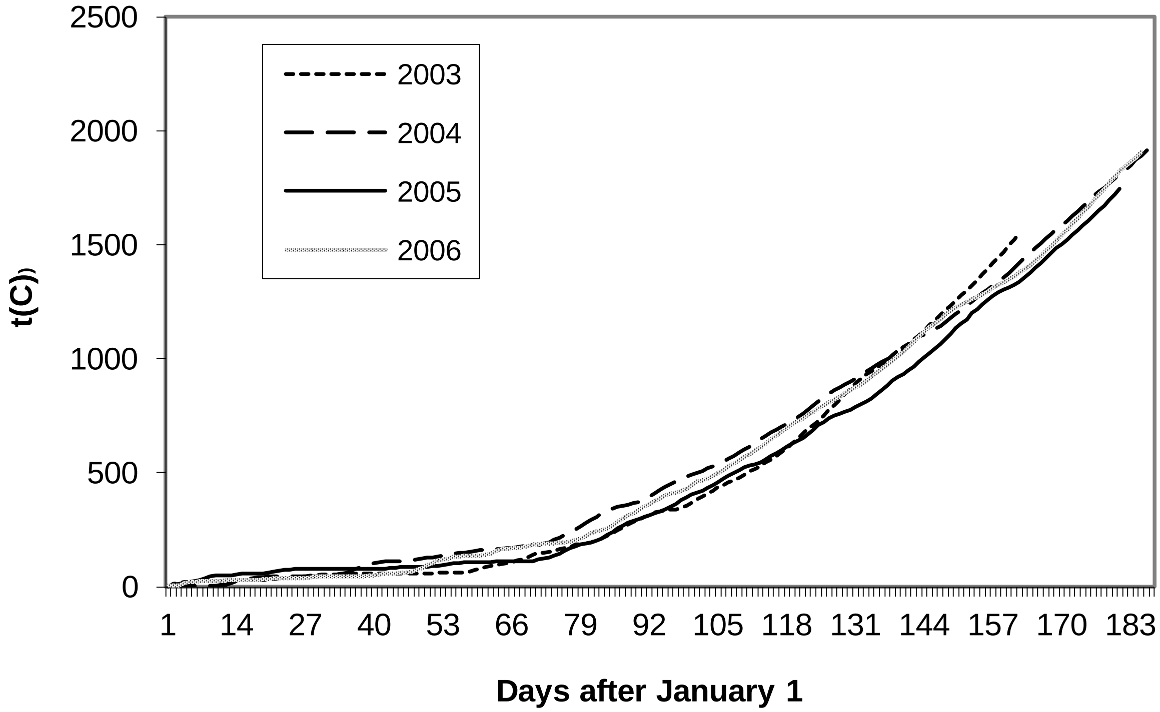

Figure 1. Growing degree days during four consecutive years in Italian ryegrass grown for seed

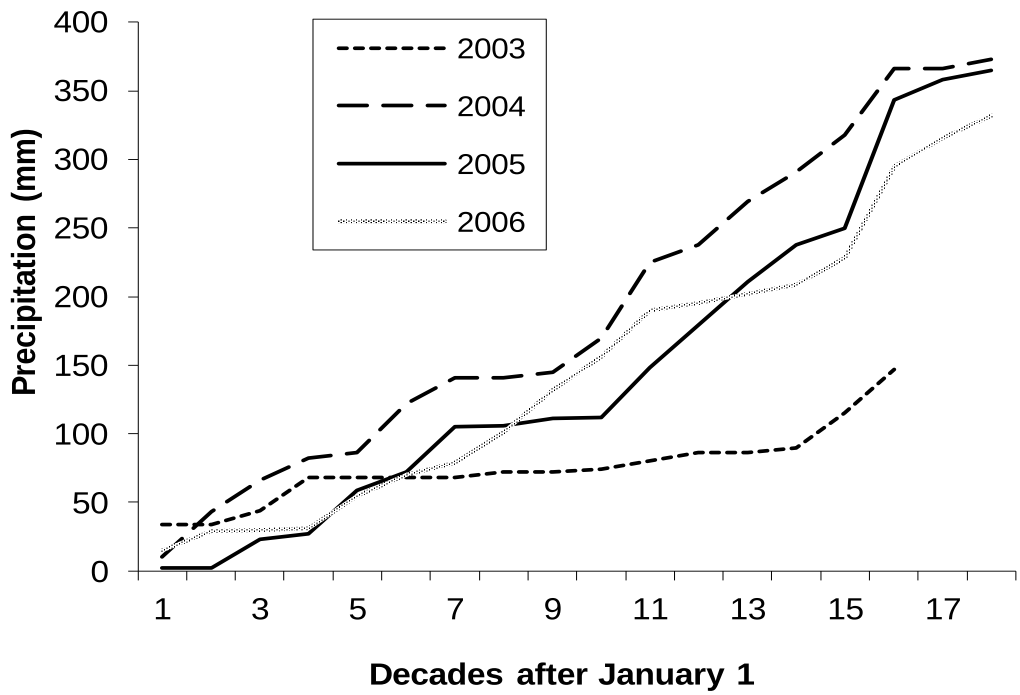

Figure 2. Accumulated precipitation during 4 consecutive years in Italian ryegrass grown for seed.

2003. Regarding low seed yield and reduced herbage production, the harvest index could not be considered an objective indicator in this production year. The highest harvest index was obtained in the first harvest year (29.2%), but without significance among treatments. The lowest harvest index was in the second year (12.6%),

Table 1. Tiller characteristics responses to spring applied nitrogen during the period of 2003 - 2006.

Nitrogen rate (kg ha^{-1})	Tiller length (cm)	Spike length (cm)	Spikelets per spike (no. tiller^{-1})
2003			
0	72[a]	24.1[a]	24.4[a]
50	73[a]	24.2[a]	24.7[a]
100	71[a]	23.9[a]	24.8[a]
150	73[a]	24.3[a]	24.9[a]
Average	72	24.1	24.7
2004			
0	130[a]	34.9[ab]	27.2[a]
50	127[a]	35.5[ab]	27.3[a]
100	130[a]	35.8[a]	27.4[a]
150	132[a]	33.9[b]	26.7[a]
Average	131	35.0	27.2
2005			
0	115[a]	31.7[b]	21.3[b]
50	116[a]	33.8[a]	22.2[a]
100	116[a]	31.8[b]	21.3[b]
150	115[a]	31.5[b]	21.5[b]
Average	115	32.2	21.6
2006			
0	99[a]	29.4[ab]	25.0[b]
50	99[a]	30.5[a]	26.5[a]
100	97[a]	29.2[ab]	25.3[b]
150	97[a]	28.9[b]	25.6[b]
Average	98	29.5	25.6

*Means in columns followed by the same letter are not significantly different by Fisher's protected LSD values (P=0.05).

and difference between the two consecutive years could be explained by differences in shoot dry matter (DM), influenced by precipitation rates.

The significance shown for the six production characteristics measured on the Italian ryegrass seed crop (Table 3) suggested that climatic conditions, temperature and precipitation played a major role in determining the level of N influence on ryegrass seed yield in the first production year. Vice versa, heavy rains and flooded conditions during 2006 caused a higher influence of N on tiller and harvest characteristics.

DISCUSSION

Some recent studies on N application in Italian ryegrass seed crop production reported that lower rates maximize seed yield. Acikgoz and Karagoz (1989) reported that in perennial ryegrass grown for seed, uptake of N fertilizer in dry conditions by plants was greatest and the highest seed yield was obtained when N was applied in rate of 40 kg ha^{-1} per year. Choi et al. (2002) applied different N rates of 50, 75 and 100 kg ha^{-1} at Italian ryegrass seed crop and found that the lowest rate provided the highest seed yield. Also, lodging tolerance appeared to be the highest in the treatment including 50 kg ha^{-1} N compared with other treatments. Ahrens and Oliveira (1997) also reached the best results in Italian ryegrass seed production using 60 kg ha^{-1}N.

In dry conditions of 2003, increasing the N rates in the spring application had no effect on tiller or harvest characteristics, suggesting that principal limiting factor in ryegrass crops in general can be water deficit (Chastain, 2000). Nevertheless, the total above ground dry matter weight of the ryegrass increased as the stand imported more N. However, by the time the stand was n close to maturity, there was no difference in the total above-ground biomass.

The adverse effect of lodging on seed yield may be attributed to a reduced photoassimilate supply for developing seeds, limited pollination, and low set seed (Griffith, 2000), as pre- and post-anthesis assimilate reserves play an important role in seed filling when current photoassimilate supply is reduced. Lodging combined

Table 2. Harvest characteristics responses to spring applied nitrogen during the period of 2003-2006.

Nitrogen rate (kg ha^{-1})	Seed yield (kg ha^{-1})	Shoot DM (kg ha^{-1})	Harvest index (%)
2003			
0	765[a]	1731[a]	29.8[a]
50	801[a]	1940[b]	28.6[a]
100	742[a]	1842[ab]	28.7[a]
150	833[a]	1909[ab]	29.7[a]
Average	785	1856	29.2
2004			
0	916[b]	6748[a]	12.2[b]
50	1022[a]	6516[a]	13. 8[a]
100	936[b]	6844[a]	12.2[b]
150	944[b]	6876[a]	12.4[b]
Average	955	6746	12.6
2005			
0	1448[b]	5771[a]	20.4[bc]
50	1650[a]	5650[a]	23.0[a]
100	1571[ab]	5960[ab]	21.3[b]
150	1568[ab]	6385[b]	19.8[c]
Average	1559	5941	21.1
2006			
0	823[b]	3936[c]	18.7[c]
50	907[a]	2927[a]	24.5[a]
100	843[b]	3646[bc]	20.5[b]
150	784[b]	3516[b]	19.6[bc]
Average	839	3506	20.8

*Means in columns followed by the same letter are not significantly different by Fisher's protected LSD values (P=0.05).

Table 3. Statistical summary of tiller and harvest characteristics responses to varied spring applied nitrogen during the period of 2003-2006.

Harvest components	2003	2004	2005	2006
Tiller length	NS[1]	NS	NS	NS
Spike length	NS	*	*	*
Spikelets per spike	NS	NS	*	**
Seed yield	NS	*	*	**
Shoot dry matter	**	NS	*	**
Harvest index	NS	**	**	**

[1]NS = Not significant at P value 0.05, * = significant at P value < 0.05, ** = P value <0.01.

with climatic conditions favoring new tiller growth during 2004 and 2005 hampered mechanical harvest and promoted assimilate limitation at seed sinks due to assimilate demands of young vegetative tillers. This is the reason why there was no seed yield increase with up to 100 kg ha^{-1} N. The difference in results achieved in 2004 and 2005 was due to a low accumulation of assimilates and early season lodging at the time of heading in 2004. Furthermore, the conditions of 2004 promoted new tiller development during seed filling period, resulting in new tillers competing for assimilates with seed sinks. The differences in herbage yield, seed yield, and harvest index between 2004 and 2005 were the result of these factors. Moreover, the heavy rains and floods during

2006 caused a high level of seedling mortality and lower yield compared to the other years. The results of the present study support the use of a relatively low spring nitrogen rate for Italian ryegrass seed production in the first harvest year. The data showed that by 50 kg ha^{-1} N application at the start of tillering, ryegrass seed yield could be increased without causing environmental degradation. Nitrogen application in excess of 50 kg ha^{-1} does not usually increase seed yield significantly over that of recommended rates because of increased seed abortion as a consequence of competition for assimilate supply by secondary vegetative tillers.

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