Timing of Spring Nitrogen Application in Amenity-Types of *Lolium perenne* L. Grown for Seed.

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ABSTRACT

Three amenity-type perennial ryegrass (*Lolium perenne* L.) cultivars, Elka, Taya and Pippin were undersown in 1990, 1991, 1992 and 1993 in spring barley at two locations, Roskilde and Rønhave. The objective was to determine the optimum timing for nitrogen (N) application in the spring with respect to seed yield. N was applied at a rate of 100 kg ha^{-1} on March 1 or April 1 or May 1. The effect of a split application of N on seed yield was also examined when N was applied at 50 kg ha^{-1} on March 1 and again on May 1. While delaying N application resulted in a decrease in the number of fertile tillers, seed yield did not differ among any of the N treatments, due to an increase in thousand seed weight and number of seeds per tiller. Furthermore, application time had no effect on lodging characters or plant height. A split N application did not result in a lower total seed yield as long as the early application of N was followed by a supplemental amount in early May. These findings should prove beneficial towards the development of new strategies for N application in *L. perenne* grown for seed production.

Additional index words: *Lolium perenne* L, nitrogen application, application time, split application, seed yield, seed yield components.

INTRODUCTION

For Danish seed production of forage types of perennial ryegrass (*Lolium perenne* L.) an early spring (March) application of nitrogen (N) is recommended (Nordestgaard, 1979; Nordestgaard, 1992). However, in Italian ryegrass (*Lolium multiflorum* L.), Nordestgaard (1985) recommended applying N at the beginning of April. In cocksfoot (*Dactylis glomerata* L.), red fescue (*Festuca rubra* L.) and smooth stalked meadow grass (*Poa pratensis* L.) Nordestgaard (1981a) found that delaying N application approximately two months from early March to early May resulted in decreased seed yields. In contrast, the same study revealed increased seed yields for timothy (*Phleum pratense* L.). In meadow fescue (*Festuca pratensis* Huds.), timing of spring N application (early March to late April) had no effect on seed yield (Nordestgaard, 1981b). Consequently, there appears to be little consensus regarding the timing of spring N application among grass species for seed production in Denmark.

The effects of split application on seed yield have also been examined in a number of grass species. Nordestgaard (1981a) showed that for cocksfoot, red fescue and smooth stalked meadow grass, when early N application rates were below optimum, seed yield was increased by an additional application in the last half of May. However, splitting the optimum amount of N did not increase seed yield when compared to an early full application rate (Nordestgaard, 1981a). Similar results were found for meadow fescue (Nordestgaard, 1981b).

In timothy, the split application of N has a positive effect on seed yield (Evans, 1954; Aamlid, 1997; Øverland, 1998). In Norwegian trials for example, the highest seed yield was achieved after application of one third of the total N in early spring and two thirds at the start of tiller elongation (Aamlid, 1997). In contrast, studies in perennial ryegrass have failed to demonstrate any benefit associated with a split application of N (Evans, 1954; Hebblethwaite and Ivins, 1978; Hampton, 1987).

Hampton, Clemence and Hebblethwaite (1983) reported that agricultural and amenity-types of perennial ryegrass did not differ in their response to spring applied N, but the responses of Danish amenity-type cultivars are not known. The objectives of the present research were therefore to investigate the effects of applying N at three different times in spring, and to test the effects of splitting N application on seed yield in three amenity-type cultivars of perennial ryegrass.

The effects of splitting the N application between autumn and spring have been presented by Deleuran and Boelt (1998).

MATERIALS AND METHODS

Three amenity-type cultivars of perennial ryegrass cv. Elka, cv. Taya and cv. Pippin were undersown in spring barley cv. Alexis. The three cultivars differ in plant height with cv. Elka being short (59 cm), cv. Taya intermediate (72 cm) and cv. Pippin tall (84 cm).

The field trials were conducted from 1990-1994 at the Danish Institute of Agricultural Sciences at two locations, Roskilde (55°39'N and 12°05'E) and Rønhave (54°57'N and 9°47'E) on a sandy loam soil and a clay soil, respectively. The previous crop at both locations in all four years was spring barley. Perennial ryegrass and spring barley were sown separately, with the grass seed being sown immediately after the cover crop. The spring barley sowing rate was 120 kg ha^{-1} and perennial ryegrass was sown at 200 viable seeds m^{-2}. The grass was sown at a depth of 1 cm and in rows parallel to the spring barley. Row distance in both crops was 12 cm. The dates for sowing and harvesting of cover crops and the dates for sowing, swathing and combine harvesting of the grass seed crops are shown in Table 1. Spring barley was harvested with a trial combiner and the straw removed immediately after harvest. In late September, grass re-growth was cut to approximately 10 cm stubble height (if re-growth had exceeded 15-20 cm).

In the spring of each year 100 kg nitrogen (N) ha^{-1} was provided either as a single application in March or April or May, or as a split application in March and May (Table 2). The N was applied as calcium ammonium nitrate. The only

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Table 1. Sowing and harvest date in spring barley and sowing, swathing and harvest date in the three perennial ryegrass cultivars.

	Spring barley sowing date	Spring barley harvest date	Rye grass sowing date	Swathing date cv. Elka	Swathing date cv. Taya	Swathing date cv. Pippin	Harvest date cv. Elka	Harvest date cv. Taya	Harvest date cv. Pippin
Roskilde 1991	16 Mar-90	30 Jul-90	26 Mar-90	-[1]	-[1]	-[1]	14 Aug-91	14 Aug-91	14 Aug-91
Roskilde 1992	12 Apr-91	21 Aug-91	15 Apr-91	16 Jul-92	13 Jul-92	10 Jul-92	23 Jul-92	21 Jul-92	17 Jul-92
Roskilde 1993	8 Apr-92	29 Jul-92	9 Apr-92	29 Jul-93	29 Jul-93	-[1]	5 Aug-93	5 Aug-93	2 Aug-93
Roskilde 1994	30 Mar-93	18 Aug-93	1 Apr-93	2 Aug-94	28 Jul-94	28 Jul-94	8 Aug-94	2 Aug-94	2 Aug-94
Rønhave 1991	29 Mar-90	3 Aug-90	29 Mar-90	30 Jul-91	30 Jul-91	30 Jul-91	8 Aug-91	8 Aug-91	8 Aug-91
Rønhave 1992	12 Apr-91	14 Aug-91	12 Apr-91	8 Jul-92	8 Jul-92	8 Jul-92	17 Jul-92	17 Jul-92	17 Jul-92
Rønhave 1993	9 Apr-92	6 Aug-92	9 Apr-92	19 Jul-93	19 Jul-93	19 Jul-93	2 Aug-93	2 Aug-93	2 Aug-93
Rønhave 1994	2 Apr-93	18 Aug-93	2 Apr-93	26 Jul-94	26 Jul-94	26 Jul-94	3 Aug-94	3 Aug-94	3 Aug-94

[1] *Direct harvest.*

Table 2. Rate of N application and desired and actual time of application.

Application of N	Desired application time	Actual application time[1]
100 kg N ha^{-1}	March 1	March 7
100 kg N ha^{-1}	April 1	April 1
100 kg N ha^{-1}	May 1	May 1
50 kg N ha^{-1} + 50 kg N ha^{-1}	March 1 + May 1	March 7 + May 1

[1] *Actual application time is an average of the four years and the two locations.*

exception to these timings was in 1994 when spring was very late and application was not possible until 14 and 22 March at Roskilde and Rønhave, respectively.

Grass plant density was recorded in each plot in the autumn after harvest of the cover crop, and in spring in the seed production year using a scale where 0 equals no plants and 10 equals full ground cover. Lodging was assessed at flowering, three weeks before harvest and prior to harvest using a scale where 0 equals no lodging and 10 equals complete lodging. After flowering plant height was measured and prior to harvest, one sample was cut within a frame of 0.25 m^2, and the number of fertile tillers counted.

Broad-leaved weeds were controlled in autumn with Herbalon (3.5 l ha^{-1}) (a.i. clopyralid, mechlorprop and MCPA), and the treatment was repeated in spring if necessary. Mechlorprop (6 l ha^{-1}) was used at Roskilde in autumn 1991. Annual meadow grass (*Poa annua* L.) was controlled at Roskilde during the autumn of 1993 with Avenge (5 l ha^{-1}) (a.i. difenzoquat). Mildew was controlled with Tilt top (0.5 l ha^{-1}) (a.i. propiconazol and fenpropimorph) at Rønhave in 1994.

Before shedding the grass crop was swathed and harvested approximately one week later (Table 1), following which seeds were dried to 13 % moisture. The moisture content of grass seeds at swathing and combining was not measured. Samples were cleaned using an air-screen seed cleaner by passing them through sieves. After seed drying and cleaning, one sample from each treatment was analysed for purity at the Danish Plant Directorate using internationally standardised methodology (ISTA, 1988). Only first year seed production was measured.

The experimental design was a randomised complete block with two or three replications for both locations. The net plot size was 8m x 2.5m. Data were analysed as a two-factorial block design regarding the year as a random factor. Tests of the main factors of location, cultivar, time of applied N and their interaction were performed by F-tests. To predict the effects of each treatment in the present trial in any future year, the denominator used in the F-test was the interaction between the effect in question and year. Means of main effects were separated by least significant difference (LSD) and were declared different at the $P \leq 0.05$ level. The analyses were performed using the PROC GLM module within the Statistical Analysis System, software package (SAS, 1989a, 1989b).

Meteorological data were collected at both locations by the Danish Institute of Agricultural Sciences, Department of Meteorology.

RESULTS

In 1991 growing conditions were favourable, and June was relatively wet with 70 mm and 40 mm more rainfall than normal at Roskilde and Rønhave respectively. (Table 3). No drought periods were recorded during 1991 and the grass seed established well. The 1992 growing season was dry and sunny from mid May until mid July and rainfall was far below normal. Spring and summer of 1993 had drought periods, but compared to 1992 the situation was not quite as serious. After extensive rainfall in March 1994 the season provided good climatic conditions for seed production.

Since no significant variation among years, cultivars and locations was found for the effect of time of N application, data are presented as means of these.

Time of N application had no effect on seed yield (Table 4). However, the number of fertile tillers was highest (3238 m^{-2})

Table 3. Average monthly temperature and total monthly rainfall in 1991, 1992, 1993 and 1994 and average values (1961-1990) for Roskilde[1].

	Temperature, °C					Rainfall, mm				
	1991	1992	1993	1994	Average (1961-90)	1991	1992	1993	1994	Average (1961-90)
Jan	1.7	2.2	1.7	2.4	-0.8	49	35	75	81	42
Feb	-1.3	3.0	0.8	-1.3	-0.6	33	25	20	44	28
Mar	3.9	3.9	2.6	3.1	1.7	12	50	9	77	36
Apr	6.0	5.9	7.2	7.4	7.7	24	33	4	51	37
May	9.4	12.7	13.1	10.4	10.6	31	10	8	44	44
Jun	11.7	17.5	13.8	13.0	14.5	121	1	53	51	50
Jul	17.2	17.9	14.5	19.4	16.3	76	49	120	4	66
Aug	17.0	16.4	14.1	17.2	15.7	40	57	102	57	66
Sep	13.3	12.8	10.7	12.8	12.5	70	34	148	153	56
Oct	8.7	6.2	6.9	7.7	8.9	30	61	59	38	53
Nov	4.7	4.5	1.9	6.3	4.6	59	85	64	59	56
Dec	2.6	2.6	2.0	3.8	1.1	44	38	83	84	51
Year	7.9	8.8	7.4	8.5	8.1	589	478	745	743	585

[1] *Values for Rønhave are approximately the same*

Table 4. Effect of time of N application on perennial ryegrass seed yield, number of fertile tillers and thousand seed weight[1].

Time of N application	Seed yield (kg ha^{-1})	Number of fertile tillers (m^{-2})	Thousand seed weight (g)
March 1	1314	3238	1.44
April 1	1338	3058	1.44
May 1	1359	2710	1.51
March 1 + May 1	1355	2997	1.48
LSD P<0.05	NS	157	0.03

[1] *Data are means for all three cultivars, four years and two locations.*

Table 5. Effect of perennial ryegrass cultivar on seed yield, number of fertile tillers and thousand seed weight.

Cultivar	Seed yield (kg ha^{-1})	Number of fertile tillers (m^{-2})	Thousand seed weight (g)
Elka	1209	3620	1.27
Taya	1431	2877	1.65
Pippin	1385	2505	1.48
LSD P<0.05	173	267	0.09

[1] *Data are means for four years and two locations.*

after early N application. Fertile tiller number decreased significantly with each delay in application of N after March 1 (Table 4) although the difference observed between applications of N on April 1 and the split application (March 1 + May 1) was not significant.

Late N application and the split N application resulted in an increase in thousand seed weight compared to the two earlier applications (Table 4). The number of seeds per tiller was calculated (data not presented). The lowest number (28.2) was recorded after the March 1 application and the highest number (33.2) after the May 1 application.

Seed yield was highest in the cultivars Taya and Pippin (Table 5). At Rønhave (1992 and 1993) there was a considerable amount of *P. annua* in the cv. Elka stand which depressed seed yield. The number of fertile tillers varied significantly among cultivars (Table 5) with the highest number in cv. Elka (3620 m^{-2}) and lowest number in cv. Pippin (2505 m^{-2}). A significant difference was also recorded among the three cultivars for thousand seed weight (Table 5).

Lodging score three weeks before harvest was lower (2.6) in cv. Elka than for cv. Taya (4.9) and cv. Pippin (5.7). At harvest, the lodging score was 4.2, 5.2 and 6.1 in the cultivars Elka, Taya and Pippin, respectively. Plant density was not affected by cultivar. Furthermore neither N or cultivar affected plant density in spring or lodging characters at flowering (data not presented).

DISCUSSION

Seed yield in these three amenity cultivars of perennial ryegrass was insensitive to timing of spring N application (early March to early May). This was also the case for the split application of N. These results are in general agreement with those of Hebblethwaite and Ivins (1978), who used applications of N between late March and early June. Differences in application times between British and Danish trials are likely to be related to climatic conditions.

Delaying N application resulted in a decrease in the number of fertile tillers. However, an increase in thousand seed weight and seeds per tiller was also observed, which compensated for the decreased number of fertile tillers. As a consequence, total seed yield was not influenced by application time. These results are consistent with those of Nordestgaard (1979; 1981a; b). In contrast Hebblethwaite and Ivins (1978) reported a decrease in seed yield following late N application (at 70-80% ear emergence) because of a lower number of seeds per unit area.

The number of fertile tillers recorded after the split N application was lower than for the March 1 application, but higher than for the May 1 application. Thousand seed weight following the split application was increased compared to that for the first and second application times, but did not differ from that for the May 1 application. However, seed yield did not differ for the split application compared to the three ordinary application times (March 1; April 1; May 1).

Previous studies on the effect of split application of N have shown a negative effect on tiller number and thousand seed weight (Hebblethwaite and Ivins, 1978). The present results produced a positive effect of split application on thousand seed weight compared to application at March 1, whereas Hampton (1987) and Nordestgaard (1979) found no effect on thousand seed weight by splitting N application. Consequently, it is likely that the effect of split application of N on seed yield components will differ, and will need to be assessed empirically in each case according to the physiological age of the plant.

Delaying the time of application of N had no effect on lodging or plant height. Differences in lodging for the three cultivars are thought to be related to plant height.

According to Rowarth (1997) research into N use efficiency is needed in order to minimise environmental impact whilst maintaining economic seed yields. Our results on split application allow for the development of new more environmentally and economically sound strategies. An initial 50 kg N ha^{-1} applied in spring maintained a high number of fertile tillers. This must be followed by a further N application at elongation. This last application should be based on crop demand to maintain a high N recovery.

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