RESEARCH NOTE

The Relationship Between Applied Nitrogen, Nitrogen Concentration in Herbage and Seed Yield in Perennial Ryegrass (*Lolium perenne* L.). VI. Cv. Borvi in Denmark.

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ABSTRACT

The relationship between the concentration of nitrogen (N %) in herbage and herbage N content (kg ha^{-1}) 14 days after the beginning of stem elongation, and seed yield of perennial ryegrass (*Lolium perenne* L.) cv. Borvi, was tested. Five N treatments (0, 50, 100, 150 or 200 kg ha^{-1}) were applied in various combinations of autumn and early spring timing to create a range of herbage N concentration and herbage N content. Dry matter was sampled 14 days after the beginning of stem elongation and analysed for total N. Seed yield was measured at harvest. N resulted in a significant ($P<0.05$) increase in seed yield, herbage N concentration, dry matter yield and N content. Herbage N concentration and herbage N content at 14 days after the beginning of stem elongation were significantly ($P<0.05$) related to seed yield (R^2 = 0.83 and 0.88, respectively). For 80 % relative seed yield, critical N concentration was 3.2 % and critical N content was 76 kg ha^{-1}.

Additional index words: apparent nitrogen recovery, herbage nitrogen content, nitrogen use efficiency, stem elongation.

EXPERIMENTAL AND DISCUSSION

In Denmark, nitrogen (N) use on perennial ryegrass (*Lolium perenne* L.) seed crops is restricted to 114 kg ha^{-1} *per annum* for late cultivars. In an attempt to maximise seed yields for the grower, Deleuran and Boelt (1998) and Gislum and Boelt (1998) investigated the balance between autumn and spring-applied nitrogen. They concluded that N applied at 100 kg ha^{-1} or greater in spring rendered autumn N unnecessary (Deleuran and Boelt, 1998), and that ryegrass seed crops were relatively insensitive to timing of application of that 100 kg ha^{-1} N in spring (Gislum and Boelt, 1998). As it is autumn-applied N that is at most risk of leaching (Cookson, Rowarth and Cameron, 2000), and volatilisation losses increase as soil temperatures warm up after winter (Cookson, Rowarth, Cornforth and Cameron, 1999) these results give potential for the development of new strategies for N application in perennial ryegrass seed crops. For this, an indicator of the amount of nitrogen needed to achieve a given seed yield within a season is required; crop monitoring and diagnostics can be used to manage nitrogen inputs if a reliable indicator can be found (Barraclough, 1997).

Herbage N concentration (%) 14 days after spikelet initiation has been identified as a reliable indicator of relative seed yield in research trials in New Zealand (Rowarth and Archie, 1995). More recently it has been suggested that herbage N content, also at 14 days after spikelet initiation, may be a more reliable indicator when results are being compared across countries and cultivars (Rowarth, Boelt, Hampton, Marshall, Rolston, Sicard, Silberstein, Sedcole and Young, 1998; Sicard and Rowarth, 1998; Young, Silberstein, Chastain and Rowarth, 1998). This experiment was established to test the model identified for cv. Grasslands Nui (Rowarth *et al.*, 1998) on cv. Borvi. The field trial was established at Roskilde, Denmark. The soil type was a sandy loam, pH was greater than 5.8, and, with the exception of N, nutrients were non-limiting. Throughout the trial, pesticide control was prophylactic. Perennial ryegrass cv. Borvi was sown at 8 kg ha^{-1} in autumn; plot size was 2.5 m x 8.02 m and there were four replicates in a randomised block design. Nitrogen was applied on October 5 (autumn, before soil temperatures fell below 8 °C) and on April 30 in spring at the rates given in Table 1.

On May 24 (14 days after the start of stem elongation), herbage was sampled by cutting the plants just above the leaf sheath from a known area (0.1875 m^2). The herbage was dried overnight at 80 °C, and dry weight recorded, before being analysed using the Dumas technique for total N (Hansen, 1989). Seed was harvested before seed shedding started. After air drying, threshing and cleaning, seed yield was recorded.

Nitrogen content was calculated from dry matter yield and herbage N concentration 14 days after elongation. Apparent nitrogen recovery (ANR; %) and nitrogen use efficiency (NUE; kg extra seed/kg applied N) were calculated as described by Rowarth *et al.* (1998). Relative seed yield was calculated for each N treatment relative to the maximum seed yield.

Analysis of variance and regression analysis were performed using Minitab 10.1. The Cate-Nelson separation technique, which involves partitioning data into diagonally opposite quadrats (using cross hairs), was used to establish critical

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Table 1. Effect of applied nitrogen on seed yield, herbage nitrogen, dry matter yield, nitrogen content, nitrogen use efficiency and apparent nitrogen recovery for cv. Borvi.

Nitrogen strategy[1]	Total N (kg ha^{-1})	Seed yield (kg ha^{-1})[2]	Herbage N[3] (%)	DMY[3] (kg ha^{-1})	N content[4] (kg ha^{-1})	NUE[5] (kg seed kg N^{-1})	ANR[6] (%)
00-00	0	1133	2.17	1839	40	-	-
00-50	50	1260	2.83	2068	58	2.5	36
00-100	100	1416	4.31	2422	105	2.8	65
30-120	150	1657	4.50	2727	123	3.5	55
60-140	200	1537	4.54	2829	128	2.0	44
LSD P<0.05		185	0.38	651	29	-[7]	-

1 Timing of the two nitrogen applications was: late autumn after establishment (5th October) and spring (30th April)
2 Seed yields expressed as 0 % moisture
3 Analysed 14 days after the beginning of stem elongation
4 DMY x N% 21 days after early spring nitrogen application (14 days after the beginning of stem elongation)
5 Nitrogen use efficiency
6 Apparent nitrogen recovery
7 Not available as calculated from means

Table 2. Regression relationships for cv. Borvi.

Regression equation	R^2	P
Dry matter yield = 1849 + 5.30 applied N	0.97	0.002
Herbage N concentration = 2.39 + 0.0128 applied N	0.81	0.025
Seed yield = 1159 + 2.41 applied N	0.77	0.033
Seed yield = 743 + 179 N%	0.83	0.019
Seed yield = 274 + 0.474 dry matter yield	0.89	0.010
Seed yield = 941 + 5.07 N content	0.88	0.011

thresholds for responses; the more complete the separation, the better the indication of a threshold (Cate and Nelson, 1971).

Increasing N had a significant ($P<0.05$) and positive effect on seed yield, herbage N concentration (%), dry matter yield and N content (Table 1). Response to N was maximised at 100 kg ha^{-1} in herbage N concentration (%) and herbage N content, seed yield was greatest with 150 kg ha^{-1} N and dry matter yield increased linearly with increasing N ($R^2 = 0.97$; Table 2). NUE tended to increase with increasing N to 150 kg ha^{-1} (Table 1), but overall was low in comparison with data for cv. Grasslands Nui grown simultaneously (Rowarth *et al.*, 1998). In contrast, ANR tended to be greatest at an N input of 100 kg ha^{-1} (Table 1), and was 2-3 fold greater than that recorded for cv. Grasslands Nui. These differences reflect the fact that cv. Grasslands Nui had a low seed yield when no N was applied, but responded markedly to N inputs, and also the fact that at the time of sampling, cv. Grasslands Nui had produced only half the dry matter produced by cv. Borvi (Rowarth *et al.*, 1998). As herbage N concentration (%) was similar for both cultivars, N content, and, hence, ANR, were greater in cv. Borvi than cv. Grasslands Nui.

Regressions fitted to the individual responses showed that applied N accounted for 97, 81 and 77 % of the variability in dry matter yield, herbage N concentration (%) and seed yield, respectively (Table 2). Herbage N concentration accounted for 83 % of the variability in seed yield, whereas dry matter yield and herbage N content accounted for 89 and 88 % of the variability in seed yield, respectively (Table 2). Despite the very good relationship in this trial, prediction of seed yield from dry matter yield is not recommended as at high rates of N an increase in dry matter is not associated with an increase in seed yield (e.g. Cookson *et al.*, 1999). Furthermore, dry matter yield is influenced by soil temperature and sowing date, thus rendering comparison of data between trials and years difficult. In contrast, herbage N content had a good relationship, and has already been shown to be relatively insensitive to year, cultivar and climate (Rowarth *et al.*, 1998; Sicard and Rowarth, 1998; Young *et al.*, 1998).

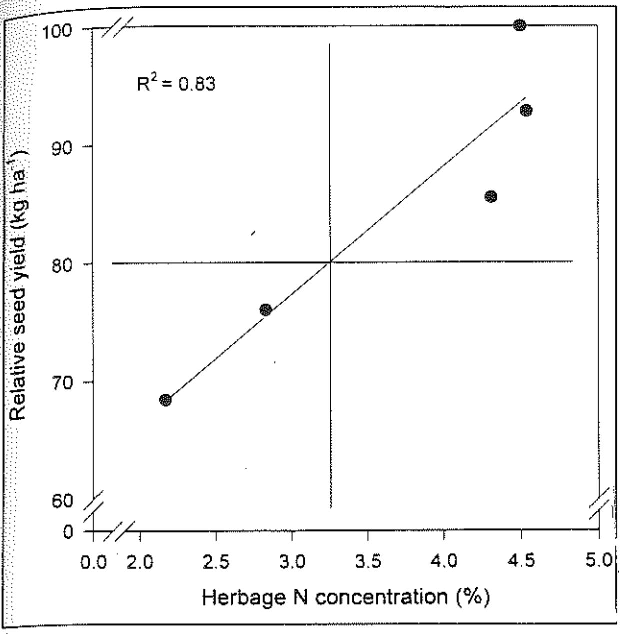

Figure 1. Relationship between herbage N concentration (%) 14 days after the beginning of stem elongation and perennial ryegrass yield relative to the maximum yield. Cate Nelson separation technique (Cate and Nelson, 1971) is used to show a critical threshold.

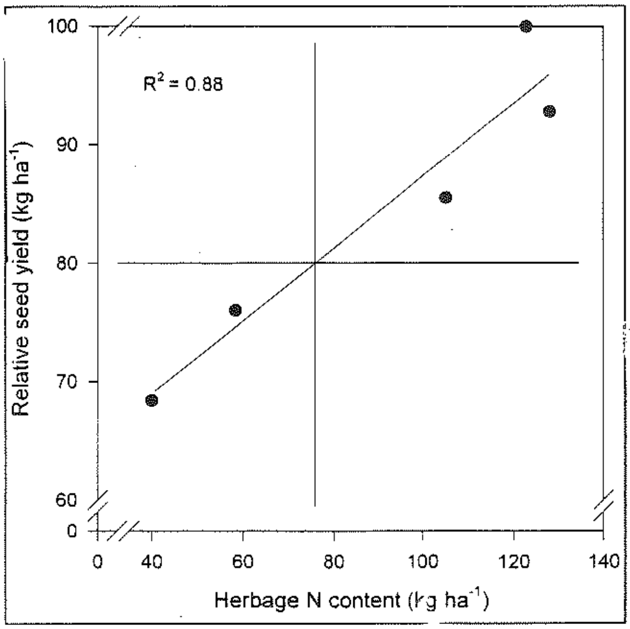

Figure 2. Relationship between herbage N content (kg ha⁻¹) 14 days after the beginning of stem elongation and perennial ryegrass seed yield relative to the maximum yield. Cate Nelson separation technique (Cate and Nelson, 1971) is used to show a critical threshold.

The regression equation for herbage N concentration and applied N showed that applying 50 kg ha^{-1} would change the herbage N concentration by 0.64 %. The equation was similar to that reported for cv. Grasslands Nui on the same site (Rowarth *et al.*, 1998).

Cate-Nelson analysis (Cate and Nelson, 1971) indicated that 80 % relative seed yield could be achieved with a herbage N concentration of approximately 3.2 % (Fig. 1) and a herbage N content of approximately 76 kg ha^{-1} (Fig. 2). These figures compare well with data for cv. Grasslands Nui: 80 % relative seed yield has been associated with 3 % N globally, and a herbage N content of approximately 70 kg ha^{-1} (Rowarth *et al.*, 1998). Furthermore, no increase in seed yield was obtained with a herbage N content greater than 120 kg ha^{-1}, thus supporting earlier data (Rowarth *et al.*, 1998).

These results suggest that herbage N analysis can be used, in conjunction with dry matter yield, to identify whether further spring N is required after a base spring dressing at spikelet initiation. Results were similar to those reported for cv. Grasslands Nui (Rowarth *et al.*, 1998). The large window of response identified for ryegrass in Denmark (Gislum and Boelt, 1998) is in marked contrast to that in New Zealand, where there are only three weeks after spikelet initiation before extra N leads to vegetative tillers rather than extra seed (Rowarth, Cookson and Cameron, 1998). There is therefore more flexibility in the Danish production system and, as the amount of N required for a crop is always dependent upon climatic conditions (because of the effect on crop growth, N demand, and N supply, through the balance between organic matter mineralisation and immobilisation in the soil), this allows an improved chance of predicting the coming season and, hence, N requirements. As growers increase their expectations for high yield and demands for improved technology to help them maximise their profit margin, and the general public increases demands for sustainable growing systems, it behoves the scientist to continue to investigate tools which will allow N to be used with maximum efficiency.

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