Effects of sowing depth and additional nitrogen on emergence and establishment of a range of New Zealand pasture grasses

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Abstract

The effects of sowing depth (10, 30 or 60 mm) and additional nitrogen (0, 50 or 100 kg N ha^{-1}) on emergence and establishment of autumn sown (10 March 1992) prairie grass (*Bromus wildenowii* Kunth., mean seed weight 12.0 mg), annual ryegrass (*Lolium multiflorum* Lam., 5.0 mg), tall fescue (*Festuca arundinacea* Schreb., 2.3 mg), perennial ryegrass (*L. perenne* L., 1.8 mg), phalaris (*Phalaris aquatica* L., 1.5 mg), cocksfoot (*Dactylis glomerata* L., 0.8 mg) and timothy (*Phleum pratense* L., 0.3 mg) were examined. Addition of 50 or 100 kg N ha^{-1} did not affect emergence percentage (plant number on 10 May 1992 as a percentage of seed sown) or establishment percentage (plant number on 12 November 1992 as a percentage of seed sown) of any of the grasses. At all sowing depths, emergence percentage for the different species was positively correlated (correlation coefficient = 65 - 83%) with mean seed weight. For all species, emergence percentage decreased with increased sowing depth but the magnitude of this decrease was greater with smaller seeded grasses. In general, percentage survival of emerged plants over winter increased with increased sowing depth. Despite this, establishment percentage was similar to emergence percentage in that it was positively correlated (correlation coefficient = 50 - 67%) with mean seed weight at all sowing depths and in general decreased with increased sowing depth. Species and depth effects on emergence from 10 and 30 mm sowing depths under controlled environment conditions were similar to those in the field. Inclusion of 5 mol m^{-3} nitrate in the nutrient medium did not affect emergence percentage at 10 mm sowing depth but decreased emergence percentage by 15% at 30 mm sowing depth.

Additional key words: Bromus wildenowii, Dactylis glomerata, Festuca arundinacea, Lolium multiflorum, L. perenne, Phalaris aquatica, Phleum pratense, *seed weight, nitrate.*

Introduction

Perennial ryegrass (*Lolium perenne* L.) is the main pasture grass sown in New Zealand and Grasslands Nui is the most widely used cultivar (Sangakkara *et al.*, 1982; Langer, 1990). Alternative species to perennial ryegrass which are available in New Zealand include prairie grass (*Bromus wildenowii* Kunth.), annual ryegrass (*L. multiflorum* Lam.), tall fescue (*Festuca arundinacea* Schreb.), phalaris (*Phalaris aquatica* L.), cocksfoot (*Dactylis glomerata* L.) and timothy (*Phleum pratense* L.). Evidence is strong that under specific conditions, these grasses can have advantages over perennial ryegrass (Charlton and Thom, 1984; Rumball, 1984; Langer, 1990).

There have been reports of poor/slow establishment of tall fescue, phalaris, cocksfoot and timothy (Charlton and Thom, 1984; Rumball, 1984; Lancashire, 1985; Caradus, 1988). Rate of establishment of a particular grass species is dependent on environmental factors such as water availability, nutrient availability and ambient temperature and genotypic and phenotypic characteristics of the seed and seedling (Hill *et al.*, 1985; Askin, 1990). There is some evidence from within and between grass species comparisons that emergence percentage from deeper sowings is positively correlated with seed weight. For example, at a sowing depth of 15 mm, emergence percentage of perennial ryegrass was similar for small (0.9 - 2.1 mg) and large (2.5 - 3.6 mg) seeds but at sowing depths of 25 - 75 mm, emergence percentage was greater for the large seeds (Arnott, 1969). Mean seed weight is usually less for phalaris, cocksfoot and timothy than for perennial ryegrass and this may be a factor causing low establishment of these grasses.

Nitrogen fertiliser 'banded' with the seed can cause decreased emergence and establishment of a range of cereals but for wheat (*Triticum aestivum* L.), additional N up to 300 kg ha^{-1} did not affect emergence when incorporated into the soil (Hines *et al.*, 1991). However, under controlled environment conditions, additional nitrate (NO_3^-), at concentrations likely to occur in cultivated soil, caused decreased emergence of wheat from deeper sowings (Andrews *et al.*, 1991).

The present study which was carried out under field and controlled environment conditions, examined the effects of sowing depth and N availability on emergence and establishment of seven pasture grass species differing in mean seed weight. The objectives of the study were to determine if across grass species, relationships exist between mean seed weight and emergence and establishment from different sowing depths, and if endogenous soil N or additional N incorporated into the soil affects emergence and establishment of these grasses.

Materials and Methods

Plant material

Seed of prairie grass (*Bromus wildenowii* Kunth. cv. Grasslands Matua, mean seed weight 12.0 mg), annual ryegrass (*Lolium multiflorum* Lam. cv. Grasslands Moata, 5.0 mg), tall fescue (*Festuca arundinacea* Schreb. cv. Grasslands Roa, 2.3 mg), perennial ryegrass (*Lolium perenne* L. cv. Grasslands Nui, 1.8 mg), phalaris (*Phalaris aquatica* L. cv. Grasslands Maru, 1.5 mg), cocksfoot (*Dactylis glomerata* L. cv. Grasslands Wana, 0.8 mg) and timothy (*Phleum pratense* L. cv. Grasslands Kahu, 0.3 mg) obtained from Seedlands (N.Z.) Ltd., Timaru, New Zealand was used in the field and controlled environment experiments. Germination percentage at 15 ± 2°C was >85% for all species.

Experimental procedures

The field experiment was carried out in a Wakanui silt loam soil (Wakanui series: Udicustochrept) at the Lincoln University research farm in 1992. The previous crop on the site was wheat. The soil was ploughed, rolled, rotary hoed then rolled twice, two weeks prior to spraying. Before rotary hoeing, 35 mm of water was applied by spray irrigation. The experiment was a split-split plot design with sowing depths (10, 30 and 60 mm) as main plots, N treatments (0, 50 and 100 kg ha^{-1}) as subplots and grass species (20 seeds of each) as sub-subplots. There were five replicates. The initial experiment (which is described in detail) and the repeat experiment were sown on 10 March and 17 March 1992 respectively. Seed was sown by hand using a Cullen frame technique (Cullen, 1965). Plots were rolled twice after sowing then N (calcium ammonium nitrate) was broadcast by hand and immediately washed into the soil with 30 mm of water. Soil cores (5 cm depth) taken from five of the 0 and 100 kg N ha^{-1} subplots were analysed for NO_3^- one week after sowing. Nitrate was extracted into potassium chloride solution (2 kmol m^{-3}) and determined as described in Mackereth *et al.*, (1978). Soil NO_3^- is expressed as a concentration relative to soil water content for ease of comparison with the controlled environment experiment. Counts of emerged seedlings were taken weekly until emergence remained unchanged for two weeks (10 May 1992). A final count was taken on 12 November 1992 to determine establishment. Details of temperature and rainfall during the experiment were obtained from the Broadfield meteorological station which is within 4 km of the field site.

In the controlled environment experiment, seed was sown at either 10 or 30 mm depth in 100 mm diameter, 200 mm tall pots (10 seeds per pot) containing a vermiculite/perlite/sand (1:1:1 volume) mixture soaked with a basal nutrient solution containing either 0 or 5 mol $^{-3}$ potassium nitrate (Porter *et al.*, 1992). Potassium concentration in the 0 NO_3^- treatment was made equal to that at 5 mol m^{-3} NO_3^- by the addition of 2.5 mol m^{-3} potassium sulphate. Plants were grown in darkness at 15 ± 2°C in a controlled environment chamber. All pots were flushed with nutrient solution twice a week. Emerged plants were counted weekly after sowing. Emergence was considered complete when plant number did not change for three weeks. The experiment was of completely randomised design with five replicates and was carried out twice.

An analysis of variance was carried out on all data from the field and controlled environment experiments. All effects discussed have a probability $P < 0.05$ and were obtained in the repeat experiments unless stated otherwise. Variability quoted in the text is SEM.

Results

One week after sowing in the field experiment, soil NO_3^- concentration was 10.4 ± 0.6 and 13.5 ± 0.9 mol m^{-3} in the 0 and 100 kg N ha^{-1} subplots respectively. From March to May, monthly mean values for mean daily air and soil (10 cm depth) temperature ranged from 7.7 to 13.4°C and 4.7 to 11.7°C respectively (Table 1). These values were respectively 1 - 2°C and 2 - 3°C lower than the long term means. Over winter, the range of values for air temperature (5.3 - 6.9°C) was similar to long term means, but soil temperatures (1.8 - 3.2°C) were 2 - 3°C lower than average. Rainfall was lower than average in March but in other months was similar to or greater than the long term mean.

Additional N did not affect emergence percentage of any of the grasses in the field and data for N treatments

Table 1. Monthly mean values for mean daily air, grass minimum and soil (10 cm depth) temperature and monthly rainfall during the field experiment in 1992 compared with long term means (values in parentheses).

Month	Temperature (°C) Air		Grass		Soil		Rainfall (mm)	
March	13.4	(14.6)	3.9	(7.3)	11.7	(14.7)	10	(57)
April	10.4	(12.0)	2.1	(3.7)	8.2	(11.0)	47	(56)
May	7.7	(8.7)	-0.1	(0.9)	4.7	(6.9)	107	(71)
June	5.3	(6.2)	-2.1	(-1.6)	1.8	(4.5)	57	(61)
July	6.9	(5.7)	-0.2	(-1.3)	2.2	(4.0)	64	(68)
August	6.0	(6.7)	-0.3	(-0.6)	3.2	(5.2)	167	(62)
September	7.0	(9.4)	1.2	(0.6)	4.6	(7.6)	74	(47)
October	10.6	(11.7)	4.7	(2.6)	8.0	(10.8)	281	(49)
November	13.8	(13.6)	7.3	(5.1)	11.6	(13.5)	46	(53)

were pooled for analysis of sowing depth effects. At all sowing depths, emergence percentage for the different species was positively correlated (correlation coefficient = 65 - 83%) with mean seed weight (Table 2). Emergence percentage for all species decreased with increased sowing depth but the magnitude of this decrease was greater with smaller seeded species.

Survival of emerged seedlings over winter was dependent on species and sowing depth but not N. In general, there was greater survival with increased sowing depth (Table 3). This effect was especially obvious with timothy which showed least survival of all species at 10 mm sowing depth. For perennial ryegrass, a few plants emerged from 60 mm sowing depth after the final emergence count on 10 May but this did not occur in the repeat experiment. In the repeat experiment, survival was dependent on species but the depth effect had a probability P = 0.08. However, as in the initial

Table 2. Effect of sowing depth on emergence percentage of a range of tempera tepasture grasses. Seed was sown on 10 March 1992 and emergence was determined on 10 May 1992.

Depth sown	Prairie grass	Annual ryegrass	Tall fescue	Perennial ryegrass	Phalaris	Cocksfoot	Timothy
10 mm	74	79	66	65	56	63	54
30 mm	69	79	57	60	50	47	28
60 mm	64	63	36	38	31	21	10
LSD				10			

Table 3. Effect of sowing depth on overwinter survival (%) of emerged seedlings of a range of temperate pasture grasses. Seed was sown on 10 March 1992, emergence percentage was determined on 10 May 1992 and percentage survival was determined on 12 November 1992.

Depth sown	Prairie grass	Annual ryegrass	Tall fescue	Perennial ryegrass	Phalaris	Cocksfoot	Timothy
10 mm	64	82	57	77	66	53	31
30 mm	84	81	71	91	60	61	47
60 mm	73	90	73	109	92	65	95
LSD				19			

experiment, survival of timothy increased greatly (20 to 85%) with increased sowing depth from 10 to 60 mm. Establishment percentage was similar to emergence percentage in that it was positively correlated (correlation coefficient = 50 - 67%) with mean seed weight at all sowing depths and in general decreased with increased sowing depth (Table 4). Establishment of timothy was < 20% at all sowing depths.

Under controlled environment conditions, emergence percentage was dependent on species, sowing depth and applied NO_3^- concentration and there were species x sowing depth and sowing depth x NO_3^- interactions. As in the field, emergence percentage at 10 and 30 mm sowing depth was positively correlated with mean seed weight (Table 5). Also, with the exception of prairie grass and annual ryegrass, emergence percentage for all species decreased with increased sowing depth and the relative decrease was greater with smaller seeded species. At 10 mm sowing depth, emergence percentage was not affected by NO_3^- supply but at 30 mm sowing depth, values were 68 and 53% at 0 and 5 mol m^{-3} applied NO_3^- respectively.

Discussion

Sowing depth can greatly affect emergence percentage of grasses. Emergence percentage for perennial ryegrass was found to decrease with increased sowing depth from 12.5 to 70 mm and this decrease was greater with smaller seed (Arnott, 1969). Similarly, at all sowing depths in the field study, emergence percentage for the different grasses was positively correlated with mean seed weight and although values for all species decreased with increased sowing depth, the magnitude of the decrease was greater for smaller seeded species (Table 2). Optimum temperature for germination of temperate pasture grasses is usually greater than 15°C and temperatures below this can differentially affect germination of grass species (Hill *et al.*, 1985; Askin, 1990). Daily average air and soil (10 cm depth) temperatures were lower than 15°C throughout the field experiment (Table 1). Thus the possibility that differences in emergence percentage for the different species were due to low temperature effects on germination must be considered. This is unlikely to have been the case however, as species and depth effects on emergence percentage in the controlled environment experiment (carried out at 15 ± 2°C) were similar to those observed in the field (Tables 2,5). Also, any possible effects of low rainfall in March were avoided by irrigating during the soil preparation and after sowing. Studies are being carried out to determine if decreased emergence of grasses with decreased seed weight and increased sowing depth is related to utilisation of seed reserves prior to

Table 4. Effect of sowing depth on establishment percentage of a range of temperate pasture grasses. Seed was sown on 10 March 1992 and establishment percentage determined on 12 November 1992.

Depth sown	Prairie grass	Annual ryegrass	Tall fescue	Perennial ryegrass	Phalaris	Cocksfoot	Timothy
10 mm	47	64	37	50	37	33	16
30 mm	58	64	40	54	32	28	13
60 mm	47	57	26	40	29	14	10
LSD				8			

Table 5. Effect of sowing depth on emergence percentage of a range of temperate pasture grasses grown in darkness at 15 ± 2°C under controlled environment conditions.

Depth sown	Prairie grass	Annual ryegrass	Tall fescue	Perennial ryegrass	Phalaris	Cocksfoot	Timothy
10 mm	86	82	77	80	64	59	40
30 mm	89	87	64	66	50	43	26
LSD				4			

emergence from the substrate and/or emergence of leaf 1 from the coleoptile underground (Andrews *et al.*, 1991; Hines *et al.*, 1991).

Fertiliser N 'banded' with the seed can greatly reduce emergence percentage of cereals, but addition of up to 300 kg N ha^{-1} was found not to affect emergence of wheat if incorporated into the soil (Hines *et* al., 1991). Similarly, in the present study, surface broadcasting of 50 or 100 kg N ha^{-1} followed by irrigation did not affect emergence percentage of any of the grasses. Cultivation of soil usually results in relatively high soil NO_3^- levels due to stimulation of nitrification. This was the case here, with the 0 N treatment having a soil NO_3^- concentration around 10 mol m^{-3}. Under controlled environment conditions, where it is possible to grow plants in a N free medium, additional NO_3^- at concentrations in the range 1 to 20 mol m^{-3} caused decreased emergence of wheat from deeper sowings (Andrews *et al.*, 1991). Here also, inclusion of 5 mol m^{-3} NO_3^- in the nutrient medium caused decreased emergence of grasses at 30 mm but not 10 mm sowing depth. For wheat, decreased emergence with additional NO_3^- in the range 1 to 20 mol m^{-3} was associated with increases in mobilisation of seed reserves, water uptake and shoot growth (Andrews *et al.*, 1991). Also, seedlings which were affected by NO_3^- had short coleoptiles which opened within the substrate. It was proposed that NO_3^- caused increased expansion of leaf 1 within the substrate. This resulted in a more open leaf structure which folded more easily and was more prone to damage. Experiments will be carried out to determine if NO_3^- affects the rate of mobilisation of seed reserves of pasture grasses and if the NO_3^- effect on emergence of grasses is related to coleoptile length.

In general, survival of grasses over winter increased with increased sowing depth (Table 3). This was especially obvious for timothy, the grass with the lowest seed weight. Deeper sowing may result in increased survival through placement of the root system further down the soil profile where fluctuations in temperature and moisture are not as great as in the soil above. Smaller seeded species often have a smaller root system and thus may experience greater temperature and moisture stress (Jurado and Westoby, 1992). Also, there is some evidence that shoot to root dry weight ratio is greater for timothy than for the other grasses studied here (Porter *et al.*, 1992). This may be a factor causing low survival of this species from shallow sowing (Baker, 1972). Further work is required to determine reasons for increased over-winter survival of grasses with increased sowing depth. Despite over-winter survival increasing with increased sowing depth, establishment percentage was similar to emergence percentage in that it decreased with smaller seed size and greater sowing depth (Tables 2,4). This emphasises the importance of seedling emergence in pasture establishment.

Conclusions

1. Additional N is unlikely to affect emergence percentage of grasses if spread throughout the soil.
2. Emergence percentage of grass species is likely to decrease with increased sowing depth in the range 10-60 mm but the magnitude of the decrease is likely to be greater with smaller seeded grasses.
3. Endogenous soil NO_3^- is likely to be a factor causing decreased emergence of grasses from deeper sowings.
4. Establishment percentage of grass species is positively related to emergence percentage.

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