Shoot strength and seedling emergence of a range of pasture grasses and seed lots of timothy (*Phleum pratense* L.) of different mean seed weight

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Abstract

Inter-specific relationships between mean seed weight (MSW), coleoptile and mesocotyl length and width, shoot strength and emergence from a 15 mm sowing depth were examined for one seed lot each of timothy (*Phleum pratense* L., MSW 0.34 mg), cocksfoot (*Dactylis glomerata* L., 0.77 mg), tall fescue (*Festuca arundinacea* Schreb., 1.73 mg), perennial ryegrass (*Lolium perenne* L., 2.19 mg), annual ryegrass (*Lolium multiflorum* Lam., 5.20 mg) and prairie grass (*Bromus willdenowii* Kunth., 10.4 mg) under controlled environment conditions. Across species, emergence percentage was not significantly correlated with coleoptile + mesocotyl length, but there were significant positive correlations between emergence and MSW, coleoptile and mesocotyl width and shoot strength. Shoot strength increased with increased MSW when three sub-lots were separated on seed size from within a timothy seed lot. At 10 - 30 mm sowing depth under field conditions, emergence of the timothy sub-lots increased 21% (10 mm sowing) and 88% (30 mm sowing) as MSW increased from 0.38 - 0.66 mg. Increased emergence with increased MSW across species at a 15 mm sowing depth is likely to be due primarily to increased coleoptile/mesocotyl width resulting in increased shoot strength and hence an increased ability to penetrate the substrate. Removing small seed from timothy seed lots would often result in increased emergence at 10-30 mm sowing depth under field conditions, but emergence is unlikely to be as great as that for perennial ryegrass.

Additional key words: Bromus willdenowii, Dactylis glomerata, Festuca arundinacea, Lolium multiflorum, Lolium perenne, *coleoptile, mesocotyl.*

Introduction

Perennial ryegrass (*Lolium perenne* L.) is the major grass species sown in perennial pastures in New Zealand (Langer, 1990). However, under certain conditions, the little used timothy (*Phleum pratense* L.) can have an advantage over perennial ryegrass with respect to productivity and/or palatability, but it has the disadvantage that in comparison with perennial ryegrass, seedling emergence and establishment are often low and/or slow (Charles, 1972; Robson, Ryle and Woledge, 1988; Langer, 1990). The recommended sowing depth for pasture grasses is usually 10-30 mm depending on species and environmental conditions (Robson *et al.*, 1988; Askin, 1990). Under both field and controlled environment conditions, low emergence of timothy relative to perennial ryegrass was more pronounced at a 30 mm sowing depth than at a 10 mm sowing depth (Porter, Lucas and Andrews, 1993; Jones, Andrews, Bolstridge and Percival, 1995).

Usually, at sowing depths around 10 mm or less, the primary leaf of a developing grass seedling extends within the coleoptile to a point close to the soil surface, then emerges from the coleoptile and with little impedance to growth emerges from the soil (Langer, 1990). For some grass species at deeper sowings, the young shoot within the coleoptile can be carried to the soil surface by elongation of the mesocotyl, a subcoleoptile internode (Newman and Moser, 1988; Robson *et al.*, 1988; Jones *et al.*, 1995). If the primary leaf emerges underground, it is less likely to reach the soil surface as it is less rigid than the coleoptile and folds more easily (Andrews, Scott and McKenzie, 1991; Hines, Andrews, Scott and Jack, 1991). Potential mesocotyl elongation has been reported to increase with seed size across species (Robson *et al.*, 1988). Mean seed weight (MSW) is less for timothy than for perennial ryegrass and it has been proposed that low emergence of timothy relative to perennial ryegrass is due to timothy having a shorter mesocotyl (Robson *et al.*, 1988). However, in a recent study under controlled environment conditions, emergence of six pasture grasses including timothy and perennial ryegrass was not significantly correlated with coleoptile + mesocotyl length at 10 and 30 mm sowing depths (Jones *et al.*, 1995). Across species at both sowing depths, there were significant positive correlations between emergence, MSW and coleoptile and mesocotyl width. Timothy, the grass with the lowest MSW, had the narrowest coleoptile and mesocotyl and the lowest emergence. It was proposed that shoot strength will decrease with decreased coleoptile-/mesocotyl width, and that lower emergence of timothy relative to the other grasses was due to a lower shoot strength, and hence a reduced ability to penetrate the substrate. In the same study it was found that for three sub-lots of timothy of different MSW graded from within one timothy seed lot, coleoptile and mesocotyl width and emergence increased with increased MSW. The objectives of the present study were to determine if shoot strength increased with increased MSW and coleoptile width across grass species and within a timothy seed lot, and if selection of seed lots of timothy with increased MSW would result in increased seedling emergence under field conditions.

Materials and Methods

Seeds of timothy (cv. Grasslands Kahu, MSW 0.34 mg), cocksfoot (*Dactylis glomerata* L. cv. Grasslands Wana, MSW 0.77 mg), tall fescue (*Festuca arundinacea* Schreb. cv. Grasslands Roa, MSW 1.73 mg), perennial ryegrass (cv. Grasslands Nui, MSW 2.19 mg), annual ryegrass (*Lolium multiflorum* Lam. cv. Grasslands Tama, MSW 5.20 mg) and prairie grass (*Bromus willdenowii* Kunth. cv. Grasslands Matua, MSW 10.4 mg) used in experiments 1 and 2 were obtained from the N.Z. Institute for Crop and Food Research Ltd. Lincoln N.Z. Seeds of timothy (cv. Grasslands Kahu, MSW 0.48 mg) used in experiment 3 were obtained from Wrightsons, Christchurch, N.Z. Seed lots of timothy of different MSW used in experiments 2 and 3 were obtained by sieving the original seed lots. Germination percentage was determined for all seed lots of all species (Jones *et al.*, 1995). In experiments 1 and 2, germination was 84-92% for the seed lots of all species except tall fescue (55%). In experiment 3, germination was 97-99% for the timothy seed lots. All emergences are expressed as a proportion of the expected germination.

In experiment 1, seed of each species was sown at 15 mm depth in 0.8 litre pots (10 seeds per pot) containing a vermiculite/perlite/sand (1:1:1 by volume) mix, soaked in a basal nutrient solution containing 5 mol m^{-3} potassium nitrate (Andrews, Love and Sprent, 1989). The experiment was a completely randomised design with five replicate pots per treatment. The pots were maintained at 15 ± 1°C in the dark in a controlled environment chamber and flushed with nutrient solution every three days. Counts of emerged seedlings were taken weekly until emergence did not change for three weeks (six weeks after sowing). When counting had finished, coleoptile and mesocotyl length and width at the midpoint were determined for all emerged and all non-emerged plants which were recovered (Jones *et al.*, 1995).

In experiment 2, seed of each species was germinated on filter paper saturated with distilled water in petri dishes at 15 ± 1°C in a controlled environment chamber. When the coleoptile had reached a length of approximately 3 mm, shoot strength was determined by growing the shoot against a strain gauge transducer within a polypropylene tube. The strain gauge transducer was connected to a Grass 79D EEG/polygraph data recording system (Grass Instruments Co. Quincy, Massachusetts, USA). There were four replicate seedlings per seed type. Coleoptile width was determined as in experiment 1. In addition, shoot strength was determined for three size gradings (MSW of 0.21 mg, 0.38 mg and 0.62 mg) from the timothy seed lot.

Experiment 3 was carried out in a Wakanui silt loam soil at the Lincoln University research farm in 1996. The site was fallow during the year prior to the experiment. The soil was ploughed, harrowed then rolled 10 days prior to sowing. The experiment was a split plot design with sowing depths (10 and 30 mm) as main plots and the three timothy sub-lots (0.38 mg, 0.47 mg and 0.66 mg MSW) from experiment 2 (500 seeds of each) as subplots. Seed was sown on 7 May 1996. There were three replicates. The area was levelled with timber then seeds were sown by hand. After sowing, 10 or 30 mm thick timbers as appropriate, were placed around the plots, soil was added to obtain the required sowing depth and screeded level. Counts of emerged seedlings were taken weekly until emergence did not change for two weeks (4 June 1996). Details of temperature and rainfall during the experiment were obtained from the Broadfield meteorological station which is within 4 km of the field site.

An analysis of variance was carried out on all data from all experiments. All effects discussed have a probability of $P < 0.01$. An arcsine transformation was carried out on emergence data prior to analysis. Ranking of species/timothy seed lots is on the basis of an LSD ($P < 0.05$) value. Correlation and regression analysis were carried out on data where appropriate; straight line and quadratic models were tested. Experiment 2 was repeated as described. Data were similar for the initial and repeat experiment 2 and were pooled for presentation.

Results and Discussion

In experiment 1 there was a strong positive correlation between emergence and MSW across grass species: a quadratic model of percentage emergence against MSW gave an R^2 value of 92% (Table 1). This relationship between emergence and MSW across grass species was reported previously in associated work and is consistent with reports from other workers (Jones *et al.*, 1995). Potential mesocotyl elongation has been reported to increase with seed size across grass species, and it has been proposed that low emergence of small seeded grasses such as timothy relative to larger seeded grasses such as perennial ryegrass is due to the smaller seeded grasses having a shorter mesocotyl (Robson *et al.*, 1988). Results obtained in experiment 1 indicate that at a sowing depth of 15 mm, coleoptile + mesocotyl length is a factor determining emergence within grass species, as in all cases coleoptile + mesocotyl length was less for emerged than non-emerged seedlings (Table 1). However, the results clearly show that at a 15 mm sowing depth, differences in emergence between species were not due to differences in coleoptile + mesocotyl length, as values were not significantly different for timothy, cocksfoot, tall fescue, perennial ryegrass and prairie grass, yet emergence increased consistently with MSW across these species (Table 1).

Previously we reported a strong positive correlation between coleoptile/mesocotyl width and emergence across these six grass species (Jones *et al.*, 1995). Results obtained in experiment 1 substantiate this finding (Table 1). Also, within all species, except annual ryegrass, coleoptile and mesocotyl width were greater for emerged than non-emerged seedlings. Jones *et al.* (1995) proposed that shoot strength increased with increased coleoptile and mesocotyl width, and that increased emergence of large relative to small seeded grasses is due to increased shoot strength and hence increased ability to penetrate the substrate. Experiment 2 results are consistent with this proposal, as shoot strength increased consistently with increased coleoptile width across the six grass species (correlation coefficient = 99%, Fig. 1). Shoot strength also increased with increased MSW within a timothy seed lot. Values were 0.15 ± 0.014 g $shoot^{-1}$, 0.30 ± 0.038 g $shoot^{-1}$ and 0.45 ± 0.070 g $shoot^{-1}$ for timothy sub-lots of 0.21 mg, 0.38 mg and 0.62 mg respectively.

At 15 ± 1°C under controlled environment conditions, emergence of the timothy sub-lots from 10 and 30 mm sowing depth increased with increased MSW (Jones *et al.*, 1995). Also, although emergence for all timothy

Table 1. Emergence, coleoptile + mesocotyl length and coleoptile and mesocotyl width of six pasture grasses of different mean seed weight (MSW) sown at 15 mm depth under controlled environment conditions. Variability quoted is SE, n=5.

Species	MSW (mg)	Emergence (%)	Coleoptile + mesocotyl length (mm)		Coleoptile width (mm)		Mesocotyl width (mm)	
			emerged	non-emerged	emerged	non-emerged	emerged	non-emerged
Timothy	0.34	22 ± 2.8	17.2 ± 1.22	15.7 ± 1.33	0.40 ± 0.016	0.33 ± 0.022	0.32 ± 0.025	0.20 ± 0.020
Cocksfoot	0.77	33 ± 3.8	17.0 ± 1.24	15.2 ± 1.68	0.42 ± 0.034	0.36 ± 0.021	0.35 ± 0.031	0.21 ± 0.019
Tall fescue	1.73	64 ± 3.6	19.6 ± 1.33	14.1 ± 0.82	0.57 ± 0.042	0.49 ± 0.020	0.35 ± 0.023	0.25 ± 0.010
Perennial ryegrass	2.19	80 ± 4.0	17.4 ± 0.85	15.3 ± 1.45	0.66 ± 0.030	0.43 ± 0.078	0.48 ± 0.014	0.20 ± 0.023
Annual ryegrass	5.20	93 ± 3.7	40.9 ± 1.94	10.7 ± 1.20	0.79 ± 0.017	0.78 ± 0.075	0.46 ± 0.008	0.52 ± 0.001
Praire grass	10.4	96 ± 3.9	16.6 ± 1.31	11.0 ± 1.00	0.85 ± 0.034	0.72 ± 0.065	-	-

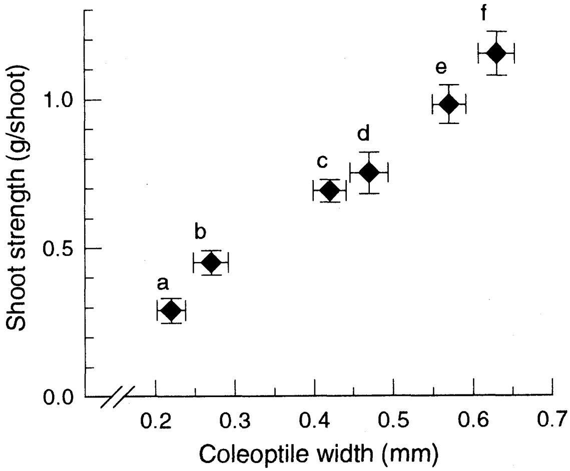

Figure 1. Relationship between shoot strength and coleoptile width of six pasture grasses of different mean seed weight (MSW). Grasses are: a. timothy, MSW 0.34 mg; b. cocksfoot, MSW 0.77 mg; c. tall fescue, MSW 1.73 mg; d. perennial ryegrass, MSW 2.19 mg; e. annual ryegrass, MSW 5.20 mg; f. prairie grass, MSW 10.4 mg. Variability quoted is SE, n=8.

Table 2. Monthly mean values for mean daily air, grass minimum and soil (10 cm depth) Temperature and monthly rainfall during experiments 3.

	Temperature (°C)			Rainfall
Month	Air	Grass	Soil	(mm)
April	12.3	5.0	11.6	56
May	8.9	1.0	8.1	32
June	6.3	-0.3	5.4	79

Table 3. Emergence of three sub-lots of timothy graded on seed weight from within one seed lot sown at different depths in experiment 3. Variability quoted is SE, n=3.

	Sowing depth	
MSW (Mg)	10 mm	30 mm
0.38	56 ± 5.3	17 ± 1.4
0.47	62 ± 4.6	21 ± 2.3
0.66	68 ± 0.8	32 ± 5.5

sub-lots decreased with increased sowing depth from 10 to 30 mm, the relative magnitude of the decrease was less with larger seeded sub lots. Similar results were obtained at substantially lower temperatures (Table 2) under field conditions in experiment 3. The increase in emergence as MSW increased from 0.38 mg to 0.66 mg was 21% and 88% at the 10 and 30 mm sowing depths respectively (Table 3). The finding that emergence increased with increased MSW of timothy sub-lots under controlled environment and field conditions despite differences in growth conditions and source of seed indicates that selection of seed lots of timothy with increased MSW or further cleaning to remove small seed will often result in increased field emergence. Nevertheless, the consistency of the relationship between field emergence and MSW across grass species and timothy seed lots (Table 1; Porter *et al.*, 1993; Jones *et al.*, 1995) makes it unlikely that emergence will be as great for timothy as for perennial ryegrass.

Conclusions

1. Seedling emergence was not significantly correlated with coleoptile + mesocotyl length across grass species.
2. Across grass species, there were significant positive correlations between seedling emergence and MSW, coleoptile and mesocotyl width, and shoot strength.
3. Increased seedling emergence with increased MSW across grass species is likely to be due primarily to increased coleoptile/mesocotyl width, resulting in increased shoot strength, and hence an increased ability to penetrate the substrate.
4. Shoot strength increased with increased MSW within a timothy seed lot.
5. Selection of seed lots of timothy with increased MSW (or further cleaning to remove small seed) will often result in increased seedling emergence under field conditions, but emergence is unlikely to be as great as that for perennial ryegrass.

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