The effect of sowing depth on the emergence and early development of six pasture species

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Abstract

An experiment was conducted in the heated glass houses at Lincoln university to measure the effects of sowing depth on the establishment of grasses (ryegrass and cocksfoot), legumes (white clover and lotus) and herbs (chicory and plantain). The aim was to determine possible management practices to manipulate the composition of a pasture by altering establishment. Emergence of ryegrass and plantain were not affected by sowing depth. Increasing sowing depth from 5 to 25 mm reduced white clover, lotus and cocksfoot emergence. Increasing sowing depth from 5 to 15 mm reduced chicory emergence. The most important differences in seedling development were between species with ryegrass and plantain having the best seedling establishment. Pasture establishment management needs to target good legume establishment. Sowing depth should be as shallow as possible without risking seed desiccation.

Additional key words: *chicory, cocksfoot, germination, lotus, plantain, ryegrass, white clover*

Introduction

Good seedling establishment is vital to the development of a successful and productive pasture. Most New Zealand pastures are comprised of a mixture of grass and legumes; the grass fraction producing the majority of growth, the clover fraction growing in the base of the canopy, intercepting light the grass misses and fixing nitrogen. It is now also becoming common to include a herb in the mixture to improve animal health and production in drought prone areas (Fraser *et al.*, 1999). Pasture species are usually sown together to minimise cost of establishment. However, different species have different optimal sowing depths for maximum establishment (Lueck *et al.*, 1949; Cornish, 1982; Woodman *et al.*, 1990).

The New Zealand pastoral industry is characterised by the dominance of ryegrass (*Lolium* spp.) and white clover (*Trifolium repens* L.) pastures. While this combination is tolerant of a wide range of grazing situations and temperate environments it is disadvantaged by low rainfall, high soil temperature and attack from grass grub and Argentine stem weevil (MacFarlane, 1990). More complex mixtures termed multi-species pastures (MSP), also known as a mixed herb leys, have the potential in some environments to overcome some of the problems commonly associated with ryegrass-based pastures. Daly *et al.* (1996) reported that MSP (based on chicory/plantain) produced more dry matter than ryegrass/white clover pasture (2550-2700 kg DM/ha for MSP, 2100 kg DM/ha for ryegrass/white clover pasture) in the summer months in a dryland situation at Winchmore, Canterbury.

Assuming seed is of a similar quality, both rate and total emergence are dependent on rate of germination, subsequent shoot extension and sowing depth. Sowing too deep can reduce establishment as the seedling has insufficient reserves to reach the surface (Andrews *et al.*, 1997). Jones *et al.* (1995) reported that under controlled environmental conditions percentage emergence was 100 and 93% for annual ryegrass, 89 and 78% for perennial ryegrass and 66 and 28% for cocksfoot at 15 and 30 mm sowing depths respectively. However, sowing too shallow can reduce emergence if the soil dries out. Increased sowing depth can also reduce root growth (Cornish, 1982) and tiller development (Lueck *et al.*, 1949).

Smaller seeds are less able to reach the surface from greater depths. There are many examples of this relationship with grasses (Limbach and Cull, 1994; Naylor, 1979; Porter *et al.*, 1993) and legumes (McKersie and Tomes, 1982; Rowarth and Sanders, 1996).

In general, germination of ryegrass is faster and final emergence is greater than it is in cocksfoot (Scott and Hanson, 1976; Charlton *et al.*, 1986). White clover germinates faster than lotus. Hampton *et al.* (1987) recorded white clover cv. Grasslands Huia taking 3 and 2.2 days and lotus cv. Grasslands Maku 10.4 and 5.9 days to reach 75% germination at 15 and 20°C respectively. A number of authors have reported the same trend (Scott and Hanson, 1976; Charlton, 1989).

Ryegrass establishes rapidly which accounts for its ability to dominate slower establishing associate species (Askin, 1990). Tillering at early stages is dependent on rate of emergence. This indicates that faster emerging species will start tillering and competing for light at an earlier stage. Establishment of legume seeds is usually greater than that of grasses especially where nitrogen is limiting. Chapman et al. (1985) who measured establishment of 24% for cv. Grasslands Nui and 52% for cv. Grasslands Huia oversown into sprayed hillsides demonstrated this. White clover seedling growth is greater than that of lotus. Woodman *et al.* (1998) measured white clover cv. Grasslands Tahora seedlings weighing 107 and 407g (fresh weight) 9 and 13 weeks after sowing respectively. Over the same period cv. Grasslands Maku seedlings had grown to 45 and 138 g (fresh weight).

The objectives of this experiment were to 1: test the effects of sowing depth (5, 15 and 25 mm) and pasture species (ryegrass, cocksfoot, white clover, lotus, chicory and plantain) on establishment. Establishment was measured in two parts, emergence and early seedling development (up to 4 weeks), and 2: determine the requirements for good establishment of each species and suggest possible strategies to alter establishment and therefore the long term composition of various species in the pasture

Materials and Methods

Experimental design

The experiment was conducted in pots in a Lincoln University heated glass house (16 °C ±2 °C). It was set out as a randomised complete block factorial in a split plot with six replications, using planting trays as plots. Main plot treatments for each tray were three sowing depths: 5, 15 and 25 mm. Sub plots at each sowing depth were perennial ryegrass (*Lolium perenne* L.) cv. Grasslands Nui, cocksfoot (*Dactylis glomerata* L.) cv. Grasslands Wana, white clover (*Trifolium repens* L.) cv. Grasslands Huia, lotus (*Lotus pedunculatus* Cav.) cv. Grasslands Maku, chicory (*Chicorium intybus* L.) cv. Grasslands Puna and plantain (*Plantago lanceolata* L.) cv. Tonic.

Plots were established on 24 July 1999 in 6 planting trays 42 x 30 x 6 cm (0.126 m^2). Sand was used as a growing medium. A basal nutrient mixture of 600 g m^{-3} of superphosphate (9% P), 900 g m^{-3} Osmocote (37% K), 1000 g m^{-3} Dolomite lime and 300 g m^{-3} Micromax (trace elements) was incorporated prior to sowing.

Germination and Emergence

Germination tests (Table 1) were carried out using International Seed Testing Association (ISTA, 1985) protocol and enough seed was counted onto each sub-sub plot to give 30 viable seeds.

Table 1. Germination and thousand seed weight for a single seed lot of each of the six pasture studied

Species	TSW (g)	Germination (%)
Ryegrass[1]	2.77	86
Cocksfoot[1]	0.80	80
White clover[2]	0.77	100
Lotus[2]	0.97	90
Chicory[1]	1.60	61
Plantain[2]	2.10	87

[1] 20 °C/12 h + 30 °C/12 h;
[2] 20 °C all the time

Pots were observed daily. Seedling number was counted on the first day of emergence and 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 13 and 19 days subsequently. Emergence was recorded when the coleoptile was clear of the soil surface. At four weeks after emergence five seedlings from each sub plot were chosen randomly to measure their height and above ground dry weight (oven dried for 48 h at 70 °C).

Emergence analysis

Final emergence was calculated as a percentage of the viable seeds sown. Initially Richards function (Venus and Causton, 1979) curves were fitted to emergence data to provide parameters for analysis. This model gave a good indication of final emergence, but it proved to be inaccurate in calculating the duration of emergence (from 5 to 95% of final emergence) and the weighted mean absolute emergence rate (WMAE, rate of emergence over the duration). Because of this, duration was assessed visually by graphing emergence of each sub plot. This was used with final emergence from the Richards model to calculate mean WMAE from 5 - 95% of final emergence (Equation 1).

$$WMAE = \frac{\text{final emergence} * 0.9}{\text{duration}} \qquad \text{Equation 1}$$

Parameters from emergence and height and weight variables measured were analysed using split-split plot ANOVA. Paired comparisons were carried out between grass, legume and herb species. Thousand seed weight was measured and regressions were performed between seed weight and measured variables.

Results

Figure 1 shows the mean emergence patterns for the six species (grasses, Fig. 1a; legumes, Fig. 1b; herbs, Fig. 1c) and each of the three sowing depths (Fig. 1d). The parameters of these curves and interactions are described in the following section.

Final emergence

An interaction ($p < 0.01$) occurred between species and sowing depth for final emergence (Table 2). Figure 2 shows that white clover emergence decreased ($p < 0.01$) when sowing depth was increased from 15 - 25 mm (from 71 - 25 %) but not when sowing depth was decreased from 5 - 15 mm; chicory emergence was reduced ($p < 0.01$) from 71 - 25 % as sowing depth increased from 5 - 15 mm, but not when sowing depth was increased from 15 - 25 mm. Increasing sowing depth from 5 - 25 mm reduced ($p < 0.01$) emergence of cocksfoot (from 100 - 43 %) and lotus (from 78 - 42 %). Emergence of ryegrass and plantain showed no response to increased sowing depth.

Paired comparisons showed grasses (82 %) had greater ($p < 0.01$) emergence than legumes (64 %) and herbs (51 %) (Table 3). Emergence of legumes was greater ($p < 0.01$) than that of herbs (Table 3).

WMAE

There was an interaction ($p < 0.05$) between sowing depth and species for WMAE. White clover's WMAE decreased from 11 %/day at 5 mm sowing depth to about 2 %/day at 15 and 25 mm sowing depth (Fig. 3). Increasing sowing depth did not effect WMAE for any other species (Fig. 3). Main effects are displayed in Table 2. Paired comparisons showed no difference in WMAE between grasses and legumes (about 7.5 %/day) which were greater ($p < 0.01$) than WMAE for herbs (4 %/day) (Table 3). The correlation between seed thousand weight and WMAE was poor ($p > 0.05$).

Duration of emergence

An interaction ($p < 0.01$) between sowing depth and species was recorded in that duration was higher at the 5 and 15 mm sowings for white clover (about 6 days) and chicory (11 days) and decreased when sowing depth was increased to 25 mm (0.5 and 3 for white clover and chicory respectively). Increasing sowing depth did not affect the duration of any other species. Herbs (9.2 days) had a longer ($p < 0.05$) duration than grasses (8.1 days), which had a longer duration than legumes (6.3 days; Table 3). Main effects are shown in Table 2.

Seedling height 4 weeks after first emergence

Four weeks following first emergence seedling height for the 25 mm sowing depth (54 mm) was lower ($p < 0.01$) than for the 5 and 15 mm sowing depths (about 70 mm) (Table 4). Ryegrass (151 mm) was the tallest ($p < 0.000$) species, followed by plantain and cocksfoot (about 65 mm), chicory (47 mm), white clover and lotus (about 31 mm) (Table 4). Grass species (108 mm) were taller ($p < 0.000$) than legume and herb species (58 mm) and herbs were taller than legumes ($p < 0.000$). Regressions performed between seed thousand weight and seedling height 4 weeks after emergence showed poor ($p > 0.05$) correlations.

Seedling dry weight 4 weeks after first emergence

An interaction ($p < 0.01$) occurred between species and sowing depth for seedling dry weight 4 weeks after emergence. This was caused by the different response to increased sowing depth for different species. There was a reduction ($p < 0.01$) in seedling weight for chicory (14 - 16 g) and ryegrass (16 - 6 g) as sowing depth decreased from 5 - 25 mm (Fig. 4). The increased sowing depth (Fig. 4) did not affect the other species. Herbs (11.6 g) were heavier than legumes and grasses (Table 5) and grasses (8.4 g) were heavier ($p < 0.001$) than legumes (4.3 g). There were weak ($p > 0.05$) correlations between thousand seed weight and seedling dry weight at 4 weeks.

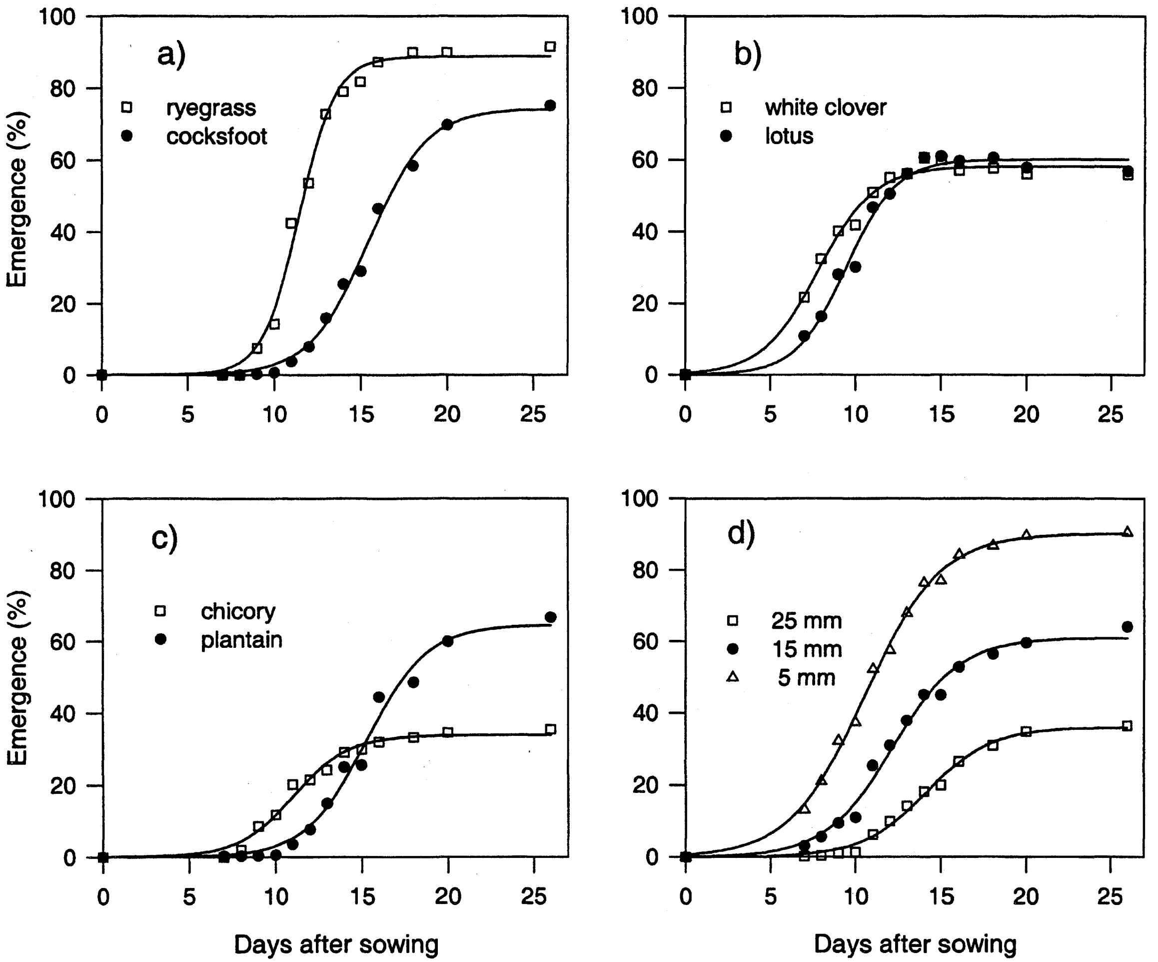

Figure 1. Emergence as a percentage of viable seed sown for the means for the six species (a, b, c) and for three sowing depths (d).

Discussion

Emergence was dependent on depth with the greatest emergence ($p < 0.001$) recorded at 5 mm depth and subsequent deeper sowings having lower ($p < 0.01$) emergence for cocksfoot, legumes and chicory (Fig. 2). This is consistent with the findings of Newman and Moser (1988), Woodman *et al.* (1990) and Jones *et al.* (1995), who showed reduced emergence with increased sowing depth. However, all these experiments were carried out at sowing depths where seedlings were not prone to drying or were in fully watered conditions. In dryland conditions emergence can be reduced at shallow sowing depth due to drying of the soil.

Table 2. Final emergence, weighted mean apparent emergence (WMAE) and duration of emergence for six pasture species sown at three depths.

Treatment	Final emergence (% viable seed)	WMAE (% /day)	Duration (days)
Sowing depth			
5 mm	90.7	8.5	8.3
15 mm	64.6	6.0	8.9
25 mm	41.7	4.4	6.1
significance	***	***	***
LSD $_{p<0.05}$	13.73	1.98	1.97
Species			
ryegrass	88.6	9.7	6.6
cocksfoot	74.9	6.0	9.5
white clover	65.1	7.5	5.5
lotus	62.9	6.7	7.0
chicory	33.7	2.8	7.8
plantain	69.0	5.1	10.5
significance	***	***	***
LSD $_{p<0.05}$	13.53	1.8	4.90
Interaction			
Species x depth	**	*	**

* = p < 0.05; ** = p < 0.01; *** = p < 0.000

Table 3. Paired comparisons for seedling emergence weighted mean apparent emergence (WMAE) and duration of emergence between grasses (ryegrass and cocksfoot), legumes (white clover and lotus) and herbs (chicory and plantain).

Comparison	Final emergence (% viable seed)	WMAE (% /day)	duration (days)
grass vs legume	81.6 vs 64.0	7.9 vs 7.1	8.1 vs 6.3
	**	ns	**
grass vs herb	81.6 vs 51.3	7.9 vs 4.0	8.1 vs 9.2
	***	***	*
legume vs herb	64.0 vs 51.3	7.1 vs 4.0	6.3 vs 9.2
	**	***	***

* = p < 0.05; ** = p < 0.01; *** = p < 0.000

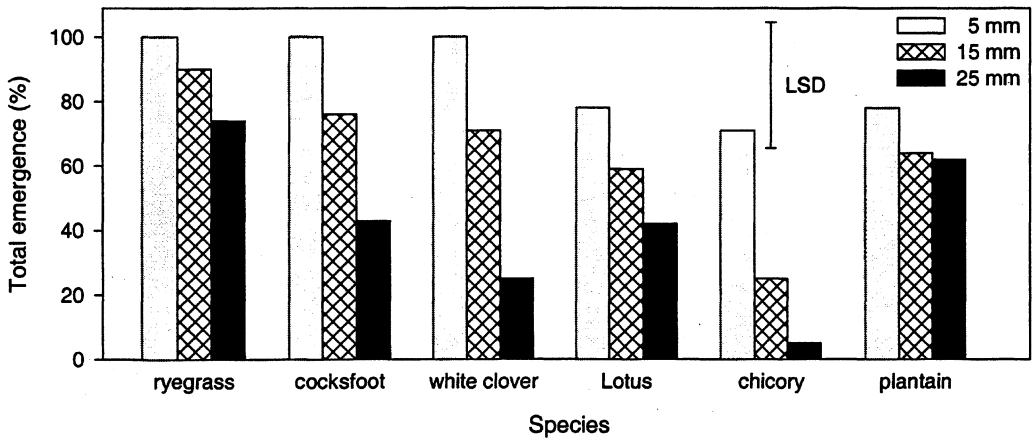

Figure 2. Final emergence (as a percent of viable seed sown) for six species at three sowing depths.

Shoot shape has an effect on emergence. Grasses, which had the greatest ($p < 0.01$) emergence (Table 3) have a pointed shoot which can push through the soil with ease. Legumes have a broader emerging shoot (cotyledons) which is more likely to get caught in the soil and explains why emergence was poorer ($p < 0.000$) than that for grasses (Table 3). Plantain has two pointed, ridged cotyledons that would penetrate the soil with greater ease than chicory, which emerges with two broad, soft cotyledons. This is indicated by the lower ($p < 0.000$) emergence of chicory (Table 3), although the low chicory seed quality (Table 1) may have also been a contributing factor.

Table 4. Seedling height at 4 weeks after first emergence and seedling weight 4 weeks following first emergence for three sowing depths and six species treatments.

Treatment	Height (mm)	Weight (mg/seedlings)
Sowing depth		
5 mm	73.3	10.2
15 mm	69.6	8.7
25 mm	54.2	5.3
significance	**	**
LSD	15.33	3.29
Species		
ryegrass	150.6	13.0
cocksfoot	65.2	3.8
white clover	32.4	3.7
lotus	30.1	4.8
chicory	46.6	10.9
plantain	69.3	12.3
significance	***	***
LSD $_{p<0.05}$	8.15	1.76
Interactions		
Species x depth	ns	**

* = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.000$

Table 5. Paired comparisons for seedling height and seeding weight between grasses (ryegrass and cocksfoot), legumes (white clover and lotus) and herbs (chicory and plantain) at 4 weeks following emergence.

Comparison	Height (mm)	Weight (mg/seedling)
grass vs legume	107.9 vs 31.2 ***	8.4 vs 4.3 ***
grass vs herb	107.9 vs 57.9 ***	8.4 vs 11.6 ***
legume vs herb	31.2 vs 57.9 ***	4.3 vs 11.6 ***

*** = $p < 0.000$

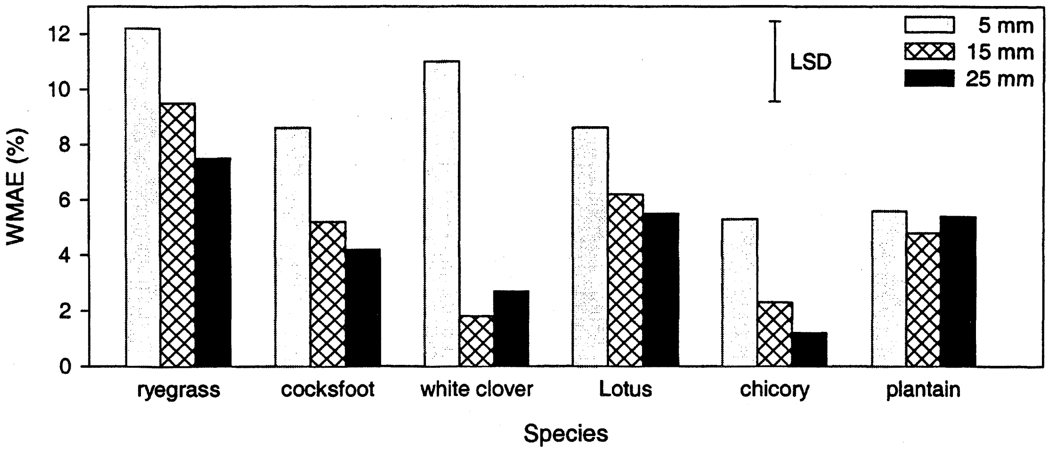

Figure 3. Weighted mean absolute emergence (WMAE) (percent of final emergence per day) for six species at three sowing depths.

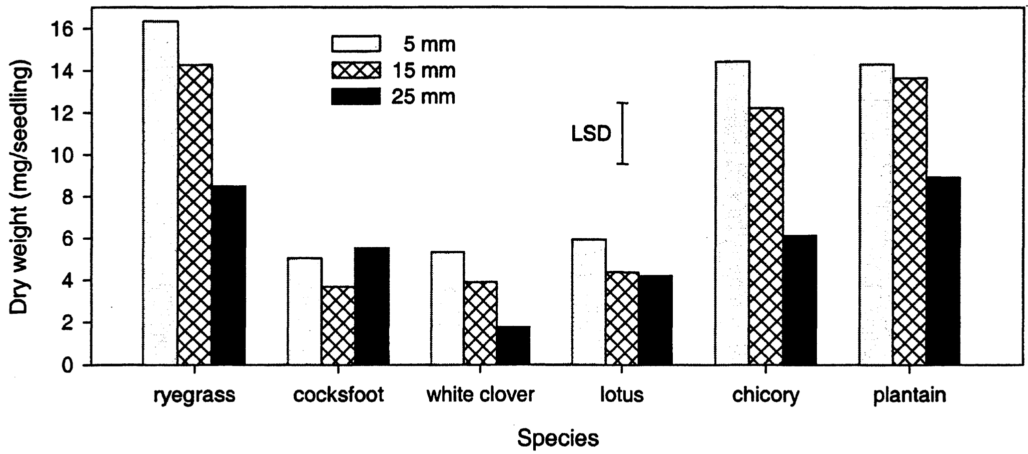

Figure 4. Seedling weight (mg/seedling) 4 weeks after emergence for six species sown at three depths

The differences in final emergence were due to a combination of two factors; rate of emergence (WMAE) and duration of emergence. The reduced final emergence for cocksfoot and lotus at 25 mm was caused by small differences in both WMAE and duration of emergence. The reduction in white clover emergence can be attributed to a reduction in WMAE and emergence.

Rate of emergence is dependent on rate of germination and the rate of subsequent shoot extension. Ryegrass has a higher rate of germination (4 days to reach 75 % germination) than cocksfoot (14 days to reach 75 % germination) (Charlton *et al.*, 1986). Ryegrass is also able to rapidly mobilise energy reserves in its endosperm giving rapid shoot elongation and subsequently rapid emergence, which contribute to a faster rate of emergence than cocksfoot. Legumes have a higher germination rate than grasses (Scott and Hanson, 1976). This mean subsequent shoot development must be slower than that of ryegrass, cancelling the difference out.

At greater sowing depths it takes longer for emergence to begin and fewer seeds reach the surface. It would be expected that duration of emergence would not be affected because seed germination and shoot elongation rates control emergence and are constants for a population of seeds (Porter *et al.*, 1993). There was an artificial reduction in duration for the deepest sowing caused by the reductions in duration for white clover and chicory, which were lower because in each 25 mm sowing replicate only 0 - 5 seeds emerged in close proximity to each other. The shorter duration was therefore a function of the few seeds that emerged.

Legumes had the shortest duration, which is consistent with reports of Scott and Hanson (1976) and Charlton (1989). Ryegrass had the highest WMAE and the same duration as other species (except plantain) giving it the greatest emergence. Cocksfoot, white clover and lotus had the same WMAE and the same duration giving them the same emergence. Plantain had a lower WMAE than white clover. However it also had a longer duration giving them the same emergence.

Seedling weight 4 weeks after emergence was lower for the deepest sowing treatments for chicory and ryegrass but not for any other species. This suggests that although there were no differences in seedling height there was still a sowing depth effect on final growth 4 weeks after sowing for ryegrass and chicory. One possibility for this difference is that the affected plants produced thinner leaves giving the same length but lower weight. Herbs were heavier than grasses and legumes, as their wider leaves giving them a greater weight for each mm of leaf height. This enables them to intercept more light at early growth stages; however their lower growth habit still leaves them susceptible to shading

Legumes had poorer emergence than grasses at 25 mm sowing depth and emerged seedlings had slower establishment than grasses and herbs at all sowing depths. This exemplifies the problems of establishing legume in a mixed pasture.

Conclusions

- Ryegrass had the strongest establishment of all species tested.
- Legumes were less able to cope with deep sowing , thus sowing depth must be considered when sowing a mixture of pasture species
- Plantain was a strong establishing herb and may be a better species than chicory to establish in a ryegrass pasture.
- Cocksfoot is a weaker establishing grass and will allow a greater proportion of legumes and herbs to establish.
- Pasture composition could be adjusted by altered seeding rates of various constituents.
- Sowing depth should not exceed 15 mm

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