Field establishment of Russell lupin

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Abstract

Three field experiments in 1988 and 1989, evaluated agronomic factors affecting the emergence and establishment of Russell lupin (*Lupinus polyphyllus* x *L. arboreus*). The first experiment in 1988 looked at the effect of sowing depth and sward treatment prior to sowing, while the second examined the effect of seed scarification on seedling emergence and establishment. The third experiment in 1989 produced data for a predictive model of establishment based on thermal time.

The amount of herbage present at sowing had no effect on the total emergence. Depth of sowing had a highly significant effect on cumulative percent emergence with 55% emergence from 2 cm sowings. Surface, 1 and 3 cm sowings gave emergences of 35, 50 and 40% respectively.

Establishment of 37% occurred where vegetation had been sprayed with a contact herbicide, but this was not significantly different from where vegetation had been burnt (35%). Live herbage gave an establishment of 26%. Establishment was highest at the 2 cm depth at 40%.

At 13 days after sowing there was no significant difference between acid and mechanical scarification. But at 18 days after sowing there were significant differences ($P > 0.01$) between treatments, with mechanical scarification giving the highest cumulative emergence of 81%.

The third experiment showed that as mean temperature (°C) decreased the number of days to emergence and establishment increased. The number of degree days to emergence remained approximately constant at 190 while for establishment it was about 412.

Additional key words: Lupinus polyphyllus x L. arboreus, *sowing depth, seedling emergence, seed scarification, degree-days*

Introduction

New Zealand's economy depends on the pastoral farming industry. The present conventional pasture species used are ryegrass (Lolium perenne) and white clover (Trifolium repens). New Zealand's hill and high country are characterized by low soil fertility with deficiencies of N, P, Mo, low pH soil, low winter temperatures, seasonal moisture deficits and low DM production (Sinclair and McIntosh, 1983; Chapman and Macfarlane, 1985; Scott *et al.*, 1985). Profitable return from these pastures has often called for high nutrient inputs and lime to adjust soil pH. At a time when fertilizer and development costs are escalating, there is a need to look for alternative pasture species which will be highly productive with lower inputs and thus give higher marginal returns. In recent New Zealand work Russell lupin (*Lupinus polyphyllus* x *L. arboreus*) has been suggested as a possible candidate (Fitzgerald, 1980; Davis, 1981b; Scott and Covacevich, 1987; Scott, 1988; Scott *et al.*, 1988; Miller, 1989; Tesfaye, 1989).

Russell lupin is a garden plant bred by Yorkshire gardener - George Russell in the early 1930's (Anderson, 1959; Gorer, 1970). In New Zealand, it was introduced as a garden ornamental plant and it has escaped into river beds and onto road verges (Wendelken, 1974). The later propagation of this species in the Mackenzie country in the south has been attributed to deliberate introduction by Mrs Connie Scott in the 1950's (Tesfaye, 1989). Experience in New Zealand with the Russell lupin indicates it has potential as an alternative legume forage species to clovers. It grows better on soils lacking in phosphorus (Fitzgerald, 1980; Davis, 1981a,b; Scott and Covacevich, 1985; Miller, 1989). It gives a higher yield at zero or low levels of phosphorus fertilizer (Davis, 1981b; Scott and Covacevich, 1987; Scott *et al.*, 1988; Miller, 1989).

However, there is very little information on the agronomic requirements of Russell lupins for establishment. Scott (1988) provided some provisional guide lines for field establishment, while Tesfaye (1989) reported the effect of seed treatment and sowing depth in glasshouse trials. The trial reported here was designed to:

1. assess the field establishment of Russell lupin under a) different levels of residual herbage, b) at different sowing depths and c) with different scarification treatments, and
2. construct a predictive temperature based model for the field emergence and establishment of Russell lupin.

Materials and Methods.

There were three experiments conducted in 1988 and 1989. Experiment 1 (1988) looked at the effects of sowing depth and sward preparation of the resident pasture on the emergence and establishment of Russell lupin. Experiment 2 (1989) assessed the best scarification method to break down hard seed to obtain optimum field emergence and establishment. The third experiment (1989) was designed to provide data to construct a predictive model based on temperature accumulation, to predict the field emergence and establishment of Russell lupin.

In experiments 1 and 2, emergence was defined as the appearance of a seedling with two fully split cotyledons above the ground. Seedlings were considered fully emerged when the emergence count was similar at two or more successive counts. Plants were considered established six weeks after sowing.

In experiment 3, emergence was defined as the appearance of a true leaf between the cotyledons while establishment was taken as attainment of two fully expanded true leaves by the seedling. Establishment was considered to be achieved when 50% of emerged seedlings were established as per the definition.

Experiment 1

There were three levels of residual pasture consisting of live untreated herbage, regrowth from burnt herbage and regrowth from chemically killed herbage. The four sowing depths were 0 (surface), 1, 2 and 3 cm. The trial design was a 3 x 4 factorial completely randomized block with three replicates. Plot size was 1.5 m by 2.5 m with guard rows of 0.25 m between plots.

Acid scarified seed (36N H_2SO_4 for 45 minutes) was sown at the soil surface, and at 1, 2 and 3 cm depth with the help of a Cullen frame and a sharp, calibrated metal rod. Seed was placed on the soil surface and covered with a small quantity of loosened soil. One hundred and twenty five seeds were sown in each plot at 25 cm apart within the row and at 10 cm between rows.

Emergence and establishment counts were made every day until emergence of the first seedling then at five day intervals. After 45 days seedlings were harvested and analysed for DM/plant in response to residual pasture and sowing depths.

Experiment 2

The seed scarification treatment consisted of acid and mechanical, and an unscarified control. Acid scarification was by immersing Russell lupin seeds in concentrated H_2SO_4 (36N) for 45 minutes at two volumes of acid to one volume of seed. After 45 minutes seed was washed in running tap water and air dried at room temperature. Seed was mechanically scarified by placing about 100 seeds in a container lined with sand paper and perforated at the bottom. Compressed air 40 kg/cm^2 was applied though an inlet in the side of the container for 5 minutes to abrade the seeds against the sand paper.

The experiment was a completely randomized block design with eight replicates. Plot size was 1 x 2.9 m. Each plot was divided into two sub-plots each of 1 x 1.2 m for sampling. There was a guard row of 0.25 m between plots and sub-plots.

In each sub-plot, 78 seeds were sown at the soil surface as in experiment 1. Seed was spaced 20 cm apart within rows, with 10 cm between rows using a Cullen frame. At 30 days after sowing (DAS) all emerged seedlings were dug out of one sub-plot of each plot. Seedlings were assessed for normality and abnormality according to the rules of the International Seed Testing Association (ISTA, 1966). Abnormality observed included attached testa and curled and twisted roots. The harvested seedlings were also analysed for DM/plant.

Experiment 3

The treatments were six sowing dates; 20 April, 24 May, 23 June, 27 July, 29 August and 20 September, and three sowing depths; 0, 2 and 4 cm in four replicates. The experimental design was a split plot randomized complete block factorial with sowing dates as main plots. Plot size was 1.5 m x 10 m.

Prior to the first sowing the soil was ploughed, harrowed, rolled and later grubbed. Mechanically scarified seeds were sown using a cone seeder with in five rows at 30 cm between rows.

Temperature was recorded hourly (an average of readings every 10 m) by a Datataker (model DT100F, Data electronics, Australia Pty. Ltd.) with 10 thermocouple probes set at different depths in the soil.

Two physiological stages of Russell lupin, emergence and establishment, were recorded.

Results

Experiment 1

Emergence: The herbage treatments did not have any effect on emergence, therefore the mean emergence figures only are shown in Figure 1. First seedling emergence was observed at 5 DAS. It increased linearly until 20 DAS when it reached a maximum of 45%. There was no further emergence by the end of this phase at 40 DAS.

Sowing treatment had a greater influence on emergence. The highest emergence of 55% was from 2 cm whilst the lowest at 34.6% was from surface sown seed. Emergence from 1 cm was not significantly different than from 2 cm (Fig. 2).

Establishment: The highest establishment at 37% was from seed sown into pasture which had been treated with a contact herbicide (Table 1). This was considerably less than the maximum emergence of 45%. Both herbicide treated and burnt pasture treatments gave significantly higher numbers of established plants than the untreated pasture at 26%.

In response to sowing depth establishment was highest from 2 cm (40%) while the lowest was from surface sowing at 25% (Table 1). Establishment from 2 cm was not significantly different from establishment at 1 cm but was significantly higher ($P < 0.05$) than from the surface or 3 cm sowing.

Dry matter production: At 45 DAS, the highest DM production at 0.596 g/plant was produced from plants sown into herbicide treated pasture. Herbicide treated and burnt pasture produced 817 and 442% more DM than plants sown into live pasture (Table 1). However, by 45 DAS, sowing depth had no significant effect on DM production (Table 1).

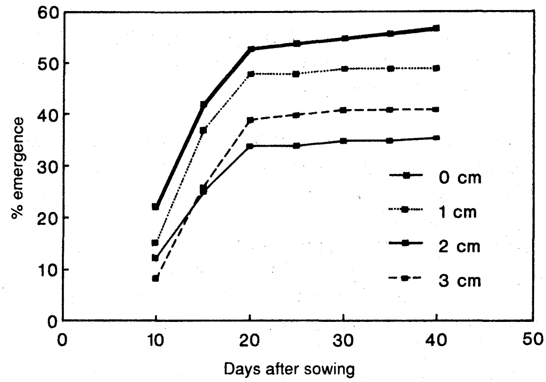

Figure 2: The effect of depth of sowing on emergence (%) of Russell lupin seedlings.

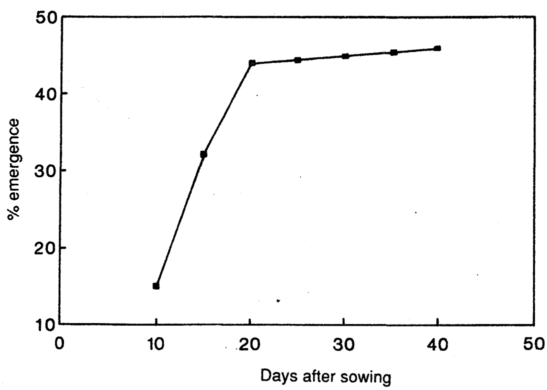

Figure 1: Mean emergence (%) of Russell lupin seedlings.

TABLE 1: The effect of herbage treatment and sowing depth on establishment and DM production at 45 DAS.

	Establishment (%)	DM Production (mg/plant)
Herbage treatment:		
Live	26	50
Dead	37	600
Burnt	34	320
SE	4.3	32
Sowing depth (cm):		
0	25	330
1	35	350
2	40	300
3	29	310
SE	5.0	37

Experiment 2

Emergence: The highest emergence at 80% was from mechanically scarified seeds at 28 DAS, while acid treated and control seeds had an emergence of 67 and 54% respectively. Differences in emergence were significant from 8 DAS except for the mechanical and the acid scarification treatments where the difference became significant only at 18 DAS (Fig. 3).

Establishment: Mechanically scarified seed also gave the highest establishment at 76%. This was significantly higher than establishment from acid treated and control seeds at 64 and 55% respectively.

Proportion of normal and abnormal seedlings: There were no significant treatment effects on the proportion of abnormal seedlings.

Dry matter production: At 24 DAS, the highest DM production of normal seedlings was from acid treated seed (0.065 g/plant) and mechanically treated seed (0.051 g/plant) (NS).

Normal seedlings from control seed were significantly ($P < 0.05$) lighter (0.031 g/plant) (Table 2).

Seed treatment had no significant effect on DM production of abnormal seedlings which had a mean weight of 0.036 g/plant.

Final above ground DM production at 43 DAS, irrespective of whether seedlings were normal or abnormal, was highest from mechanically scarified seed (0.503 g/plant) and acid treated seed (0.438 g/plant) (NS). The DM produced by control seed was significantly lower than the DM from the scarified seed (Table 2).

Experiment 3

Model results: The reported results are based on mean screen temperature recorded at the DSIR meteorological station near Lincoln.

Temperature effect on emergence: The relationship between development rate from sowing to emergence and mean temperature was linear (Fig. 4). Extension of the regression line suggested a base temperature of about 2°C for the field emergence of Russell lupin.

Degree days for emergence and establishment: Russell lupin required 190 growing degree days (GDD) for emergence and 412 GDD for establishment above a base temperature of 2°C (Table 3).

TABLE 2: The effect of scarification treatment on DM (mg/plant) production of normal Russell lupin seedlings at 24 and 43 DAS.

Scarification method	24 DAS	43 DAS
Control	31	320
Acid	65	440
Mechanical	51	500
SE	10	37

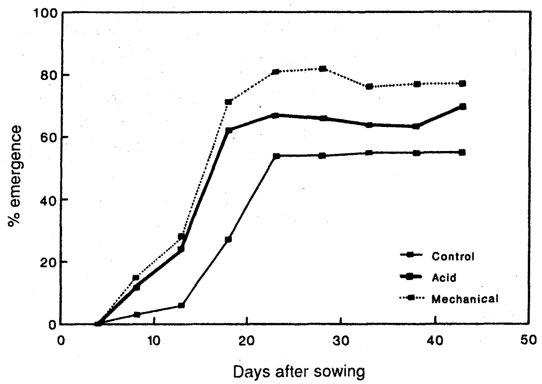

Figure 3: The effect of scarification method on emergence (%) of Russell lupin seedlings.

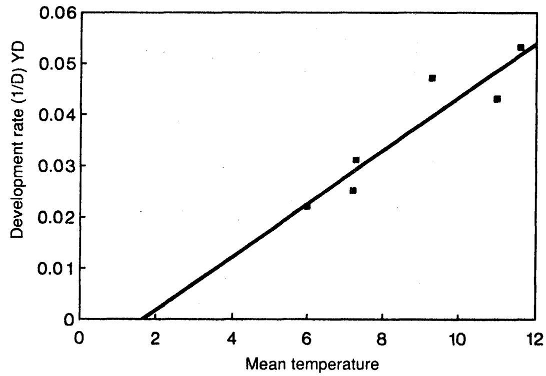

Figure 4: The relationship between development rate of Russell lupins and mean temperature ($R^2 = 0.80$).

TABLE 3: Thermal time required from sowing to emergence and from sowing to establishment of Russell lupins for different sowning times (T_b = 2°C).

Sowing date	Growing degree days from sowing: to Emergence	to Establishment
April	216	473
May	207	461
June	206	461
July	187	387
August	152	391
September	169	388
Mean	190	412

The GDD values obtained were used as threshold values for predicting Russell lupin emergence and establishment.

Actual and predicted days for field emergence and establishment: The period to field emergence and establishment was predicted with reasonable accuracy. The largest discrepancy between actual and predicted dates of emergence of a six day delay occurred in the May sowing.

In general, the predictions were within a range of 6 days with two of the six sowing dates emerging within two days and one within one day (Fig. 5).

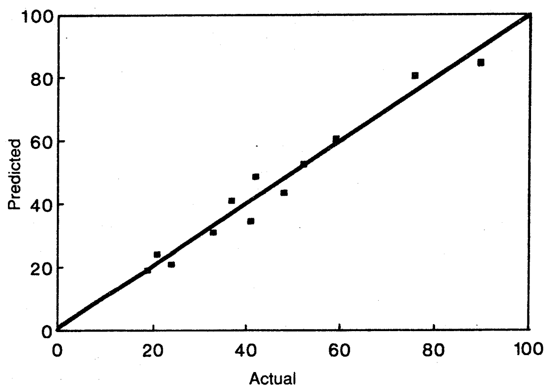

Figure 5: The relationship between actual and predicted days from combined data for sowing to emergence and sowing to establishment of Russell lupins.

The predicted number of days from sowing to establishment were more variable. Only one out of six sowing dates established within one day of the predicted value. This greater variability could be expected as this is a much longer period (McKenzie, 1987) than the emergence. In general, the prediction for establishment was within about 7 days (Fig. 5).

Discussion

Effect of residual herbage and sowing depth

The results showed that the emergence of Russell lupins was not influenced by burning or spraying the sward with contact herbicide before sowing. This supports the work of Janson (1970) on lucerne establishment. He found no significant effect among sward treatments (control, burnt, and paraquat sprayed) on total germination of lucerne. Wu Ying (1987) found that sub clover seedlings gave a 90% seedling emergence irrespective of cover provided moisture was not limiting.

However, establishment was favoured in the burnt and sprayed plots (Table 1). This was probably due to reduced competition in these plots from the slower recovery of the pasture compared to the regrowth in the untreated plots by the end of the experiment. In a Danthonia infested area, Janson (1970) found that for successful establishment of lucerne complete destruction of danthonia prior to sowing was important.

Sowing depth had an effect on both the emergence and the establishment of Russell lupin. The highest number of emerged and established seedlings was obtained by sowing at 1 or 2 cm. Despite its larger seed than most herbage legume this suggests that Russell lupin should be sown at the depths recommended for other herbage legume species. The results can be compared with the optimum sowing depth of 0.6 to 1 cm recommended for clovers and lucerne (Moore, 1943), 1 cm for birdsfoot trefoil (Stickler and Wasson, 1963), 1.3 cm for most forage legumes (Cooper, 1977) and 1 to 3 cm deep for tagasaste seed (Voon, 1986). Peiffer *et al.* (1972) obtained an emergence of 80% or more from crownvetch, lucerne and red clover by sowings at 1.3, 1.9, and 2.5 cm but a significantly lower emergence from sowing at 3.8 cm.

These results support the glasshouse experiments of Tesfaye (1989) who obtained the highest seedling emergence from 1 and 2 cm sowings for Russel lupin.

Seedling dry matter production was significantly affected by the pasture treatment. Herbicide treated and burnt plots gave the highest DM/plant. Again, this was probably due to the reduced competition from pasture in these plots. Established Russell lupin seedlings in the untreated pasture plots were tall and slender and had few leaves. Janson (1970) obtained similar results with lucerne where the weight of plant tops was greater in treatments where resident vegetation was set back with paraquat at or prior to sowing.

Dry matter production was not affected by sowing depth. This could be due to the relatively large seed size of Russell lupin and the range of sowing depths used (0 - 3 cm) not being large enough to affect final seedling DM. Tesfaye (1989) found that seed sown deeper than 3 cm died after their food reserve was exhausted and before the seedlings emerged.

Effects of scarification

The results of Experiment 2 suggest that the best emergence and establishment of Russell lupins should be obtained from mechanically or acid scarified seed.

The scarification results agree with those of Hamly (1932) on *Melilotus alba*, Akamine (1942) on *Leucaena leucocephala*, Brant *et al.*, (1971) on crown vetch, Horn and Hill (1974) on *Lupinus cosentinii*, Wan Mohamed (1981) on broom and Tesfaye (1989) on Russell lupin.

Using hand scarification, Horn and Hill (1974) obtained a 96% emergence from *L. cosentinii*, Wan Mohamed (1981) improved the emergence of broom from 2.5% in the control to 79% and Tesfaye (1989) obtained germination and emergence of 98 and 92% respectively from chipped Russell lupin seed. However, a large proportion of abnormal seedlings were produced by mechanically scarified seed.

Wan Mohamed (1981) and Tesfaye (1989) reported 29% of abnormal broom seedlings and 36% abnormal Russell lupin seedlings from chipped seed.

Contrary to Tesfaye's (1989) work, the proportion of abnormal seedling in this work was higher from acid scarified seed than in mechanically scarified seed. This may have been due to the methods of mechanical scarification used. Tesfaye (1989) used nail clippers to cut away a small part of the seed coat. In this experiment the seed was abraded against sand paper inside a container for five minutes. It could also be due to the different soil environment in which the seeds were sown. Tesfaye (1989) sowed his seed in sand. In this experiment root growth may have been restricted by soil compaction under the seed as a result of the method of sowing used.

Improved germination of Russell lupins after treatment with concentrated H_2SO_4 is similar to the results of Horn and Hill (1974), Wan Mohamed (1981), Liu *et al.* (1981), Voon (1986) and Tesfaye (1989) who reported improved germination of *L. cosentinii*, broom, three woody legumes (honeylocust, kentucky coffeetree, and redbud), tagasaste and Russell lupin seed following treatment with sulphuric acid.

The DM/plant of normal seedlings from scarified seed was considerably higher than that in unscarified seed at 24 DAS (< 0.01).

These results indicate that the DM of established Russell lupin plants is higher from scarified seeds which should be of importance where the plant is being established in areas where moisture supply is uncertain. This was probably helped by the considerably more rapid germination of scarified seed which thus were exposed to sunlight for longer than seedlings from control seed.

Predictive model

The model used in this experiment is very simple and is based only on thermal time. Soil moisture was assumed to be constant in this work, and other factors like solar radiation, evaporation and evapotranspiration were not considered.

The largest discrepancies between actual and predicted values were for the May sowings. This may be because this model did not account for the very low temperatures, i.e. those below the base temperature, which occurred towards the end of May and throughout most of June. Similarly, the earlier emergence of the August and September sowings may suggest an optimum temperature for Russell lupin and the model may need to be corrected for temperatures above the optimum as high temperatures prevailed during those months. The discrepancies may also have been due to water stress. Plots were irrigated but the actual amount of water applied was not measured.

The model was designed to predict two stages of phenology based on temperature accumulation. It mechanistically described the growth and development of Russell lupin up to establishment. It must be emphasized that this is only a preliminary model which attempted to establish the relationship between the development of Russell lupin and the mean temperature in one location in Canterbury. To be of use for predicting other phenological stages such as flowering, seed production and DM accumulation other subroutines may need to be incorporated into the model.

Over all, the model was reasonably accurate in the prediction of emergence and establishment of Russell lupin.

Conclusion

These results show that for optimum establishment Russell lupins should be sown:

1. into killed or burnt herbage.
2. approximately 2 cm deep.
3. only after being scarified.

Russell lupins will emerge and establish after about 190 and 412 degree-days respectively for a base temperature of 2°C.

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