Harvest date influence on field emergence and on laboratory indicators of quality in lupin (*Lupinus angustifolius* L.)

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Abstract

Seed production research in narrow-leafed lupin (*Lupinus angustifolius* L.) has concentrated on agronomic yield rather than quality. A sequential harvesting experiment was established at Lincoln University to determine the effect of time of harvesting on seed quality as indicated by seed moisture, mean seed weight, laboratory germination, bulk conductivity and field emergence. Maximum mean seed weight (0.18 g) and germination (96%), were achieved 52 days after peak flowering (DAPF), which coincided with minimum bulk conductivity (< 50 µs/cm/g) and 32% seed moisture content (SMC). Field emergence (FE) did not increase significantly after 52 DAPF (>70%). Delaying harvesting until 14% SMC did not have a detrimental effect on field emergence although the increase in conductivity indicated seed ageing was occurring. Laboratory germination could be used to predict FE (R^2=0.95) when a range of seed maturities, and therefore germinations (<50% to >90%), was included. For these seed lots the bulk conductivity test was also a good indicator of likely FE (R^2=0.79). Examination of a subset of the data (52-95 DAPF), however, where laboratory germination was > 96%, revealed that laboratory germination was only poorly related to FE (R^2=0.28) whereas FE did have a significant relationship with conductivity (R^2=0.53).

Additional key words: *conductivity, germination, harvest, seed vigour*

Introduction

Narrow-leafed lupin (*Lupinus angustifolius* L.) are an important source of protein for livestock, and have potential for human consumption (Petterson *et al.*, 1986). Western Australia exports over one million tonnes of lupin seed, worth over A$200 million (Hill, 1997). Lupin also contribute an estimated A$90 million in increased value of animal production; their value in terms of their place in the crop rotation (they increase yields of Western Australian cereal crops which follow the lupin by approximately 25%), has not been estimated (Hill, 1997). In New Zealand, lupin have been shown to have potential as a forage crop (Burtt and Hill, 1990), but they are mostly grown for seed to meet the demand from home gardeners for green manure crops (G.D. Hill, Lincoln University, pers. comm., 1997).

Lupin have been the subject of agronomic research for maximum yields in terms of establishment (e.g., French *et al.*, 1994; Burch and Perry, 1986), fertiliser (e.g., Bolland, 1992; Seymour and Brennan, 1995) and of harvesting techniques (e.g., Burch, 1986). Harvesting losses have been reduced (and, hence, yields increased) with the development of non-shattering cultivars (Burch, 1986), which remove much of the 'risk' involved with assessing time of harvesting for maximum yield. However, seed harvested later than physiological optimum can deteriorate in quality (Hampton, 1991).

Seed quality has been defined as a collection of seed components considered to be of importance for the value of seed for sowing purposes (Esbo, 1980). In the past, analytical purity and germination capacity have tended to be the only properties of seed considered in assessing seed quality (Scott and Hampton, 1985). More recently emphasis has been placed on aspects of seed vigour (Hampton and Coolbear, 1990; Hampton and Hill, 1990; Hampton, 1991, 1994, 1995).

Seed vigour is defined by the International Seed Testing Association as the sum total of those properties of the seed which determine the level of activity and performance of the seed or seed lot during germination and seedling emergence (Hampton and TeKrony, 1995). Seed ageing, which begins at physiological maturity of the seed, i.e., before harvest (Hampton and TeKrony, 1995), is a major cause of reduced seed vigour (Powell, 1988); the latter can have implications for field establishment and subsequent agronomic performance of a crop (Hampton and Scott, 1982).

Time of harvesting, and its effect on seed damage, has been shown to be of importance in seed vigour of garden peas (Castillo *et al.*, 1994). The latter is indicated by conductivity and hollow heart measurements which, combined with germination data, can be used to calculate an 'expected field emergence' value (Hampton and Scott, 1982). Lack of suitable vigour tests for many species has been cited as a reason for slow uptake of vigour testing by the seed industry (Hampton, 1994).

This research was established to examine the effect of time of harvesting of lupin on subsequent field emergence. Laboratory indicators of germination and vigour, plus their relationship to field emergence, were also examined.

Materials and Methods

A field plot of lupin (cv. Fest) was drilled on 3 November, 1995, on a Templeton silt loam at Lincoln University. Irrigation was applied throughout December and January. Management of the trial has been described by Kelstrup *et al.* (1996). Peak flowering was identified visually by intensity of colour. Approximately 500 g wet weight of lupin pods were collected at random every 2-4 days from 14 February (when pods started to change colour) to 14 April, 1996. This meant that pods collected were at different stages of development, as they would be during mechanical harvest. Seeds (8 x 20) were extracted by hand, weighed, oven-dried at 130°C for 1 hour and reweighed in order to calculate seed moisture and seed weight at harvest. Bulk samples were air-dried in ambient conditions (22°C ± 2°C) for three weeks in a single layer and then stored in paper bags.

Laboratory germination was performed according to ISTA (1993) procedures. Bulk conductivity (Hampton and TeKrony, 1995) was measured using a CDM210 conductivity meter (Radiometer Analytical, Copenhagen).

Field emergence was measured after hand planting 8 replicates x 20 seeds from each harvest date on 7 January, 1997, at 10 mm depth and 25 mm seed spacing. The soil was a Wakanui silt loam, at Lincoln University, Canterbury. Seedlings were counted every 2-3 days from 13 to 24 January, after which no further seedlings appeared.

Weather data were collected from Broadfields meteorological station, approximately 5 km from the experimental site.

Data were analysed using Minitab 9.2 (general linear model ANOVA) and Microsoft Xcel 5.0 (regression and curve-fitting analysis). All means were differentiated using an LSD at the 5% level of significance.

Results and Discussion

Peak flowering occurred on 12 January, 1996, 70 days after sowing. Although temperature was similar to the long term mean (LTM), and rainfall was low, January had many days with light rain, and evapotranspiration, total solar radiation and hours of bright sunshine were reduced in comparison with the LTM (Table 1). These factors are likely to have had an affect on seed development, prolonging the ripening period in comparison with normal years (Hare and Lucas, 1984).

Over the duration of harvesting, seed moisture decreased significantly until 62 days after peak flowering (DAPF), and then plateaued at 14% SMC. Mean seed weight and laboratory germination increased significantly until 52 DAPF and plateaued at 0.18 g and 96%, respectively (Fig. 1). This implies that seed maturity was achieved at 52 DAPF, but that seed drying would be necessary to bring the seed from a 30% SMC to safe storage moisture content. As flowers in this experiment were not individually tagged, there was potential for identifying peak flowering incorrectly. However, primary flowering of *L. angustifolius* has been recorded previously at 73 days after drilling in Canterbury (Burtt and Hill, 1990). Furthermore, long periods for seed development in other species have also been recorded,

Table 1. Meteorological data for the flowering and seed development of lupins. (Figures in brackets are means for the preceding seven years.)

	Temperature (°C)	Rainfall (mm)	Evapotranspiration (mm)	Solar radiation (Mj/m^2)	Bright sunshine (h)
January	16.9 (16.9)	16.0 (40.3)	123.7 (153.5)	689 (724)	187 (239)
February	16.8 (16.3)	32.4 (36.8)	113.4 (105.8)	581 (553)	209 (194)
March	13.2 (14.7)	69.5 (40.7)	78.8 (99.2)	469 (462)	na[1]
April	12.1 (11.8)	55.3 (47.8)	48.0 (68.8)	288 (293)[2]	150 (154)

[1] not available; [2] mean for preceding four years

e.g., 49 days for *Plantago lanceolata* (Rowarth *et al.*, 1993).

Bulk conductivity decreased significantly (P<0.01) between 33 and 52 DAPF (Fig. 2). From 70 DAPF onwards a slight (but not significant) increase in bulk conductivity was apparent. Conductivity measures electrolyte leakage from seeds and is associated with membrane integrity. Damage to membranes, including the seed coat, promotes leakage, which is also associated with immaturity and ageing (Powell, 1988). The slight increase in conductivity could have implications for seed storage as poor performance of aged seed has been associated with increases in conductivity, even though germination has not changed (Hampton, 1991).

Field emergence increased significantly to 52 DAPF, and plateaued at approximately 85% (Fig. 3). Field emergence was negatively and significantly (P<0.01) related to seed moisture (Table 2). Using average values to predict field emergence from seed moisture showed a curvi-linear relationship (Fig. 4). Cate-Nelson separation techniques (Cate and Nelson, 1965) revealed that to achieve a field emergence of greater than 70%, seed moisture should be below 32% at harvest. This coincides with maximum laboratory germination and

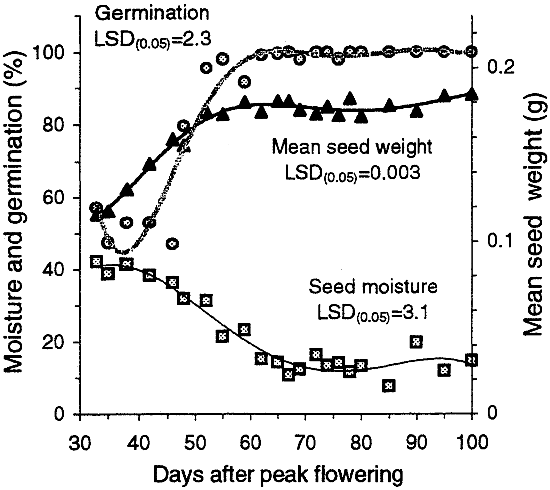

Figure 1. Relationship between time of harvesting (days after peak flowering) of lupin seed and seed moisture (%), germination (%) and mean seed weight (g).

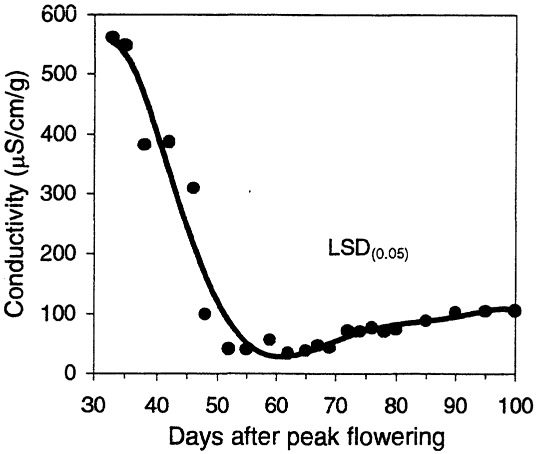

Figure 2. Relationship between time of harvesting (days after peak flowering) of lupin seed and bulk conductivity (µs/cm/g).

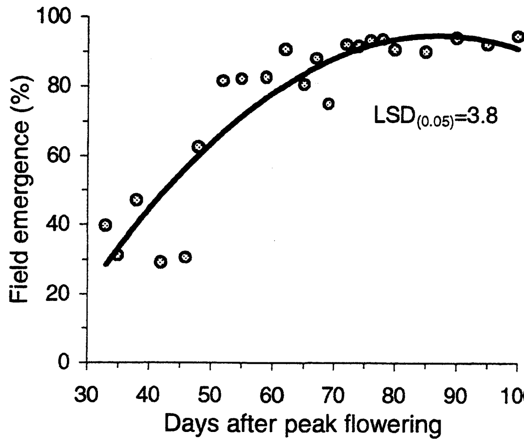

Figure 3. Relationship between time of harvesting (days after peak flowering) of lupin seed and field emergence (%).

Table 3. Relationship between field emergence (FE; %) and seed parameters for data collected 52-95 days after peak flowering.

Regression equation		R^2
FE =	93.841 - 0.359 seed moisture	0.12
FE =	49.146 + 2.2019 mean seed weight	0.30
FE =	-47.31 + 1.3725 laboratory germination	0.28
FE =	76.47 + 0.1767 conductivity	0.53

mean seed weight (Fig. 5). However, there are other factors which should be considered. For example, mechanical harvesting at high moisture content has been associated with bruising (and, hence, reduced vigour) in garden peas (Castillo *et al.*, 1994). Results from this study showed that delaying harvesting until 14% SMC was still associated with a field emergence of greater than 70% (Fig. 4) but may have resulted in cracked seed if mechanically harvested (Castillo *et al.*, 1994). Further research is required to establish the relationship between seed moisture and seed vigour during mechanical harvesting.

Regression analysis using the average values for the whole harvest period indicated that field emergence was significantly (P<0.01) related to seed moisture, mean seed weight laboratory germination and bulk conductivity (Table 2). Mean seed weight reflects carbohydrate stores for seed and has been found to indicate likely field emergence in *Lotus* species (Charlton, 1989; Rowarth and Sanders, 1996). However, seed weight does not take into account any mechanical damage and, in the commercial situation, is likely to have limited importance as seed cleaning usually imposes a minimum seed size in a seed lot. When a range of germinations (from <50% to >90%) were included, laboratory germination could be used to predict FE with confidence (R^2 = 0.95) (Fig. 6); for a field emergence of greater then 70%, laboratory germination should be at least 90%. The relationship between average bulk conductivity and field emergence was significant (R^2 = 0.79) and curvi-linear (Fig. 7). Using Cate-Nelson separation, for a field emergence of greater than 70%, conductivity should be less than 120 TS/cm/g. Laboratory germination takes ten days, plus pre-chilling for four days. Bulk conductivity takes 24 h. Bulk conductivity appears to have potential as a rapid, simple and cheap method for indicating field emergence.

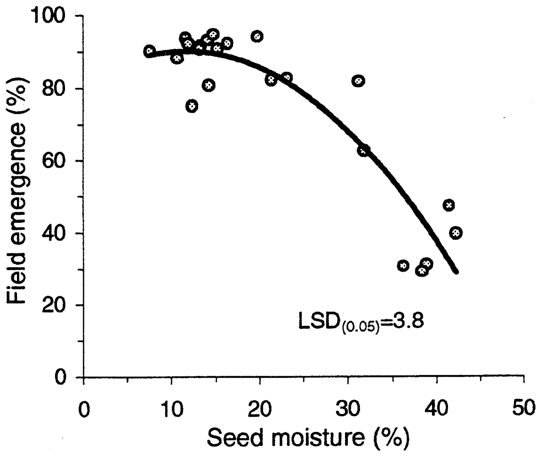

Figure 4. Relationship between seed moisture (%) of lupins at harvest and subsequent field emergence (%).

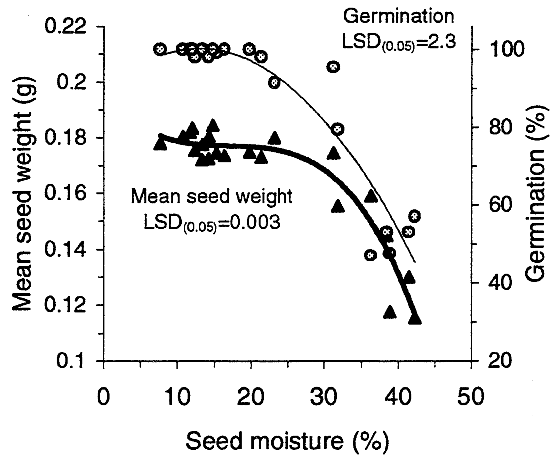

Figure 5. Relationship between seed moisture (%) of lupins at harvest and germination (%) and mean seed weight (g).

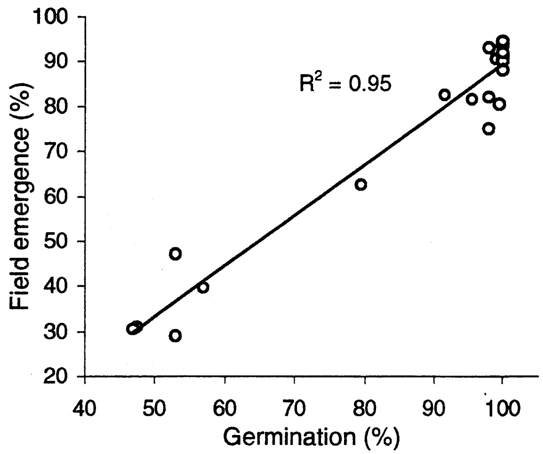

Figure 6. Relationship between laboratory germination (%) of lupin seed and field emergence (%).

Performing regression analyses on a subset of data (52-95 DAPF) (which removed the effect of immature, and hence low germinating seed) reduced the amount of variability in field emergence accounted for by all parameters (Table 3). Although the relationship between field emergence and laboratory germination was still significant, laboratory germination could not be used to predict field emergence with confidence (R^2 = 0.28). In contrast, bulk conductivity accounted for over half of the variability in field emergence (R^2 = 0.53).

Although the samples analysed in the present research were from one site, the fact that there were no management differences or mechanical harvesting differences would be expected to minimise measurable differences in seed performance. Despite this, significant differences in seed quality measurements were observed. Bulk conductivity as an indicator of seed vigour is used with success in peas and deserves further investigation as an indicator of vigour in narrow-leafed lupin.

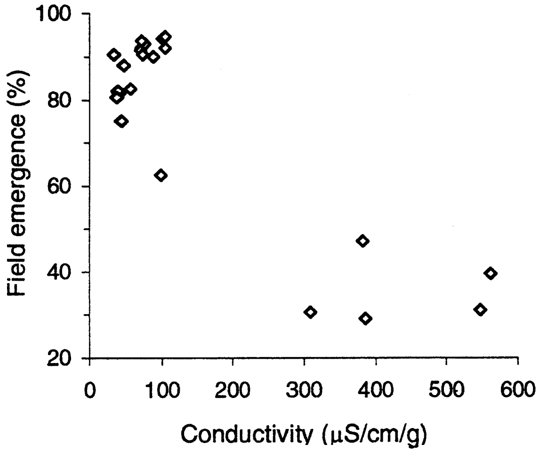

Figure 7. Relationship between bulk conductivity (µs/cm/g) of lupin seed and field emergence (%).

Table 3. Relationship between field emergence (FE; %) and seed parameters for data collected 52-95 days after peak flowering.

Regression equation		R^2
FE =	93.841 - 0.359 seed moisture	0.12
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FE =	-47.31 + 1.3725 laboratory germination	0.28
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Conclusions

- Maximum seed weight, germination, and field emergence were achieved 52 DAPF, which coincided with minimum bulk conductivity and 32% seed moisture.
- Delaying harvesting until 14% seed moisture did not have a detrimental effect on field emergence although the increase in conductivity indicated seed ageing was occurring.
- The bulk conductivity test showed potential as an indicator of field emergence.
- These tests should be performed on commercial samples in order to examine the effects of environmental conditions and mechanical harvesting on lupin seed quality.

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