Field performance of field pea seeds with varying vigour levels

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Abstract

Seedling emergence, plant growth and seed yield of field peas (*Pisum sativum* L.) were compared among seed lots with varying vigour levels sown at different dates in 1997. Treatments were arranged in a split plot design with three replicates. Two sowing dates (August and October) were main plots and 12 lots of field pea seed were sub-plots. The seed lots were six each of the cultivars Beacon and Whero which had been grown under two light levels (full sunlight or 40% shade) and harvested at three physiological seed ages (23, 35 and 47 days after flowering) from a 1996 experiment. Marked differences were found in seedling emergence among seed lots with varying vigour, especially under wet, cold conditions. High vigour seed lots emerged well at both sowings, and some lots had >90% emergence even under wet, cold conditions in August. In contrast, the lowest vigour seed lots emerged poorly (43 - 62%) at both sowings. Variation in seedling emergence of seed lots between sowing dates depended on vigour status. Seed lots with low field emergence also emerged more slowly. This resulted in lower plant establishment, low leaf area index (LAI) and leaf area duration (LAD). The number of plants per m^2 at final harvest for low vigour seed lots was reduced by 33 - 50%. This resulted in 54 - 60% less total dry matter (TDM) and a 57 - 68% seed yield reduction. Sowing date affected emergence rate but did not affect TDM or seed yield. Conductivity and accelerated ageing tests gave better predictions of field emergence than germination tests for seed lots of both cultivars at both sowings.

Additional key words: *germination, accelerated ageing, conductivity, seed vigour, field emergence, field peas.*

Introduction

Field peas are an important crop in Canterbury with an area of 19,500 ha sown in 1998 (FAO, 1998). High yields can be produced under favourable conditions but differences in growing conditions and seasons can cause inconsistent and often low seed yields (Kelly, 1987; Wilson, 1987). In general, early sowings have been found to benefit seed yield of grain legumes due to a longer crop growth duration (Summerfield *et al.*, 1982) and a larger leaf area duration (LAD) as Zain (1984) found in early spring sown peas. However, cold and wet conditions in early spring can cause poor emergence and crop establishment. This may lead to low seed yield, particularly when low quality seed is sown (Freeman, 1987; Powell *et al.*, 1997).

Seed germination has been universally accepted and used to describe the quality of a seed lot. However, the laboratory germination test is carried out under optimum conditions that are rarely found in farmers' fields. Differences in field emergence of seed lots with similar high germinations may occur due to vigour differences (Hampton and Coolbear, 1990). Seed vigour is recognised as an important quality factor and describes the potential for rapid and uniform emergence and the development of normal seedlings under a wide rage of field conditions (Perry, 1987). A number of seed vigour tests have been developed to measure vigour potential of seed lots, but only the conductivity test for garden peas and the accelerated ageing test for soybean (*Glycine max* L) have been currently accepted as recommended vigour tests (ISTA, 1995).

Differences in vigour levels of seed lots can lead to differences in crop establishment and final yield, especially in grain legumes (Powell *et al.*, 1984). In garden peas, Hampton and Scott (1982) found low vigour seed lots reduced seed yield by reducing plant population. Such seed yield differences, however, were not found when low and high vigour seed lots were sown and thinned to the same population. Plant growth and time to reach maturity were not affected by seed vigour differences. Similar findings were reported in soybeans (Egli and TeKrony, 1979). There is, however, limited information for field peas.

Differences in seed vigour can be caused by many factors including seed size, seed maturity, genetic constraints and growth conditions of the mother plant (ISTA, 1995). Certainly, the environment experienced by plants during seed development is a major determinant of seed quality, particularly seed vigour (Delouche, 1980). Low light intensity levels have been shown to affect seed development and result in smaller seed in field peas and soybeans (Wahua and Miller, 1978; Gubbels, 1980). However, information on the effects of light intensity on pea seed germination, seed vigour and the field performance of their progeny is very limited. For this reason, seed lots from plants which had received varying light levels in the previous season were used in this study.

The main objective of this work was to determine the field performance at different sowing dates of field pea seeds with varying vigour levels.

Materials and Methods

A field trial was conducted from August 1997 to February 1998 at Lincoln University Research Farm, Canterbury, on a Wakanui silt loam soil. Treatments were arranged in a split plot design with three replicates. The main plots were two sowing dates (23 August 1997 and 28 October 1997) and the sub-plots were 12 lots of pea seed from two cultivars of field peas, Beacon and Whero. The peas had been grown in the previous season under two light intensity levels during seed development (full sunlight and 40% shade); and had been harvested at 23, 35 and 47 days after full flowering (DAF). Seed quality information for the 12 lots sown is presented in Table 1. All seed lots had a laboratory germination of 94% or greater but there were differences in the thousand seed weights and seed vigour as determined by accelerated ageing and conductivity. For example, seed lots B4 and W4 had the smallest seeds and the lowest seed vigour as shown by the lowest germination after accelerated ageing and the highest conductivity. Seed lots W2, B3, W3 and W6 had the largest seeds and the highest vigour by both measurements (Table 1).

At each sowing date, fifty seeds from each lot were hand sown at a depth of 3 cm into 2 row plots 2.5 m long, with 10 cm between seeds and 50 cm between rows. Percentage seedling emergence and rate of emergence were evaluated from normal seedlings counted every other day until there was no further increase. The seedling emergence rate was calculated as $\sum x/\sum fx$, where x = seedling emergence percentage at the counting date and f = days from sowing (Nichols and Heydecker, 1968). For final emergence the last counts were used.

Samples were taken at random for dry matter (DM) and leaf area index (LAI) measurements at 21 day intervals, starting at 7 days after emergence (DAE) and continuing until 70 DAE. At each harvest all plants were cut to ground level in an area of 0.5 m^2. The leaves were put through a Licor 3100 area meter for LAI determination. Leaf area duration was calculated as the time integral of LAI (Hunt, 1978). Subsequently, all plants were oven dried at 70°C to constant weight for DM determination.

Total dry matter (TDM), seed yield and yield components were determined at 94 and 85 DAE for cv. Beacon, from August and October sown plants and at 119 and 104 DAE for cv. Whero. All plants in a 0.5 m^2 harvest area in each plot were cut to ground level and numbers of plants recorded. The number of pods per plant and seeds per pod were also determined from five plants, randomly selected from the harvested plants. All harvested plants were air dried. Seeds were hand shelled when the plants were dry and weighed for seed yield, adjusted to 12% seed moisture content. Thousand seed weight was determined from four sub-samples of 100 seeds for each plot and adjusted to 12% seed moisture content. All the plant parts were weighed for TDM.

Table 1. Seed quality parameters of the field pea seed lots sown.

Cultivar and Seed lot	TSW[1] (g)	Germination (%) before AA[2]	after AA	Conductivity (µS/cm/g)
Beacon				
B1	78c[3]	100a	67c	26.4c
B2	196ab	99ab	83b	23.3cd
B3	209a	99ab	100a	15.2e
B4	66c	94c	52d	41.8a
B5	177b	99ab	71c	33.0b
B6	180b	100a	97a	21.1d
Means	151	98	78	26.8
Whero				
W1	101d	97b	82c	23.0b
W2	245ab	98ab	97ab	14.9c
W3	261a	98ab	100a	9.3d
W4	62e	94c	67d	39.7a
W5	215c	99ab	91b	21.5b
W6	232bc	100a	94ab	12.7d
Means	186	98	89	20.2
Significance				
Cultivar	**	NS	**	**
Seed lot	**	**	**	**
CV (%)	8	2	4	9

[1] TSW = thousand seed weight; [2] AA = accelerated ageing
[3] column figures within cultivar followed by the same letter are not significantly different at $P < 0.05$.

Results

Seedling emergence

Final emergence averaged across all seed lots did not differ between sowing dates. However, there were variations in final emergence of different seed lots according to sowing conditions and seed lot vigour status (Table 2). The high vigour seed lots such as B3, W3 and W6 had >90% emergence even under wet, cold conditions (29% soil moisture content and 6.5 - 8.6°C soil temperature) in the August sowing, while the lowest final emergence came from the lowest vigour seed lots B4 (51 - 62%) and W4 (43 - 49%) for both sowings. Seed lots with low final emergence also emerged more slowly. However, some other lower vigour seed lots (B1 and B5) had less than 80% emergence in the August sowing. Under the drier and warmer conditions of the October sowing (16% soil moisture content and 11 - 12°C soil temperature) all seed lots, except B4 and W4, had an emergence of 85% or greater. Seed lot B5 had an emergence of 74% when sown in August and this increased to 92% when sown in October. Seedlings emerged more rapidly in the October sowing (7.1 %/day cf. 3.9 %/day for the August sowing). No differences in final emergence and emergence rate were found between cultivars.

Table 2. Interaction effects of pea seed lots and sowing dates on field emergence and rate of emergence.

Cultivar and seed lot	Field emergence (%)		Rate of emergence (seedling %/day)	
	August	October	August	October
Beacon				
B1	76bcd[1]	85abc	3.1cd	6.4b
B2	85abc	96a	4.1c	8.4a
B3	95ab	97a	4.6c	8.3a
B4	51e	62de	2.2d	4.6c
B5	74cd	92ab	3.4cd	7.6ab
B6	83abc	94a	3.8cd	8.6a
Means	77	88	3.5	7.3
Whero				
W1	81c	85bc	4.2cd	6.9b
W2	87bc	92ab	4.6cd	7.5ab
W3	97a	95a	5.4c	8.7a
W4	43d	49d	2.0e	3.6d
W5	85bc	92ab	4.5cd	7.3b
W6	91ab	96a	4.6cd	7.8ab
Means	79	87	4.2	7.0

[1] values within cultivar and for both sowing dates followed by the same letter are not significantly different at $P < 0.05$.

Final emergence within each cultivar was significantly related to conductivity, accelerated ageing and thousand seed weight ($p<0.01$) at both sowings (Table 3). These relationships were better than that between field emergence and laboratory germination. The best relationships were found in cv. Whero seed lots sown in August ($R^2 = 0.87$ for conductivity, 0.81 for accelerated ageing). All relationships were stronger in cv. Whero than cv. Beacon at both sowings. No significant relationship was found between laboratory germination and field emergence in cv. Beaon seed lots irrespective of sowing date.

Leaf area index and leaf area duration

Sowing date did not alter LAI at 70 DAE. However, the August sowing gave a longer LAD than the October sowing. Cultivar affected both parameters; cv. Whero

Table 3. The relationships between field emergence (FE) and field pea seed quality parameters at two sowing dates.

Cultivar	August sowing Regression equation[1]	R^2	October sowing Regression equation	R^2
Beacon	FE = 20.15 + 0.73 AA	0.59**[2]	FE = 42.85 + 0.57 AA	0.53**
	FE = 117.61 + 1.50 C	0.64**	FE = 118.24 + 1.15 C	0.55**
	FE = 48.30 + 0.19 TSW	0.46**	FE = 60.08 + 0.18 TSW	0.61**
	FE = -104.50 + 1.85 G	0.10ns[2]	FE = -96.76 + 1.87 G	0.15ns
Whero	FE = 45.30 + 1.43 AA	0.81**	FE = 26.84 + 1.26 AA	0.72**
	FE = 114.74 + 1.67 C	0.87**	FE = 114.68 + 1.48 C	0.78**
	FE = 46.59 + 0.19 TSW	0.63**	FE = 51.92 + 0.18 TSW	0.66**
	FE = -651.95 + 7.43 G	0.53**	FE = -589.44 + 6.83 G	0.51**

[1] AA = accelerated ageing; C = conductivity; TSW = thousand seed weight; G = laboratory germination.
[2] ** = highly significant relationship ($P < 0.01$); ns = non significant ($P > 0.05$).

had a higher LAI and longer LAD (Table 4). The lowest vigour seed lots (B4 and W4) gave rise to both low LAI and LAD compared to the other lots (Table 4). Leaf area duration influenced seed yield as shown by the highly significant relationships in seed lots of cv. Beaon (R^2 = 0.92**) and cv. Whero, (R^2 = 0.87**).

Total dry matter, seed yield and yield components

At final harvest TDM did not differ between sowing dates but did differ between cultivars and among seed lots (Table 5). Cv. Whero gave a higher mean TDM than cv. Beacon. Plots for the lowest vigour seed lots (B4 and W4) had 54 - 60% less TDM compared with others. Seed yield was not influenced by sowing date or cultivar but was significantly influenced by seed lot.

Table 4. Leaf area index (LAI) at 70 DAE and leaf area duration (LAD) of field pea plants grown from seed of varying vigour.

	LAI	LAD (days)
Sowing date		
August	3.25	65
October	2.98	52
Significance	NS	*
Seed lots		
Beacon		
B1	3.3ab[1]	51.8b
B2	3.1b	65.0ab
B3	3.6ab	68.3ab
B4	0.7d	14.1d
B5	3.3ab	52.5b
B6	3.3ab	52.9b
Means	2.88	51
Whero		
W1	3.9a	71.6a
W2	3.7ab	77.5a
W3	3.8ab	76.3a
W4	1.5c	33.6c
W5	3.5ab	71.8a
W6	3.7ab	66.0ab
Means	3.35	66
Significance		
Cultivar	**	**
Seed lot	**	**
CV (%)	17	17

[1] column figures within cultivar followed by the same letter are not significantly different at $P < 0.05$.

Again, in the lowest vigour seed lots (B4 and W4) seed yield was reduced by 57 - 68%. Pods per plant and TSW were also lower in these low vigour seed lots.

Discussion

Clear field performance differences, both in final emergence and emergence rate were apparent among seed lots with different vigour levels, especially when they were sown under cold, wet conditions. In both cultivars, high vigour seed lots exhibited the ability to withstand wet and cold conditions, with some seed lots having an emergence >90%. Low vigour seed lots emerged poorly and more slowly in the August sowing. This was not unexpected as Powell (1988) and TeKrony and Egli (1991) have reported that high vigour seed lots emerged better and faster than low vigour seed lots under stress conditions despite the fact that they had similar high laboratory germination percentages. Mean seedling emergence over all seed lots did not differ between sowing dates. However, most seed lots showed increased emergence under the warmer conditions following the October sowing, even to the extent that one low vigour seed lot (B5) had a significant increase (18%). This indicates the importance of seed vigour status and the effect that environmental conditions can have on field emergence variation (ISTA 1995).

Physiological deterioration associated with membrane damage may be implicated as a cause of low seed vigour (ISTA, 1995). The low vigour seed lots used in this experiment had been harvested early from plants grown under shade. Mechanical damage was unlikely to be involved since all seeds were hand harvested. Poor membrane integrity allows greater electrolyte leakage from seed during the conductivity test, and high conductivity values are associated with low vigour. This membrane damage has been linked to immaturity and post-harvest drying damage (Matthews, 1973; Bedford and Matthews, 1975; Powell, 1988). In addition, receiving limited assimilate supply from the mother plant grown under shade may disadvantage seed development, as has already been shown by the smaller seeds (Table 1). Conductivity of seed lots B4 and W4 was high (c. 41 µS/cm/g). Membrane integrity and the ability to withstand post-harvest drying damage increases in more mature seed (Bedford and Matthews, 1975; Powell, 1988). However, markedly inferior vigour seeds harvested from shaded plants were still present in cv. Beacon harvested 35 DAF (conductivity of this seed lot (B5) was 33 µS/cm/g). Other seed lots including all those harvested from plants grown in full sunlight had higher vigour and lower conductivity (< 30µS/cm/g).

Table 5. The influence of sowing date and field pea seed lot vigour on seed yield and yield components of the subsequent crop.

	TDM (g/m²)	Plants/m²	Pods/plant	Seeds/pod	TSW (g)	Seed yield (g/m²)
Sowing date						
August	779	17	25.8	5.4	220.4	418
October	865	18	22.5	5.8	227.8	404
Significance	NS	NS	NS	NS	NS	NS
Seed lots						
Beacon						
B1	809a[1]	18a	23.4ab	6.8a	187.5c	433a
B2	795a	20a	22.7ab	6.5ab	194.2c	407a
B3	915a	18a	26.6a	6.9a	191.8c	510a
B4	362b	12b	16.5b	6.0c	155.2d	176b
B5	835a	20a	23.9ab	6.4ac	183.0cd	470a
B6	793a	20a	23.0ab	6.3bc	190.3c	426a
Means	752	18	22.7	6.5	183.7	404
Whero						
W1	941a	17a	29.0a	4.5b	239.7ab	416a
W2	1087a	18a	25.9a	4.7ab	269.3a	534a
W3	1001a	20a	28.1a	4.6ab	251.3a	456a
W4	408b	10b	21.7ab	4.3b	211.2bc	169b
W5	934a	18a	27.6a	5.0a	245.7a	466a
W6	986a	19a	21.6ab	4.3b	250.0a	415a
Means	893	17	25.6	4.6	242.7	418
Significance						
Cultivar	**	NS	*	**	**	NS
Seed lots	**	**	*	**	**	**
CV (%)	20	15	25	8	9	29

[1] column figures within cultivar followed by the same letter are not significantly different at $P < 0.05$.

This presumably reflects better developed membranes and perhaps a greater ability to withstand post-harvest drying damage of these seed lots.

Conductivity, accelerated ageing and TSW were better field emergence predictors than the laboratory germination test. The conductivity test has been extensively used to predict field emergence in wrinkled-seeded peas (Hampton and Coolbear, 1990; Castillo *et al.*, 1993), and other legume seeds (Powell *et al.*, 1984). Accelerated ageing has mainly been used to predict field emergence in soybeans (ISTA, 1995). Both conductivity and accelerated ageing are now accepted as recommended vigour tests (ISTA, 1995). However, the variation between cultivars found in the present work, supports the suggestion of Powell *et al.* (1997) that the relationships between conductivity and ageing tests and field emergence in field peas may need to be evaluated for each cultivar, or possibly for groups of cultivars (e.g., white seeded).

Seed weight was also well related to field emergence. Seed weight indicates the extent of stored food reserves in the seed which are important for both germination and seedling emergence. However, the small seeds used in the present work (TSW < 70 g) would be discarded during seed cleaning in commercial seed processing plants. This suggests the value of a minimum seed size standard for commercial pea seed, rather than indicating the field emergence potential of the seed lot generally.

Laboratory germination tests had little or no relationship with field emergence in cv. Beacon seed lots. This supports previous works by Lilley (1989) and Powell *et al.* (1997) who both indicated that germination was generally a poor field emergence predictor in field peas.

Low vigour seed lots gave lower plant populations which resulted in low LAI and this was translated through to low LAD. The lower rate of emergence may also have reinforced the lower LAI and LAD. Moot (1993) reported that variation in emergence dates causes differences in plant height, weight and ground cover between high and low vigour cultivars of peas. Therefore, crops from low vigour seeds had a substantially lower potential to capture solar radiation and produce seed yield. LAD had an important role in seed yield as shown by the highly significant relationship in both cv. Beaon (R^2 = 0.92**) and cv. Whero (R^2 = 0.87**). This finding is supported by Laing *et al.* (1984) who reported similar relationships in eight legume species (R^2 = 0.99**).

At final harvest, low plant population from low vigour seed lots B4 and W4, resulted in reduced TDM and seed yield. This agrees with work by Egji and Burris (1971), Egli and TeKrony (1979) and Hampton and Scott (1982) who have all reported reductions in seed yield from sowing low vigour seed because of lower plant populations.

Conclusions

1. Field pea seeds with low vigour had a reduced final emergence and emergence rate, especially when sown under wet, cold conditions. The reduction in seedling emergence of seed lots under adverse conditions varied according to the vigour status of a seed lot.
2 The reduction in seedling emergence of low vigour seed lots resulted in low plant populations, low LAI and LAD. These led to lower plant growth and seed yield at both sowing dates.
3. Conductivity and accelerated ageing tests were both useful in predicting field emergence potential of field peas in seed lots of both cultivars, especially in situations where seed was sown directly into a wet, cold seed bed.

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