SEEDLING VIGOUR IN WINTER
GRAIN LEGUMES

by

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Grain legumes often have a slower rate of establishment and less vigorous early growth compared to cereals. This reduces their competitiveness with weeds and may lower their water use efficiency because of the high proportion of evapotranspiration from soil evaporation early in the season. Consequently, grain legumes may not be achieving their maximum yield potential and improvements in seedling vigour may increase productivity. A series of experiments was therefore conducted to study the level of variation in seedling vigour among and within species of grain legumes, to examine some factors that might affect their early vigour and to examine the importance of early vigour to grain yield.

Experiments were conducted on chickpea, lupin and pea in the field and glasshouse; within each experiment, a number of varieties of each species were compared. The length of the experiments varied according to the aims of study. In studies on the effects of seed size and seed composition on early growth, the experiment was limited to the first 5 weeks after sowing, while to examine the effects of these factors on both early growth and yield, the experiment lasted the whole of the plant growing season. A series of glasshouse experiments was set up to examine the effect of seed size on early growth between and within species each with at least 4 varieties. The effect of seed size on early growth and grain yield between and within species was also studied under both glasshouse and field conditions. Another set of experiments was conducted to determine the effect of seed protein concentration on early vigour in chickpea, lupin and pea. On the basis of the results of this experiment the effect of seed protein and the seed mineral composition on the early growth of pea cultivars were examined. Other glasshouse and field experiments were carried out to study the genetic aspects of seedling vigour in chickpea, lupin and pea. These experiments were followed by a detailed examination of genetic variation of seedling vigour in a wide
range of pea genotypes under glasshouse and field conditions.

**Methods**

A number of statistical methods were used to analyse the data. Apart from analysis of variance, Pearson simple correlation, Spearman's rank correlation, multiple regression, and multivariate analysis (principal component analysis) were used extensively in most of experiments to interpret the variation in the original data.

In a number of experiments seed was graded into small and large sizes. Initial seed size and early growth of individual plants in 3 grain legumes (chickpea, lupin and pea), but its effect tended to diminished with plant age. Experiments conducted in both the glasshouse and in the field demonstrated that generally the effect of seed size on grain yield is not important, despite its positive affect on early growth. However, in one glasshouse experiment (Chapter 4), seed size positively affected both early growth and yield in lupin, while there was no such effect in chickpea and pea.

In a glasshouse experiment (Chapter 3) in which early growth of pea, lupin and chickpea were compared, seed protein concentration was positively correlated with early vigour in pea cultivars, whereas there was no significant relationship in lupin and chickpea. Subsequent experiments with a wider range of pea cultivars (Chapter 6) found that besides seed protein concentration, P, Mn, Zn, Ni, K and S were positively correlated with seedling growth, while the correlations between seed B and Al concentrations and seedling growth were negative. Using seed from different sites, which had significantly different seed mineral concentrations, had no significant effect on early growth, this was possibly because the differences in concentration for many nutrients were small. However, there was significant genotypic variation in the concentration of seed micro-elements among pea cultivars, which was considerably greater than that between sites. Variation in seedling growth between cultivars was correlated with their mineral composition. From these results the following con-
cclusions on variations in the seedling vigour can be drawn: the effect of environment during seed filling was not important to early growth, but genotype was the main factor which affected seedling growth; the vigorous cultivars were those able to accumulate more nutrients in the seed; or the differences in seed composition were not large enough to affect seedling vigour.

The experiments found significant variation in early growth within grain legumes, both between species and between cultivars within a species. Although seed size and seed composition were correlated with early growth, the correlation between seed composition and early growth in these experiments was mainly due to genotype. To identify vigorous genotypes early in the growing season, and to relate early vigour to higher biomass production and grain yield, two indices, Varietal Efficiency (VE) and Emergence Efficiency (EE%) were devised. VE was based on an individual plant growth rate and its initial seed weight, and EE% was based on the number and speed of seedling emergence per unit area. The formulae for VE and EE% are:

\[
VE = \frac{\text{Growth Rate (mg. day}^{-1})}{\text{Seed Weight (mg)}}
\]

where growth rate was calculated for the dry weight increase between 21 and 35 days after emergence, and

\[
\text{EE}\% = \left(\frac{1}{2} + \frac{b}{3} + \frac{c}{4} + \frac{d}{5} + \frac{e}{S}\right) \times 100
\]

where a, b, c, d, and e are the number of seeds which emerge after 1, 2, 3, 4 and 5 days after sowing and S is the total number of seeds to have emerged.
In a number of experiments which examined early growth only, genotypic differences in VE were noted and these were positively correlated with early vigour. It appeared that there were differences in early growth independent of seed size. However the results of both glasshouse and field experiments showed no significant correlation between VE and grain yield. However, in one field experiment (Chapter 5) when VE was measured over the period between 50 and 100 days after sowing (equal to 21 and 71 days after final emergence) there was a significant correlation between VE and grain yield in chickpea and lupin, but not in pea. This suggested that growth of the plant at later stages of growth may be more important to grain yield than early growth. There was no consistent relationship between EE% and crop growth and yield in the 3 grain legumes. Although the experiments found a positive effect of EE% on growth and yields in pea, there was no such effect in chickpea and lupin. However, emergence number had a positive effect on crop growth and yield in all 3 species. A set of experiments which was conducted in a variety of environmental conditions demonstrated that there is a genetic variation in seedling emergence among grain legumes which strongly affect crop productivity. A later experiment also found that in pea EE% is an important factor in the yield. This indicates that apart from emergence number, speed of emergence can affect crop growth and yield in pea cultivars.

The relationship between early vigour and grain yield per plant was not consistent in all genotypes. More vigorous cultivars did not necessarily produce high yield. For example, among pea cultivars, Alma, Dundale and Maitland had higher early growth per plant, while only Alma and Dundale had higher grain yield. There was a significant correlation between total biomass at maturity and yield in chickpea, lupin, and pea. Principal component analysis (PCA) was used to identify the genotypic differences among cultivars within species. Among 6 chickpea cultivars, the 3 desi types had greater vegetative growth and yield per plant than the 3 kabuli types. However the early growth of kabuli types was higher than desi types, which might be due to the larger initial seed weight of kabuli types compared with.
dest types. In lupin, Merrit, Gungurr and Dunja showed greater early growth and yield per plant and per m². Among pea cultivars, Alma and Permaht had the highest early vigour per plant, while Derminut with lower early vigour per plant, produced the highest grain yield per plant and per m². In another field experiment which was conducted on a wider range of pea cultivars (15 cultivars) with different growth habits (conventional and semi-sealless), varieties such as Derminut, Maitland, Glenroy and Alma which had higher EE% and higher leaf area early in the season had higher grain yield per unit area in comparison with varieties such as Dinkum, Bluey and A163-5 with a lower EE% and lower leaf area. Although the early growth of the individual plants in varieties such as Derminut was low, their greater and more rapid emergence resulted in higher field performance and grain yield per m². In this experiment there was a high density of the weed bedstraw (Galium triflorum), but the growth and seed yield of weeds in the plots were lower in plots of cultivars with higher EE% and greater early growth. It was concluded that genotypes with faster and higher emergence are able to compete very efficiently with weeds and have higher genetic potential for yield production. Seed of varieties from different sources (sites, years) was compared in experiments. This showed that the genotypic differences were similar irrespective of the seed source, i.e., the genotype × environment interaction appeared to be small. There was also a positive association between EE% and WUE among pea cultivars. The cultivars with higher EE% produced higher dry matter throughout growing season, competed more efficiently with weeds, and finally had higher WUE and grain yield. This suggests that cultivars with high number and faster emergence can cover the soil surface, prevent soil evaporation and weed growth, therefore grow better and produce higher grain yield.

One of the important results which all experiment showed was the importance of the later vegetative growth of the crop, in particular growth near flowering, to grain yield in all 3 species. This suggests that identifying those factors which directly or indirectly may have an effect on vegetative growth around flowering may also effect grain yield. Dry matter pro-
duction at this period was not correlated with early vigour.

Therefore, it is concluded that the most of the observed variation in seedling vigour is due to genetic factors. Initial seed weight less important to crop productivity in grain legumes in contrast to the many reports of its positive effect in cereals. Seed composition was not greatly affected by seed source and had little influence on seedling growth in pea cultivars. However, the differences in early growth between genotypes mirrored their differences in seed composition. This may suggest that the effect of environment on seedling vigour is small in comparison with genotype. However, to confirm this, a wider range of sites needs to be examined. Early vegetative growth is not associated with grain yield, however later vegetative growth near flowering time appears to be more important. Therefore, any means which affects the vegetative growth at later stages of crop growth may affect grain yield in grain legumes.