Population and sowing depth effects on yield components of grain legumes

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ABSTRACT

Desi chickpeas (*Cicer arietinum*), lentils (*Lens culinaris*), narrow leafed lupins (*Lupinus angustifolius*) and field peas (*Pisum sativum*) were sown at three plant populations (10, 100 and 400 plants/m^2) and three depths (2, 5 and 10 cm) at Lincoln University during 1999/2000. Lupins produced the most total dry matter (TDM) (972 g/m^2) and lentils the least (468 g/m^2). As there was relatively little variation in harvest index (HI) (0.54, lupin; 0.61, lentil), seed production followed a similar trend to TDM and ranged from 293 g/m^2 in lentil to 527 g/m^2 in lupin. There were a number of significant interactions. Pods/plant was the most variable yield component. It fell rapidly as plant population increased.

Key words

Grain legumes, plant population, sowing depth, seed yield, yield components.

INTRODUCTION

Yield variability is a global problem in grain legumes, which can lead to low yields (1,8). This variability can be reduced by manipulating population density and sowing pattern. More uniform sowing may give rise to less variable populations with reduced plant to plant variation and increased yields (9).

As plant density increases, intensity of interplant competition increases and yield/plant declines, although total yield/unit area may increase (10). Seed yield, total dry matter (TDM) and harvest index (HI) of lentils (*Lens culinaris*), chickpeas (*Cicer arietinum*), peas (*Pisum sativum*) and faba beans (*Vicia faba* L.) increase as plant populations increased (2,3,5,18). Optimum yields (e.g. in *Phaseolus*, (12)) have been found at equidistant inter, - and intra-row spacings (16). Many components of seed yield are inversely related to population density (2,3,14).

Increased sowing depth may benefit crop establishment if additional moisture is available in the subsoil or it may lead to increased variability in time to emergence. Deep sowing (10 cm) has often been shown to increase seed yield in chickpeas, faba beans, lentils and field peas (17,18). In contrast, Wangdi *et al*. (21) found no significant effect of sowing depth on TDM of lupins while Siddique *et al*. (19) reported reduced yield with deep sowing.

The Canterbury area of New Zealand has a high yield potential for grain legumes (10,13). The only published data on the effect of sowing depth on legumes under field conditions in Canterbury is for Russell lupins (21). However, there is little published information on the effect of the combination of grain legume plant population and sowing depth. This study was conducted to investigate the effect of population density and sowing depth on; variability in yield and HI; the relationship between TDM and seed yield; and the relationship between seed yield and its components in four grain legumes.

MATERIALS AND METHODS

The experiment was conducted at the Henley Research Area, Lincoln University, Canterbury (47?^{o} 38 'S)during the 1999/2000 growing season. The four legume species, *desi* chickpeas, lentils, narrow leafed lupins and field peas were main plots. Each was sown at three populations (sub-plots, 10, 100 {optimum} and 400 plants/m^2) and three depths (sub-sub-plots, 2, 5 and 10cm)). All species were sown between 19 and 24 October 1999 (one replicate/two days) in an equidistant arrangement of 31.5 x 31.5 cm, 10?x?10?cm and 5 x 5 cm, using hand dibbers. Seed was treated with captan (125 g ai/100 kg of seed). Before sowing, the field was prepared by ploughing, harrowing and rolling to produce the seedbed. A pre-

sowing spray of glyphosate at 360 g a.i./ha, a pre-emergence spray of cynazine at 500 g a.i./ha and a post emergence spray of haloxyfop at 100 g a.i./ha were applied in 237 litres of water/ha. Further weed control was by hand weeding soon after weed emergence. No irrigation (due to sufficient rainfall) and no fertiliser were applied. The experiment was a split-split plot design with three replicates.

At crop maturity, when more than 95 % of the plants in any species had completely lost their green colour, an area of 0.2 m^2 of plants was hand harvested. Yield and its components were determined on a dry matter basis after drying at 70 ^oC. Data were analysed statistically using SYSTAT. Fisher's protected LSD was used for mean separation.

RESULTS AND DISCUSSION

To understand the effect of a treatment on a character both the significance and magnitude of the effect need to be considered. Thus, Table 1 gives the significance and proportion of the total sum of squares associated with each main effect and interaction. For the characters, species and population and their interaction were significant and accounted for at least 96% of the total variability. Depth was also highly significant in all situations though generally accounting for relatively little of the total variability. The interactions with depth were occasionally significant but of insufficient magnitude to be important. Therefore, the discussion will concentrate on species, population and their interaction.

Table 1. Significance levels for legume species, population, depth and their interaction for total DM, harvest index, seed yield and yield components.

	TDM (g/m^2)	Seed yield (g/m^2)	HI	Pods/plant	Seeds/pod	Seed weight (mg)
Legume species	54@***	30***	17*	24***	91***	69***
Population	43***	65***	62***	59***	3***	5.5***
Depth	0.14***	0.43***	2.00***	0.06***	0.09***	0.85***
Species x population	2***	3***	6***	16***	0.88*	2*
Species x depth	0.03**	0.05*	0.41 ns	0.02*	0.06 ns	0.78*
Population x depth	0.01 ns	0.02 ns	0.82 ns	0.01*	0.04 ns	0.44 ns
Species x population x depth	0.04 ns	0.04 ns	0.61 ns	0.01ns	0.09ns	0.64 ns

@ values are the mean square for the factor divided by the total sum of squares.
*p < 0.05; **p < 0.01;*** p < 0.001; ns = not significant.

Total dry matter yield

The highest mean total dry matter (TDM) production over all populations and depths, was 972 g/m^2 from lupins followed by chickpeas at 800 g/m^2 (Table 2). Species differences in TDM were dependent on growth duration. Lupins and chickpeas had a much longer growth period than peas or lentils (3) and the opportunity to intercept more light and consequently produced more dry matter (6). The regressions of TDM and other characters against Log_e[population] indicated a high degree of linearity, hence slopes and regression coefficients for all characters are presented in Table 3. Lentil TDM production varied the most over the three populations with a 200 % increase compared with only a 35 % increase in lupins. When the slopes of the regressions are compared (Table 3), chickpea was the most responsive (b = 143, r^2 = 0.99) and lupin the least responsive (b = 77, r^2 = 0.96). Lupins, had a very long growth duration, with most of their growth occurring after canopy closure irrespective of plant population. Consequently, they were less responsive to population density (3).

Seed yield

The highest seed yield (527 g/m^2) was produced by lupins while the lowest (293 g/m^2) was produced by lentils (Table 2). Chickpea responded strongly (b = 118, r^2 = 0.99) to population while lupins responded least (b = 70, r^2 = 0.96). The effect of plant population on seed yield was consistent with published data (2,3,5,12). Overall, yield approximately doubled as population increased from 10 to 100 plants/m^2. However, the additional four-fold increase in plant population to 400 plants/m^2 only increased yield by about 30 %. The lowest seed yield was for a low population of faba bean (2). The results indicate that as spacing increased, branching increased (data not shown). Over all, seed yield was negatively and strongly correlated (r = -0.72 **) with pods/plant. However, the correlation between yield and seed weight was weak (r = 0.23 *) and for seeds/pod it was not significant (r = 0.03 ^{ns}).

Harvest index

Harvest index was variable over species, populations and depths. The highest HI (0.61) was recorded in lentils and the lowest (0.54) in lupins (Table 2). Compared with plants sown at 10 plants/m^2, plants sown at 400 plants/m^2 significantly ($p < 0.001$) increased their HI from 0.50 to 0.63. The interaction between species and crop population showed that HI varied in all species from low to high population. Moot and McNeil (15) also found variation in the HI of peas from 0.53 to 0.62.

Table 2. Main effect values for seed yield and yield components of four legume species at three plant populations (plants/m^2) and three sowing depths (cm).

Legume species	TDM	Seed yield	HI	Pods/plant	Seeds/pod	Seed weight
Chickpeas	800	458	0.55	52.0	1.3	141
Lentils	468	293	0.61	67.4	1.4	56
Lupins	972	527	0.54	22.8	4.2	132
Peas	595	351	0.58	12.9	5.2	106
S.E.	7.2	5.3	0.01	1.80	0.17	6.7
Significance	***	***	*	***	***	***

Population						
10	484	236	0.50	87.3	3.3	118
100	742	423	0.58	19.2	3.1	112
400	900	563	0.63	9.7	2.6	96
S.E.	3.7	2.8	0.004	1.64	0.06	2.5
Significance	***	***	***	***	***	***
Depth						
2	696	394	0.56	37.3	3.1	114
5	711	407	0.57	39.1	3.0	107
10	720	420	0.58	40.0	2.9	106
S.E.	1.8	1.6	0.003	0.23	0.019	1.5
Significance	***	***	***	***	***	***
CV %	1.5	2.4	3.3	3.5	3.8	8.2

Table 3. Slopes (b) and regression coefficients (r^2) for plots of species vs $\log_{(e)}$ population.

	Total DM		Seed yield		Harvest index		Pods/plant		Seeds/pod		Seed weight	
Species	b	r^2	b	r^2	b	r^2	b	r^2	b	r^2	b	r^2
Chickpeas	143	0.99	118	0.99	0.10	0.99	-29.6	0.90	-0.10	0.83	-9.4	0.71
Lentils	118	0.99	84	0.99	0.03	0.99	-35.8	0.95	-0.11	0.98	-1.0	0.83
Lupins	77	0.96	70	0.96	0.03	0.99	-14.5	0.92	-0.34	0.97	-6.2	0.99
Peas	111	0.99	78	0.99	0.02	0.99	-7.4	0.93	-0.23	0.81	-5.4	0.66

A high TDM resulted in a high HI (Table 1). At 400 plants/m^2, all species had a high HI, but the highest increase (45 %) in going from low to high population from 0.44 to 0.64 was in chickpeas (b?=?0.10, r^2 = 0.99). For peas the increase was only about 17 % (b = 0.02, $r^{2?}$= 0.99). Effendi *et al*. (5) and Ayaz *et al*. (3) also reported increases in HI with increased population. There were strong negative correlations between HI and pods/plant (r = -0.51 **) and HI & mean seed weight (r = -0.46 **).

There was a positive, linear and highly significant relationship between TDM and seed yield (data not presented). The r^2 was more than 90 %. Effendi *et al*. (5) also in a plant population study found that seed yield was strongly associated with TDM in lentils. Other studies have shown similar correlations for chickpeas, lentils, lupins and peas (3,4,19).

Yield components

All yield components were highly influenced by population (Table 1). Mean seed weight (141?mg), pods/plant (67) and seeds/pod (5.2) were greater at low populations for chickpeas, lentils and peas, respectively (Table 2). All species showed this tendency. The interaction of species by population showed that chickpeas produced the highest (155 mg) and lowest (117 mg) seed weights (b? = -? 9.4, r^2 = 0.71) when sown at the lowest and highest densities. Lentils produced their maximum seed weight of 57 mg at the low population and this changed little with increased population (b = -1.0, $r^{2?}$= 0.83). Heath *et al*. (7) also reported a trend for decreased seed weight with increased plant population.

The number of pods/plant and seeds/pod were inversely related to crop population. Lentils consistently had more pods/plant than chickpeas, lupins and peas. Among species, lentils produced more (66) pods/plant at shallow sowing and this increased to 69 pods/plant at the deepest sowing. Heath *et al*. (7) and McKenzie *et al*. (15) reported similar trends in peas and lentils.

The number of seeds/pod decreased as crop population increased. Maximum seed number/pod (5.5) was recorded in peas at the lowest population. The greater number of pods/plant, seeds/pod and seed weight at the low plant population of grain legumes were also reported by Hernandez?(11), McKenzie *et al.* (15) and Heath *et al*. (7). Heath *et al*. (7) further mentioned that as plant population decreased, individual plants produced progressively more branches and more seeds/pod and pods/plant.

CONCLUSIONS

1. This study showed that higher yields of grain legumes can be achieved as row spacing is reduced where inter, - and intra-row spacings are similar.

2. For all of the legumes studied, seed yield, TDM and HI increased slightly with deep (10 cm) sowing.

3. Chickpeas were most responsive to increased population for TDM, seed yield and HI while least for seeds/pod.

4. All yield components were inversely related to plant population.

5. Not all yield attributes were related to seed yield.

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