EFFECT OF PLANT POPULATION AND INOCULATION ON YIELD AND YIELD COMPONENTS OF CHICKPEA (*CICER ARIETINUM* L.)

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ABSTRACT

Chickpeas (*Cicer arietinum* L.) were sown at four populations from 33 to 133 plants/m² with and without inoculation. Seed yield per unit area decreased linearly with increasing plant population. The highest yield of 208 g/m² was obtained at a population of 66 plants/m². Inoculation with *Rhizobium* strain CC1192 increased yield by 29%. This increase was associated with significant increases in branches per plant and number of pods per plant. Correlation analyses showed that pods per plant and seed yield per plant were positively related to yield per unit area. Mean seed size and seed nitrogen concentration were not affected by the treatments imposed.

INTRODUCTION

Chickpea (*Cicer arietinum* L.) also known as gram or garbanzo is the third most widely-grown grain legume in the world. Over 6 million tonnes of this crop are produced annually in many countries of Asia, Africa, Europe and South, Central and North America (FAO, 1982).

Almost 90% of the world's chickpea is grown in the Indian sub-continent where the crop consists primarily of ancient land races grown on poors soils without the benefit of irrigation. As a result, yields averaged only about 700 kg/ha (FAO, 1982). Yields however can be increased considerably by using improved cultivars and sound agronomic practices. For example, yields from 2.5 to 3.0 tonnes/ha have been achieved in the U.S.A. using improved cultivars (Muehlbauer *et al.*, 1982) and up 3.4 tonnes/ha have been recorded in Australia following timely sowing, effective weed control and non-limiting soil moisture (Knights *et al.*, 1980).

Chickpeas have been divided into two broad groups based on seed size, shape and colour. The kabuli types produce seeds in excess of 26 g per 100 seeds and are rounded and pale cream. The desi types produce seed less than 26 g per 100 seeds and can be irregularly shaped and of various colours. Kabuli types account for 10 to 15% of world chickpea production (Hawtin *et al.*, 1980).

Chickpea is a cool season annual crop with an erect or spreading growth habit. It is freely branched, indeterminate and reaches a height of 25-50 cm. The non-shattering pods are held several centimeters above the ground surface and each pod contains one or two seeds. Eighty-five percent of the pods come from the primary and secondary branches and only 10% from the main stem. The tertiary branches contribute little to the total yield (Saxena and Sheldrake, 1976).

When effectively nodulated, the chickpea crop can enrich the soil through its nitrogen fixing characteristics and therefore may have a place in a crop rotation system, especially after cereals. Chickpea however, has been considered *Rhizobium* specific (Raju, 1936) and introduction of strains of rhizobia has been necessary to nodulate the crop when grown on new land (Corbin *et al.*, 1977).

The crop is virtually unknown in New Zealand and all of our requirements for culinary chickpeas are met by imports. To evaluate the potential of the crop in the Canterbury environment, a trial was sown to investigate the effect of plant population and inoculation on seed yield and components of yield.

MATERIALS AND METHODS

The experiment was conducted at the Lincoln College Research Farm on a Templeton silt loam soil previously cropped with wheat. Phosphate fertilizer at the rate of 25 kg P/ha was broadcast and incorporated before sowing. Treflan pre-emergence herbicide was applied at 2 kg a.i./ha in early November 1981.

Seed of kabuli type, variety Asia, pre-treated with Thiram fungicide was sown using a Stanhay seeder on 17 December 1981 in 15 cm rows at four populations ranging from 33 to 133 plants/m² with and without inoculation. Marble chips inoculated with strain CC1192, were drilled into respective plots immediately before sowing at 40 kg/ha. Plots were 1.5 by 10.0 m, arranged in randomised blocks with four replicates.

The crop received a total of 60 mm of water in two irrigations during the flowering and pod filling stages.

Plant population counts were made fortnightly from 4 weeks after sowing. On the eighth week, 10 plants from each were dug for nodule assessment. Nodules were scored on a scale of 0-5 based on the classification of Corbin *et al.* (1977). At maturity (25 April 1982), an area of 0.9 by 3.0 m from the centre six rows of each plot was manually harvested for yield determination. At the same time, 20 plants were taken at random from each plot for determination of components of yield. Sub-samples were taken and ground. A 300 mg sub-sample of seed meal was then analysed for seed nitrogen using micro-kjeldahl digestion and Autoanalyser measurement of the ammonia produced.

TABLE 1: Climatic data, Lincoln College, December 1981 to April 1982.

Year	Month	Temperature °C Mean max.	Mean min.	Photoperiod mean h/day	Rainfall (mm)
1981	December	22.2 (+1.8)*	12.0 (+1.6)	16.58	15.1 (-41.9)
1982	January	23.0 (+1.7)	11.3 (-0.2)	16.14	28.2 (-31.8)
	February	23.7 (+2.8)	11.0 (-0.4)	14.94	15.5 (-38.5) 30.0#
	March	21.3 (0)	10.6 (+0.7)	13.48	12.2 (-44.8) 30.0#
	April	15.5 (-1.2)	4.7 (-2.7)	11.98	46.6 (-9.4)

* Figures in parentheses indicate deviations from long term average
# Irrigation

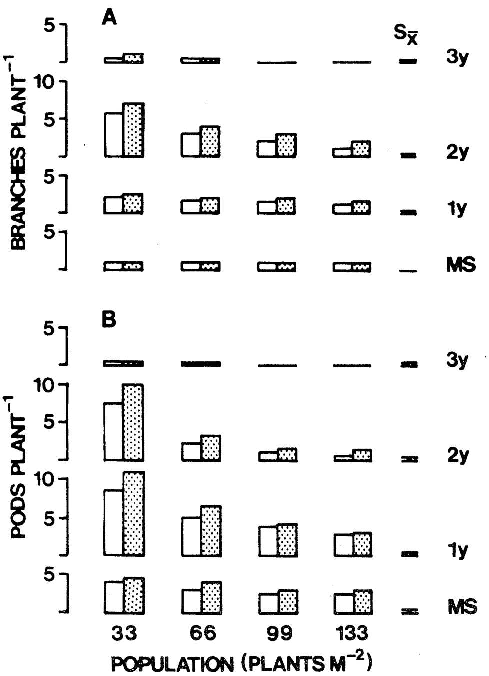

Figure 1: Influence of population and inoculation on (A) branches per plant and (B) pods per plant of *Cicer arietinum*. (shaded = inoculated).

RESULTS

Climate

The season was warmer and considerably drier than average until February (Table 1). The mean photoperiod of 14.6 h/day was considered long enough for the crop's growth and development (Roberts *et al.*, 1980).

Population and Nodulation

Table 2 gives the established plant populations 4 weeks after sowing and at maturity (18 weeks). The mortality rate ranged from 0.38 to 1.35 plants/m²/wk and increased as population increased. Inoculated plants nodulated well but no differences were observed between population treatments. The uninoculated plants did not form any nodules and were therefore not included in the analysis of variance.

Yield and Nitrogen Concentration

Seed yield per unit area decreased linearly with increasing population (Table 3). The quadratic response was also significant ($p \leq 0.05$). The highest yield of 298 g/m² was achieved at a population of 66 plants/m². Inoculation increased seed yield by 29% but neither population nor inoculation treatments affected seed nitrogen concentration.

Components of Yield

There were no significant differences between treatments in the number of seeds per pod and mean seed weight (Table 3). Seed weight per plant decreased linearly ($p \leq 0.001$) with increasing populations. Seed production ranged from 1.9 g/plant at 133 plants/m² to 6.5 g/plant at 33 plants/m². Variation in seed weight per plant was associated with significant differences in branches per plant and number of pods per plant.

The total numbers of branches and pods per plant were greatly influenced by both population and inoculation treatments (Table 3; Fig. 1). Branching was considerably suppressed at the highest population (133 plants/m²) which produced only 4.2 branches/plant while more than twice as many (10.3 branches/plant) were formed at 33 plants/m². The number of secondary branches contributed most to this increase. At 33 plants/m² without inoculation, each plant formed 5.7 branches; inoculation increased this to 7.1 branches/plant. In contrast, plants grown at 133 plants/m² formed 1.3 branches without inoculation and 2.1 branches/plant when inoculated.

The number of pods per plant also declined with increased plant population, ranging from 22.7 at 33 plants/m² to 7.1 pods/plant at 133 plants/m² (Table 3). This difference was mostly due to the greater number of pods produced on the primary and secondary branches at low populations (Fig. 1). Plants at 33 plants/m² had 8.3 and 7.4 pods/plant on the primary and secondary branches respectively without inoculation; these were increased to

TABLE 2: Plant populations at 4 and 18 weeks after sowing and nodule score in *Cicer arietinum* L.

Desired	Population (plants m²) 4 weeks	18 weeks	Mortality rate (plants/m²/wk)	Nodule Score* (0-5)
33	39.0	33.8	0.38	4.33
66	73.5	67.5	0.43	4.18
99	100.5	88.8	0.84	3.78
133	122.6	103.8	1.35	3.47

*Means for inocluated treatment (i.e. nodules absent in uninoculated plants)

11.0 and 9.8 pods/plant respectively with inoculation. On the other hand, plants grown at 133 plants/m² had 0.5 pods on the secondary branches when not inoculated and 1.6 pods/plant when inoculated. Overall, variation in mainstem pod numbers was less, with a difference of only 1.7 pods/plant between the lowest and highest populations compared with differences of 5.2 and 7.6 pods/plant for primary and secondary branches respectively. Few pods (0.11/plant) were formed on the tertiary branches at low populations (33 and 66 plants/m²) and none at high populations (99 and 133/m²). There was a significant ($p \leq 0.05$) population by inoculation interaction in the number of pods per plant due to the small increase in pod number at high populations for inoculated plants (8.2 to 8.4 pods/plant) compared to the much larger increase for inoculated plants (6.0 to 7.5 pods/plant).

Characters Correlated with Yield

There were positive correlations between yield per unit area and yield per plant and both the number of branches and pods per plant (Table 4). Plant population was negatively correlated with yield per plant, branch per plant and pods per plant. The relationship between yield per plant and branch per plant was highly positive as was the relationship between yield per plant and pods per plant.

DISCUSSION

The yields obtained from this trial were considerably higher than those reported form India (Saxena and Sheldrake, 1978) and compare favourable with those achieved in Victoria, Australia (Pye, pers. comm.). Lack of published information on chickpea yields in New Zealand prevents a better comparison. However, preliminary experimental results (Goulden, pers. comm.) showed that chickpeas can yield about 200 kg/ha under Canterbury conditions. The mean seed nitrogen concentration of 2.81% was within the range obtained from kabuli cultivars in India (Saxena and Sheldarke, 1976).

Plant population and inoculation had large effects on branch and pod formation. As many as ten branches per plant were formed at the lowest population, and compensated for the lower plant number. Roberts *et al.* (1980) also reported that more primary, and especially secondary branches were produced when effectively nodulated chickpeas are grown is well spaced and well irrigated conditions. At 133 plants/m², particularly without inoculation, branching was considerably suppressed with the secondary branches being the most sensitive to population increase. This indicates that interplant competition was sufficiently intense at high populations

TABLE 3 The effect of population and inoculation on seed yield, seed nitrogen and components of yield in *Cicer arietinum* L.

Population (plants/m²)	Yield (g/m²)	Seed nitrogen (%)	Branches/ plant	Pods/ plant	Seed/ pod	Seed wt g/plant	Mean seed wt (mg)
33	200	2.85	10.3	22.7	1.12	6.5	270
66	208	2.88	6.4	11.6	1.03	3.4	270
99	178	2.74	5.1	7.9	1.02	2.2	270
133	151	2.75	4.2	7.1	1.02	1.9	260
$S\bar{x}$	7.6	0.089	0.23	0.54	0.04	0.21	0.5
Significance	**L	NS	**L	**L	NS	**L	NS
Inoculation:							
Nil	161*	2.7	5.9	10.8	1.04	2.9	260
40 kg/ha	208*	2.8	7.2*	13.9*	1.06	3.9*	270
Interaction	NS	NS	NS	*	NS	NS	NS
C.V. (%)	11.6	9.0	10.1	12.4	10.9	12.6	5.9

TABLE 4: Correlation coefficients for plant population, yield and components of yield in *Cicer arietinum* L.

Character	Yield (g/m^2)	Plants $/m^2$	Yield/ plant	Branch/ plant	Pods/ plant	Seeds/ pod	Mean seed wt (g)
Yield (g/m^2)	1.000						
Plants/m^2	-0.472	1.000					
Yield/plant	0.708*	-0.913**	1.000				
Branch/plant	0.741*	-0.914**	0.990***	1.000			
Pods/plant	0.778*	-0.900**	0.997***	0.990***	1.000		
Seeds/pod	0.359	-0.391	0.479	0.493	0.371	1.000	
Mean seed wt (g)	0.497	-0.430	0.491	0.565	0.500	0.567	1.000

that severe limitation occurred in environmental resources available to individual plants. As a consequence interplant competition for nutrients and metabolites needed in the initiation and elaboration of reproductive structures might have occurred (Adams, 1967).

The growth of chickpea is indeterminate, i.e. the main stem and branches continue to develop during the reproductive phase. At this stage there is an increase in competition for assimilates and other nutrients between reproductive and vegetative sinks (Sheldrake and Saxena, 1979). Such competitive stress could have resulted in the lower number of pods formed in the higher order branches, as found here and other crops (e.g. Herbert, 1977). Greater vegetative growth in inoculated high-density plants as a result of nitrogen fixation may have intensified internal competition leading to a smaller increase in the number of pods as compared to the uninoculated plants.

Increase in populations did not affect seed number per pod and mean seed weight confirming the findings of Saxena and Sheldrake (1976). This suggests that competition was not severe enough to impose any limitations in these components of yield. Similar results were reported for navy beans (Goulden, 1976) where populations ranging form 25 to 104 plants/m^2 gave no significant differences in the number of seeds per pod or 100- seed weight.

Character association among yield components suggests that the positive correlations between the number of pods and branches which in turn were associated with seed yield may serve as a basis for selection. Pandya and Pandey (1980) also reported similar results indicating that the number of pods and number of branches are important yield — contributing characters in chickpea. Combined selection for high yield and good seed size may also prove effective in increasing yield as the latter had been shown to have a high heritability (Pandya and Pandey, 1980).

CONCLUSION

Chickpeas could be a potential new grain legume crop for Canterbury. Plant population of 66 plants/m^2 gave the highest yields per unit area but did not significantly differ with those obtained at 33 plants/m^2. It appears then that there is a need for further plant population studies to determine the optimum sowing rates for seed production, particularly with free-branching cultivars. The rhizobium specificity of the chickpea crop necessitates appropriate inoculation in fields where the crop has not been previously grown.

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