Leaf growth and canopy development in chickpea

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Abstract

Three experiments were conducted in 1990/91 and 1991/92 at Lincoln University examining the effects of sowing rate, sowing date, nitrogen application and rhizobial inoculation on growth and yield of chickpea (*Cicer arietinum* L.). The glasshouse study showed that the application of nitrogen at 6 rates from 0-100 kg N/ha gave increases in dry weight and leaf area per plant of 36-42%. Nodule dry weight per plant was reduced from 0.33 g with 0 kg N/ha to 0.18 g with 100 kg N/ha.

In the field experiments added N increased dry weight and seed yield significantly. Applied N at 100 kg/ha gave increases in leaf area index of 45, 35 and 0% at 191, 206 and 220 days after emergence respectively in the May sowing. Increased population significantly reduced solar radiation transmissivity from 0.45 at 15 plants/m^2 to 0.28 at 60 plants/m^2. Increased LAI gave significant increases in solar radiation interception from 638 to 713 MJ/m^2, 569-612 MJ/m^2 and 401-413 MJ/m^2 in May, August and October sowings respectively. Rhizobial inoculation had no effect on leaf area or yield. Increases in intercepted solar radiation were correlated with yield increases due to N application and sowing date. The utilization coefficient was 0.91 g DM/MJ PAR.

Introduction

Chickpea (*Cicer arietinum* L.) is the fourth most widely grown grain legume in world agriculture (F.A.O. 1989). Chickpea has very similar husbandry requirements to lentils (*Lens culinaris* Medik.), which over the past ten years have become an important part of the rotation of many Canterbury cropping farmers. There are two distinct types of chickpeas: Desi, which are usually dark in colour and have a 1000 seed wt of less than 260 g and Kabuli, which are beige and much larger, ranging from 260 g to 640 g/1000 seeds.

The world market for Kabuli chickpeas is increasing (McNeil, 1991). Chickpea is not grown commercially in New Zealand, but preliminary work by Hernandez (1986) showed that the plants grow well in Canterbury and yields of Kabuli of up to 2.7 t seed/ha were obtained. There is a lack of information on physiological responses of chickpea to the Canterbury environment. Therefore the objectives of this work were to determine the response of chickpea to sowing date and fertility level. In particular canopy development and radiation interception were studied.

Materials and Methods

Three experiments, conducted at Lincoln University, are described in this paper. Experiment 1 was a randomized split plot factorial design consisting of two varieties (Kabuli and Desi) and six applied nitrogen rates (0, 12.5, 25, 37.5, 50 and 100 kg N/ha) replicated 4 times. Inoculated seeds were sown in low N potting mix in 150 mm diameter pots. The plants were grown in a glasshouse under natural late summer daylight with a photoperiod of 12-14 hours. Water content was not allowed to fall below 0.75 of Field Capacity. Plants were harvested 5 weeks after sowing and leaf area (Licor model LI 3100 area meter), and leaf, stem and nodule dry weight measured.

Experiments 2 and 3 were field trials conducted on a Templeton silt loam soil at the Lincoln University Henley site. Experiment 2, replicated four times, was a randomized complete block factorial design with Kabuli and Desi type chickpeas sown at 15, 30, 45 and 60 plants/m^2 with 0 or 50 kg N/ha. The experiment was sown on 6 November 1990 into plots of 21 m^2. Dry matter production was estimated from 0.2 m^2 cuts and solar radiation interception was measured using tube solarimeters model TSM (Delta-T devices, Cambridge, U.K., see Szeicz, 1965).

The third experiment was another field trial located on a Templeton silt loam at the University Henley site. This was again a randomized complete block design with a factorial combination of three sowing dates (22 May, 29 August and 11 October, 1991). Two levels of Rhizobium inoculation (0, recommended rate) and two levels of nitrogen (0 and 100 kg N/ha). There were four replicates.

Sowing rate was 30 plants/m^2. The rhizobium inoculation treatment was applied as a seed coating at recommended rates (Coated Seeds Ltd, Christchurch). Leaf area index was measured using a LICOR LAI 2000 Plant Canopy Analysis.

Weather during the two field experiments is shown in Figure 1. In 1990-91, temperatures were near the long term means. However, rainfall in August was nearly 2.5 times the long term mean. The most important weather occurred in the 1991-92 season when mean daily temperatures during the months of November and December were much lower than long term means. These low temperatures were accompanied by higher than average rainfall in these months.

Results

Under glasshouse conditions, leaf area and shoot dry weight per plant increased with additional N over the entire range used (Fig. 2). Increases ranged from 36-42% over 0 N. Nodule DM per plant however decreased linearly from 0.33 g at 0 kg N/ha to 0.18 g at 100 kg N/ha.

Under field conditions, as in the glasshouse, the addition of 100 kg N/ha gave increased total DM by 28 %. Also, with 100 kg N/ha seed yield and harvest index (HI) increased 44 and 12% respectively over 0 kg N/ha (Table 1).

Inoculation had no effect on any growth parameter.

Sowing date also had a highly significant effect on yield with DM production ranging from 702 g/m^2 in the May sowing to only 407 g/m^2 in the October sowing (Table 1). Seed yield however was not affected by sowing date. This produced a highly significant increase in harvest index with delayed sowing (Table 1).

Leaf area index increased with applied nitrogen at all three sowing dates (Fig. 3). With the May and August sowings, the increases were up to 45% and 33% respectively resulting in increased levels of intercepted radiation with nitrogen application (Table 2). While LAI was not measured in experiment 2, transmissivity measurements showed that more radiation was intercepted at 45 and 60 plants/m^2 than at 15 plants/m^2 (Table 2).

There was a relationship between intercepted solar radiation and maximum total DM (Fig. 4). This regression indicated that for each MJ of intercepted PAR chickpeas produced 0.91 g of DM.

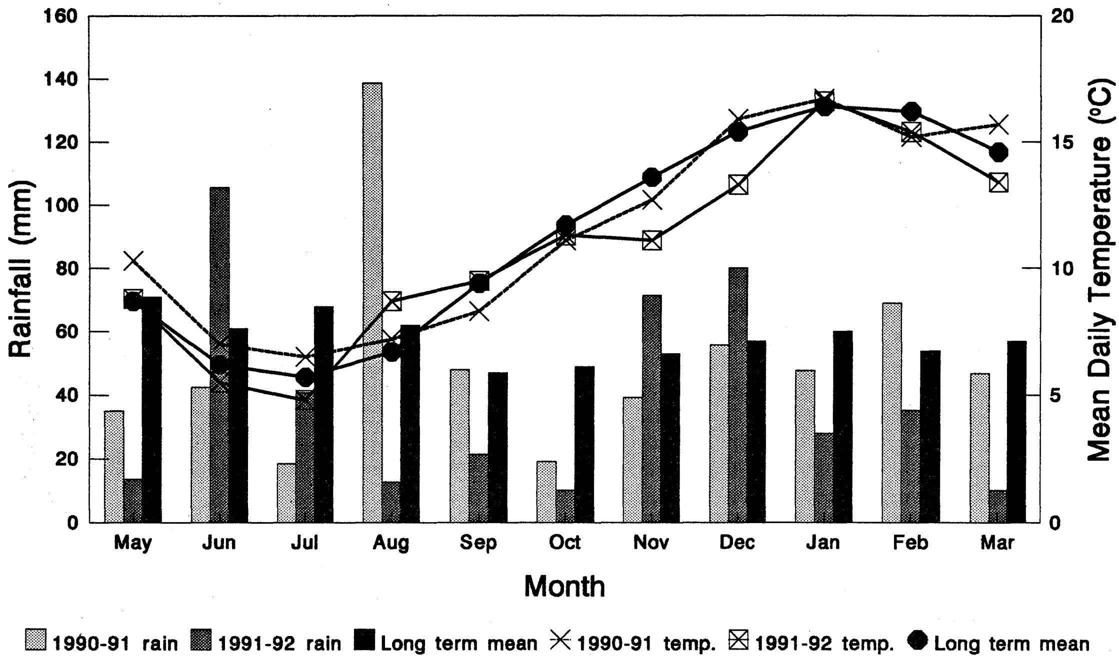

Figure 1. Weather data (bars = rainfall and symbols = temperature) over the two years of the field experiments, 1990-91 and 1991-92.

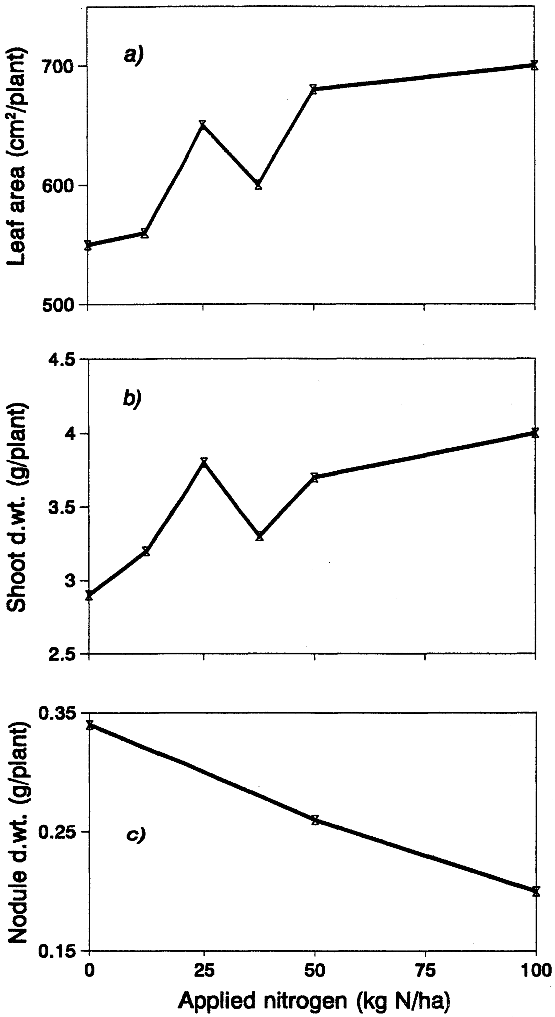

Figure 2. Effect of rate of nitrogen application on a) leaf area, b) shoot dry weight and c) nodule dry weight per plant of Kabuli chickpea.

Discussion

These experiments have conclusively shown that high yields of chickpeas can be produced in Canterbury. In 1990/91 maximum seed yields of over 3.5 t/ha were

Table 1. The effect of nitrogen and rhizobia inoculation on yield and harvest index of chickpeas sown in May, August and October.

	Total DM (g/m^2)	Seed (g/m^2)	Harvest index
Sowing Date			
May	702	175	0.25
August	527	182	0.33
October	407	206	0.51
SEM	33.0	15.8	0.011
Significance	***	NS	***
Nitrogen (kg N/ha)			
0	479	154	0.34
100	611	221	0.38
SEM	27.0	12.9	0.009
Significance	**	***	*
Inoculation			
0	519	173	0.35
Inoc.	572	202	0.38
SEM	27.0	12.9	0.009
Significance	NS	NS	p = 0.052

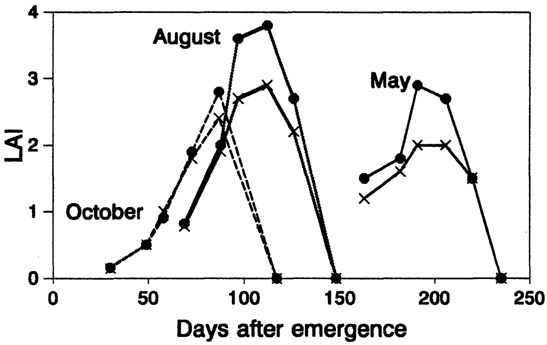

Figure 3. Leaf area index of chickpea with 0 (×) and 100 (•) kg N/ha at three sowing dates (May, August and October).

higher than the 2.3 t/ha in 1991/92. These yields compare favourably with those of Hernandez 1986 at 2.7 t/ha. While there is little other published data on chickpea yields in Canterbury the yield results sharply contrast with those for lentils. McKenzie and Hill (1990) reported similar dry matter results from sowings ranging from April until November. However, they also found seed yield HI declined significantly with late sowings. Hernandez (1986) with chickpeas found no effect of sowing date on HI while seed yield declined from 2.7 t/ha from a 27 September sowing to 2.1 t/ha from a 22 November sowing.

This work indicates that while autumn sowing will give increased DM yields, seed yields will not be increased. This may be due to both flower and seed abortion as the early sowings flower much earlier than the spring sowings when night temperatures are low. The reduction in yield in late sowing (Hernandez,1986) was due to lower mean seed weight caused by water stress. All sowings in this trial were not severely affected by water stress. Yields were however lower than expected due to a minor weed problem.

One interesting aspect of this work is the indication that chickpeas will withstand a Canterbury winter. Mean daily minimum and mean daily temperatures in July 1991 were 1.6°C and 0.9°C respectively cooler than the long term means. While the plants grew very little over the winter months, there was little plant mortality. Plant populations increased from 21 plants/m^2 on 26 July to 29.4 plants/m^2 on 9 October. This indicates there were late germinating and emerging seeds in the May sowing. While chickpeas are not considered frost tolerant, Singh *et al.* (1981) reported plant survival of 10% of 3158 accessions tested after 47 days under snow cover in Turkey with air temperatures as low as -26.8°C.

Table 2. The effect of nitrogen, sowing rate and sowing date on transmissivity at maximum LAI and radiation interception of chickpeas.

	Intercepted PAR (MJ/m^2)	Transmissivity at maximum LAI
Sowing Date		
May	676	0.37
August	591	0.28
October	407	0.35
Nitrogen (kg N/ha)*		
0	569	0.32
100	612	0.23

* data from August sowing presented.

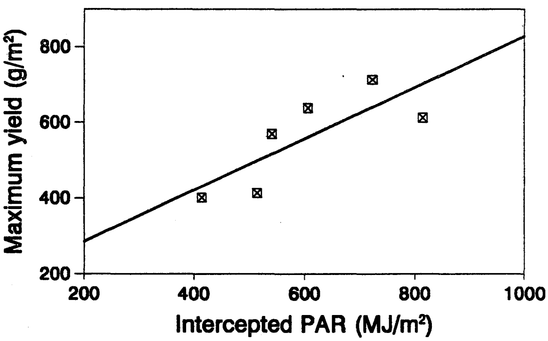

Figure 4. The relationship between intercepted photosynthetically active radiation (PAR) and maximum DM production of chickpeas; $r^2 = 0.62$, DM = 94 + 0.91 x PAR, p = 0.064.

Nitrogen effect

As reported here, Hernandez (1986) also found in a pot trial the addition of nitrogen gave increases in shoot DM. However the highest yields of 4.8 g/plant at 75 DAS were obtained with inoculation and 30 kg N/ha applied 30 DAS. The field trials reported here support Hernandez (1986) claim that chickpeas do not fix adequate atmospheric N for their needs. While there were no responses to rhizobial inoculation in the third experiment, this is not surprising. Keatinge *et al.* (1985) reported that dryland chickpea fixes from 27-82% of its nitrogen requirement. Furthermore, chickpea rhizobium strains are quite variable in their ability to fix atmospheric N (Bohlool *et al.*, 1988). In the field *R. leguminosarum* which is not effective at nodulating chickpeas may strongly compete with introduced chickpea *Rhizobium* for soil resources. This may reduce chickpea Rhizobium numbers and result in reduced nodulation (Bohlool, 1988). Also, the cold July may have killed introduced Rhizobium.

There has been little information published on the growth of leaves and canopy of chickpeas. Kuhud *et al.*, (1988) reported that water stress reduced leaf dry weight and area. Hernandez (1086) found that maximum leaf area of chickpea was about 3.5. This is very similar to the maximum reported here of 3.7. He reported that population, rhizobial inoculation and sowing date all affected LAI. Except for inoculation these factors and nitrogen affected LAI in these experiments as well.

The increased LAI gave increases in intercepted solar radiation (Table 2). There was a relationship between intercepted radiation and total maximum dry matter production (Fig. 4). While the regression was only significant at p = 0.064 it is similar to the relationship between these variates reported by Hernandez, 1986. Huda and Virmani (1987) also found a relationship between total dry matter and intercepted radiation. They reported that only 0.46 g DM was produced per MJ solar radiation. For this work 0.91 g DM was produced per MJ of intercepted PAR. This compares to the 1.3 g DM produced per MJ intercepted PAR found by Hernandez (1986).

The variation in these utilisation coefficients may be due to several factors. Plants supplied with adequate soil N may have a higher μ due to less internal energy requirement for the Rhizobium symbiosis. Additionally, water stress or variable night temperatures may affect μ through variations in maintenance respiration.

Conclusions

1. Chickpeas will respond to applied nitrogen. However, effective rhizobia strains may increase nodulation and N fixation efficiency.
2. Chickpeas should be sown in mid spring for highest yields. Autumn sowing will provide higher DM yields, but not increased seed yields. More work is required to determine why HI declines with early sowings.
3. Chickpea growth is related to radiation interception, but the utilisation coefficient is low.

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