Development of yield and variability in yield components of chickpeas

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Abstract

Two experiments were conducted in 1992-93 and 1993-94 to examine the effect of different levels of nitrogen fertilizer (0, 15, 45 and 90 kg N/ha in 1992-93; and 0 and 90 kg N/ha in 1993-94) and sowing dates (3 July and 30 September, 1992 and five dates ranging from 9 July 1993 to 10 November, 1993) on the development of yield and the variability of yield components in chickpeas. Variability in yield components, and therefore yield has been a major problem in chickpeas, (*Cicer arietinum* L.). In 1992-93 two levels of Rhizobium inoculation (0 and 480g/100kg seed) were also applied. The experimental treatments followed a randomised split-plot design. Data collected included that for yield, yield components, yield development and phenological development.

In the first year seed yield was high, averaging 2.85 t/ha, but did not differ with either sowing date or nitrogen treatments. In 1993-94 both sowing date and application of nitrogen significantly affected total seed yield by influencing yield components. The number of plants/m^2 ranged from 6 to 22 in the July and November sowings respectively. The number of pods/plant was most variable, with 129.7 produced in the July sowing and only 66.5 in the November sowing. The addition of 90 kg N/ha gave about 92 pods per plant while the plants receiving no N produced only 79 pods per plant. Randomly selected plants were tagged to monitor yield development from the 0 kg N/ha plots in the July 1992 sowing. On the main stem, 39% of filled pods were located on the middle third of the branch, while the bottom and top thirds had 35 and 26% of the filled pods respectively. On the largest primary branches location of filled pods was unrelated to their position on the branch. On the main stem or the three largest primary branches the first filled pod was normally located on nodes 11-13. Maximum seed yield was obtained from the secondary branches.

In the second season, phenological development was strongly influenced by sowing date. Early sown plants reached 50 % flowering 124 days after sowing (DAS) and the latest sown plants reached flowering 71 DAS. Selecting the right sowing time is an important consideration to be made to optimise and stabilise chickpea seed yields.

Additional key words: *chickpea,* Cicer arietinum, *yield components, harvest index, total seed yield*

Introduction

Growing spring sown pulse crops after cereals in cropping rotations is common practice in the Canterbury region. Peas (*Pisum sativum*) and lentils (*Lens culinaris*) grown in this way have substantial commercial value in New Zealand agriculture (Hill and McKenzie, 1993). Preliminary research (Hernandez and Hill, 1983, 1984; McKenzie *et al.*, 1992) has shown that chickpea, the third most important pulse in the world, can also be successfully grown in the Canterbury area and has the potential to become a new revenue earning pulse crop for New Zealand (Verghis *et al.*, 1993).

In New Zealand the only part of this crop of any value is its seed. High seed yield depends on maximising yield components, thereby producing a high harvest index (HI). One of the problems faced in chickpea cultivation around the world is its variable HI (Chopra and Sinha, 1987; Hernandez, 1986). Since the HI of a crop depends on its yield components, variability in the total seed yield (TSY) is the result of yield component variability. The TSY of a crop can be defined as follows:

$$TSY = P_l \times P_p \times S \times W_t$$

where P_l is the number of plants per unit area, P_p is the mean number of pods per plant, S is the mean number of seeds per pod and W_t is the mean seed weight (Wilson, 1987).

The main causes of yield component variability are genotypic (Sandhu and Mandal, 1989), genotype by location interaction (Srivastava *et al.*, 1990), growing season in terms of temperature regimes and moisture availability (Saxena, 1990; Poma and Fiore, 1990; Pala and Mazid, 1992), and plant population (Saxena, 1987; Singh *et al.*, 1988). Addition or absence of agronomic inputs such as fertilizer (Subba Rao, 1988), irrigation (Saxena, 1987), inoculation (Rupela and Dart, 1980), and weed and pest control (Shaktawat and Sharma, 1986) also contribute to yield component variability. This variation is very genotype and location specific, so it has to be investigated locally to develop crop management recommendations to stabilise chickpea yields for any particular region.

Past work in Canterbury on the related grain legumes lentils (McKenzie and Hill, 1991) and peas (Moot, 1993) and the work of Hernandez (1986) has shown that environmental conditions, (most easily altered by changing sowing date), and soil conditions have large effects on yield and development of yield components. Rhizobium inoculation can increase chickpea yields (Rupela and Dart, 1980) but responses to applied nitrogen are very varied. Low rates of nitrogen have been found useful in soils low in available nitrogen (Chowdhury *et al.*, 1972; Saxena, 1987), whereas high rates of nitrogen tended not to increase yield (Saxena and Sheldrake, 1980).

The treatments selected for these trials were therefore sowing date, nitrogen application and Rhizobium inoculation. The main objectives of this experiment were to investigate the effects of these varying treatments on yield component variability and development of yield of chickpea in Canterbury.

Materials and Methods

Experiments were conducted in 1992-93 and 1993-94 on a Templeton silt loam soil located at the Henley farm, Lincoln University (New Zealand Soil Bureau, 1954). The sites were previously in pasture and barley respectively. Both were a randomised split plot design, with sowing dates as main plots. In 1992-93 subplots consisted of a factorial combination of two levels of Rhizobium inoculation and four levels of nitrogen, while in 1993-94 subplots were two levels of applied nitrogen. A MAF soil quick test gave the following results: pH 6.1, Ca 14, K 16, P 26, Mg 24, Na 4 and S 2 for 1992-93 and pH 6, Ca 11, K 14, P 18, Mg 23 N 7, S 10 and total nitrogen 0.15 for 1993-94. Apart from the experimental treatments no additional fertilizer was applied. Climate data for both seasons were obtained from the Broadfield meteorological station located about one kilometre from the experimental site.

Weed control was achieved with two applications of cyanazine at 1.7 kg a.i./ha applied at both pre sowing (seven days before) and pre-emergence (seven days after) in 1992-93. In 1993-94 weed control in all sowing date treatments was achieved by applying a pre-emergence spray of metribuzin at 350 g a.i./ha. In the August to November sowings a pre-sowing application of glyphosate at 540 g a.i./ha was made. All post-emergence weeding was done by hand.

Locally obtained "Kabuli" chickpea seed, with a 1000 seed weight of 450 g (1992-93) and 309 g (1994-95) and germination of 60 and 75% respectively was sown with a tractor driven cone seeder to produce a population of approximately 45 plants/m^2. Seed was treated with the fungicide Apron (a.i. Metalaxyl 350 g/kg and Captan 350 g/kg) at 200 g/100 kg seed to control *Fusarium* wilt and *Ascochyta* blight. The plot size was 23.1 m^2 (11 x 2.1 m).

In 1992-93 there were two sowing dates, 3 July (winter) and 30 September (spring) and four levels of nitrogen fertilizer 0, 15, 45 90 kg N/ha and two levels of Rhizobium inoculation (Rhizobium strain CC1192 at 0 and 480g/ha, which is twice the recommended rate). The nitrogen was broadcast as calcium ammonium nitrate (27% N) just before sowing. The 1993-94 trial had five sowing dates (9 July, 9 August, 14 September, 8 October and 10 November) and two nitrogen levels 0 and 90 kg N/ha supplied and applied as above. Since Rhizobium proved to have a significant effect in the first year (based on the subsample taken for yield components), all treatments were inoculated with *Rhizobium* strain CC1192 as a blanket treatment at twice the recommended rate (480 g/100 kg seed).

During the second season two sprays of Benomyl at 1 kg a.i./ha and one spray of Chlorothalonil at 1 kg a.i./ha were applied to prevent and control fungal diseases. One application of Dichlorvos at 750 g a.i./ha was made to control thrips. Two irrigations were applied to maintain available moisture to the plants using a water budget calculated from the technique of Penman (1962).

Phenological development of the crop was monitored at two to three day intervals from the start of flowering. The stages recorded were emergence, flowering, green pod, expanded pod, mature pod and harvest maturity. Flowering was defined as the stage when 50% of the plants in a plot had at least one flower. This 50% standard was maintained for all other stages recorded. A pod emerged through senescing petals was defined as a green pod. As pods expand they become slightly brittle before they start filling. This was defined as the expanded pod stage, and judged by pressing the pods slightly to test firmness. A yellowing to brown pod was considered a mature pod. When more than 90% of the plants in a plot reached the mature pod stage the crop was considered to have reached harvest maturity.

In the 1992-93 season yield was measured from 2m^2 samples/plot from 24 plots. In the 1993-94 season yield and yield components were measured on 2.4 m^2 samples/plot at final harvest from 40 plots. The yield components measured were number of plants/m^2, pods/plant, seeds/pod and mean seed weight. This was done using the whole 2.4 m^2 sample. A plant count was done at final harvest. Pods were removed from every plant, counted and machine threshed. The weight of stems and empty pods provided for straw weight. The seeds were passed through a sieve to eliminate all seed of less than 2mm in size. Then they were counted using a seed counter and weighed and from this information total seed yield was calculated from the yield components using the formula presented in the introduction.

The development of seed yield was monitored on 9 tagged plants in the 0 kg N/ha plots in the July sowing of the first year only by tagging plants at three day intervals from the appearance of the first flower. A different colour wire tag was used for each of the tagging days. At every reproductive node on a plant a colour tag was placed when a flower formed and another when it became a pod. Data from the reproductive nodes as to how many flowers were formed, how many actually went on to become mature pods, what percentage of flowers and pods aborted and yield from different branches on the plant were collected at final harvest.

Results

Climate

The 1992-93 winter and spring seasons were atypical of the Canterbury region, both being exceptionally cold and wet. Rainfall was much higher than the 50 year average monthly values for August, September and October of 62, 47 and 49 mm respectively (Fig.1). Similarly, maximum and minimum air temperature for December, January and February were about 3°C lower than the monthly 50 year average.

The 1993-94 season had a drier winter and spring (Fig. 2). Rainfall in July, August, and October was only

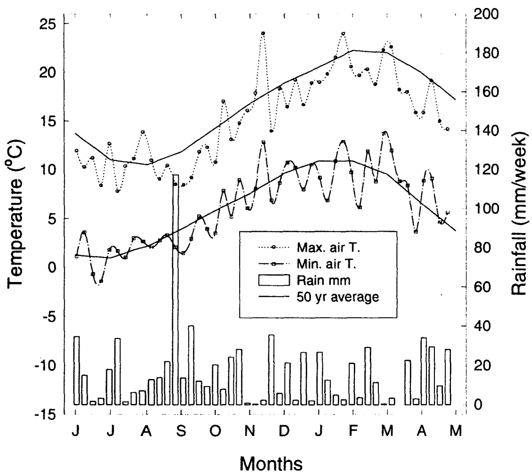

Figure 1. Mean weekly and 50 year monthly average maximum and minimum air temperatures, and weekly total rainfall at Lincoln during 1992-93 season.

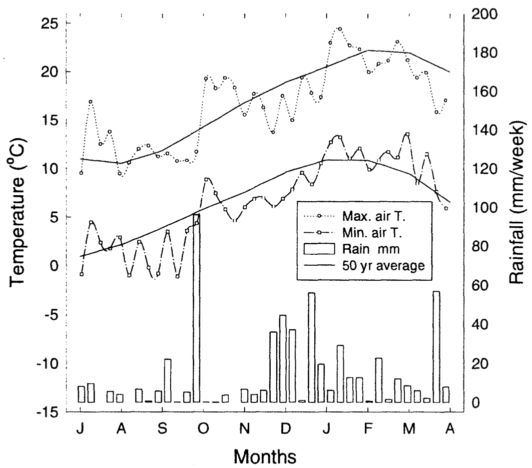

Figure 2. Mean weekly and 50 year monthly average maximum and minimum air temperatures, and weekly total rainfall at Lincoln during the 1993-94 season.

14, 17 and 9 mm respectively compared to 50 year corresponding mean values of 61, 58, and 50 mm (Fig. 2). The exception was the unusually high rainfall of 133 mm (highest in the season) in September. The summer, however, was wetter with total rainfall of approximately 306 mm compared to about 204 mm in 1992-93. The maximum and minimum air temperatures during December, January and February were lower than the monthly 50 year average by 1°C and 0.5°C respectively. In general, the air temperatures were higher in 1993-94 season than in 1992-93.

Yield

In 1992-93 there was no significant effect of sowing date on seed yield (which averaged 287 g/m^2) or HI (which averaged 40%). The only significant effect of nitrogen was to reduce HI from 0.42% to 0.40%, although real yield did not differ. Since Rhizobium inoculation had no significant effect on any measured parameter, results are not presented for this factor.

In 1993-94, sowing date had a highly significant effect on all yield parameters (Table 1). Seed yield was highest in the November sown crop (321 g/m^2) and this was double the yield of the July sown crop (159 g/m^2). TDM peaked in September, increasing by 21%, from July and 8% from November. HI was lowest in August at 21%, but increased from 25% in July to 44% in November. Nitrogen significantly increased seed, straw and TDM yields by 15, 10 and 11 % respectively, but did not affect HI.

Yield components

The contribution of yield component differences to seed yield variation in 1993-94 is shown in Table 2. Sowing date had a highly significant effect on all components except number of seeds/pod. This was mainly due to the differences in plant population through the season. The number of plants/m^2 increased from 6 in July to 22 in November. At emergence it ranged from 18 in July to 30 plants/m^2 in September. The number of pods/plant changed in the opposite direction, ranging from 130 in July to 67 in November. TSY increased 100% from 165.7 g/m^2 in July to 325.7 g/m^2 in November. In 1992-93 the plant population at final harvest was the same for both winter and spring sowings at approximately 40 plants/m^2.

Table 1. Effect of sowing date and nitrogen on seed and straw yield, total dry matter (TDM) and harvest index (HI) in the 1993-94 season.

Factors	Seed (g/m^2)	Straw (g/m^2)	TDM (g/m^2)	HI
Sowing date				
July	159.3	464.6	623.9	0.25
August	161.8	616.0	777.8	0.21
September	293.9	494.6	788.5	0.37
October	298.1	474.8	772.9	0.38
November	320.8	407.4	728.2	0.44
Significance	***	***	***	***
SEM	19.2	23.0	28.8	0.021
Nitrogen				
0	227.0	466.1	693.1	0.32
90	266.6	516.8	783.4	0.33
Significance	*	*	**	NS
SEM	12.1	14.5	18.2	0.013
Interactions				
Significance	NS	NS	NS	NS
CV %	22.0	13.2	11.0	17.1

* = P<0.05; ** = P<0.01; *** = P<0.001

Table 2. The effect of sowing date and nitrogen on yield components of the 1993-94 season chickpea crop and its influence on calculated total seed yield (TSY).

Factors	Plants per m^2	Pods per plant	Seeds per pod	Mean seed wt (g)	TSY (g/m^2)
Sowing date					
July	6	129.7	1.07	0.199	165.7
August	13	72.5	0.99	0.189	176.4
September	15	78.1	1.09	0.236	301.4
October	16	82.2	1.02	0.227	304.5
November	22	66.5	1.06	0.210	325.7
Significance	***	**	NS	**	
SEM	0.7	10.9	0.028	0.0009	
Nitrogen					
0	14	79.1	1.03	0.210	239.5
90	14	92.4	1.06	0.215	294.8
Significance	NS	NS	NS	NS	
SEM	0.516	6.9	0.018	0.0006	
Interactions					
Significance	NS	NS	NS	NS	
CV %	16.3	36.1	7.77	11.4	

* = P<0.05; ** = P<0.01; *** = P<0.001

Nitrogen did not affect any of the yield components significantly, but it increased TSY by about 19%.

Yield development

The position of the first full pod on the main stem and the three primary branches varied from node 13 on the main stem to node 11 on the third primary. The total number of mature pods per plant was 70.2, of which only 56% contained seeds. The highest number of mature pods was on the secondary branches (37.4) which was 53% of the total per plant (Table 3). However only 54% of them contained seeds. Seed number and weight were also maximum on secondary branches at 51 and 52% respectively.

On the main stem, 39% of filled pods were located on the middle third of the branch while the bottom and top thirds had 35 and 26 % of the filled pods respectively. Further analysis shows that the primary and secondary branches showed the same trend of maximum filled pods in the middle third of the branch, with 37% and 47% respectively. The lowest percentage of filled pods was consistently on the top third of the branches, except on the tertiaries. The tertiary branches had maximum filled pods on the top third (43%). However the tertiary branches only accounted for about 5% of total seed yield. On average, the bottom third of all branches together accounted for 35% of all filled pods, the middle third for 40% and the top third for 25%.

The percentage of pods that were full or empty was not related to the position of the branch. There was an average of about 40% empty pods over all the branches.

Flower abortion was 48% more than pod abortion. Of total abortion, maximum occurred on the secondary branches. In relation to position on the branch, the bottom and top third of all branches accounted for 33 and 39% of total abortion respectively.

Table 3. Pod and seed development on the main stem, primary, secondary and tertiary branches (on a per plant basis) for chickpeas sown in July 1992-93 with 0 kgN/ha. Data were taken at final harvest.

Branch	Total no. of mature pods	Total Full pods	% Full pods	Total seed no.	Total seed wt (g)
Main stem	8.2	4.8	58.5	5.3	1.39
Primaries	21.3	12.4	58.2	14.3	3.85
Secondaries	37.4	20.0	53.5	23.4	6.46
Tertiaries	3.3	2.3	69.7	3.1	0.703

Total number of seeds on the branches varied from 5.3 on the main stem to 14.3, 23.4 and 3.1 on the primary, secondary and tertiary branches respectively. The total seed weight on the branches followed a similar trend (Table 3).

Phenology

In both seasons the phenological development was strongly influenced by sowing date. The crop sown early reached flowering in 140 and 124 days after sowing (DAS) and harvest maturity 241 and 258 DAS in 1992-93 and 1993-94 respectively. The latest sown crop in 1992-93 (September) flowered at 71 DAS and reached harvest maturity at 165 DAS. For the same month (mid season) in 1993-94, flowering was at 79 DAS and harvest maturity at 189 DAS. The latest sowing in 1993-94 (November) flowered at 61 DAS and reached harvest maturity at 133 DAS.

Discussion

Yield variability

There was a marked variability in both seed yield and HI among the sowing dates in 1993-94, but no differences were recorded in 1992-93. The low yield in the 1993-94 winter sowing was due to a significantly lower plant population than in the spring sowings. Similar findings have been reported by McKenzie and Hill (1994). The high plant mortality in the winter sowing was attributed to the long, cold and very dry winter in 1993-94 (Fig. 2). The very low population meant that the plants had less interplant competition and hence their vegetative growth was enhanced. The indeterminate nature of the plants allows continued growth if resources are available; however, the number of pods produced and or the pod filling period do not keep pace with vegetative growth. In 1992-93 the advantage of having sufficient moisture during winter would have reduced the plant mortality rate. Plant nutrition influences yield variability in chickpeas. In 1993-94 nitrogen application significantly increased seed and straw yield. However, in 1992-93 the response to nitrogen application was not significant, possibly because of leaching due to high rainfall (Fig.1), but more probably because of more available soil nitrogen as the paddock had previously been in pasture. The significant response to nitrogen in 1993-94 is attributed to low available soil nitrogen (Hernandez and Hill, 1984) due to the previous barley crop. Positive response to nitrogen application has been shown by other workers (McKenzie and Hill, 1994), and Beck *et al.*, (1991) found that chickpeas generally do not fix adequate nitrogen for their own needs even if vigorous nodules are present.

Yield components

The lower plant population in the winter sowing resulted in very large plants with almost twice as many pods/plant as spring sown plants. However the TSY was about approximately 100% higher in the spring sowing. This emphasises the impact that plant population variability has on yield stability (Table 2). Winter or spring sowing had no effect on the number of seeds/pod, but the spring sown crops had much larger seeds. This may have been due to less competition for photosynthate in the smaller spring sown plants. Indeterminate species such as chickpeas tend to produce vegetative and reproductive growth at the same time. This can result in vegetative apices competing with reproductive structures for photosynthate. It is evident that variation in TSY was mainly associated with variation in plant population and mean seed weight.

Nitrogen had little effect on yield components. However minor cumulative effects resulted in a significant yield response.

Yield development

There was no marked difference in the position of the first full pod between the main stem and first three primary branches. Maximum filled pods were found on the secondary branches and most of the filled pods were situated in the middle third of all branches, indicating that pods set very early or late in the season either did not fill properly or were senescent. Another reason is that there were more secondary branches/plant. The low number of filled pods on the lower third of the branches, especially the main stem, was because of flowers, pods or seeds aborting. One reason for this abortion may have been the unusually cold and wet weather at that time causing unsuccessful pollination, but this requires further investigation. At minimum temperatures less than 10°C chickpeas fail to develop pods successfully (Saxena N.P., 1980). Low temperatures can slow down photosynthesis, thereby slowing down carbohydrate production resulting in low available carbohydrate to be utilized in pod filling. Shade conditions that are associated with the wet periods could also be a cause of abortion, as research has shown that cloudy weather can result in flower and pod abortion in chickpeas (Muhammad Abdul Aziz *et al.*, 1960; Dahiya *et al.*, 1987). Liyanage and McWilliam (1981) have reported that in mung beans shading decreased yields by decreasing the number of pods/plant and seeds/pod. Dutta *et al.* (1993) reported that higher temperatures caused accelerated pod development and shorter duration of grain filling. The low filling on the upper third of the branches may be attributed to the shorter filling period available to the crop as the crop rapidly approached maturity. This also explains why the branches formed mid season (secondary branches) had more pods and higher seed yields on them. This however is slightly different to lentils where the maximum number of pods was located on the primaries (Erskine and Goodrich, 1991).

Phenology

Crops in the early sowings took longer to reach each phenological stage than those in the late sowings. The mean temperatures for the winter (July and August) and spring (September, October and November) sown crops over the whole season were 13°C and 16°C respectively. Since progress towards the reproductive stage and harvest maturity in chickpeas is a function of accumulated thermal units above a base temperature (Roberts *et al.*, 1985), or of accumulated photothermal units above a base temperature (McKenzie and Hill, 1989), the warmer temperatures in spring combined with the effect of photoperiod to reduce the number of days taken to reach the thermal units required for each phenological stage.

Conclusions

1. Seed yields were variable ranging from 1.5 to 3.2 t/ha.
2. Variability in yield was due primarily to variability in the number of plants/m^2, and mean seed weight. Highest plant populations, seed weight and therefore yields were from spring or late spring sowings (September to November).
3. Secondary branches produced the greatest number of pods per branch, and the highest seed yields per branch.
4. Pods produced either early in the season or near maturity tended to abort due to cold stress or natural senescence respectively.

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