Response of pinto beans (*Phaseolus vulgaris* l.) to irrigation, sowing date and inoculation

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Abstract

The response of pinto beans (*Phaseolus vulgaris* L.) cv. Othello sown in October and November 1994 to irrigation and inoculation was investigated. The experiment was a split-plot randomised complete block with two irrigation treatments as main plots and a 2 x 3 factorial combination of sowing date and inoculation as sub-plots. Seed yield and harvest index (HI) were significantly affected by sowing date and irrigation by sowing date interaction. Overall, late sowing resulted in an 18% increase in seed yield and a 14% increase in HI. The response of seed yield to irrigation ranged from a 10% increase (262 to 288 g/m^2) in the October sowing to a 42% increase (267 to 378 g/m^2) in the November sowing. However, for HI, while irrigation decreased HI from 0.58 to 0.55 in the October sowing, it did not decrease HI of the November sowing. Total dry matter at final harvest was also significantly increased by the irrigation by sowing date interaction and followed similar trends to seed yield. Irrigated crops produced 15% and 37% more dry matter than unirrigated crops in the early and late sowings, respectively. Dry matter accumulation during the season followed a sigmoidal pattern with weighted mean absolute growth rates ranging from 6.54 to 9.98 g/m^2/day. Maximum crop growth rates ranged from 9.86 to 15.56 g/m^2/day. Unirrigated crops sown in November flowered and reached physiological maturity earlier than the other plants. Generally, there was no significant response to inoculation. The results suggested that pinto beans have the potential to yield well in Canterbury and that a yield advantage could be obtained when sown late in November and with irrigation if the season is dry.

Additional key words: *pinto beans*, Phaseolus vulgaris, *irrigation, sowing date, seed yield*

Introduction

About two decades ago, Goulden (1976) indicated an increased interest in navy beans (Phaseolus vulgaris L.) from the New Zealand seed industry and growers. However since then, the area sown to the crop has only increased slowly, with an estimated 800-1000 ha currently grown each year (McKenzie, pers. comm.). Although navy beans have been shown to produce up to 3 tons/ha of dry seed in Canterbury (Love *et al.*, 1988), these yields have tended to be variable (Love *et al.*, 1988; McKenzie, 1989). A combination of dry conditions (in the absence of irrigation) and low night temperatures, characteristic of the Canterbury growing season, can result in low yields and poor seed quality.

Since pinto beans (*Phaseolus vulgaris* L.) have been grown successfully in Saskatchewan, Canada, (Vandenberg, 1991) they may have the potential to do well in Canterbury. There is the need however, to gain an improved understanding of the factors (of which sowing date and irrigation are powerful determinants) responsible for yield variability.

McKenzie (1989) observed that wet seasons and late sowings of navy beans (mid to late November recommended) could lead to delayed maturity causing harvesting and seed quality problems. With irrigation, seed yields have been consistently high (about 3 tons/ha) and even in a wet season, irrigation resulted in small but significant yield increases (Love *et al.*, 1988). Response of Phaseolus beans to inoculation overseas has been extremely variable. While inoculation was found to have a positive effect on seed yield (Taylor *et al.*, 1983; Bengtsson, 1991), other reports showed slight or no effects despite the increased effects on nodulation (Weiser *et al.*, 1985; Buttery *et al.*, 1987; Bengtsson, 1991).

This experiment was designed to determine an appropriate sowing time for pinto beans and to examine their response to irrigation and inoculation in an attempt to maximize seed yield in the Canterbury environment.

Materials and Methods

The experimental design was a split plot randomised complete block with two irrigation treatments (none and full) as main plots. Sub-plots consisted of a factorial combination of two sowing dates (October 27 and November 24) and three inoculation treatments (none, *Rhizobium phaseoli* strains CC511 and RCR3644). The six sub-plot treatments were randomly assigned within each main plot. There were four replicates. Each sub-plot measured 8 m x 1.5 m. Irrigation was applied through mini-sprinklers, and 16 mm of water was applied whenever the calculated soil moisture deficit reached 25 mm. There were three irrigation applications on 9/12/94, 17/01/95 and 31/01/95. There were two occasions (27/12/94 and 26/01/95 irrigation equipment was not available (because it was being used in other fields) when irrigation needed to be done.

The experimental site was at Iversen field, Lincoln University on a Wakanui silt loam (New Zealand Soil Bureau, 1968) and had been in potatoes during the previous growing season. Soil nutrient analysis (MAF Quick Soil Test) showed pH, Ca, K, Olsen P, Mg, Organic C and Total N of 5.7, 12, 10, 24, 26, 2.0 and 0.3, respectively. The site was cultivated by ploughing, dutch harrowing and rolling. Trifluralin was applied pre-emergence at 800 g a.i/ ha to control weeds. Further weed control was by hand.

The plots were sown using pinto bean (Phaseolus vulgaris L.) cv. Othello treated with captan streptomycin sulphate (a fungicide-bactericide). The *Rhizobium* strains were applied at 240 g of inoculum per 100 kg of bean seed in a slurry form. The inoculated seeds were allowed to dry and planted 2-3 h after inoculation. This was to prevent the effects of the streptomycin, if any, on the rhizobium. Plots were planted in 15 cm rows to give approximately 60 plants/m^2.

Plants were sampled for dry matter accumulation, leaf area index, number and dry weight of nodules, number of leaves, branches, pods and seeds, plant height and seed weight. For estimation of dry matter, cuts from 0.2 m^2 quadrats were taken at random on each plot every two weeks from 28 days after planting (DAP). Final seed yield and total dry matter were taken at final harvest from 2 m^2 marked harvest area from the central 4 rows in each plot. The palnts were cut to ground level and air dried. They were then weighed for TDM and threshed with the Kurtpelz stationary thresher for seed yield.

Five stages of crop development were determined from the marked harvest area of 2 m^2. These were emergence (50% of the plants within the area had emerged), flowering (50% of the plants had at least one open flower), podding (50% of plants had at least one emerged green pod), physiological maturity (50% of plants had at least one filled drying off/brown pod) and harvest maturity (when plants appeared dry enough to be harvested).

Generalized logistic curves of the form $Y = C/(1+T \exp(-b(x-m)))^{1/T}$ (where C is the above ground dry matter and T, b and m are constants) were used to describe dry matter accumulation of the crop using the MLP programme from Rothamsted (Ross *et al.*, 1987). The weighted mean absolute growth rate (WMAGR), maximum crop growth rate (C_m) and duration of exponential growth (DUR) were derived for the crop. The curves that were fitted to the dry matter accumulation were from the means of the four replicates; hence statistical analysis of the derived growth variates (WMAGR, C_m and DUR) was not possible.

All statistical analysis were performed using the Statistical Analysis Institute Inc. (SAS) package (SAS, 1988).

Results

Climate

The weather during the growing period was drier and slightly warmer than the normal/long term average (Table 1). Rainfall from October 1994 to March 1995 was 155 mm, which was approximately 50% of the long term average of 313 mm. Except for the mean monthly minimum temperature for October 1994, and mean monthly maximum temperatures for October 1994 and January 1995, all other months had mean monthly minimum and maximum temperatures slightly higher than the long term, making the growing season slightly warmer than normal.

Total dry matter

Total dry matter (TDM) at final harvest was only affected by the irrigation x sowing date interaction (Tables 2 and 3). When sown in October, irrigation

Table 1. Rainfall and temperature data for the 1994/95 growing season and long term averages at Lincoln.

Month	Rainfall (mm)	Mean Max. temp. (°C)	Mean Min. temp. (°C)
October	20 (50)	15.5 (16.8)	4.9 (5.8)
November	22 (54)	20.2 (18.9)	8.3 (7.5)
December	24 (58)	22.6 (20.5)	10.0 (9.6)
January	32 (51)	21.6 (22.2)	11.5 (10.9)
February	24 (51)	21.0 (21.9)	12.3 (10.8)
March	32 (57)	21.3 (20.0)	10.1 (9.5)

Long term means are in brackets and are for 50 years (1944-1993).

increased TDM from 453 to 523 g/m^2 (15% increase). For the November sowing, irrigated plots produced 579 g TDM/m^2, 37% more TDM than unirrigated plots. Maximum total dry matter production was about 600 g/m^2 (Fig. 1a,b). Dry matter production followed sigmoidal curves for both irrigation and sowing date treatments. Generally, the November sowings

Table 2. Effect of irrigation, sowing date and inoculation on total dry matter at harvest, seedyield and harvest index of pinto beans in Canterbury, 1994/95.

	Total DryMatter (g/m^2)	Seed yield (g/m^2)	Harvest index
Irrigation (Irri)			
Nil	438	265	0.60
Full	551	333	0.60
SEM	42.2	25.7	0.002
Significance	NS	NS	NS
Sowing date (Sdate)			
October	488	274	0.56
November	501	323	0.64
SEM	15.3	10.1	0.006
Significance	NS	***	***
Inoculation (Inoc)			
Nil	480	288	0.60
CC511	510	310	0.60
RCR3644	494	299	0.61
SEM	15.3	10.1	0.006
Significance	NS	NS	NS
CV (%)	10.69	11.71	3.35
Sig. interactions	Irri x Sdate **	Irri x Sdate ***	Irri x Sdate ***

NS = not significant, * = $p<0.05$, ** = $p<0.01$, *** = $p<0.001$

Table 3. The irrigation x sowing date interaction for total dry matter at harvest, seed yield and harvest index of pinto beans in Canterbury, 1994/95.

	Total dry matter (g/m^2)		Seed yield (g/m^2)		Harvest index	
Sowing	**Irrigation**		**Irrigation**		**Irrigation**	
date	Nil	Full	Nil	Full	Nil	Full
October	453	523	262	288	0.58	0.55
November	423	579	267	378	0.63	0.65
SEM	27.6		18.3		0.01	
Significance	**		***		***	

* * = $p<0.01$, *** = $p<0.001$

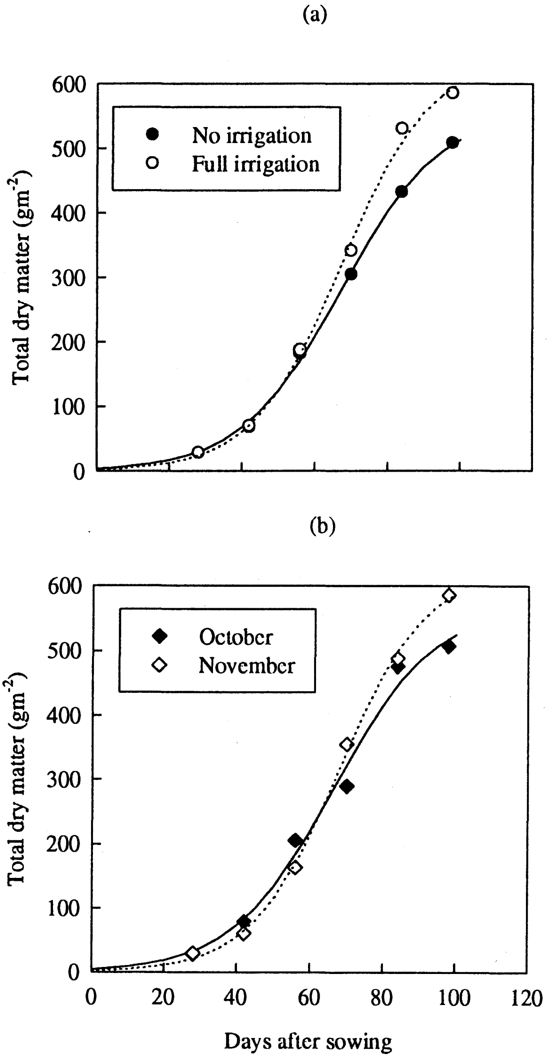

Figure 1. Dry matter accumulation of pinto beans with irrigation (a) and at two sowing dates (b) in Canterbury, 1994/95.

accumulated dry matter slowly at first, but crop growth became rapid later (Fig. 1b). Maximum crop growth rates (C_m), WMAGR (the mean growth rate over the period when the crop accumulated most of its total dry matter) and DUR (the duration of the period of exponential/rapid growth) derived from the fitted curves ranged from 9.86 to 15.56 $g/m^2/day^1$, 6.54 to 9.98 $g/m^2/day^1$, and 57 to 78 days, respectively (Table 4). Generally the November sowing had the higher C_m, while the October sowing had the longer DUR. Similarly irrigated crops had higher C_m, while the unirrigated crops had the longer DUR.

Seed yield and harvest index

Seed yield ranged from 262 to 378 g/m^2 and was strongly influenced by sowing date and irrigation by sowing date interaction (Tables 2 and 3). There was no significant response to irigation and inoculation. Compared with October sowing, sowing in November increased seed yield by 18% (Table 2). Seed yield response to irrigation depended on sowing date (Table 3). Whereas irrigation gave an increase of only 10% (262 to 288 g/m^2) in the October sowing, it gave an increase of 42% when plants were sown in November. Furthermore, there were no yield differences in the unirrigated crops at both sowing dates, but the irrigated crop sown in November yielded more than the irrigated crop sown in October.

Harvest index (HI) was similarly affected by sowing date and irrigation by sowing date interaction. The effect of sowing date was quite marked, with the November sowing giving a HI of 0.64, approximately 14% higher than the HI of 0.56 from the October sowing. Unlike seed yield, HI in the November crop was not affected by irrigation, while irrigation depressed HI in the October crop from 0.58 to 0.55.

Table 4. The effect of irrigation and sowing date on the weighted mean absolute growth rate (WMAGR), duration of exponential growth (DUR) and maximum crop growth rate (C_m) of pinto beans in Canterbury, 1994/95.

	WMAGR ($g/m^2/day$)	DUR (days)	C_m ($g/m^2/day$)
Irrigation			
Nil	7.19	74	10.85
Full	8.98	69	13.60
Sowing date			
October	6.54	78	9.86
November	9.98	57	15.56

Phenology

All phenological stages, except emergence were either influenced by irrigation, sowing date or the irrigation x sowing date interaction (Table 5). No significant effects of inoculation were obtained. Unirrigated crops generally produced flowers, pods and reached physiological maturity earlier than fully irrigated crops (Table 5). The October sowing also flowered and podded at 45 and 55 days, respectively, compared with 44 and 50 days for the November sowing. The unirrigated crop sown in November flowered and reached physiological maturity significantly earlier than other plots in other treatments (Table 6).

Table 5. Effect of irrigation, sowing date and inoculation on days to emergence, flowering, podding and physiological maturity of pinto beans in Canterbury, 1994/95.

	Days to			
	emergence	flowering	podding	physiol. maturity
Irrigation (Irri)				
Nil	8.9	43.8	52.2	91.0
Full	8.9	44.4	53.0	97.4
SEM	0.10	0.18	0.08	0.52
Significance	NS	*	**	***
Sowing date (Sdate)				
October	9.0	44.7	54.8	94.6
November	8.8	43.5	50.3	93.8
SEM	0.11	0.18	0.17	0.45
Significance	NS	**	***	NS
Inoculation (Inoc)				
Nil	9.0	44.1	52.6	93.8
CC511	8.9	44.1	52.5	94.1
RCR3644	8.8	44.1	52.6	94.8
SEM	0.11	0.18	0.17	0.45
Significance	NS	NS	NS	NS
CV (%)	4.41	1.42	1.11	1.66
Significant. interactions	NS	* Irri x Sdate	NS	* Irri x Sdate

NS = not significant, * = $p<0.05$, ** = $p<0.01$, *** = $p<0.001$

Table 6. The irrigation x sowing date interaction for days to flowering and physiologicalmaturity of pinto beans in Canterbury, 1994/95.

	Days to flowering		Days to physiol. maturity	
Sowing date	**Irrigation** Nil	Full	**Irrigation** Nil	Full
October	44.6	44.8	92.0	97.3
November	42.9	44.0	90.0	97.5
SEM	0.24		0.67	
Significance	*		*	

* = $p<0.05$

Discussion

Total dry matter (TDM) at harvest was increased by the irrigation x sowing date interaction. The response to irrigation depended on the sowing date. The irrigated November sowing gave a higher TDM because the warmer conditions may have promoted an increased rate of leaf expansion, higher leaf area, shoot extension growth, branch production and generally, the partitioning of more dry matter into the shoot versus the root. November sown plants might have also intercepted more radiation as a result of their higher LAI (results not presented here) and slightly longer crop duration. It is possible that the increased leaf expansion, or growth rate, could lead to increased metabolic demands on the crop, but as suggested by Andrew *et al.* (1989) this demand can be met at high and not low temperatures. Similar observations have been made for other legumes in Canterbury such as field beans (Husain *et al.*, 1988), lentils (McKenzie *et al.*, 1985) and chickpeas (Hernandez and Hill, 1985). The maximum total dry matter yield of about 600 g/m^2 was similar to previously reported values for navy beans in Canterbury (Hill *et al.*, 1977; Owens, 1980). The higher crop growth rate after irrigation was consistent with work on field beans (Husain *et al.*, 1988) and lentils (McKenzie and Hill, 1990) in Canterbury. The C_m's reported here compare well with the 14 to 18 g/m^2/day^1 reported for beans by various studies as indicated by White and Izquierdo (1991). These growth rates are however, lower than those of other grain legume crops grown in Canterbury: 22 g/m^2/day for autumn sown field beans (Husain *et al.*, 1988) and 25 g/m^2/day for irrigated peas (Zain, 1984). The decline in DUR as sowing date was delayed from late spring to early summer was a result of increased crop growth rates resulting from increased temperatures. The duration of exponential growth (DUR) and crop growth rate are usually inversely related (Littleton *et al.*, 1979).

Seed yields of 333 and 323 g/m^2 obtained, in general, for irrigated and November sown crops, respectively (Table 2) or 378 g/m^2 obtained, specifically, for the irrigated November sown crop (Table 3) were high. Warmer seasons usually favour larger yields of beans than cool ones (Austin and MacLean, 1972; Hardwick *et al.*, 1978; Masaya and White, 1991). This might have accounted for the higher yield in the November sowing over the October sowing. The first month of growth for the October sowing experienced the lowest temperatures (especially minimum temperatures) during the growing season. This may have affected early growth of the crop, probably through reduced leaf expansion rates and reduced radiation interception. Thomas and Sprent (1984) observed that the development of primary leaves (time to reach final leaf length and rate of elongation) in two cultivars of *P. vulgaris* was retarded at 15/10 °C compared with warmer temperatures (20/15 °C and 25/15 °C). The slow development of leaf area, as a result of the cool temperatures, resulted in poor canopy development and less interception of incident radiation.

The higher seed yield from the irrigated November sowing over the irrigated October sowing was due to the warmer conditions, the timing of irrigation and rainfall and the slightly longer crop duration (Table 6). The first irrigation of the experiment was one week after the emergence of the November sowing with subsequent irrigations at approximately 4 and 6 weeks later. There was 49mm of rain between the first two irrigations. This coupled with the warmer growing conditions gave more favourable climatic conditions for the late sown crop, giving it an edge over the early sown crop. The slightly longer crop duration and higher leaf area index (LAI) (results not presented here) may have also given higher radiation interception for the November sowing, which might have led to more pods being produced and filled.

The main effect seed yields of 333 and 323 g/m^2 obtained for irrigated and November sown crops were similar to those obtained by Goulden (1976) and Love *et al.* (1988) for navy beans in Canterbury. However, the 378 g/m^2 of seed obtained from the November sowing irrigated three times (52 mm of water plus 135 mm rainfall during the growing season) gave a yield about 20% higher than that obtained by Love *et al.* (1988) for navy beans sown a week earlier in November and also irrigated three times (90 mm of water plus 350 mm rainfall). This suggests that additional irrigation may have resulted in a higher pinto bean yield than navy bean yield in Canterbury, as a significant soil moisture deficit probably existed because of the warm and dry season. These results also suggest that in a dry Canterbury summer as experienced in 1994/95, irrigation would be necessary to produce high seed yield. Love *et al.* (1988) and Stansell and Smith (1980) noted that *P. vulgaris* responded to irrigation under greater soil water deficits or dry conditions. Love *et al.* (1988) found that irrigation more than doubled the yield of navy beans in Canterbury in a very dry season when the rainfall was only 66% of normal.

The high HIs obtained in this study could be as a consequence of complete loss of leaf and petiole tissues (constituting about 20-30% of plant dry matter, Khanna-Chopra and Sinha, 1987) by harvest. The significant reduction in HI of the irrigated October sown crop was because of increased TDM (Table 3) without a corresponding increase in seed yield.

The lack of response to inoculation might be associated with an already existing/indigenous Rhizobium strain capable of inoculating pinto beans (as even uninoculated plots had as many nodules as inoculated plots), or possibly because of more available soil nutrients, especially nitrogen, as some nitrate fertilizer was applied to the previously cultivated potatoes.

The lack of irrigation during the very dry and warm conditions experienced, reduced vegetative growth, canopy development, general plant development, and accelerated the rate of plant development to maturity in the unirrigated crops. This resulted in less days to flowering, podding and physiological maturity compared to the irrigated crops. These combined effects of the very dry and warm conditions accelerating the rate of crop development were clearly demonstrated (Table 6), where the unirrigated November sown crop reached flowering and physiological maturity stages significantly earlier than the other treatments. For sowing date, the effect of warmer temperatures combined with the effect of increased photoperiod perhaps accounted for the reduction in the number of days to flowering and podding in the late (November) sowing compared with the early sowing (Table 5). Several studies have found that the time taken for flowering (and thus progress towards the reproductive stages and maturity) in lentils (Summerfield *et al.*, 1985; Roberts *et al.*, 1988; McKenzie and Hill, 1989), chickpeas (Roberts *et al.*, 1985) and field beans (Husain *et al.*, 1988) is a function of accumulated thermal time above a base temperature or accumulated photothermal time above a base temperature and photoperiod. Increased mean diurnal temperature and photoperiod may reduce the time taken for flowering in these crops.

Conclusions

1. Seed yield ranged from 262 to 378 g/m^2.
2. In a dry season in Canterbury, farmers with irrigation could obtain high yields from late November sowings.
3. Inoculation of the crop may not be needed as there was no response to inoculation.
4. Pinto beans have the potential to grow and yield well in Canterbury and may provide a new profitable crop for farmers.

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