Root growth and nodulation of pinto bean (*Phaseolus vulgaris* L.) cv. Othello

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Abstract

The effects of rhizobial inoculation and pH on the growth of pinto beans (*Phaseolus vulgaris* L.) were investigated in a glasshouse experiment. Plants which were either inoculated or not inoculated with *Rhizobium* strain CC511 and, were grown at pH of 5.3, 6.5 or 7.3. Inoculation was necessary for nodule formation. This resulted in significant yield increase of 5.36 to 6.15 g/plant over non-inoculated plants. Changing pH level had a much greater effect on plant growth than did inoculation. Optimum pH level for roots and shoots was about 6.5. However, the plants showed little difference in growth response at the lower pH of 5.3. The highest pH of 7.3 caused large and significant decreases in growth rate and total yields. Yield losses were primarily due to reduced leaf area per plant.

Additional key words: *pinto bean,* Phaseolus vulgaris, *root, growth, nodulation, yield*

Introduction

Common bean (*Phaseolus vulgaris* L.) is one of the most important pulses worldwide. In 1993 approximately 24 million ha were sown to beans (FAO, 1993). Beans have been grown in New Zealand for a number of years. However, in the South Island work has shown that navy beans, which are used in tinned baked beans, have variable yields and often produce seed of low quality (McKenzie *et al.*, 1991).

Pinto beans are presently being successfully grown in Saskatchewan, Canada (Vandenberg, 1991). This would suggest that pinto beans are likely to grow well in Canterbury which experiences cool summer nights similar to those in Saskatchewan. Pinto bean is a new crop for Canterbury. It will supply a small domestic market and is potentially an export crop for the large North American Mexican fast food market. Since little is known about the growth of this plant in Canterbury, the most commonly recommended cultivar in Saskatchewan, Othello, was imported for experimental evaluation in Canterbury. Basic agronomic information was sought.

This initial experiment was conducted with the following objectives:

1. to determine the effect of pH on nodulation
2. to determine if inoculation with Rhizobium increases
3. to examine how these two factors influenced shoot and root growth.

Materials and Methods

Pinto bean cv. Othello was sown on 20 February 1995 into 80 cm deep x 15 cm diameter pots. Planting medium was 50% soil, 25% perlite and 25% crusher sand. Plants were grown in a glasshouse under natural light with a mean daily temperature of 19°C.

The treatments consisted of a factorial combination of three pH levels (5.3, 6.5, 7.3) and two levels of *Rhizobium* inoculation (nil and inoculated). The six treatments were replicated three times and the entire experiment was repeated four times to allow for sequential sampling.

The pH of the pots was adjusted using calcium hydroxide at 0, 14 and 35 g per pot. *Rhizobium* inoculation (strain CC511 supplied by Coated Seeds, Christchurch) was applied at the recommended rate as a solution at sowing. Pots were watered using a measured water budget to replace water lost through evapotranspiration. After emergence, plants were thinned to one per pot.

Measurements commenced three weeks after sowing and plants were harvested at two weekly intervals. Roots and tops were washed and dried to constant weight at 70°C in a forced air oven. Before drying the area of all leaves was measured using a LICOR 3100 area meter. Nodules were counted and weighed before drying. All results were analysed using ANOVA and all results presented as significant had a value of 0.05 or less.

Results

The final harvest at 91 DAS showed that both factors had significant effects on most variates (Table 1). While inoculation did not affect leaf or stem dry matter, inoculated plants had 15%, 10% and 100% heavier pods, roots and nodules respectively than non-inoculated plants. The effects of pH were much greater than those of inoculation with *Rhizobium*. All variates showed marked reductions at the highest pH level (Table 1). For example, leaf dry weights declined 45% from 1.29 g/plant at a pH of 4.5 to 0.71 g/plant at a pH of 7.3. Root dry weight was less affected than top growth, but was still reduced by 14%.

Dry matter accumulation over time showed similar trends. Figure 1 shows there was a consistent, but small response of shoot growth to Rhizobial inoculation. Root growth however, responded much less and it was only at the final harvest that the effect of inoculation was significant.

The effect of pH however was highly significant for shoot growth by 35 DAS and for root growth by 77 DAS (Fig. 2). Generally, the major reduction in growth occurred at the highest pH level. There were few significant differences between the pH levels of 5.3 and 6.5.

The maximum slope of the graphs in Figure 2 shows that shoots had a maximum growth rate of about 0.22

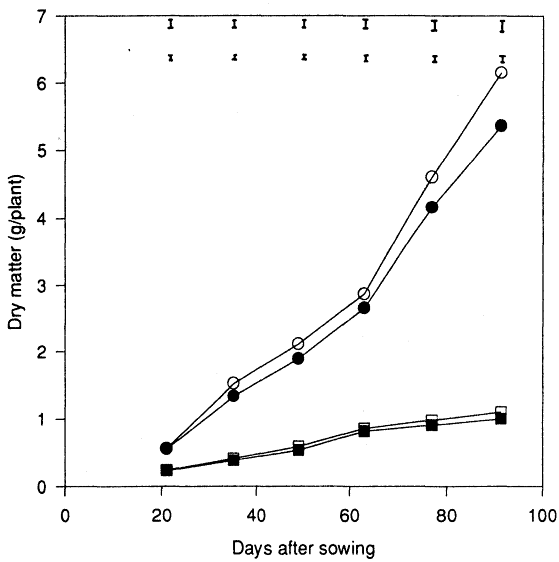

Figure 1. The effect of rhizobial inoculation on shoot and root growth of pinto beans; (O) shoot, inoculated; (●) shoot, no inoculation; (□) root, inoculated; (■) root, no inoculation. Top bars = SEM for shoots, bottom bars = SEM for roots.

Table 1. The effects of rhizobial inoculation and pH on dry matter production of pinto beans at 91 days after sowing.

	Dry matter (g per plant)					
Treatment	Leaf	Stem	Pod	Root	Nodules	Shoot
Inoculation						
nil	0.99	1.03	3.34	1.00	0	5.36
inoculated	1.12	1.18	3.85	1.10	0.069	6.15
SEM	0.060	0.052	0.114	0.028	0.0024	0.130
Significance	ns	ns	*	*	**	*
pH						
5.3	1.17	1.14	4.13	1.09	0.041	6.44
6.5	1.29	1.29	4.03	1.13	0.048	6.61
7.3	0.71	0.90	2.62	0.94	0.015	4.22
SEM	0.073	0.062	0.140	0.034	0.0029	0.160
Significance.	**	**	**	**	**	**
Interactions	ns	ns	ns	ns	**	ns
CV (%)	13	12	16	8	9	10

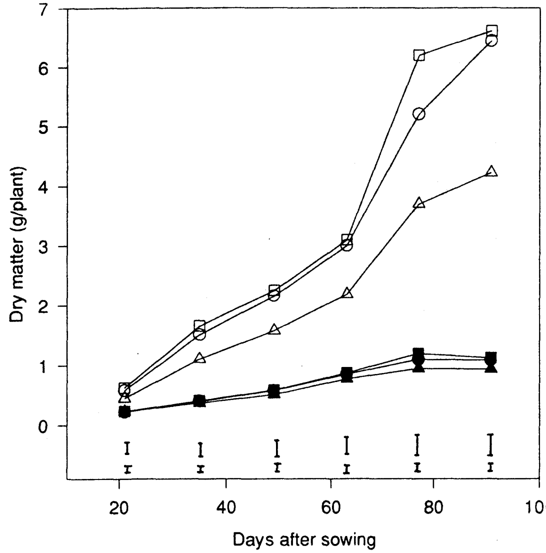

Figure 2. The effect of three pH levels on shoot and root growth of pinto beans: shoots are open symbols, roots are closed symbols (○) pH 5.3; (□) pH 6.5; (△) pH 7.3. Top bars = SEM for shoots, bottom bars = SEM for roots.

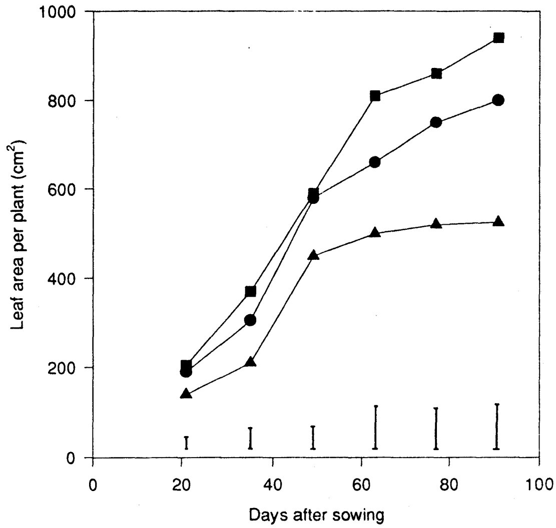

Figure 3. The effect of three pH levels on leaf area per plant of pinto beans: (●) pH 5.3, (■) pH 6.5, (▲) pH 7.3. Bars = SEM.

g/plant per day and roots had a maximum growth rate of about 0.032 g/plant per day.

Leaf growth was affected in a similar manner to shoot growth (Fig. 3). At all pH levels there was a rapid increase in leaf area per plant until 49 (pH 7.3) or 63 DAS (pH 6.5 and 5.3). Maximum leaf area per plant was approximately 500 cm^2 for plants grown at a pH of 7.3 and 800 and 950 cm^2 for plants grown at pH of 5.3 and 4.5 respectively. Inoculation had no effect on plant leaf area.

Discussion

Inoculation

As expected, inoculation proved beneficial to bean growth. While leaf and stem dry weights were not increased by 91 DAS with inoculation, total shoot, pod and root dry weights were. Generally, regardless of source, increased N supply results in larger plants and higher yields (Andrews, 1993).

The effect of additional nitrogen from the nodulated plants resulted in a cumulative effect of larger plants. It is likely however that internal N supply was limited as a significant effect on leaf growth did not occur. The lower than expected response to inoculation could also be due to low insolation levels of the indoor growing season March to May. Graham (1992) showed that symbiotic N fixation in beans is primarily influenced by supply of photosynthate to the nodules.

pH

The response to pH was much greater than the response to inoculation. As shown in Table 1 and Figures 2 and 3, a pH of 6.5 was clearly optimum for this species. This is similar to the report of Nuwamanya (1984) who reported an optimum pH range for beans of 5.5 - 6.7.

The lowest pH level of 5.3 did not cause the large decreases in yield or growth rate as did the highest pH (7.3). High pH levels have been shown to result in reduced growth of beans (Nuwamanya, 1984) and this may be due to induced nutrient deficiencies (Sumner *et al.*, 1978).

The agronomic reason for the reduced growth rates at high pH is clearly shown in Figure 3. Leaf area per plant was reduced approximately 47%. This would give a much lower LAI in the field, resulting in reduced intercepted radiation thus reduced growth rates.

The only significant interaction in this experiment was that of inoculation and pH on nodule growth. There were no nodules in the non-inoculated plants therefore no pH response, whereas there was a pH response for the inoculated, hence nodulated, plants. The major effect of pH was a reduction in nodule dry matter at pH 7.3. Graham (1992) found little reduction in nodulation under moderately low pH levels (5.3). This suggests that pinto beans are somewhat acid tolerant. The work also suggests that indigenous *Rhizobia* suitable for inoculating pinto beans may not be present in Canterbury soils.

Conclusions

1. The optimum pH for pinto bean growth is about 6.5, but they can tolerate slightly acid soils.
2. Inoculation with a suitable rhizobial strain is likely to increase growth and yield.
3. Increased plant growth rates with optimum pH are due to increased leaf area.

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