N_2 Fixation Of Common Bean In Dryland Production Systems: Effects Of Cultivar And Inoculation Method

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Introduction

Common bean ***(Phaseolus vulgaris)*** is generally considered to be a poor N_2 fixer. The host genotype, the ***Rhizobium*** strain, and/or the interaction between the inoculation method and environmental conditions may all be contributing to this poor fixation (Pena-Cabriales et al. 1993, Buttery et al. 1997). Bean cultivars vary in the ability to fix N_2 (Rennie and Kemp 1983b, Buttery et al. 1997) The inoculation process itself may limit the efficiency of N_2 fixation. For instance, the common practice of inoculating the seed may be limiting the N_2 fixation in an epigeal germinating crop such as common bean. This is because the seed coat and the Rhizobia adhering to it are forced above the ground exposing the Rhizobia to potentially adverse conditions (de Silva 1998). The length of the N_2 fixation period may be related to the season length and growth habit of the bean genotype (Rennie and Kemp 1983a, b). However, environmental conditions may influence season length and growth habit, thus, interfering with the N_2 fixation cycle. The purpose of this study was to determine the amount of N_2 fixed by bean cultivars differing in growth habit and season length.

Materials and Methods

The study was conducted at two locations in 1998; Saskatchewan Pulse Growers (SPG) farm (Dark Brown Chernozemic soil) and Seager Wheeler Farm near Rosthem (Black Chemozemic soil). The soil at SPG had 10 kg/ha available N at the O-60 cm depth whereas the soil at Rosthem had 19 kg/ha available N at the same depth. Four bean cultivars/lines (92235 – full season, indeterminate; CDC Camino – full season determinate; 92802 – early season, indeterminate and C962 – early season determinate) were used in the study. The study was arranged in a randomised complete block design with four replications. Two treatments, granular inoculant placed with the seed and granular inoculant side-banded (2.5 cm on the side of the furrow and 2.5 cm below the seed) and a control with no inoculation were applied to the four cultivars in a factorial design giving a total of 12 treatments. Triple superphosphate (0-45-O) at the rate of 20 kg/ha P_2O_5 was applied in the furrow at planting. Flax was used as a reference crop for the assessment of %Ndfa. At harvest seed yield was determined from a square metre quadrant from the centre of each plot and converted to kg/ha. Seed N concentration and %Ndfa for the seed were determined from a lmg subsample of 100 g finely ground seed sample from each plot. Nitrogen fixation was determined by the natural abundance method (Bremer and van Kessel 1990). The $\delta^{15}N$ of dry bean grown in N-free medium was considered to be 0.00 (de Silva 1998). Data from the two locations were combined and analysed together using analysis of variance.

Results and Discussion

Inoculation treatments and cultivars produced similar results at both locations, hence the results presented here are averaged over locations. Inoculation and bean cultivar had a significant effect on %Ndfa (Table 1). Applying granular inoculant increased %Ndfa compared to the control though the two inoculation treatments did not differ from each other. Bean lines differed in %Ndfa The bean line 92235 derived an average of 50% of the seed N from fixation while CDC Camino derived only 26% of the seed N from fixation. Applying granular inoculant increased the N yield for the seed (Table 1). The N yield varied with cultivar but was the same for inoculated treatments. The N_2 fixed also varied with cultivar from 6 kg/ha in CDC Camino to 45 kg/ha in 92235 (Table 1). Applying granular inoculant increased seed yield compared to the control (Table 1). On average, granular inoculant placed with the seed produced significantly higher seed yield than granular inoculant side-banded. A significant interaction between inoculation treatment and bean cultivar was observed for %Ndfa, amount of N_2 fixed and seed yield. The interaction for %Ndfa and amount of N_2 fixed was due primarily to the low amount of nitrogen fixed by the cultivar CDC Camino in inoculated treatments. The interaction

Table 1. Effect of inoculation treatment on N_2 fixation of four dry bean cultivars in 1998 in Saskatchewan (averaged over two locations)

	Cultivar/Line				
	92235	**CDC Camino**	**92802**	**C962**	**Mean**
Growth habit	Indeter	Deter	Indeter	Deter	
Days to maturity	101	102	95	94	
Treatment	**% Nitrogen derived from atmosphere (Ndfa)**				
Control	37.1	17.0	18.9	23.6	**24.2 a**
Granular with seed	63.4	33.5	47.2	49.3	48.4 b
Granular side-banded	60.3	28.0	50.8	46.4	46.4 b
Mean (cultivar)	**53.6 c**	**26.2 a**	**39.0 b**	**39.8 b**	
	Seed N (kg/ha)				
Control	40.7	34.0	42.6	47.6	41.2 a
Granular with seed	71.5	47.3	64.8	71.3	63.7 b
Granular side-banded	70.3	52.2	59.2	61.6	60.8 b
Mean (cultivar)	**60.8 b**	**44.5 a**	**55.5 b**	**60.2 b**	
	N_2 fixed (kg/ha)				
Control	15.1	6.3	7.8	11.6	**10.2 a**
Granular with seed	45.0	15.5	31.0	35.6	**31.8 b**
Granular side-banded	42.0	14.9	30.2	27.8	**28.7 b**
Mean (cultivar)	**34.0 c**	**12.2 a**	**23.0 b**	**25.0 b**	
	Seed yield (kg/ha)				
Control	1392	1057	1477	1647	1393 a
Granular with seed	1912	1432	1987	2187	1880 c
Granular side-banded	1816	1513	1687	1657	1668 b
Mean (cultivar)	**1707 b**	**1334 a**	**1717 b**	**1830 b**	

***-** Means followed by the same letter are not significantly different

for seed yield was due to the lower seed yield in the side-banding treatment for early maturing cultivars (C962 and 92802) in comparison to seed yield for the late maturing cultivars under the same treatment (Table 1).

This study shows that common beans can derive up to 50% of their plant N requirement from N_2 fixation. This is the same level of fixation as was reported for the crop by other researchers (Rennie and Kemp 1983 a, b; Bliss 1993). The actual amount fixed varied from as low as 6 kg/ha to 45 kg/ha depending on the cultivar. Rennie and Kemp (1983) reported that semi-vine (indeterminate) bean cultivars were superior in N_2 fixation compared to bush (determinate) cultivars. In the present study the top cultivar was an indeterminate full season type (92235) while the lowest ranking cultivar was a determinate short season type (CDC Camino). The other two cultivars (92802, indeterminate, short season and C962, determinate short season) had about the same %Ndfa. In addition to growth habit, the length of N_2 fixation period may have a bearing on the amount of N_2 fixed. Recent reports indicate that nodulation occurring in lateral roots during reproductive development accounts for a substantial portion of the total plant Ndfa (Bliss 1993; Kyei-Boahen et al. 1998). In early maturing cultivars, the short duration of root growth may limit the benefits from lateral root nodulation especially under terminal drought stress conditions.

In soybean, alfalfa and chickpea, applying granular inoculant below the seed supported high levels of lateral root nodulation during reproductive plant growth (Kamicker and Brill 1987; Hardarson et al. 1989; Rice and Olsen 1992. High level of lateral root nodulation was correlated with high seed yield (Wolyn et al. 1989; Kyei-Boahen et al. 1998). In the present study, side-banding granular inoculant below the seed did not have any advantage compared to seed placement or gave lower seed yield. However, the observed response may be specific to the past season growing conditions characterised by dry weather during reproductive phase of crop growth.

In summary, differences in N_2 fixation were observed between common bean cultivars. The amount on N fixed ranged from 6 kg/ha to 45 kg/ha depending on the cultivar. Side-banding granular inoculant and placing granular inoculant with the seed in the furrow gave similar levels of N_2 fixation. This study will be repeated in 1999 to confirm the results and to determine the effect of growing season conditions on N_2 fixation and yield.

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Literature cited

Bliss, F.A. 1993. Utilizing the potential for increased nitrogen fixation in common bean. **Plant and Soil 152: 157-160.**

Bremer, E. and van Kessel, C. 1990. Appraisal of the Nitrogen-15 natural-abundance method for quantifying dinitrogen fixation. **Soil Sci. Soc. Am. J. 54: 404-411.**

Buttery, B.R., Park, S.J. and van Berkum, P. 1997. Effects of common bean *(Phaseolus vulgaris* L.) cultivar and *Rhizobium* strain on plant growth, seed yield and nitrogen content. **Can. J. Plant Sci. 77: 347-351.**

de Silva, N.K.D.C. 1998. Nitrogen and inoculation response in common bean. **MSc Thesis, University of Saskatchewan, Saskatoon, Canada.**

Hardarson, G., Golbs, M. and Danso, S.K.A. 1989. Nitrogen fixation in soybean (Glycine max L. Merril) as affected by nodulation patterns. **Soil Biol. Biochem. 21: 783-787.**

Kamicker, B.J. and Brill, W.J. 1987. Methods to alter the recovery and nodule location of *Bradyrhizobium japonicum* inoculant strains on field grown soybeans. **Appl. Environ. Microbial. 53: 1737-l 742.**

Kyei-Boahen, S., Walley, F.L. and Slinkard, A.E. 1998. Effect of inoculum placement on chickpea inoculation. **Proceedings of the Soils and Crops workshop '98. P 77-80.**

Pena-Cabriales, J.J., Gradeda-Cabrera, O.A., Kola, V. and Hardarson, G. 1993. Time course of N_2 fixation in common bean *(Phaseolus vulgaris* L.). **Plant and soils 152: 115-121.**

Rennie, R.J. and Kemp, G.A. 1983 a. N_2- fixation in field beans quantified by ^{15}N isotope dilution. I. Effects of strains of *Rhizobium phaseoli.* **Agron. J. 75: 640-644.**

Rennie, R.J. and Kemp, G.A. 1983 a. N_2- fixation in field beans quantified by ^{15}N isotope dilution. II. Effects of cultivars of beans. **Agron. J. 75: 645-649.**

Rice, W.A. and Olsen, P.E. 1992. Effects of inoculum method and size of Rhizobium meliloto population in the soil on nodulation of alfalfa. **Can. J. Soil. Sci. 72: 57-67.**

Wolyn, D.J., Attewell, J., Ludden, P.W. and Bliss, F.A. 1989. Indirect measures of N_2 fixation in common bean (Phaseolus vulgaris L.) under field conditions: The role of the lateral root nodules. **Plant and Soil 113: 181-187.**

Keywords

Common bean, N_2- fixation, ***Phaseolus vulgaris,*** cultivar, inoculant