# Rhizobium Inoculant Formulation and Placement in Lentil and Chickpea in the Semiarid Canadian Prairies

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## Abstract

Lentil and chickpea are the major pulse crops grown in western Canada, but little is known about the responses of these annual legumes to rhizobium inoculant formulation, placement, and their interaction to fertilizers under semiarid environments. A field study was conducted from 1999 to 2002 on a medium-textured soil at Swift Current and on a heavy clay soil at Stewart Valley, both in Saskatchewan. The objectives were to (i) determine the effects of rhizobium inoculation and fertilization on nodule formation, $N_2$-fixation, and their impacts on growth, yield, and seed quality in chickpea and lentil, and (ii) develop recommendations for optimizing rhizobium inoculation, P-solublizing inoculation, and fertilizer N and P application for direct-seeding of chickpea and lentil with 1-, 2-, and 3-tank delivery systems. The results of the six site-years showed that use of rhizobium inoculation increased seed yield by 35% for desi, 7% for kabuli, and 23% for lentil. Inoculation reduced desi plant population by 10%, but not in kabuli or lentil. Granular inoculant increased yield by 7% in chickpea and 8% in lentil, compared to peat-based powder inoculant. Placement of granular inoculant (seed-row vs side-banding) had the same effect in all three pulses. Starter-N and starter-P at a rate of 15 kg $ha^{-1}$ each had a marginal effect on plant growth and seed yield, but a higher rate of P (34 kg $P_2O_5$ $ha^{-1}$) increased kabuli seed size. Chickpea and lentil did not show any response to *Penicillium bilaii* (fungus contained in the products JumpStart and TagTeam) under the semiarid growing conditions.

## Introduction

Canada is a leading exporter of lentil and chickpea. These two drought-tolerant pulse crops have been integrated into the farming systems in the semiarid regions of western Canada as a means of diversifying crop production and improving whole-farm economics. However, little information is available regarding rhizobium inoculation and fertilization requirements of these pulses. For example, many producers want to use granular inoculants with their pulse crops, but in a 2-tank delivery system, the use of granular inoculant precludes application of fertilizer P, while annual pulses require sufficient P supply to maximize $N_2$ fixation. Use of P-solublizing seed inoculant such as JumpStart (a product that contains fungus *Penicillium bilaii*) in one tank and granular rhizobial inoculant in another tank is one option; such an option may be beneficial when soil residual phosphate level is relatively low and when the crop is to be grown on land that had not grown pulses before. Another option is that peat-based powder rhizobium inoculant is applied to the seed in one tank with the second tank used for fertilizer-P. In 3- and 4-tank seeding systems, there are more options to accommodate the multiple requirements, but little is known about the relative performance of pulses that received a side-banded, compared to seed-row placed, granular inoculant. This field study was conducted (i) to determine the effects of rhizobium inoculation and fertilization on nodule formation, $N_2$-fixation, and their impacts on plant growth, seed yield, and market quality of chickpea and lentil grown in the semiarid prairies, and (ii) to develop recommendations for pulse growers in optimizing rhizobium and P-solublizing inoculants and fertilizer N and P in direct-seeding of kabuli- and desi-chickpea and lentil with 1-, 2-, and 3-tank seeding systems.

## Materials and Methods

Kabuli-chickpea (CDC Xena or Sanford), desi-chickpea (Myles), and lentil (CDC Glamis or Laird) were seeded from 1999 to 2002 at two sites; one on a silt loam soil at Swift Current, and the other on a heavy clay soil at Stewart Valley, Saskatchewan. Plots were directly seeded into wheat stubble using a hoe press seeder. The field used in this study had a low to medium level of residual soil N and P, and had no pulse crops grown in the past five years. These conditions of the land allowed the determinations of potential responses of pulses to fertilizer and rhizobium inoculants. Both rhizobium granular soil inoculant and seed-applied peat-based powder inoculant were used at the recommended rates. These two formulations of inoculants contain identical *Bradyrhizobium* strains, allowing us to make true comparisons between the two. The drill compartments were cleaned between treatments using a high-pressure air flow and sand running through the hoses and openers, to avoid potential cross-contamination from rhizobium inoculants among treatments. The experiment was conducted using a randomized complete block design with 4 replicates at each site. Other detailed agronomic information regarding the cultivars, seeding dates and soil temperatures at seeding, harvest dates, and the soil residual nutrients are summarized in Table 1.

## Results and Discussion

### *A) Inoculation vs. Non-inoculation with Rhizobium.*

There was a tendency that rhizobium inoculation reduced plant population density significantly in 5 of the 6 site-years for desi-chickpea, but this tendency was not evident for kabuli or lentil. The reason for the reduction in desi plant establishment with inoculation is not known, but we suspect that there might exist some interactions between seed coat and rhizobium bacteria. The chemical components (pigment) of the desi seed coat might be more sensitive to the rhizobial bacteria, compared to kabuli chickpea or lentil. More research is needed to address these different responses to rhizobium inoculation among pulse species/classes.

Rhizobium inoculation is critically needed for all three pulses in the semiarid growing environment. Plants inoculated with rhizobium, compared to the non-inoculated check, increased seed yield by an average of 35% in desi chickpea, and 23% in lentil. Kabuli chickpea expressed less drastic responses to inoculation, with the increases in seed yield ranging from 1 to 30% or an average yield increase of 7% across the six site-years. Kabuli chickpea grown at the Swift Current site responded less to rhizobium inoculation than when grown at Stewart Valley. These results suggest that kabuli chickpea has stronger ability to fix N or a stronger rooting system to uptake the needed N from deep soil layers even if a rhizobium source is not provided. However, on the clay soil at Stewart Valley this ability is limited. Nevertheless, a 7% yield increase of kabuli chickpea with inoculation is still economically significant, because such a level of yield increase translates into an average net return of 15 to $30 /ac (based on 10-yr results at Swift Current). The increased net return from inoculation is far more than the cost of using inoculant at the recommended rate. However, more research is needed to elucidate whether a high rate of nitrogen application in kabuli chickpea would produce a higher seed yield than use of rhizobium inoculant under semiarid growing conditions.

***B) Peat-based Powder versus Granular Inoculant***s

There was a tendency that plant population density decreased in plots receiving peat-based powder, compared to plots that received granular inoculation. This tendency, with a few exceptions, was found in both desi and kabuli chickpea, suggesting that peat-based powder inoculating the seed produces a certain degree of damage to the emerging seedlings. However, such a tendency was not found in lentil. More research is needed to further understand this effect.

On average, the granular inoculant increased seed yield by 7% in desi chickpea, 7% in kabuli chickpea, and 8% in lentil, compared to peat-based powder inoculation. Lentil showed a wide range of response to inoculant formulation with granular increasing seed yield from 3 to 38%, except for one site-year (2000 SC) where yield was lower with granular inoculation. Therefore, use of granular in both chickpea and lentil is strongly encouraged. The extra cost associated with the use of a granular inoculant product is less than the extra net income earned due to increased seed yield from granular inoculation. The two different formulations of rhizobium inoculants produced identical response in terms of plant height, lowest pod height, or days to maturity.

***C) Placement of Granular Inoculant***

In this study, the granular inoculant was placed in the seed-row and was compared with side-banding treatments. The results showed that the placement of rhizobium inoculant did not affect plant establishment for any of the three pulses. Seed yield or seed weight was not related to the inoculant placement in general, although in 4 of the 6 site-years the seed yield of desi chickpea was slightly (2%) higher for seed-row application compared to side-band treatments. No differences were found between the two application methods for kabuli chickpea or for lentil.

Use of granular inoculant allowed producers to efficiently inoculate the soil instead of the seed, resulting in a more uniform distribution of rhizobia in the soil profile. The findings that the inoculant placement, either applied in the seed-row or was side-banded, had no effects on plant establishment, seed yields, or harvestability, may encourages growers to adopt this practice with whatever seeding systems they have.

***D) Starter N***

Prior to seeding each year, the residual soil N was measured to a 120-cm soil depth in several fields, then the field with a low to medium level of nutrients was selected for conducting this experiment. The residual soil N ranged from 10 to 20 kg N $ha^{-1}$ (except in 2002 at Swift Current) and residual soil P ranged from 10 to 28 kg $P_2O_5$ $ha^{-1}$; the variation among site-years was due to a different pieces of land used each year for the experiment.

Starter N at the rate of 15 kg N $ha^{-1}$, compared to the non-N check treatment, did not affect plant establishment for chickpea or lentil, although the N application slightly reduced plant population (by 3%) for lentil, but it was not statistically significant. Lentil has a thinner seed coat than desi chickpea, and it might be more sensitive to the Starter N that was applied in the seed-row.

Starter N increased seed yields by an average of 2% for desi chickpea, 5% for kabuli chickpea, and 4% for lentil. Although the increases in seed yield were found in 5 out of 6 site-years, they were only statistically significant for kabuli chickpea. Nevertheless, the increases in seed yield due to N application were marginal. Given the fact that kabuli chickpea responded to rhizobial inoculation much less than desi chickpea (as described earlier) and kabuli responded better to N fertilizer than desi, it is strongly suggested that further study involving different N rates should be conducted, to determine if a higher rate of N would provide kabuli chickpea with more benefits than use of rhizobium inoculant in improving yield potential.

The application of Starter N improved harvestability by increasing plant height and the lowest pod height in all pulses studied. This improvement in plant height and the lowest pod height was due to applied N boosting vegetative growth in the early growth stage. We observed in the field that plots that received Starter N were greener, more vigorous before flowering than plots that did not receive N. Starter N at the rate of 15 kg N $ha^{-1}$ accelerated plant maturity by a merely 0.5 to 0.7 days, which is marginal, despite being statistically significant in many cases.

***E) Phosphate Effect***

Phosphate at a rate of 15 kg $P_2O_5$ $ha^{-1}$, compared to the non-P check treatment, did not affect any of the growth- or yield-related variables measured in this study. No P response was found, except for lentil in which the application of P increased lentil seed yield in 4 of 6 site-years by an average of 4%. However, the application of P increased the lowest pod height of kabuli chickpea by an average of 11 mm, which suggests an improvement in harvestability of 5%.

In an adjacent trial at Swift Current, kabuli chickpea was seeded in mid- to late-May with three levels of phosphate. The phosphate at the rate of 34 kg $P_2O_5$ $ha^{-1}$, compared to 0 and 17 kg $P_2O_5$ $ha^{-1}$, increased the proportion of the ∃9-mm diameter seeds (54% vs 59%), implying an increase of the price premiums from the large-sized seed. However, such a response was not observed when the kabuli was seeded in early-May. The earlier-seeded chickpea had a longer period of time to develop stronger rooting systems that may help to uptake nutrients from deeper soil layers, thus no effect of fertilizer P application on kabuli seed size was detected in the present study.

**F) *Penicillium bilaii***

The soil-isolated fungus *Penicillium bilaii* is believed to make residual soil phosphate more available to emerging seedlings. Studies with cereal and oilseed crops have shown some positive responses to this fungus, but not in all cases. There was no information available whether pulse crops would respond to this fungus under semiarid growing conditions. In the present study, we applied *Penicillium bilaii* from the product JumpStart using recommended methods and rates, and compared them with the treatments that received no JumpStart. The results indicated that JumpStart did not affect plant establishment or seed yield for any of the three pulse crops tested. JumpStart did not result in any improvement in harvestability (such as plant height, lowest pod height, maturity) of the pulses. The only exception was in 1999 at Swift Current when JumpStart increased desi seed yield by 10%, but not for kabuli or lentil. In 17 of the 18 crop site-years, the plots that received *Penicillium bilaii*, compared to plots received no *Penicillium bilaii*, produced identical seed yields for all three pulses studied. The analyses indicated that JumpStart did not improve any growth- or yield-related variables, or harvest conditions such as plant height and maturity, compared to non-JumpStart plots. Similarly, plots that received TagTeam (which contains *Penicillium bilaii* and rhizobium) produced identical plant establishment and seed yields as the plots that received rhizobium inoculant without *Penicillium bilaii*.

**Table 1. Agronomic information for chickpea and lentil studies conducted at Swift Current (SC) and Stewart Valley (SV), Saskatchewan, 1999-2002.**

| Year | Cultivar | Seeding date SC | Seeding date SV | Soil temperature (ºC) SC | Soil temperature (ºC) SV | Soil residual N-P-K-S (kg ha$^{-1}$) | Kernel weight (mg seed$^{-1}$) | Seeding rate (kg ha$^{-1}$) | Harvest date SC | Harvest date SV |
|---|---|---|---|---|---|---|---|---|---|---|
| 1999 | Laird | 25 May | N/A | 17 | N/A | 16-20-0-0 (SC) | 69 | 99 | 10 Sep | N/A |
| | Myles | 26 May | N/A | 17 | N/A | 21-25-0-0 (SC) | 181 | 103 | 14 Sep | N/A |
| | Sanford | 26 May | N/A | 17 | N/A | 16-16-0-0 (SC) | 499 | 224 | 17 Sep | N/A |
| 2000 | CDC Glamis | 3 May | 4 May | 16 | 12 | 9-28-0-0 (SC)<br>18-10-0-0 (SV) | 60 | 84 | 11 Aug | 17 Aug |
| | Myles | 3 May | 4 May | 16 | 12 | 10-26-0-0 (SC)<br>17-10-0-0 (SV) | 178 | 100 | 28 Aug | 8 Sep |
| | CDC Xena | 4 May | 5 May | 16 | 13 | 11-21-0-0 (SC)<br>17-10-0-0 (SV) | 554 | 244 | 1 Sept | 1 Sep |
| 2001 | CDC Glamis | 26 Apr | 30 Apr | 10 | 9 | 15-18-0-0 (SC)<br>17-10-0-0 (SV) | 63 | 88 | 10 Aug | 10 Aug |
| | Myles | 27 Apr | 30 Apr | 10 | 9 | 15-18-0-0 (SC)<br>17-10-0-0 (SV) | 170 | 95 | 21 Aug | 10 Sep |
| | CDC Xena | 26 Apr | 30 Apr | 10 | 9 | 15-18-0-0 (SC)<br>17-10-0-0 (SV) | 489 | 246 | 11 Sep | 12 Sep |
| 2002 | CDC Glamis | N/A | 17 May | N/A | 11 | 20-18-0-0 (SV) | 61 | 85 | N/A | 10 Sep |
| | Myles | 16 May | 17 May | 11 | 11 | 45-28-0-0 (SC)<br>18-16-0-0 (SV) | 172 | 96 | 23 Oct | 24 Oct |
| | CDC Xena | 16 May | 17 May | 11 | 11 | 45-28-0-0 (SC)<br>21-21-0-0 (SV) | 496 | 218 | 15 Oct | 26 Sep |