

NODULATION AND YIELD RESPONSES TO “STARTER” N AND P IN FIELD PEA, LENTIL, AND CHICKPEA IN THE SEMIARID NORTHERN GREAT PLAINS

Y. Gan¹, G.W. Clayton², G. Lafond³, F. Walley⁴, and B.G. McConkey¹

¹Agriculture and Agri-Food Canada, Swift Current, SK, ²Lacombe, AB, and ³Indian Head, SK; and ⁴The University of Saskatchewan, Saskatoon, SK

gan@agr.gc.ca (306)778-7246

INTRODUCTION

Grain legumes require a high level of N fertility to achieve maximum yield and protein (Sosulski et al., 1974; Sosulski and Buchan, 1978). In these 1970's and 1980's studies, nodulation and nitrogenase activity were generally poor even when the legumes were inoculated with rhizobia (Sosulski and Buchan, 1978). Although indigenous populations of rhizobia are often present in the soils, they might be ineffective for inducing N₂ fixation under semiarid environments (Kucey and Hynes, 1989). Small doses of N applied to a pulse may be beneficial especially if nodule initiation is delayed (Mahon and Child, 1979). In dry bean, it is recommended to add sufficient amounts of N to optimize seed yield (McAndrew and Mills, 2000). With improvements of inoculant formulations (granules) and methods of inoculation (inoculating the soil), dramatic improvements in seed yield have been observed in the past decade (Rennie and Hynes, 1993; McKenzie et al., 2001a; Kyei-Boahen et al., 2002; McConnell et al., 2002; Clayton et al., 2004a and 2004b; Gan et al., 2004). Most producers currently inoculate seed or the soil with an appropriate rhizobial strain and provide none or little additional fertilizer N to their pulse crops. It has been argued that due to the lag period between rhizobium root colonization and the onset of nodule functioning, the young legume plants may require additional N from external sources to achieve vigorous growth and establish the N-fixing symbiosis. It is hypothesized that initial crop growth and subsequent N₂ fixation can be enhanced by the addition of a low dose of Starter N.

RESPONSE TO “STARTER” N

Field Pea (*Pisum sativum* L.):

There are significant interactions between Starter N and rhizobial inoculant formulations (Lafond and Johnston, 2002; Clayton et al., 2004b). Field pea seed yield increased with applied N when it was uninoculated or inoculated with seed-applied liquid formulation, and there was no effect when the crop was inoculated with seed-applied peat or soil-applied granules (Lafond and Johnston, 2002). Pea inoculated with liquid formulation formed poor nodulation patterns and thus additional N was needed for its growth. Field pea inoculated with granular soil inoculant produced 22% higher biomass yield than the uninoculated check when Starter N was <20 kg N ha⁻¹ (Clayton et al., 2004a). The biomass yield increase due to the granular soil inoculant was a mere 4% over the uninoculated pea when fertilizer N was applied at 40 to 80 kg ha⁻¹. McConnell et al. (2002) found that application of 100 kg N ha⁻¹ of fertilizer to uninoculated field pea maintained shoot biomass similar to the granular inoculant control. In studying continuous pea rotation to a wheat-pea rotation where three rates of starter N fertilizer were used, Lafond (unpublished data) found that starter N only had a positive effect on grain yield in the first two

years of the nine year study. The nine-year mean seed yields for the 0, 20 and 40 kg N ha⁻¹ treatments were 2280, 2300 and 2390 kg ha⁻¹, respectively. This level of response was not economically significant. These results indicate that the N requirements of field pea are met by N₂ fixation when the crop is well inoculated with an appropriate inoculant formulation, and that additional fertilizer N is required to increase biomass yield of pea that fail to produce sufficient nodules. With poor inoculation, fertilizer N is needed to compensate the N requirement of pea plants.

Residual soil N status and indigenous rhizobia influence N₂ fixation and seed yield in field pea. Application of N at 20 to 60 kg N ha⁻¹ increased pea yield by an average of 9% in ¼ of the 58 trials conducted in Alberta (Mckenzie et al., 2001a). When spring soil NO₃-N (30-cm soil depth) was less than 20 kg N ha⁻¹, application of N increased pea yield in 1/3 of the trials by an average of 11%. In these trials, the benefits of Starter N was moderate despite appreciable deficits between soil NO₃-N and accumulation of N by pea; this was likely due to adequate nodulation of pea by indigenous rhizobia. The frequency of response to N fertilizer was slightly related to legume history, with yield benefit being greater in trials with no history of legumes (10%) than in trials with a history of legumes (5%).

Addition of N fertilizer increased protein concentration in field pea, especially when soil NO₃-N (30-cm soil depth) is less than 20 kg N ha⁻¹ (Mckenzie et al., 2001a). In trials showing the benefit of applied N, protein concentration increased by 0.9% at 20 kg N ha⁻¹ and 2.9% at 60 kg N ha⁻¹. Seed protein concentration increased by 12 to 15% when inoculant was soil-applied compared with seed-applied or uninoculated pea (Clayton et al. 2004b). In general, field pea expresses less severe N-related stress symptoms during early growth of the crop compared to other grain legumes such as field bean (*Phaseolus vulgaris*) or soybean (*Glycine max*). Physiologically, field pea often exports the first fixed N to the shoot system rather than use it for nodule growth (Sprent and Thomas, 1984). Also, field pea only acquire a small dose of N from soil or applied fertilizer N for their root growth and pass the majority of the absorbed N directly to shoots.

Lentil (*Lens culinaris* Medik.):

Lentil has a strong indeterminate growth habit. When growing conditions are favourable, lentil will continue its vegetative growth and set fewer pods or none. A vigorous growth early in the growing season will accelerate depletion of soil water and nutrients, resulting in a timely maturity. Starter N at a rate of 30 kg ha⁻¹ significantly promoted early growth and increased lentil seed yield when residual soil NO₃-N was around 10 kg N ha⁻¹ (Lafond et al., 2002). Fields with a history of summer fallow every third year (often the case in southwest Saskatchewan) where little N fertilizer is used in previous seasons; the use of Starter N in lentil is beneficial. However, there is no effect of Starter N on lentil when conditions are dry or when fields have a long history of continuous cropping with adequate N fertilizer used in the previous seasons.

A low dose of Starter N stimulates vegetative growth of lentil. Lafond (unpublished data) measured Normalized Difference Vegetation Index (NDVI, the ratios of the infra-red and red bands) using a GreenSeeker instrument, and found that the chlorophyll content of lentil plant canopy was significantly greater when lentil was fertilized with a small dose of Starter N (Table 1). At the mid-flowering stage of lentil, NDVI values increased linearly with N rate regardless of the tillage practices. Gan et al. (2003) found that addition of N fertilizer to lentil at a rate of 15 kg N ha⁻¹ advanced days to maturity, reduced nodule dry weight significantly, but there was no effect on seed yield (Table 2).

Table 1. The effects of Starter N on Normalized Difference Vegetation Index (NDVI) measured in long-term and short-term no-till plots for lentil grown in Indian Head, Saskatchewan (Lafond, 2004).

Nitrogen-N rate (kg ha ⁻¹)	NDVI		
	Long Term No-Till	Short Term No-Till	Mean
0	0.44	0.45	0.45
15	0.47	0.52	0.49
30	0.58	0.59	0.59
60	0.62	0.67	0.64
Unpublished data			

Table 2. Effects of Starter-N on seed yield, maturity, and nodulation for lentil, and desi- and kabuli-chickpea grown in southwest Saskatchewan, 1999-2002 (Gan et al., 2003)

Starter-N (kg ha ⁻¹)	Lentil	Kabuli chickpea	Desi chickpea
	Seed yield (kg ha ⁻¹)		
0	1103	1705	1708
15	1150	1783	1746
<i>P</i> value	0.06	<0.01	0.26
Days to maturity (d)			
0	95.0	107.2	108.9
15	94.5	106.5	108.3
<i>P</i> value	<0.01	<0.01	0.21
Nodule dry weight (g plant ⁻¹)			
0	0.11	0.57	0.54
15	0.04	0.51	0.47
<i>P</i> value	<0.01	<0.01	<0.01

Chickpea (*Cicer arietinum* L.):

When growing conditions are favourable, chickpea plants continue their vegetative growth without setting pods or seeds, reflecting their strong indeterminate growth habit. A vigorous growth early in the growing season will accelerate depletion of soil water and nutrients, resulting in a timely maturity. Gan et al. (2003) reported that Starter N at the rate of 15 kg N ha⁻¹, compared to non-N check, increased seed yield significantly for kabuli-type chickpea, but did not affect seed yield for desi chickpea (Table 2). This was coincidental to the fact that kabuli-type chickpea responded to rhizobial inoculant much less than desi chickpea. In addition, the application of the Starter N improved harvestability by increasing plant height and the lowest

pod height from the soil surface in both chickpea types (Data not shown). This was due to applied N boosting vegetative growth in the early growth stage. Chickpea plots that received Starter N were greener, more vigorous before flowering than plots that did not receive N. Starter N accelerated plant maturity by a mere 0.5 to 0.7 days, which is marginal in practice.

The addition of Starter N reduced the number of nodules and nodule weight in both chickpea types (Table 2). This reduction in nodule number and dry mass is expected because the plant does not require as much N₂-fixation when soil N is available.

RESPONSE TO “STARTER” P

Field pea:

The amount and placement of P fertilizer influences the production of field pea. Side-banding of mono-ammonium-phosphate (MAP) fertilizer from 0 to 44 kg P ha⁻¹ in Saskatchewan increased pea seed yield in a quadratic response curve (Henry et al., 1995). With seed-placement of P, pea emergence was inversely proportional to the rate of P and seed yield was reduced accordingly. Using triple superphosphate (TSP) fertilizer at 52 trials across Alberta from 1995 to 1998, McKenzie et al. (2001b) found that application of TSP at 13 kg P ha⁻¹ was sufficient to maximize pea seed yield when soil test P levels (Modified Kelowna extractable-P) were less than 30 kg P ha⁻¹. Similarly, Karamanos et al. (2003) tested five rates (0, 6.5, 13, 19.5 and 26 kg P ha⁻¹) at 13 sites in Alberta, and found a significant response of field pea to P application at sites where Modified Kelowna extractable-P was <10 mg per kg soil. There was no significant yield increase when soil test P was greater than 10 mg MK-P kg⁻¹ soil. Maximum pea seed yield increase (650 kg seed ha⁻¹) was obtained with application of 19.5 kg P ha⁻¹. The soil texture influences P response in pulse crops. Karamanos et al. (2003) found that the magnitude of P response in field pea was greater on loamy (540 kg seed ha⁻¹) than on clay loam soils (290 kg seed ha⁻¹) at P=19.5 kg ha⁻¹ in Alberta.

Phosphorus is considered immobile in the soils of semiarid northern Great Plains and it is normally placed near the seed. Alberta Agriculture, Food and Rural Development (1999) suggest that neither germination nor emergence is reduced with application of up to 15 kg of seed-placed P ha⁻¹ and that under conditions of good seedbed soil moisture, even higher rates of seed-placed phosphate are safe. Saskatchewan Agriculture, Food and Rural Revitalization (2000) and Manitoba Agriculture and Food (2001) recommend a maximum safe rate of seed-placed P at 7.3 and 9.8 kg P ha⁻¹, respectively. Adoption of direct seeding combined with the ability to side band or to spread seed and fertilizer over wider areas (i.e., increased seedbed utilization) may allow for greater rates of phosphate than currently recommended.

Lentil and chickpea:

In lentil grown in southwest Saskatchewan, Starter P at a rate of 7.4 kg P ha⁻¹ increased lentil seed yield in ¾ of the trials with an average yield increase of 4% compared to the non-P check (Gan et al., 2003). Kabuli chickpea showed a substantial increase in lowest pod height with application of Starter-P, which improved harvestability by 5%, however, chickpea seed yield was not affected.

The use of a higher rate of P increased the seed size of kabuli chickpea in southwest Saskatchewan (Gan et al., 2003). When kabuli chickpea was seeded in the mid- to late-May in the semiarid Saskatchewan, the application of P at the rate of 14.8 kg P ha⁻¹ compared to 0 and 7.4 kg P ha⁻¹, increased the proportion of the ≥9-mm diameter seeds from 54 to 59 percentage

points in the harvested seedlot. Buyers of Kabuli seed ≥ 9 -mm in diameter will pay price premiums. However, such a response was not observed when kabuli chickpea was seeded at an early-May seeding date. The earlier-seeded chickpea had a longer period of time to develop stronger rooting systems that support the uptake of nutrients from deep soil layers, thus no effect of fertilizer P application on kabuli seed size was detected.

REFERENCES

- Alberta Agriculture, Food and Rural Development. 1999. Pulse crops in Alberta. B. Pak and K. Lopetinsky, eds. AAFRD, Edmonton, AB.
- Clayton, G.W., W.A. Rice, N.Z. Lupwayi, A.M. Johnston, G.P. Lafond, C.A. Grant and F. Walley. 2004a. Inoculant formulation and fertilizer nitrogen effects on field pea: Crop yield and seed quality. *Can. J. Plant Sci.* (in press).
- Clayton, G. W., W.A. Rice, N.Z. Lupwayi, C.A. Grant, A.M. Johnston, G.P. Lafond, and F. Walley. 2004b. Inoculant formulation and fertilizer nitrogen effects on field pea: Nodulation, nitrogen fixation and nitrogen partitioning. *Can J. Plant Sci.* (in press)
- Gan, Y., F. Selles, K.G. Hanson, R.P. Zentner, B.G. McConkey, S.V. Angadi, and C.L. McDonald. 2003. Rhizobium Inoculant Formulation and Placement in Lentil and Chickpea in the Semiarid Canadian Prairies. *In Proc. (CD-ROM) Soils and Crops Workshop 2003*, Saskatoon, SK. Feb 17-18, 2003.
- Gan, Y., F. Selles, K.G. Hanson, R.P. Zentner, B.G. McConkey, and C.L. McDonald. 2004. Formulation and placement of Rhizobium inoculant on chickpea in the semiarid northern Great Plains. *Field Crops Research* (in press).
- Henry, J.L., A.E. Slinkard, and T.J. Hogg. 1995. The effect of phosphorus fertilizer on establishment, yield and quality of pea, lentil and faba bean. *Can. J. Plant Sci.* 75: 395–398.
- Karamanos, R.E., N.A. Flore, and J.T. Harapiak. 2003. Response of field peas to phosphate fertilization. *Can. J. Plant Sci.* 83:283–289.
- Kucey, R.M.N., and M.F. Hynes. 1989. Populations of *Rhizobium leguminosarum* biovars *phaseoli* and *viceae* in fields after bean or pea in rotation with nonlegumes. *Can. J. Microbiol.* 35: 661–667.
- Kyei-Boahen, S., A.E. Slinkard, and F.L. Walley. 2002. Evaluation of rhizobial inoculation methods for chickpea. *Agron. J.* 94:851-859.
- Lafond, G., and A. Johnston. 2002. Field pea yield – effect of inoculant formulation and nitrogen fertilizer. Agri-Food Innovation Fund research report 2002. Saskatchewan, Canada.
- Lafond, G., E. Johnston, and B. Nybo. 2002. Lentil yield – starter nitrogen fertilizer and inoculant effects. Agri-Food Innovation Fund research report 2002. Saskatchewan, Canada.

- Mahon, J. D., and J.J. Child. 1979. Growth response of inoculated pea (*Pisum sativum*) to combined nitrogen. *Can. J. Bot.* 57:1687–1693.
- Manitoba Agriculture and Food. 2001. Field pea – production and management. [Online] Available:<http://www.gov.mb.ca/agriculture/crops/pulsecrops/bhe01s01.html#fertilizer>. [March 2001].
- McAndrew, D.W., and K. Mills. 2000. Nitrogen fertilizer in dry bean in Manitoba. Page 72-75. *In* Proc. Third Pulse Crop Research Workshop. Winnipeg, MB. 19-21, November 2000.
- McConnell, J.T., P.R. Miller, R.L. Lawrence, R. Engel, and G.A. Neilsen. 2002. Managing inoculation failure of field pea and chickpea based on spectral responses. *Can. J. Plant Sci.*: 82: 273-282.
- McKenzie, R.H., A.B. Middleton, E.D. Solberg, J. DeMulder, N. Flore, G.W. Clayton, and E. Bremer. 2001a. Response of pea to rhizobia inoculation and starter nitrogen in Alberta. *Can. J. Plant Sci.* 81: 637-643.
- McKenzie, R.H., A.B. Middleton, E.D. Solberg, J. DeMulder, N. Flore, G.W. Clayton, and E. Bremer. 2001b. Response of pea to rate and placement of triple superphosphate fertilizer in Alberta. *Can. J. Plant Sci.* 81: 645–649.
- Rennie, R.J., and R.K. Hynes. 1993. Scientific and legislative quality control of legume inoculants for lentil and field pea. *J. Prod. Agric.* 6: 569–574.
- Saskatchewan Agriculture, Food and Rural Revitalization. 2000. Phosphorus fertilization in crop production. [Online] Available: http://www.agr.gov.sk.ca/docs/crops/integrated_pest_manage-ment/soil_fertility_fertilizers/phosfert.asp.
- Sosulski, F., and J.A. Buchan. 1978. Effects of *Rhizobium* and nitrogen fertilizer on nitrogen fixation and growth of field peas. *Can. J. Plant Sci.* 58: 553–556.
- Sosulski, F.W., L.A. McLean, and H.M. Austenson. 1974. Management for yield and protein of field peas in Saskatchewan. *Can. J. Plant Sci.* 54: 247–251.
- Sprent, J., and R. Thomas. 1984. Nitrogen nutrition of seedling grain legumes: some taxonomic, morphological and physiological constraints. *Plant Cell Environ.* 7: 637–645.