Development of a Rating Scheme to Evaluate Root Nodulation in Chickpea (*Cicer arietinum*)

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Introduction

Chickpea (*Cicer arietinum)* has become an important pulse crop in the Brown Soil Zone of the Canadian prairies with about one million acres (over 400 000 ha) seeded in Saskatchewan alone in 2001. As with most legumes, chickpea can fix nitrogen from the atmosphere when the plant forms active root nodules. Active root nodules are formed when the proper strain of *Rhizobium* bacterial inoculant is provided for the crop and together the plant and bacteria make a nitrogen fertilizer “factory”. Not enough active nitrogen-fixing root nodules can result in substantially decreased plant production and grain yield potential (Green and Biederbeck 1995). Root nodulation rating schemes have been developed for other legume crops and these have been useful for researchers and producers to evaluate production potential (Rice et al. 1977, Rice and Clayton 1996). The presently available schemes emphasize nodule number, size, colour and in some cases distribution of nodules throughout the root system as important factors for assessment.

Preliminary field investigations have shown that existing root nodulation rating schemes are inadequate for use as tools to predict chickpea grain yield potential. The objective of this study was to develop a root nodulation rating scheme to assess the effective root nodulation of chickpea that may determine if maximum yield potential will be realized.

Materials and Methods

This study was conducted in conjunction with an existing field trial that evaluated legume inoculant form and fertilization accompanying seeding in lentil, desi chickpea and kabuli chickpea (Gan et al. 2002). For the purposes of our portion of the study, desi (cv. Myles) and kabuli (cv. CDC Xena) chickpea plants were sampled from select *Rhizobium* inoculant treatments at three times during the growing season in field trials at two locations, Swift Current and Stewart Valley. The inoculant treatments included granular inoculant, peat-based powder and an uninoculated control. The times for sampling were chosen to be at approximately two weeks before flowering, at flowering and two weeks after flowering. Root nodules were counted and weighed (fresh and dry weight) at all sampling times and at flowering nodule size, colour and distribution assessed. The percentage of nitrogen in the plant material was determined at flowering and grain yield determined at harvest.

Means of the parameters were determined from the data collected and the geometric mean diameter generated. The data was analyzed using ANOVA and means separated using single degree of freedom contrasts (JMP, SAS, Gary NC). The means were correlated with grain yield and assessed for significant relationships.

Results and Discussion

Detailed measurements of the nodules were only conducted at flowering because the majority of nodules were not actively fixing nitrogen as indicated by pink colour at the other sampling times. Nodules at the sampling two weeks prior to flowering were very small, white in colour and few in number. Nodules at flowering showed a range of colours, sizes and distribution while those sampled two weeks after flowering were found to be senescing and poorly attached to the root and thus losses may have occurred.

Means of the data for kabuli chickpea tended to be significantly greater for the inoculated treatments compared to the uninoculated control (Table 1). The exception was geometric mean diameter of the nodules which were not different between treatments. The geometric mean diameter of nodules for kabuli chickpea was found to have a negative correlation with yield for kabuli chickpeas (Table 1). Other nodule measurements were better correlated with yield, and the number of nodules greater than 5 mm in diameter showed the highest correlation with grain yield (Table 1).

Table 1. Effect of inoculant type on measurements† of kabuli chickpea (cv. CDC Xena) from field trials conducted at two locations (Swift Current and Stewart Valley) in 2001.

Inoculant Type	Geometric Mean (mm)	Nodule Mass (mg)	Nodule Number	Nodules >5 mm	Yield (kg/ha)
Granular	4.50 a	62 b	10 a	5 a	749 a
Peat Powder	5.06 a	99 a	12 a	6 a	750 a
Control	5.61 a	31 b	3 b	2 b	536 b
Correlation With Yield	-0.3627	0.7514	0.8565	0.9427	

† Nodule mass, number and nodules >5 mm in diameter are expressed on a per plant basis. Means followed by different letters are significantly different at p=0.05.

The granular inoculant treatment in desi chickpea was consistently the highest for all parameters measured (Table 2). For the majority of parameters measured the granular treatment was significantly greater in value than the control and in the case of nodule number per plant was also significantly greater than the peat powder treatment. The peat powder treatment was consistently intermediate to the granular and uninoculated control treatments (Table 2). Correlation between the geometric mean and grain yield was poor compared to the other parameters measured. The best correlation to grain yield was again shown by the number of nodules greater than 5 mm in diameter (Table 2).

Both kabuli and desi chickpea showed relatively poor correlation between the nitrogen content measured in the aboveground plant material and grain yield (data not shown). The correlation between nitrogen content and the measured nodule parameters was also quite poor (data not shown). Due to poor correlations with yield and the long period of time to get results from plant analysis, it was determined that this is not an important component to measure for assessing root nodulation as an indicator of yield potential.

Table 2. Effect of inoculant type on measurements of desi chickpea (cv. Myles) from field trials conducted at two locations (Swift Current and Stewart Valley) in 2001.

Inoculant Type	Geometric Mean (mm)	Nodule Mass (mg)	Nodule Number	Nodules >5 mm	Yield (kg/ha)
Granular	5.17 a	76 a	11 a	6 a	869 a
Peat Powder	5.42 a	57 ab	7 b	4 ab	691 ab
Control	4.88 a	30 b	4 c	2 b	570 b
Correlation With Yield	0.4672	0.8515	0.7814	0.9971	

† Nodule mass, number and nodules >5 mm in diameter are expressed on a per plant basis. Means followed by different letters are significantly different at p=0.05.

When the majority of nodules were in the crown, for both desi and kabuli chickpeas, higher yield was observed (Table 3) however, this probably reflects the impact of the lower yielding uninoculated treatments which had most of their nodules in the tap and side roots. Distribution of the nodules has been found to be an important factor with forage legumes (Rice et al. 1977) but may not affect pulse crops since it is not a component of the pulse nodule rating scheme (Rice and Clayton 1996).

Table 3. Yield response to nodule distribution in chickpea at two locations in 2001. The number of field observations is represented by n.

Chickpea Type	Nodule Location	n	Yield (kg/ha)
Kabuli	Crown	9	735
	Tap & Side Roots	9	685
Desi	Crown	7	738
	Tap & Side Roots	11	693

Nodule colour analysis revealed that pink nodules were not necessarily the best indicators of high grain yield for either chickpea type (Table 4). There appeared to be no difference in yield response of kabuli chickpea comparing pink to pink/green nodule colour. Desi chickpea showed a marked increase in yield with pink/green nodules compared to pink or off white nodules (Table

4). This lack of yield decrease due to the presence of pink/green nodules is contrary to other nodulation schemes.

Table 4. Yield response to nodule colour in chickpea at two locations in 2001. The number of field observations is represented by n.

Chickpea Type	Nodule Colour	n	Yield (kg/ha)
Kabuli	Pink	12	709
	Pink/green	6	714
Desi	Off white	2	518
	Brown/pink	1	697
	Pink	6	637
	Pink/green	9	804

An important point to remember when assessing this data is that 2001 was a drought year at the site locations and that is reflected in the low yields. The correlations, colour and distribution responses observed might change considerably in years with more precipitation. In addition, the correlations were generated with only three data points thus the validity of the correlation is questionable.

Conclusions

The relationship between the number of nodules greater than 5 mm in diameter and grain yield was fairly strong for both chickpea types. Distribution of the nodules throughout the root system did not affect yield. Contrary to findings with other pulse crops pink nodules may not be the best indicator of effective root nodulation or at least of the nodule's effect on final yield. Due to the dry conditions in 2001, yields were low and the drought conditions may have affected the other parameters measured resulting in non-representative results. A continuation of the field trial in 2002 will be required to verify the responses observed in 2001. In turn, this will hopefully result in the development of a root nodulation scheme that can be used under field conditions. If agrologists and/or producers are able to determine that nodulation is not adequate early enough in the growing season it may help them determine if nitrogen fertilizer application is required to maximize chickpea yield potential.

References

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