Influence of pea cultivars on soil N balance and sequent crop production

Y. K. Soon, N. Z. Lupwayi

Agriculture & AgriFood Canada, P. O. Box 29, Beaverlodge, AB, T0H 0C0.

Key words: N budget, N balance, N_2 fixation, pea varieties, wheat

Abstract
Three field experiments were conducted in northwestern Alberta to determine the influence of pea cultivars on the N economy and the performance of the sequent wheat crop: four pea cultivars were tested with barley as the check. All but one experimental year had below average growing season rainfall. Dinitrogen fixation decreased in the following order among the pea cultivars: Grande > Carerra ∃Eiffel∃ Swing, the same order as net productivity. Only Grande pea resulted in balanced soil N; soil N deficit, in kg N ha^{-1}, was 7-38 for Carrera, 20-37 for Swing, and 18-37 for Eiffel. Grain N uptake by the sequent wheat was well-correlated with N fixed by pea (r =0.843**). Even where the soil N balance was negative, wheat following pea mostly had higher seed protein content and yield than wheat following barley. The greater N availability after pea is attributed to higher net N mineralization from pea root and rhizodeposits than barley roots and rhizodeposits. It is concluded that selection of a high net productivity pea cultivar should typically result in greater N and yield benefits to the sequent cereal crop than a low net productivity cultivar.

Introduction

Pulse crops such as peas (*Pisum sativum* L.) can increase soil N availability, and their inclusion in rotations with cereal crops has typically led to increased yields (Armstrong et al. 1994). Maximizing the benefits accruing from the N_2 fixation capacity of legume crops is desirable in order to reduce the reliance of crop production systems on synthetic N fertilizers and the associated economic and environmental costs. Nitrogen is gained when the amount of N fixed by the legume crop exceeds the N content of the exported seed. Since cultivars of pulse crops can exhibit significant differences in the proportion as well as the amount of plant N derived from the atmosphere (i.e., fixed N), they may influence the soil N balance in crop rotations (Wolyn et al. 1991; Ndiaye et al. 2000). The amount of N_2 fixed is the product of the proportion of plant N derived from symbiotic N_2 fixation and the legume N accumulation which is largely influenced by biomass production (Peoples et al. 1995). This suggests that one way to benefit the N economy of a pulse crop-cereal rotation, through enhanced N_2 fixation, may be to grow varieties of pulse crops with high biomass production and/or N_2 fixation efficiency. Peas are cultivated on approximately 1.4 million ha. of land in Canada, mostly in the prairie provinces (Saskatchewan Agriculture and Food 2005). However, there is little information on the influence of pea cultivar on the N economy of a pea-cereal rotation and the performance of the sequent cereal crop in the Canadian prairie. Therefore, we conducted a study over 3 site-years to evaluate the influence of pea varieties on the N budget of the pea and the following wheat (*Triticum aestivum* L.) crop.

Materials and Methods

Two experiments (hereafter named experiments A and B, respectively) were conducted on Dark Grey Luvisolic soils in Beaverlodge, Alberta, during 2002/2003 and 2003/2004, and one experiment (experiment C) in Fort Vermillion, Alberta, during 2003/2004. Three pea varieties were grown the first year and wheat the following year. There were eight replications per treatment. The check plots were seeded to a barley (*Hordeum vulgare* L.) -wheat sequence which during the first year provided the reference crop for determination of N_2 fixation. Pea cultivars Carrera and Swing were used in all the experiments. The third cultivar for experiment A was Grande and for experiments B and C, Eiffel. The reason for the change was the non-availability of Grande cultivar seeds in 2003. Carrera is an early maturing variety with a short vine length (52 cm); Swing is also early maturing with a vine length of 63 cm, Grande is a late-maturing variety with a vine length of 88 cm, while Eiffel is a medium maturing cultivar with a vine length of 77 cm (Alberta Agriculture, Food and Rural Development 2005). Despite its long vine length, Grande has the highest standing ability, and Swing the least. Maturity is estimated to be about 3-4 d later in Grande than in Swing, the earliest maturing of the test cultivars (Alberta Agriculture, Food and Rural Development 2002). Only Grande is a normal-leafed variety, the others are semi-leafless (Alberta Agriculture, Food and Rural Development 1999). The barley variety was AC Harper, and wheat was Teal variety. Plot size was 4 m by 12 m. Pea and barley received 55 kg ha^{-1} of 12-51-0 as a side band at seeding with seed-rows spaced 23 cm apart. The plots were managed under zero tillage, and weeds were controlled chemically as required. No N fertilizer was added to the first year crops other than N added with ammonium monophosphate (12-51-0). In 2003, wheat following pea received 50 kg N ha^{-1} and wheat following barley 70 kg N ha^{-1}, in addition to 55 kg ha^{-1} of 12-51-0. In 2004, the wheat grown at the Beaverlodge site received 40 kg N ha^{-1}, and at Fort Vermillion 50 kg N ha^{-1}, and 30 kg ha^{-1} of 12-51-0. Nitrogen fertilizer was applied in a side band as urea. All crops were typically seeded about the middle of May.

At Beaverlodge, N_2 fixation by pea was estimated at the flat-pod stage by the ^{15}N natural abundance and the total N difference methods, and at maturity by the total N difference method. At Fort Vermillion, N_2 fixation was estimated by the total N difference method at the flat pod stage and maturity. Nitrogen balance following pea harvest was calculated as fixed N minus seed N content (or grain N uptake).

Results and Discussion

Four of the five site-years had below average growing season rainfall (Table 1). Adequate rainfall is especially essential in June and July for normal crop growth. The one site-year with average growing season rainfall, Beaverlodge in 2004, was drier than normal in May and June and wetter than normal in July and August. The growing season in 2004 at Fort Vermillion, with less than half the normal rainfall, was especially stressful for the crop.

The performance of the pea varieties and the check barley in the three trials are summarized in Table 2. Crop productivity was average to below average for the region as a result of mostly below average growing season rainfall. The dry soil conditions appeared to have limited N uptake as indicated by the low values for barley. Except for Grande pea, N_2 fixation also tended to be low. From the flat pod stage to maturity, an additional 56 kg N ha^{-1} was fixed by Grande pea whereas with the other cultivars fixed only an additional 8-16 kg N ha^{-1}.

Table 1. Growing season monthly precipitation (mm) and the 30-yr average at Beaverlodge and Fort Vermillion during the experimental years

Month of year	Beaverlodge				Fort Vermillion		
	2002	2003	2004	30-y mean	2003	2004	30-y mean
May	41.9	14.4	14.8	39.3	8.4	27.7	39.0
Jun	50.4	54.6	48.7	73.5	39.3	14.6	58.7
Jul	54.8	43.3	95.6	70.7	76.7	25.1	57.5
Aug	31.1	69.5	85.5	63.7	54.0	43.7	62.2
Total	178.2	181.8	244.6	247.2	178.4	111.1	217.4

Dinitrogen fixation at the Beaverlodge site in 2003 was the lowest achieved in our study (7-17 kg N ha^{-1}). Several workers have expressed concerns on the loss of photosynthate capacity with semi-leafless peas (Lafond and Evans 1981; Pyke and Hedley 1985). Total biomass and seed production were typically lower for the semi-leafless varieties than Grande pea in our study. The reduced capacity of those varieties for photosynthesis may have resulted in lower N_2 fixation as well. The proportion of N in Grande pea derived from N_2fixation was 0.70 whereas its nitrogen harvest index was 0.72. When those two values are identical, the soil N is balanced. Thus, soil N balance was essentially achieved with the Grande cultivar; with the other cultivars soil N balance was not substantially different from the barley plots. The nitrogen harvest index was virtually similar among pea cultivars at any one site; the lower values in Table 2 are those from the Fort Vermillion site.

The influence of pea cultivar compared to barley on wheat production and N uptake are summarized in Table 3. Wheat yields were relatively low in 2004 probably because of dry soil during the first half of the growing season in Beavelodge and an overall dry growing season in Fort Vermillion. Although the 2003 growing season in Beaverlodge was also drier than normal, wheat growth was less constrained. At the Beaverlodge site in 2003, wheat grain yield was significantly higher following Grande and Swing peas than following barley. The increase in wheat yield following Carrera pea was not significantly higher than following barley. However, wheat N uptake followed the trend among previous pea cultivar: Grande > Swing > Carrera, and was significantly higher following peas than barley. Wheat grain N concentration was also higher following peas than barley. In 2004 at Beaverlodge, wheat grain N uptake was significantly higher following Eiffel and Swing peas than following barley. Wheat grain N concentration was also higher following all pea cultivars than following barley. At Fort Vermillion, wheat yields following peas generally tended to be higher than following barley, but only (total N difference method Carrera pea resulted in a significant yield increase. Wheat grain N uptake was higher following peas than following barley, however, only Swing pea resulted in significantly increasing wheat grain N concentration as compared to barley as the previous crop. At Beaverlodge, grain N uptake by the sequent wheat was well-correlated with N fixed by pea (r=0.843**). No correlation was done for Fort Vermillion because of its smaller data set.

Table 2. Effect of pea cultivar on dry matter (DM) and N accumulation at the flat pod growth stage and at maturity (in kg ha^{-1})

Crop response	Barley (3)[a]	Carrera (3)	Grande (1)	Eiffel (2)	Swing (3)
Flat pod stage					
Shoot DM	2200-3600	2700-3300	3300	2600-3000	2400-3000
N uptake	29-60	34-75	69	37-52	36-60
Fixed N	na	6-42	35	1-17	0-26
Maturity					
Grain DM	900-1900	1300-1900	2500	1200-1600	1200-1700
Straw DM	800-2300	1600-2200	3000	1800	1600-2200
Grain N uptake	29-31	38-65	93	34-58	38-53
Straw N uptake	8-22	14-25	37	15-20	15-20
N harvest index	0.58-0.79	0.65-0.75	0.72	0.64-0.77	0.66-0.75
Fixed N	na	7-50	91	17-30	11-38
N balance	-7 to -40	-15 to -38	-3	-18 to -37	-20 to-37

[a] numbers within ( ) refer to number of site-years.

Table 3: Effect of previous crop on dry matter (DM) and N accumulation by wheat

Crop response	Barley (3)	Carrera (3)	Grande (1)	Eiffel (2)	Swing (3)
Grain DM, Mg ha^{-1}	1.1-1.7	1.4-2.1	2.3	1.3-1.5	1.4-2.3
Straw DM, Mg ha^{-1}	2.9-3.4	2.7-3.1	2.9	1.5	1.5-2.8
Harvest index	0.27-0.38	0.30-0.43	0.44	0.32	0.31-0.45
Grain N uptake, kg ha^{-1}	37-39	45-51	57	49	49-54
Straw N uptake, kg ha^{-1}	21-32	21-31	22	37	21-34
N harvest index	0.54-0.63	0.58-0.71	0.73	0.59	0.58-0.72
Grain N conc., mg g^{-1}	22-31	25-33	25	27-33	24-33

Conclusions

The production and N_2 fixation of the normal-leafed Grande was higher than any of the semi-leafless variety tested. Our study showed that pea cultivars can affect the performance and seed quality of the sequent wheat. Wheat following peas generally have higher grain N uptake than wheat following barley, and the wheat grains also tend to have higher protein content. Although the soil N balance can vary following different pea cultivars, its influence on the performance of the sequent wheat appears to be less than suggested by the magnitude of the N balance. Our study included only one site-year with a normal-leafed pea variety compared to eight site-years with the semi-leafless type. More experimentation is needed to definitively determine if the morphology of the pea variety has an influence on the growth and N nutrition of the sequent cereal crop.

References

Alberta Agriculture, Food and Rural Development. 1999. Pulse crops in Alberta. Eds. B. Park and K. Lopetinsky. 149 pp. Edmonton, AB.

Alberta Agriculture, Food and Rural Development. 2002. Varieties of special crops for Alberta.. Agdex 140/32-1.

Alberta Agriculture, Food and Rural Development. 2005. Varieties of pulse crops in Alberta. Agdex 142/32-1. 8 pp.

Armstrong, E. L., Pate, J. S., and Unkovich, M. J. 1994. Nitrogen balance of field pea crops in south Western Australia, studied using the ^{15}N natural abundance technique. Aust. J. Plant Physiol. **21**: 533-549.

Lafond, G. and Evans, L. E. 1981. A comparative study of conventional, leafless and semi-leafless phenotypes of peas: photosynthetic CO_2 fixation in vitro. Can. J. Plant Sci. **61**: 665-671.

Ndiaye, M. A. F., Spencer, M. M. and Gueye, M. 2000. Genetic variability in dinitrogen fixation between cowpea (*Vigna unguiculata* L.)cultivars determined using the nitrogen-15 isotope dilution technique. Biol. Fertil. Soils **32**: 318-320.

Peoples, M. B., Ladha, J. K. and Herridge, J. F. 1995. Enhancing N_2 fixation through plant and soil management. Plant Soil **174**: 83-101.

Pyke, K. A. and Hedley, C. L. 1985. Growth and photosynthesis of different pea phenotypes. Pages 297-305 *in* P. D. Hellbethwaite, M. C. Heath and T. C. K. Dawkins, eds. The pea crop: a basis for crop improvement. Butterworths, London.

Saskatchewan Agriculture and Food. 2005. Crops-StatFact. November estimate of 2005 crop production. Regina, SK.

Wolyn, D. J., St Clair, D. A., DuBois, J., Rosas, J. C., Burris, R. H. And Bliss, F. A. 1991. Distribution of nitrogen in common bean (*Phaseolus vulgaris* L.) Genotypes selected for differences in nitrogen fixing ability. Plant Soil **138**: 303-311.