IMPACT OF P FERTILITY ON DRYLAND LEGUME N PRODUCTION

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ABSTRACT

Field pea acreage in Montana has nearly quadrupled since 1997 because of its suitability to the climate and soils of the region and changes in the farm program. Usually in rotation with cereals, field pea provides a means to manufacture nitrogen from the atmosphere by nodulation with *Rhizobium leguminosarum*. This study attempts to determine whether P fertility has an impact on nitrogen production by the pea crop and the amount of N contributed to the following spring wheat crop. Treatments included two tillage systems, no-till and till, two crops (wheat and pea), and four P rates. Phosphorus was banded in no-till and broadcast in tilled plots at rates of 0, 20, 40, and 80 kg P_2O_5 ha^{-1} in both wheat and pea plots. Wheat received additional N as urea to total 80 kg N ha^{-1}. Initial soil P levels were 19 mg kg^{-1} soil. Pea yield ranged from 1.58 to 3.18 Mg ha^{-1}, linearly increasing with increased P rate. Total N uptake and biomass remaining on the field after harvest were not significantly different although N in harvested pea was different. Wheat yield did not respond to P fertility. Soil nitrate was greater after pea than wheat in fall; increasing 75% the following spring. This suggests that fertilizer P application prior to seeding field pea may be advantageous to increase yields even if soil test P levels are adequate. Also, the resultant N produced by field pea may increase soil N levels for the following wheat crop. Pea fertilizer rates of 40 kg P_2O_5 ha^{-1} maintained soil test P levels.

INTRODUCTION

The Farm Security and Rural Investment Act of 2002 (2002 Act) provides, for the first time, marketing assistance loans and loan deficiency payment provisions for dry peas (*Pisum sativum* L.), lentils (*Lens culinaris*), and small chickpeas (*Cicer arietinum* L.) for the 2002-2007 crops. As a result, pulse production in the northern Great Plains has exploded with 135,000 acres planted in 2005, an increase of 321 percent compared to 2002 (USDA, 2005). The typical cropping practice in the northern Great Plains is spring wheat (*Triticum aestivum* L.) followed by tilled fallow used to store water and control weeds (Zentner et al., 2002). Producers are moving towards more intensive rotations, such as wheat – field pea rotations, primarily based on economics. Field pea is well suited to the northern Great Plains because it is a short, cool season legume with planting and harvest schedules different than those of spring wheat. This allows producers adequate time for field operations in a wheat – pea rotation and a reduction in economic risk.

Field pea is an attractive alternative to fallow in the Northern Great Plains because it can manufacture nitrogen from the atmosphere. However, the actual nitrogen return to the following wheat crop has not been extensively explored (Miller et al., 2002). Results show that increasing soil phosphorus levels may increase yield (Campbell et al., 1984, Karamanos et al., 2003 but will this increase in yield result in an increase in nitrogen carryover the following season?

Most of the soils sampled in Montana and North Dakota are low in soil-test phosphorus (Fixen, 2002). Karamanos et al. (2003 and Miller et al. (2003a and b) have intensively investigated the use of phosphorus fertilizer on field pea production in the northern Great Plains. Their work shows a positive response of pea seed yield to phosphorus application rate when soil test values are low. Soil test levels in excess of 20 to 30 kg P ha^{-1} appear to be the threshold where addition of P need only be applied at crop removal rates. Montana State University (MSU) Extensions recommends about 40 kg P_2O_5 ha^{-1} to fields with no bicarbonate extractable P (available P). North Dakota State University Extension recommendations are similar except that they call for no additional P when available P is greater than or equal to the 40 kg P_2O_5 ha^{-1} threshold. At this available soil P level MSU calls for P fertilizer at crop removal rates.

Current production practices in Eastern Montana and Western North Dakota, as well as in Canada, have seen some producers switching from conventional tillage to no till systems to enhance soil quality, aid in water availability, and limit soil erosion. Broadcast fertilizer application followed by tillage with sweeps is the most popular management regime, herein termed conventional. Fertilizer under no-till systems, especially phosphorus, is banded near or with the seed. These different management strategies also have an impact on soil N dynamics.

Thus, the goals of this experiment are to investigate the role of tillage, fertilizer placement, and phosphorus fertilizer rate on water use, yield, N-production, and soil N dynamics in wheat – pea rotation.

MATERIALS AND METHODS

The study was conducted near Culbertson, MT on a glacial till Williams loam (fine-loamy, mixed, Typic Argiborolls) with a 2 to 4% slope. The site had been in plot borders cropped with small grains for over 5-years and no P-containing fertilizer had been applied since 1968 (Halvorson and Black, 1985) when rates as high as 180 kg P ha^{-1} were applied.

The plots (3 × 9 m) were arranged as a split-plot with tillage as the whole plot and crop and Prate as the subplots. The crops were spring wheat and field pea with both components of the rotation present each year. P-rates were 0, 20, 40, and 80 kg P_2O_5 ha^{-1} was applied as mono-ammonium phosphate (11% N, and 52% P_2O_5) resulting in concomitant application of 0, 4, 8, and 16 kg N ha^{-1}. For pea plots, N as urea was added so the total N applied was 16 kg N ha^{-1}. For spring wheat plots, N as urea was added so the total N applied was 78 kg N ha^{-1}. During the second year of the study, triple super phosphate (46% P_2O_5) was applied resulting in no N applied for field pea and similar rates as previous year for spring wheat.

Fertilizer was broadcast for tilled plots. Fertilizer was banded 5 cm below and 5 cm to the side of the seed for no-tilled plots. Tillage was accomplished with a tool bar fitted with sweeps. Tillage was about 15 to 20 cm deep.

Soil samples were taken in spring and fall 2004 and 2005 for determination of water content, nitrate, ammonia, and phosphate. Nitrate and ammonia will be analyzed by 5M KCl extraction and phosphate by 0.5M bicarbonate with pH adjusted to 8.5 (Olsen et al., 1954).

Statistical analyses were run with SAS using PROC MIXED.

RESULTS AND DISCUSSION

It was expected that bicarbonate extractable P (labile P) concentrations would be less than 10 mg P kg^{-1} soil since the last P fertilizer application occurred over 30 years ago. Despite the length of time scince P fertilizer application and continuously cropped small grains cut for grain or hay, labile P concentrations averaged 19 mg P kg^{-1} over all plots at the 0 to 0.15 m depth.

Labile soil P levels ranged from below 6 to over 30 mg P kg^{-1}. Soil nitrate, ammonia, and total inorganic N averages were 136, 206 and 342 kg N ha^{-1} to a depth of 90 cm.

Average annual precipitation is 340 mm with 80% (270 mm) occurring between April and September. Growing season precipitation in 2004 was near the average while precipitation in 2005 was about 90 mm above the annual average. Initial soil water at the start of the experiment was between 10 and 11.5% (w/w), equivalent to 55 mm of water in the top 120 cm soil.

Water use was determined based on a mass balance approach (Water Use = Rain - Change in Storage). It was assumed that runoff and deep percolation were negligible; however, visual observations of site conditions indicated that runoff did occur during one event in 2005. Preplant and post-harvest soil water and water use is presented in Table 1. After the first season, there was more water after pea than wheat. Water use for field pea in 2004 was significantly less than wheat.

Table 1. Spring and Fall Soil Water and Water Use for Pea and Wheat in 2004 and 2005.

Date/Item	**Field Pea**	**Spring Wheat**	**Significance**
	mm Water		
Spring 2004	86.3	89.5	ns
Fall 2004	69.9	60.7	P=0.0006
Water Use 2004	269	281	P<0.0001
Spring 2005	65.2	73.9	ns
Fall 2005	70.1	55.1	P<0.0001
Water Use 2005	353	377	P<0.0001

Winter and spring recharge of soil water was enough so that there were no differences in soil water during spring 2005, although field pea (after wheat) began with less soil water. Very dry conditions during the first month of the growing season caused poor establishment of pea and delayed emergence. With above average rain in 2005, soil water actually increased for field pea over the growing season. Soil water was significantly less for spring wheat during the fall. Pea used significantly less water than wheat.

Pea Yield and Quality

Pea yield varied by year and phosphorus fertilization rate. Pea in 2004 had significantly greater yields (2.36 Mg ha^{-1}) than 2005 (1.08 Mg ha^{-1}). Phosphorus fertilizer rates induced changes in yields (Figure 1). There was also a significant linear effect of yield. It appears that maximum yield of field pea occurred at around 40 kg P_2O_5 ha^{-1}.

Total pea biomass was significantly greater in 2004 than 2005. Visual observations noting obvious differences in plant growth

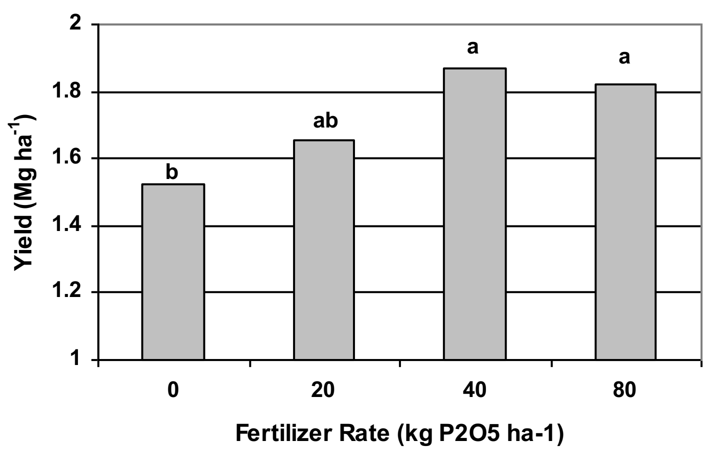

Figure 1. Pea yields ove the various phosphorus application rates averaged over 2004 and 2005 growing seasons.

were apparent with much greater production in 2004. There were no differences in pea biomass yields over P or tillage treatments. As with total biomass, there were no significant differences in residue remaining in the field after harvest. Field pea variety Majorette is a semi-leafless variety, thus little residue remained.

Wheat Yield and Quality

Wheat grain yield did not differ among treatments or years. Average wheat yield was 2.96 Mg ha^{-1}. Test weight in 2005 (886 kg m^{-3}) was less than in 2004 (938 kg m^{-3}). No-till plots had significantly higher test weight (915 kg m^{-3}) than conventionally tilled plots (908 kg m^{-3}). There was also a tillage × year interaction with no differences in test weights in 2004 tillage treatments; no till had higher test weights than conventionally tilled treatments in 2005; and wheat stands were significantly greater in 2005 than in 2004, due to heaver seeding in 2005.

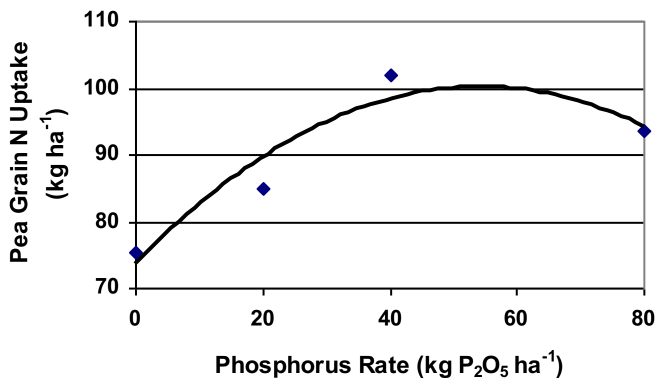

Figure 2. Pea grain N uptake over various P rates for 2004 and 2005 growing seasons.

Plant Nitrogen Dynamics (2004 Data Only)

Pea grain N content (average, 3.76%) did not vary significantly among treatments. Spring wheat grain N content had significant tillage and P rate effects: higher grain N was observed under conventional tillage and grain N decreased with increasing P applications. Pea grain N uptake was significant under the various P rates (Figure 6), with a significant linear effect and maximum grain uptake occurring at around the 40 kg P_2O_5 ha^{-1} application rate. There were no significant differences in spring wheat grain N uptake.

No differences for pea were observed in biomass N concentration, total N uptake or residual N. Tillage significantly increased biomass N concentration, total N uptake, and residual N in wheat. P application rate was also significant for wheat biomass N concentration and total N uptake.

Soil Phosphorus and Nitrogen

Initial soil P was 19.0 mg P kg^{-1} soil. This was surprising since the last P application at the site was over 30 years prior to initiation of this study (Halvorson and Black, 1985). According to results of Halvorson and Black, soil P levels had asymptotically declined over their 15-year study period to near background levels. After one growing season, fall soil P in 2004 average 16.6 mg P kg^{-1} soil. Spring soil P in 2005 increased slightly from fall 2004 and averaged 16.7 mg P kg^{-1} soil. A significant P rate response was detected in the fall of 2005 (Figure 3.). Prior to Fall 2005, no significant differences in soil P were observed however after one complete rotation, soil P had been depleted under the control and had been maintained at the 40 kg P_2O_5 ha^{-1} rate.

Soil at the beginning of the experiment contained 136 kg NO_3^--N ha^{-1} to a depth of 120 cm. At the end of the first growing season, soil nitrate under pea (113 kg NO_3^--N ha^{-1}) was significantly greater than under wheat (76 kg NO_3^--N ha^{-1}). By the spring of 2005, soil nitrate increased about 75% with similar significant trends as fall 2004. Also in spring 2005, a significant P rate × crop interaction was observed (Table 2).

Table 2. P rate × Crop interaction during spring 2005 soil sampling to 120 cm.

P rate (kg P2O5 ha-1)	After Pea		After Wheat	
	Soil NO_3^--N (kg ha^{-1})			
Control	177	b	147	bcd
20	172	b	153	bc
40	156	a	111	cd
80	187	b	128	cd

CONCLUSION

Initial soil P levels in plots were greater than expected. At levels in the plots, State of Montana recommendations suggest limited P application. However, a significant yield response was observed to increased application of phosphorus fertilizer. This suggests that fertilizer P application prior to seeding field pea may be advantageous to increase yields even if soil test P levels are adequate. Also, the resultant N produced by field pea may increase soil N levels for the following wheat crop. Pea fertilizer rates of 40 kg P_2O_5 ha^{-1} maintained soil test P levels.

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