Effect of Soil Amendment with Alfalfa Pellets and Glycerol on Nutrition and Growth of Wheat

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KEY WORDS

Alfalfa pellets, glycerol, wheat, yield, uptake, soil N and P availability, and soil organic C

ABSTRACT

Two pot experiments were carried out under controlled environment conditions in the laboratory. One was to assess the ability of alfalfa pellets to supply plant available N as an organic fertilizer. The other was to investigate the impact of applying glycerol on crop growth and soil characteristics. In the first experiment 4 different rates of two types of alfalfa pellets were tested by comparing with urea. In the glycerol addition experiment, four different rates of glycerol were tested. Wheat biomass yield, N and P uptake were measured in both experiments. Soil organic C, available N and P were also measured in the glycerol experiment.

Results from the alfalfa pellet experiment showed that application of alfalfa pellets lead to a significant wheat biomass yield response and an increase in N and P uptake, even at the lowest application rates. Glycerol addition increased wheat yield biomass and N uptake at low and medium rates (100 and 1000 kg /ha) but resulted in reduced yield at the highest rate (10,000 kg/ha). The yield reductions at the highest rates were believed to be associated with N immobilization. In general, negative impacts on wheat growth were observed only at higher rates. Higher rates of glycerol added to the soil led to an increase in soil organic C concentration and a decrease in soil extractable nitrogen and phosphorus. Future experiments with glycerol addition will evaluate the effect of combination of glycerol with commercial fertilizer urea, and its effects on microbial respiration.

INTRODUCTION

Dehydrating and pelletizing alfalfa has been traditionally used to produce animal feed but can also be an efficient means of formulating an organic fertilizer for land application. This form of organic fertilizer is easy to handle and has a higher concentration of nutrients than many other fertilizers made from plant matter. To evaluate the value of alfalfa pellets as a soil amendment, a preliminary investigation was set up to assess the potential for using alfalfa pellet as an organic source of nutrient.

Production of biodiesel from canola results in a by-product: glycerol (or glycerin). In Manitoba, a system has been set up for two processing options: high-grade glycerol for commercial resale and a raw grade for anaerobic digester use (Reynolds, 2006). The effectiveness of glycerol as a feed additive for cattle has also been assessed (McElroy, 2007). Glycerol is recognized as a safe feed additive when it is used as an energy source for broiler diets (Waldroup 2006). Direct application of crude glycerol in the field at seeding time was investigated in Western Australia. Preliminary results showed that crude glycerol could help correct water repellency of the non-wetting sandy soils in Western Australia by covering the non-wetting coatings on soil particles without adding a significant cost (Bonnardeaux, 2006). In general, information on the effects of direct application of crude glycerol to soils is limited, with no information on effects in prairie soils. The objective of the preliminary study reported on in this paper was to assess the impact of addition of glycerol on plant (wheat) growth and soil characteristics in a Brown Chernozem from south-central Saskatchewan.

MATERIALS AND METHODS

Experiment Design

Two pot experiments were set up in the spring of 2007. One was to investigate the effects of alfalfa pellet as an N source for crop growth, and the other was to investigate the effects of application of glycerol, byproduct of biodiesel, on soil properties and plant growth.

Alfalfa Pellet Experiment: In the first experiment, two types of alfalfa pellets: Pure and Blend, were tested by comparing with urea applied at the same rates of N. The "Blend" pellet was a combination of alfalfa and canola meal protein extraction by-product while the "Pure" pellet was pure alfalfa. Both pellets were supplied by MCN BioProducts. The N content is 2.67%N for Pure and 3.06%N for Blend. The experiment used 4 application rates (0, 100, 200 and 400 kg N ha^{-1}) with 4 replicates and was conducted in a light tray. Four pots were prepared for each treatment. In each pot, 800 g of air-dried soil were weighed and 200 ml of water was added, followed by application of alfalfa pellets or urea on the surface of the soil and then covered with an additional 100 g of soil. A 100-ml of blanket P, K and S solution was then applied at a rate of 25 kg P ha^{-1}, 50 kg K ha^{-1} and 25 kg S ha^{-1}. After the fertilized soils in the pots were equilibrated for 48 hours, about 10 wheat seeds were planted and then covered with another 100 g of soil. The plants were thinned to 5 plants after emergence. Soil moisture was kept at approximately 80% of field capacity in all the treatments and temperature was maintained at room temperature.

Glycerol Experiment: The glycerol experiment was set up in the laboratory under the same growth conditions as the alfalfa pellet experiment. Two kinds of glycerol: 1) Stripped of CH_3OH and 2) Refined oil, obtained from Milligan Biotech, were tested at four different application rates (0, 100, 1,000, and 10,000 kg ha^{-1}). The experiment was a completely randomized design with three replicates. The different amounts of glycerol required for each pot were diluted in water to 200 ml and the glycerol solution was added to the pot containing 850 g soil. More water was then added to bring the soil to near field capacity. After 24 hours of equilibration, ten wheat seeds were seeded, and then covered with an additional 150 g of soil. Soil moisture was kept at approximately 80% of field capacity in all the treatments.

Plant Growth and Soil Analysis

In both experiments, wheat seeds were almost completely germinated and emerged within 3 to 5 days after seeding in all the treatments. After emergence, seedlings were thinned to 5 plants per pot for the alfalfa pellet experiment and 4 seedlings for the glycerol experiment. The pots were completely randomized and rotated each week. Plants were grown to five weeks in the first experiment and 4 weeks in the second one, and then harvested. After harvesting, plants were dried at 50ºC, and weighed for dry matter yield determination. The samples were then ground and digested in a sulfuric acid-hydrogen peroxide mixture using a temperature-controlled digestion block (Thomas et al., 1967) followed by colorimetry using a Technicon autoanalyzer to determine plant N and P concentration. Plant N and P uptake was calculated by multiplying the yield by the concentration in the tissue and is expressed as milligrams of N or P taken up per kilogram of soil.

Table 1. Some characteristics of the soil used in the two experiments.

Soil	pH	EC	Texture	Available N	Available P	Organic C
		mS cm^{-1}		kg ha^{-1}	kg ha^{-1}	kg ha^{-1}
Haverhill	7.9	0.2	Loamy	9.8	40	2.1

* sum of NH_4-N and NO_3-N
**measured by modified Kelowna method

The soil used in the two experiments was collected from the 0-15cm depth of a wheat stubble field near Central Butte, SK in the fall of 2006. After collection, the soil was mixed thoroughly in a soil mixer and stored before use. For measuring basic soil properties (Table 1), a sample was collected from the mixed soil, and then air-dried, crushed, and passed through a 2-mm sieve and stored at room temperature. Texture was estimated by hand. Electrical conductivity (EC) and pH were measured using 1:1 soil:water suspension. Organic C was measured using Leco carbon analyzer. Soil available N was calculated as the sum of NO_3-N + NH_4-N. Both forms of inorganic N were extracted with 2 M KCl, and P and K by a mixed solution of 0.025 *M* HOAc and 0.25 *M* NH_4OAc as well as 0.015 *M* NH_4F with a measured pH of 4.9 (Qian et al. 1994). Selected soil characteristics are summarized in Table 1.

RESULTS & DISCUSSION

Application of alfalfa pellet and its effect on wheat yield, and N and P uptake

Significant yield response was observed from application of both types of alfalfa pellets at the 50 kg N ha^{-1} (lowest) rate of alfalfa pellets (Table 2). Increase in the application rate above this rate did not result in further significant increases in plant yield for the Blend type pellet but did result in a significant increase in plant yield for the Pure type pellet (Table 2). The 50 kg N ha^{-1} rate of urea was sufficient to maximize wheat biomass yield, similar to the Blend pellet.

Significant increases in wheat N and P uptake were also observed from addition of pellets and urea (Table 2). Increases in N uptake related to addition of alfalfa pellets and urea are a result of the amendments increasing the N availability in the soil. Per unit of N in the pellet, the blended form appeared to be superior to the pure alfalfa form in terms of availability. This may reflect a more readily mineralizable component that arises from the inclusion of the solubles from the canola meal in the pellet. At a given rate of N application, plant uptake of N in the urea treatments was more than double that of the pellet amendments, indicating higher N availability from the urea than the pellets, and that only a portion of the N in the pellet was made available for plant uptake over the five weeks of growth. To this end, we observed continued increase in N uptake with increase in the rate of alfalfa addition. The P uptake is increased as a result of greater plant growth as a response to N and there may be some contribution from P in the pellets as well.

Table 2 Effects of applying alfalfa pellets (B* and P**) and urea on wheat yield, and N and P uptake at three different rates of N.

Fert. rate	Yield			N uptake			P uptake		
kg N ha^{-1}	Alfalfa-B	Alfalfa-P	Urea	Alfalfa-B	Alfalfa-P	Urea	Alfalfa-B	Alfalfa-P	Urea
	----- g pot^{-1} -----			----- mg pot^{-1} -----			----- mg pot^{-1} -----		
0	0.18d	0.18d	0.18d	0.94c	0.94c	0.94c	0.34f	0.34f	0.34f
50	0.62b	0.43c	0.68ab	3.75d	2.75de	10.9b	1.01de	0.86e	1.97bc
100	0.64b	0.57b	0.75a	7.39c	4.03d	23.2a	1.59bc	0.92e	2.60a
200	0.69ab	0.75a	0.70ab	12.8b	11.4b	23.0a	1.52cd	1.66bc	2.04b

Means in each of the three sections (yield, N uptake and P uptake) followed by a different letter are significantly different at $p < 0.05$. * B = Blend; ** P = Pure

Application of glycerol and its effect on wheat yield and N and P uptake

Table 3. Effects of glycerol addition on wheat yield and N uptake at 3 different rates of amendment.

Rate added	Yield		N uptake		P uptake	
kg ha^{-1}	Stripped	Refined	Stripped	Refined	Stripped	Refined
	----- g pot^{-1} -----		----- mg pot^{-1} -----			
0	0.13bc	0.17ab	0.58ab	0.69a	0.36ab	0.41ab
100	0.17ab	0.16ab	0.73a	0.68a	0.45a	0.43a
1000	0.20a	0.13bc	0.62ab	0.53b	0.42ab	0.30bc
10000	0.16ab	0.10c	0.48b	0.30c	0.36ab	0.20c

Values followed by a different letter in each of the three sections (yield, N uptake, and P uptake) are significantly different ($p < 0.05$).

Overall, addition of methanol stripped glycerol had limited effect on yield and nutrient uptake, but there were some small positive effects noted at the low and medium rates of addition (Table 3). For refined glycerol, some negative impacts were observed in all three parameters. These effects became more apparent as application rates increased (Table 3). Of particular note, plant N uptake for refined glycerol was significantly decreased at a rate of 1000 kg ha^{-1}. At the lowest application rates there was no significant different between the two glycerol forms, but at higher rates, stripped glycerol was better than refined.

The addition of glycerol to the soil led to small but significant increases in the soil organic C concentration measured at the end of the experiment, and a significant decrease in soil available N and P (Table 4). The available N levels were affected most, as revealed in the large decrease in soil available N when rate of both glycerol products reached 10,000 kg ha^{-1}. A pure carbon source such as glycerol would be expected to induce considerable N immobilization by the microbial population, and benefit may be achieved by combining glycerol with a nitrogen source like urea or manure.

Table 4. Effects of glycerol addition on soil properties at 3 different rates of amendment.

Rate added kg ha^{-1}	Soil Available N Stripped	Soil Available N Refined	Soil Available P Stripped	Soil Available P Refined	Soil Organic C Stripped	Soil Organic C Refined
	mg kg^{-1}				%	
0	27.6a	24.8a	8.53ab	8.45ab	1.96b	1.96b
100	27.6a	22.7a	8.73ab	8.60ab	2.11b	2.07b
1,000	11.4bc	20.3ab	7.59bc	8.93a	2.05b	2.09a
10,000	7.3c	7.1c	6.84cd	6.04d	2.40a	2.10a

Values followed by the same letter in each of the three sections (soil available N, P and organic C) are significantly different ($p < 0.05$).

CONCLUSION

Amendment of soil with alfalfa pellets was found to result in improved plant nutrition, as indicated by an increase in wheat yield and plant N uptake with increasing rate of addition. Only a portion of the N in the pellet is available for plant uptake in the first few weeks following application. Glycerol addition slightly increased or had no significant effect on wheat yield biomass and N and P uptake at low and medium rates (100 and 1000 kg /ha) but resulted in reduced yield at the highest rate (10,000 kg/ha) that appeared to be associated with N immobilization.

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