

Effectiveness of Meat & Bone Meal and Distillers Grain Ash as a Phosphorus Source for Crops

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Abstract

Production of biogas from organic materials via gasification also generates a valuable byproduct of ash. Ash contains the original nutrient present in organic materials, except carbon, nitrogen and sulfur that are lost as gases during this process. Therefore, the ash is concentrated in the important macronutrient of phosphorus and potassium. To determine the feasibility of land application of ash in providing phosphorus for crops, a study was carried out using Brown chernozemic soil in growth chamber and field. This study aimed to investigate the influence of two ashes applied at three rates of P in comparison with mineral P fertilizer on crop yield, and P species that resided in soil after harvest using a sequential extraction procedure. The experimental treatments for the growth chamber study included 3 P sources: distillers grain ash, meat & bone meal ash and mono-calcium phosphate fertilizer. Each P source was applied at 3 rates: 25, 50 and 100 kg P ha⁻¹ in addition to a control. Each treatment was supplemented with 200 kg urea-N ha⁻¹ to ensure that N is not a limiting factor. For the field study, the experimental treatments consisted of the same P sources with 3 rates of application: 20, 40 and 80 kg P₂O₅ ha⁻¹ plus a control. Each treatment was also supplemented with 100 kg urea-N ha⁻¹. Analysis of ashes co-produced from gasification of distillers grain and meat & bone meal showed that they are rich in phosphorus, ranging from 13 – 16 % P. This high content of P was observed to benefit crop growth, providing a significant increase in crop yield compared to the control. Both ashes produced yields similar to that of mineral phosphorus, suggesting the high availability of ash P for plant uptake. A high proportion of residual P from the meat & bone meal ash was present in the form of calcium phosphate in the soil.

Introduction

The gasification process is defined as the thermo-chemical decomposition of organic materials under high temperature (800 – 900 °C) and in presence of oxygen (Ferreira et al., 2009). As shown in Figure 4, this process does not only produce biogas or syngas (CO, H₂, CH₄, CO₂), but it also produces ash as another end product. The ash contains all the P and K originally present in the gasified materials (Kuligowski and Poulsen, 2009), and the ash fraction comprises only about 1% of the raw waste mass. As such there is a significant reduction in processed waste volume and nutrient is significantly concentrated (especially P and K) in ash generated, lowering cost of transport. The ash generated from gasification of organic materials contains a relatively high P content. Kuligowski et al. (2008) reported a P content of approximately 5.4% P; however, this is influenced by the type of materials gasified and their original P content. In our laboratory testing,

ash from gasification of dried distillers grain and meat and bone meal were found to contain 16% and 13% of total P, respectively.

Growing interest in producing bioenergy from sustainable sources through gasification has led to a large quantity of ash byproduct being generated. In the light of the shrinking global phosphate rock reserves and increasing demand for P fertilizer in agricultural production, recycling P-rich ash would be a better option to replenish P-depleted soil. Therefore, there is a renewed interest in using ash as phosphorus fertilizer source. This study aimed to investigate the effect of ashes generated from different feedstocks applied at different rates on crop yield under controlled environment and field conditions. P species that resided in soil after harvest were also investigated in some selected treatments of growth chamber study.

Materials and Methods

Growth Chamber Study

Soil used in this experiment was collected from layer surface (0-20 cm) in fall 2009, from wheat stubble field located near the town of Central Butte, Saskatchewan. Soil was mechanically mixed using a stationary mixer to provide a homogenized sample and then stored under laboratory condition until its use. Ash materials were obtained from biogas production via gasification facility, Agricultural and Bioresource Department, University of Saskatchewan. They were collected in plastic bag and brought to the laboratory. Subsamples were taken from each type of ash to determine their content of nutrient. Then, 1 kg soil was placed into 1-L plastic pot, followed by treatments application. The ashes and mineral fertilizers were mixed with the top 3 cm of the soil. The experimental treatments included: 3 rates (25, 50, 100 kg P ha⁻¹) of meat & bone meal ash, dried distillers grain ash and mono-calcium phosphate fertilizer. Each treatment was supplemented with 200 kg N ha⁻¹ as urea, including the control. Each treatment was replicated 4 times. Pots were seeded to canola and grown for 5 weeks.

After harvesting, plants were dried at 50 °C and weighed for dry matter determination. Pots soil was air-dried and ground to pass a 2-mm sieve mesh. Soil samples were sequentially extracted for phosphorous forms characterization. A 0.5 g sample of air-dried and sieved soil collected from the soil in each pot after harvest was sequentially extracted by Hedley procedure as described by Tiessen and Moir (2007) to determine the forms and amounts of P in the different pools as a function of extractant strength according to the following scheme:

1. Resin-P (P_i): 30 mL deionized water and 2 strips of anion exchange membrane shaken overnight.
2. NaHCO₃-P (P_{inorganic} and P_{organic}): 30 mL 0.5 NaHCO₃ (pH 8.5), shaken overnight.
3. NaOH-P (P_{inorganic} and P_{organic}): 30 mL 0.1 M NaOH, shaken overnight.
4. HCl-P (P_{inorganic}): 30 mL 1.0 M HCl, shaken overnight.
5. Conc. HCl (P_{inorganic} and P_{organic}): 15 mL concentrated HCl, heated for 20 min at 80 °C.

Inorganic P (orthophosphate) in the various soil extracts was measured colorimetrically using an ascorbic acid reduction method (Murphy and Riley 1962). Treatments selected for sequential P extraction were the two ashes at the rate of 100 kg P ha⁻¹).

Field Study

A field experiment was initiated in the spring of 2010 at a private farm located near the town of Central Butte, southwestern Saskatchewan, Canada. The soil at the experimental site was classified as Orthic Brown Chernozem (Soil Association: Ardill Loam), with a loamy texture. The experimental plots dimensions were 2 × 2 m². The field experiment was designed to include 10 treatments which are: 3 rates (20, 40, 80 kg P₂O₅ ha⁻¹) of the two ash types, mono-calcium phosphate and a control. Treatments were hand-applied as surface broadcast and incorporated before seeding spring 2010. The field was seeded to Hard Red Spring Wheat var Prodigy.

Results and discussion

Ashes co-produced from gasification of meat & bone meal and dried distillers grain are rich in phosphorus. Addition of both ashes significantly increased canola yield under controlled environment conditions (Fig.1). The increase in yield from ash treated soil was similar to that of mineral P, suggesting high availability of ash P for plant uptake. Soil P fractions were significantly affected by ash addition, especially the labile (bioavailable) P fractions. Addition of both ashes significantly increased the most labile resin-P, NaHCO₃ and NaOH (inorganic forms) when compared to the control (Table 1). Greater increases in labile inorganic P fractions from DDGA than MBMA may be due to fixation of P with the large amounts of calcium present in the MBMA. Higher content of HCl-P in MBMA amended soil supports this concept.

Response of wheat grain yield in the field was similar for mineral P and MBMA (Fig. 2), with the medium and high rates in both treatments producing significantly higher yield than the control. The reason for lower yields observed in the medium and high rate of DDGA is not known but could be due to negative effects of higher quantities of some constituent present in the DDGA ash like sodium.

Conclusion

Ash appears to be a viable alternative source of phosphorus for field crops. Means of processing the ash into forms that are easily applied are needed. Composition of ashes from different feedstock needs to be evaluated to identify any undesirable elements. Utilization of ash can be a good strategy to reduce dependency on phosphorus generated from non-renewable sources (mining).

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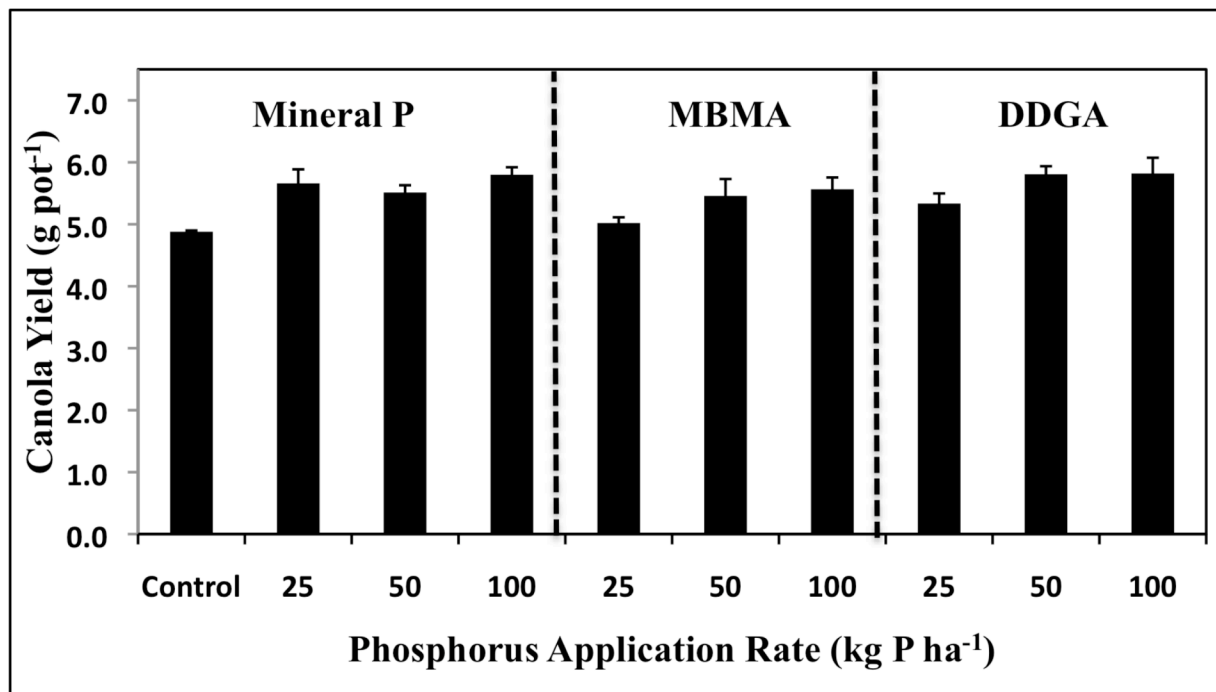


Figure 1. Effect of mineral P, meat & bone meal ash (MBMA) and dried distillers grain ash (DDGA) applied at 3 rates: 25, 50 or 100 kg P ha⁻¹) on canola seed yield under controlled environment conditions.

Table 1. P forms in selected treatments of ash-amended soil applied at a rate of 100 kg P ha⁻¹.

Treatment	Resin	NaHCO ₃		NaOH		HCl	Conc. HCl	
	P _i	P _i	P _o	P _i	P _o	P _i	P _i	P _o
	mg kg ⁻¹							
Control	1.70 A	7.50 A	6.85 A	15.59 A	26.77 A	57.02 A	25.95	27.69
DDGA	12.87 B	15.83 B	6.94 A	19.30 B	15.59 BC	57.27 A	20.02	38.76
MBMA	2.07 AC	10.32 C	6.28 A	16.90 AC	19.29 C	70.70 C	31.25	26.44
	Analysis of Variance (ANOVA)							
	<i>Pr(>F)</i>							
Treatment	0.0001	0.0001	0.698	0.0001	0.0001	0.001	0.2138	0.0579

Note: treatments followed by the same letter in a column are not significantly different at $P \leq 0.05$.

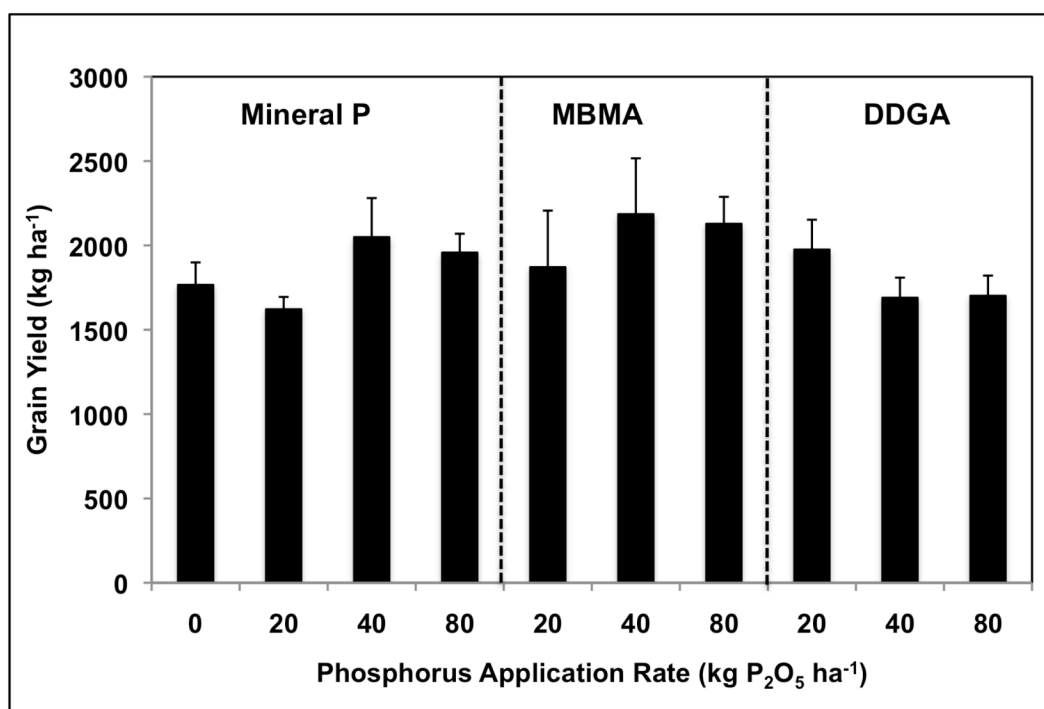


Figure 2. Effect of mineral P, meat & bone meal ash (MBMA) and dried distillers grain ash (DDGA) applied at 3 rates: 20, 40 or 80 kg P₂O₅ ha⁻¹) wheat grain yield under field conditions.