Effect of DDGS Manure on Soil and Plant: Preliminary Results of the Greenhouse Study

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Abstract

The use of dried distillers' grains with solubles (DDGS) in feedlot cattle diets is increasing as the bio-ethanol industry expands. Manure derived from dried distiller's grain with solubles (DDGS) fed cattle seem to have higher amounts of N and P than manure from regular grain fed cattle. This study investigates how DDGS manure affects soil fertility and nutrient uptake by barley grown in a controlled greenhouse environment. Both DDGS and regular manure were applied at 30, 60, 120 and 180 Mg ha^{-1} yr^{-1} to a sand soil. The results of the first 3 harvest cycles indicate that both types of manure resulted in similar increase in plant total P content. However, soil TP and available P concentrations in DDGS manure treatments were higher. Soil available in DDG treatments was twice as much of that in regular manure. Increase in soil TN and available N contents was similar with both types of manure. Plant TN content did not seem to be influenced by manure application. This study indicates that the main concern with the use of DDGS manure is its high P solubility. However, no significant increase in soil available P was observed at a manure rate of 30 Mg ha^{-1} yr^{-1}.

Introduction

Ethanol production generates a large amount of dried distiller's grains with solubles (DDGS), the main by-product of the grain ethanol fermentation industry (Berger and Good 2007). The DDGS are valuable feedstuff for animals, with relatively high crude protein and P concentrations. Increases in both ethanol production and grain prices have contributed to greater use of DDGS in the livestock industry (Ellis 2007; Berger and Good 2007). Recent studies indicate that using newer-generation DDGS could reduce hog feed cost by almost 10% (Fabiosa 2008).

The main problems associated with livestock manure production and application to agricultural land has been its ammonia and P content. Livestock manure is the main contributor to global anthropogenic NH_3 emission (Mosier 2001). Long-term manure applications seem to enhance not only soil total P content but also its solubility (Hao et al. 2008) increasing the risk of P runoff into surface water (Daniel et al. 1998). Elevated P concentration in surface water is often the key element in limiting aquatic biological productivity (Daniel et al. 1998). Since N and P concentrations in DDGS are approximately three times those in unprocessed grain (Spiehs et al. 2002; Widyaratne and Zijlstra 2007), adding DDGS to animal diets could potentially increase N and P nutrients levels in manure.

Hao et al. (2009) reported that ammoniacal N (NH_4^+ + dissolved NH_3), total and soluble P concentrations in manure from cattle fed DDGS was significantly higher than in manure from cattle fed typical diet without DDGS. Therefore understanding nutrient accumulation and plant uptake in soils receiving manure from cattle fed DDGS is crucial for recommending rates that are long-term sustainable. The objective of this study was to investigate nutrient accumulation in soil and uptake by barley forage from soil amended with manure from feedlot cattle fed with diets containing DDGS. Only preliminary plant uptake results are reported here.

Materials and Methods

In this growth chamber experiment, barley was grown in a sandy soil. The soil received equivalent rates of 30, 60, 120 and 180 Mg ha^{-1} yr^{-1} (wet weight) of regular (REG) or DDGS cattle feedlot manure. The regular manure was collected from cattle fed a typical finishing diet of 85% barley grain, 10% barley silage and 5% mineral supplement while the DDGS manure was collected from cattle fed with 25% barley grain, 60% DDGS, and the same amount of silage and mineral supplement. Additionally, a control soil treatment receiving no amendments and a mineral fertilizer treatment receiving conventional levels created a total of ten treatments (Table 1).

Table 1. Fertilizer and Manure Application Rates Used in the Barley Forage Production

Treatment	Amendment	Application rate (per growth cycle)
Control	-	-
Fertilizer	Mineral fertilizer	100 kg N and 50 kg P_2O_5
REG30	Regular manure	30 Mg ha^{-1}
REG60	Regular manure	60 Mg ha^{-1}
REG120	Regular manure	120 Mg ha^{-1}
REG180	Regular manure	180 Mg ha^{-1}
DDGS30	DDGS manure	30 Mg ha^{-1}
DDGS60	DDGS manure	60 Mg ha^{-1}
DDGS120	DDGS manure	120 Mg ha^{-1}
DDGS180	DDGS manure	180 Mg ha^{-1}

Barley was grown in pots in a growth chamber and harvested at the soft dough stage for making silage. A total of six growth cycles are scheduled for this study and the results of the first 3 growth cycles are presented in this paper. The basic properties of manure used in the first three growth cycles are given in Table 2. Manure (regular and DDGS) and fertilizers were applied at two frequencies: one time application before the first growth cycle and repeated application before each growth cycle.

Table 2. Basic Properties of Sandy Soil and Manure Used in the First Three Growth Cycles

Item*	Manure		Soil
	DDGS	Regular	
Available-P (mg kg^{-1})	1764	697	10
TP (mg kg^{-1})	10164	7556	308
NO_3-N (mg kg^{-1})	45	351	33
NH_4-N (mg kg^{-1})	2786	561	3
TN (g kg^{-1})	17.1	18.7	0.8
TC (g kg^{-1})	360	423	8.3
pH (in water)	7.3	7.8	7.9
EC (dS m^{-1})	10.9	9.4	0.3

* All data are on a dry weight basis.

Soil and barley forage samples were collected after each growth cycle and analyzed for nutrient concentrations. The oven-dried (60°C) fine-ground samples (<0.150 mm) were analyzed for total N (TN) and total C (TC) using a NA 1500 Series 2 Carlo Erba Instrument (Rodano, Italy). The total P (TP) was determined with the H_2SO_4 and H_2O_2 digestion method developed by Parkinson and Allen (1975) and the P concentration in the digested solution was determined using an auto-analyzer (Model A2, Astoria, Clackamas, OR). Olsen P (available P) and KCl-extractable NO_3 and NH_4 (available N) in soil samples was also determined.

Results and Discussion

One time application

A small but statistically significant increase in soil TN was observed with treatments REG120, REG180, DDG120 and DDG180 compared with the control and fertilizer in all three cycles (Fig. 1 a, b, and c). When both types of manure are compared no significant difference in soil TN accumulation was observed. This is expected since regular and DDG manure had similar TN content (Table 2). A small but significant increase in soil available N (AN) was also observed, but only with treatments REG60, REG120 and REG180 after cycle 1 and treatments REG120, REG180 and DDG180 after cycle 3 (Fig. 1 d, e, and f). Significant increase in soil AN was also observed with fertilizer application, but only after cycle 2 (Fig. 1 e).

Barley TN in cycle 1 was significantly higher in the fertilizer treatment compared with all the other treatments and the control reflecting N immediate availability after inorganic fertilizer application (Fig. 2 a). Contrary to what was observed in the fertilizer treatment, most manure treatments resulted in significant decrease in barley TN compared with the control indicating N immobilization.

Soil TP significantly increased with treatments REG120, REG180, DDG60, DDG120 and DDG180 compared with the control and fertilizer (Fig. 1 g, e, and f). This increase was observed only after cycles 1 and 2. When both types of manure are compared soil TP increase was significantly higher with DDG manure at 60, 120 and 180 Mg ha^{-1} yr^{-1} rates.

Soil available P (AP) was significantly higher with regular manure applications compared with the control and fertilizer only at the higher rates (120 and 180 Mg ha^{-1} yr^{-1}) (Fig. 1 j, k, and l). While DDG manure significantly increased soil AP compared with the control and fertilizer at all rates used. This increase was observed after all three cycles. When both types of manure are compared soil AP in the pots that received DDG manure was twice as much as in the pots that received regular manure for each correspondent manure rate.

Although no more manure was applied after cycle 1, elevated AP content was observed after cycles 2 and 3 compared to cycle 1. For example, soil AP in treatment DDG180 was 25.8 mg kg^{-1} in cycle 1 and increased to 58. 4 and 71.7 mg kg^{-1} in cycles 2 and 3 respectively. In the contrary, soil AP decrease in the control and fertilizer treatment and AP values after cycle 3 were less than 40% of those observed after cycle 1. Increase in soil P concentration with manure application, especially DDG manure, is of concern because it enhances the risk of P runoff into surface water possibly causing eutrophication (Daniel et al. 1998).

Barley TP content significantly increased with treatments REG60, REG120, REG180, DDG60, DDG120, and DDG180 compared with the control and fertilizer (Fig. 2 d, e, and f). This increase was observed in all three cycles. However, basically no significant difference was observed in plant TP when both types of manure are compared.

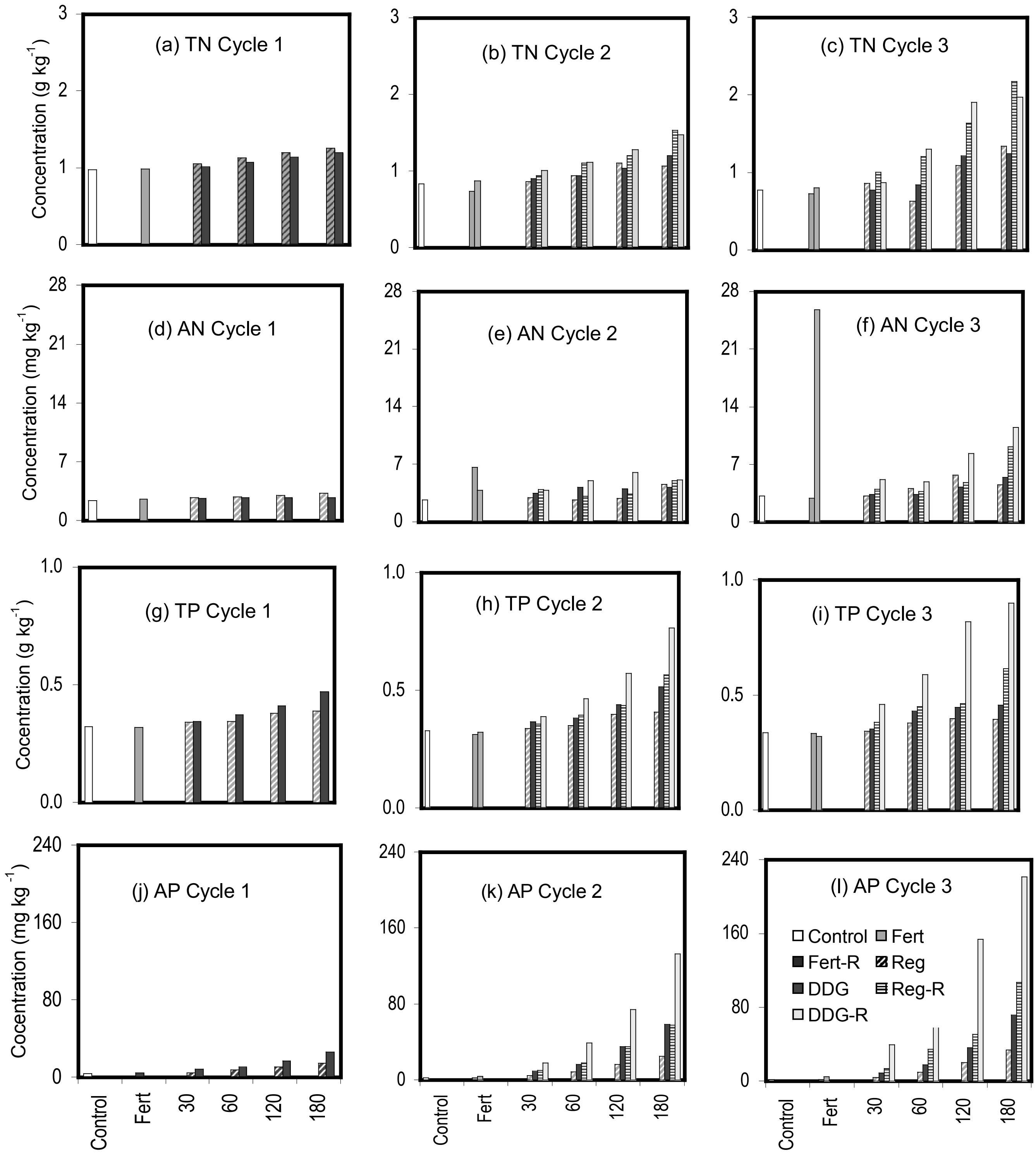

Figure 1. Soil total N (TN), available N (AN), total P (TP) results of cycles 1, 2, and 3 with one time and repeated (R) applications of inorganic fertilizer (Fert and Fert-R), regular (Reg and Reg-R) and DDG (DDG and DDG-R) manures.

Barley dry matter significantly increased with both regular and DDG manure at almost all rates used and with fertilizer application after cycle 1 (Fig. 2 g, h, and i). However, plants did not develop so well in cycles 2 and 3 probably due to the low available N content in loamy sandy soil used. Besides soil was not fallowed in between growth cycles as would in the field conditions when there are sufficient time for mineralization and release of organic N between harvesting and next growth cycle. The low AN concentration in soil are the further indication that N supply might not sufficient or meet the rate of uptake for barely production in growth chamber at higher temperature conditions.

Repeated Applications

Repeated fertilizer and manure applications before each cycle resulted in a significant increase in soil TN only at manure higher rates (treatments REG120R, REG180R, DDG120R and DDG180R) as was observed with one time application (Fig. 1 b and c). In the repeated cycles significant increase in barley TN was observed only with inorganic fertilizer applications (Fig. 2 b and c).

Soil TN content in the repeated cycles was comparable with the one time application cycles at the correspondent treatments indicating that manure application does not seem to result in soil TN accumulation. This is probably related to N loss through barley plants uptake and possible gaseous N losses.

Contrary to what was observed with soil TN, soil TP content in DDG manure treatments in the repeated application cycles was almost as twice as the ones in the one time application indicating accumulation of P in soil. Soil AP content after repeated manure application resulted in as much as 3-fold increase compared with the one time application at a correspondent DDG manure treatment. Despite soil P accumulation with repeated manure applications, when both regular and DDG manure were applied at 30 Mg ha^{-1} yr^{-1} no significant increase in either soil TP or AP content was observed compared to the control and fertilizer treatment. In the repeated cycle, significant increase in barley TP was observed only in treatments REG60R, REG180R and DDG180R compared with the control and fertilizer (Fig. 2 b and c).

With repeated applications barley dry matter increased significantly in treatments REG120R, REG180R, DDG60R, DDG120R and DDG180R cycle 2 and DDG60R and DDG180R cycle 3 (Fig. 2 b and c), reflecting a greater availability of N in the repeated application treatments.

Conclusion

This study demonstrates that DDG manure application to soil supply more P and result in higher soil P content. In order to avoid surface soil P saturation and the risk of P runoff to surface water our result indicates that DDG manure application to agricultural soil should not exceed 30 Mg ha^{-1} yr^{-1}.

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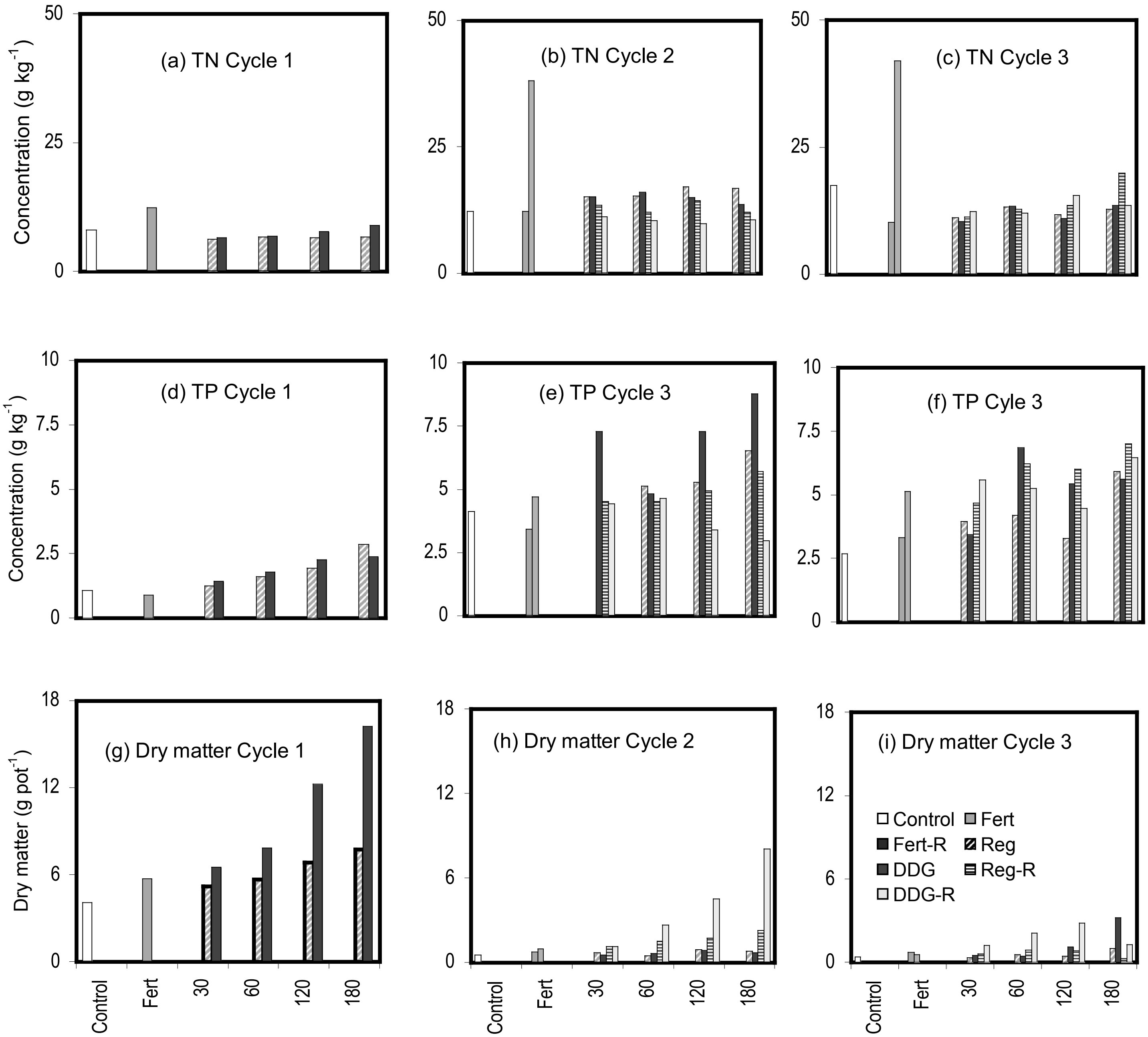

Figure 2. Barley total N (TN), total P (TP) and dry matter results of cycles 1, 2, and 3 with one time and repeated (R) applications of inorganic fertilizer (Fert and Fert-R), regular (Reg and Reg-R) and DDG (DDG and DDG-R) manures.

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