# Effect of Soil Amendment with Dry and Wet Distillers Grains on Growth of Canola and Soil Properties

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**Abstract**

Controlled environment experiments were set up to evaluate the effect of applying distillers grains to soil as organic amendments to increase soil fertility, crop growth and soil organic matter. The two distiller grains were applied at different rates in comparison with urea fertilizer. Canola was grown as the test crop in amended pots, and plant yield, composition and soil properties were measured after five weeks. Both distiller grains were found to be effective soil amendments for increasing canola biomass yield. Per unit of nitrogen added, yields were less than that of urea, due to only a portion of the nitrogen in the amendment becoming available over the five-week period. However, when nutrients other than nitrogen were limiting, canola dry matter yields with organic amendment approached or exceeded that of urea, due to the ability of the amendments to supply other nutrients in addition to nitrogen.

## Introduction

Grain ethanol production is an emerging industry in Western Canada. Its major by-product, distiller grain, contains organic matter along with plant macro and micro-nutrients. These products would normally be used as animal feeds. However, use of such products as fertilizer sources may be also possible. There are two kinds of distiller grain. One is dry distiller grain with solubles (DDG) and the other is wet distiller grain (WDG). The DDG was produced from distillation using a predominately wheat feed stock, but with a small amount of corn also used (<20%). The wet distillers grain (WDG) does not contain solubles. Dry distiller grain with solubles (DDG) or wet distiller grain (WDG) can supply nutrient in organic form that is gradually released by microbial decomposition. Information on the utilization of biofuel co-products as soil amendments and their effect on plant growth and soil properties is limited. The objective of this study is to assess the potential for using distiller grains as a soil amendment to increase soil fertility and crop growth.

## Materials and Methods

### Growth Chamber Study

Two different experiments were conducted, with one using DDG and the other using WDG. The N content is 6.31% for DDG (C:N ~ 7:1) and 3.65% for WDG (dry basis) (C:N ~ 14:1). Urea in both experiments was applied at the same rates of N as the distiller grains for comparison. Application rates for both experiments were the same (0, 100, 200 and 400 kg N $ha^{-1}$) with 4 replicates. In each pot, 800 g of air-dried soil were weighed into a pot. The distiller grain products or urea were then mixed with 10g soil and the mixture was spread on the surface of the soil, followed by addition of 200ml deionized water. An additional 100 g of soil was then added to cover the products and the soils were equilibrated for 4 days. Then 10 canola seeds were placed on the soil surface in each pot and an additional 100ml of water was added. The last 100g soil was added on the soil surface to bring the total soil weight to 1000 g for each pot. Soil moisture was kept at approximately 80% of field capacity in all the treatments. Temperature was 22 $^{o}C$ day and 13 $^{o}C$ night, with an 18-h day length and 6-h night length. After emergence, seedlings were thinned to 3 plants per pot. The pots were completely randomized and rotated each week. Canola plants were grown for five weeks, and then the above ground biomass was harvested.

Plants after harvesting were dried at 50$^{o}C$, 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. Concentrations of elements in the digest were determined by colorimetry and spectroscopy. Plant nutrient uptake was calculated by multiplying the yield by the concentration in the tissue and is expressed as milligrams of nutrient taken up per kilogram of soil.

Soil and Soil Analysis

The soil used in the experiments was an Orthic Brown Chernozem of the Ardill Association, collected from the 0-15cm depth of a wheat stubble field near Central Butte, SK in the fall of 2007. After collection, the soil was mixed thoroughly in a soil mixer and stored before use. A sample of the soil used in preparation of pots for each experiment was collected and analyzed. The initial properties of the soil used in each experiment are shown in Table 1. At the end of the experiments, the soil from each pot was removed, mixed, air-dried, crushed, passed through a 2-mm sieve and stored at room temperature before analysis. Electrical conductivity (EC) and pH were measured using 1:1 soil:water suspension. Organic C (OC) was measured using Leco carbon analyzer. Soil total N and P concentrations were determined by sulfuric acid peroxide digest. Plant available inorganic N ($NO_3$-N + $NH_4$-N) was extracted with 2 M KCl, $SO_4$-S by 0.01M $CaCl_2$ , and available P and K were extracted using the Modified Kelowna procedure. Soil available Cu, Zn and Cd were extracted by AB-DTPA.

Table 1, Initial properties of the soil used in the controlled environment experiments.

| Amendment Source | Total N mg/g | Total P mg/g | OC % | pH | EC mS cm$^{-1}$ | $NO_3$-N ug/g | $NH_4$-N ug/g | P ug/g | K ug/g | $SO_4$-S ug/g | Cu ug/g | Zn ug/g | Cd ug/g |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dry Distiller | 1.18 | 0.50 | 1.94 | 8.00 | 0.30 | 1.7 | 5.5 | 6.0 | 609 | 13.5 | 0.41 | 4.1 | 0.066 |
| Wet Distiller | 1.05 | 0.49 | 1.87 | 7.97 | 0.29 | 1.7 | 3.6 | 5.0 | 601 | 11.6 | 0.49 | 4.6 | 0.072 |

**Results and Discussion**

Effect of Amendment with DDG and WDG on Canola Yield, and N & P Uptake

Table 2. Properties of canola plants grown in dried distillers grain (DDG) with solubles and urea amended soil.

| Fertilizer Rate | Yield | Uptake | | | | |
|---|---|---|---|---|---|---|
| N | | N | P | K | Zn | Cd |
| kg $ha^{-1}$ | g/pot | mg/kg | mg/kg | mg/kg | ug/kg | ug/kg |
| 0 | 0.74d | 7.86f | 2.65e | 14.4e | 40.9a | 412 d |
| 100 DDG | 2.05c | 15.42e | 4.50c | 40.5d | 100.5a | 436 d |
| 200 DDG | 3.30b | 23.77d | 5.60b | 53.3bc | 166.5a | 598 bc |
| 400 DDG | 5.21a | 49.08b | 9.67a | 101.7a | 114.7a | 818 a |
| 100 (Urea) | 2.37c | 17.88e | 3.51d | 41.2d | 154.5a | 479 cd |
| 200 (Urea) | 3.13b | 33.55c | 3.51d | 46.0cd | 217.2a | 716 ab |
| 400 (Urea) | 3.02b | 61.40a | 2.61e | 56.9b | 185.2a | 770 a |

Numbers in a column followed by the same letter are not significantly different at $P<0.10$.

The distillers grains were from different origin and sources, so the effects of the solubles cannot be factored out in this study. Addition of both DDG and WDG resulted in very good dry matter yield responses of canola (Tables 2 and 3) after five weeks, especially for DDG. The responses of DDG at equivalent rates of total N added as DDG compared with urea were similar at low and medium rates, and greater at the high rate (Table 2). One important observation was reduced germination and emergence of the canola seedlings at the high rate of DDG or WDG addition (400 kg N $ha^{-1}$), similar to plants affected by too much fertilizer placed in the seed-row. This does not appear to be related to a salt effect, as the E.C. remains low in these treatments after five weeks. However, the canola plants recovered rather quickly and went on to do quite well at the high rates of addition as shown in Table 2.

At equivalent rates of added N, the N uptake by the canola grown with DDG was about 80% to 90% of that observed for urea, despite similar or higher yields. As for any organic amendment, not all the N was made available for plant uptake over the five week period of high demand. Other nutrients like P and S in the distiller's grain may have also contributed to yield increase in the DDG treatments. This is evident in the greater uptake of macronutrients in the DDG treatments compared to urea (Table 2).

Table 3. Properties of canola plants grown in wet distillers grain (WDG) and urea amended soil

| Fertilizer Rate | Yield | Uptake | | | | |
|---|---|---|---|---|---|---|
| N | | N | P | K | Zn | Cd |
| kg ha$^{-1}$ | g/pot | mg/kg | mg/kg | mg/kg | ug/kg | ug/kg |
| 0 | 0.51e | 4.92e | 1.56e | 8.82e | 19.6e | 260.8d |
| 100 WDG | 1.02d | 6.49de | 1.99de | 18.77d | 19.4e | 216.3d |
| 200 WDG | 1.44c | 10.68bc | 2.74bc | 26.88c | 34.1de | 297.7d |
| 400 WDG | 2.11a | 36.57b | 4.38a | 59.94a | 59.9bc | 442.4c |
| 100 (Urea) | 1.65bc | 14.10c | 2.47cd | 27.41c | 42.8cd | 402.0c |
| 200 (Urea) | 1.68bc | 38.05b | 2.53cd | 51.06b | 75.2ab | 602.1b |
| 400 (Urea) | 1.95ab | 59.38a | 3.16b | 62.49a | 84.2a | 775.7a |

Numbers in a column followed by the same letter are not significantly different at $P<0.10$.

The yields and N uptake with the WDG (Table 3) tended to be less when comparing with urea, versus DDG in comparison with urea. The same amount of total N was added for each distiller grain source, but a wider C:N ratio in the WDG can explain the slower rate of N release over the 5 week period in comparison to DDG. The solubles in the DDG contribute low molecular weight organic nitrogen compounds that have low C:N ratios and are readily mineralized by the soil microbial population. Effects of WDG on other nutrients for canola were similar to DDG (Tables 2 and 3).

Effect of Amendment with Dry and Wet Distillers Grains on Soil Properties

The DDG and WDG treatments (Tables 4 and 5) all had low content of plant available inorganic N at the end of the experiments. The high rates of urea had elevated nitrate nitrogen content, indicating some unused fertilizer urea N that was added at these rates. The total N levels in the soil were elevated to about the same extent for the distillers grain and urea amendments, with the highest rates of either one producing significantly higher total soil N contents. This residual N appears to exist mainly in the organic form in the case of the distiller grain amendments and may be anticipated to contribute to increased N availability to subsequent crops.

Limited effect was observed in other physical and chemical variables including metals, probably as a result of a one time application (Tables 4 and 5). The amendment of soil with DDG or WDG does not appear to be associated with any significant enhancement of crop functional and non-functional metal uptake or accumulation in soil compared to commercial nitrogen fertilizer. Further investigation in the field is needed to evaluate long-term effects of application and their value as alternative sources of plant nutrients.

Table 4. Soil properties in dried distillers grain amendment trial before and after canola harvest.

| Fertilizer Rate N kg ha$^{-1}$ | $NO_3$-N ug/g | $NH_4$-N ug/g | Ext-P ug/g | Ext-K ug/g | $SO_4$-S ug/g | Total N mg/g | Total P mg/g | pH | EC mS cm$^{-1}$ | OC % | Cu ug/g | Zn ug/g | Cd ug/g |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Before seeding | 1.7 | 5.5 | 6.0 | 609 | 13.5 | 1.18 | 0.50 | 8.00 | 0.30 | 1.94 | 0.41 | 4.1 | 0.066 |
| After harvest | | | | | | | | | | | | | |
| 0 DDG | 2.2b | 9.6a | 5.7a | 626a | 9.1a | 1.04d | 0.49c | 8.08ab | 0.28b | 1.88a | 0.47a | 2.9b | 0.071a |
| 100 DDG | 1.9b | 8.6a | 5.0b | 589b | 8.9a | 1.07cd | 0.49c | 8.05b | 0.26c | 1.86a | 0.42a | 3.4a | 0.070a |
| 200 DDG | 1.3b | 4.1c | 4.7bc | 570b | 8.6a | 1.16abc | 0.50bc | 8.08ab | 0.25cd | 1.87a | 0.48a | 2.9b | 0.070a |
| 400 DDG | 1.3b | 5.5b | 5.1b | 532c | 9.0a | 1.21ab | 0.53a | 8.07ab | 0.24de | 1.94a | 0.38a | 2.9b | 0.065a |
| 100 (Urea) | 1.5b | 5.6b | 4.3c | 564b | 9.0a | 1.14bcd | 0.52ab | 8.10ab | 0.24de | 1.89a | 0.45a | 3.0ab | 0.069a |
| 200 (Urea) | 2.4b | 5.0bc | 4.3c | 567b | 8.9a | 1.15abcd | 0.50bc | 8.06ab | 0.23e | 1.88a | 0.44a | 2.9b | 0.069a |
| 400 (Urea) | 35.9a | 6.0b | 4.5bc | 569b | 8.9a | 1.27a | 0.49c | 7.99c | 0.35a | 1.92a | 0.46a | 2.8b | 0.071a |

Numbers in a column followed by the same letter are not significantly different at $P<0.10$.

Table 5. Soil properties in wet distillers grain amendment trial before and after canola harvest.

| Fertilizer Rate N kg ha$^{-1}$ | $NO_3$-N ug/g | $NH_4$-N ug/g | Ext-P ug/g | Ext-K ug/g | $SO_4$-S ug/g | Total N mg/g | Total P mg/g | pH | EC mS cm$^{-1}$ | OC % | Cu ug/g | Zn ug/g | Cd ug/g |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Before seeding | 1.7 | 3.6 | 5.0 | 601 | 11.6 | 1.05 | 0.49 | 7.97 | 0.29 | 1.87 | 0.49 | 4.6 | 0.072 |
| After harvest | | | | | | | | | | | | | |
| 0 | 1.7bc | 4.8ab | 5.4b | 628a | 5.4bc | 1.10d | 0.52a | 8.08a | 0.27b | 1.88bc | 0.44a | 3.7a | 0.061b |
| 100 WDG | 1.1c | 4.9ab | 5.6b | 623a | 4.9cd | 1.22abc | 0.51a | 8.01b | 0.27b | 1.95ab | 0.46a | 3.2b | 0.068ab |
| 200 WDG | 1.2c | 5.2a | 5.6b | 619a | 3.9cd | 1.16bcd | 0.55a | 8.03bc | 0.27b | 1.93ab | 0.46a | 2.9bc | 0.069ab |
| 400 WDG | 1.8c | 3.9c | 7.1a | 592b | 8.7a | 1.29a | 0.55a | 7.96c | 0.27b | 1.98a | 0.46a | 3.0bc | 0.069ab |
| 100 (Urea) | 1.1c | 5.3a | 4.6b | 588b | 3.5d | 1.14dc | 0.51a | 7.99b | 0.24b | 1.92abc | 0.46a | 3.0bc | 0.074a |
| 200 (Urea) | 15.2b | 5.4a | 5.2b | 593b | 4.2cd | 1.08d | 0.50a | 7.96bc | 0.29b | 1.84c | 0.44a | 2.8c | 0.073a |
| 400 (Urea) | 83.6a | 4.2bc | 4.8b | 556c | 6.5b | 1.24ab | 0.51a | 7.84d | 0.57a | 1.93ab | 0.45a | 3.0bc | 0.071a |

Numbers in a column followed by the same letter are not significantly different at $P<0.10$.

## Conclusions

Availability of nitrogen from DDG and WDG amendments appears to be similar to or better than many other solid organic amendment sources such as manure and compost, owing to a relatively high N content, especially for DDG. The cause of some inhibition of canola germination and emergence that was noted at the highest rates of application of distiller grain was not determined, but is a cautionary in use of these amendments at high rates.

No adverse effects on soil conditions (salinity, pH, extractable metals) were observed resulting from the amendments as measured five weeks after addition. There were also no significant effects on metal uptake by the crop compared to commercial fertilizer amendment. Land application as fertilizer appears to be a viable alternative use for these ethanol production co-products when other use options do not exist.

## Acknowledgements

Financial support of Agriculture Development Fund is greatly appreciated.