**Evaluation of Stover Removal and Fresh Mushroom Compost on Corn Yield and Soil Quality**


**Principal Investigators**

Greg Roth, Ph.D.
Professor of Agronomy
Pennsylvania State University
116 A.S.I. Building
University Park, PA 16802

Mike Fidanza, Ph.D.
Professor of Plant Soil Sciences
Pennsylvania State University – Berks Campus
111 Luerssen Building
Reading, PA 19610

Phil Coles, M.B.A
Giorgi Mushroom Company
1161 Park Road
Reading, PA 19605


## INTRODUCTION

The objective of this field research project was to evaluate stover removal in a typical Pennsylvania corn (*Zea mays*) cropping system in conjunction with the application of fresh mushroom compost (formerly called "spent mushroom substrate") for potential improvement in crop yield and soil quality.

Specifically, in Fall 2012 an existing field corn ('dent') production site was divided into test plots and subjected to three levels of stover removal (100% or 70% removal, and 0% "control") followed-by the surface application of four fresh mushroom compost (MC) amounts (0, 5, 10 or 20 tons/acre) for each stover removal level (Table 1). The test plots were planted with corn in Spring 2013, and will be harvested in Fall 2013. All stover removal and MC treatments (Table 1) described will be repeated at the same location and within the same test plots in Fall 2013, and planted with corn again in Spring 2014 and harvested in Fall 2014.

In addition, in Fall 2012 only, other test plots were subjected to three levels of stover removal (100% or 70% removal, and 0% "control") followed-by the surface application of two MC amounts (20 or 40 tons/acre) for each stover removal level (Table 1). These test plots were also planted with field corn ('dent') in Spring 2013, and will be harvested in Fall 2013 (Table 1). No further stover removal or MC applications will be made to these test plots, but the same test plots will be planted with field corn again Spring 2014 and harvested in Fall 2014.

Corn yield will be measured in Fall 2013 and again in 2014 to determine any potential treatement effect on crop productivity. Also, soil samples were taken at the start of the project in Fall 2012 and subjected to laboratory analysis, and this will be repeated for each individual test plot in Fall 2013 and again in Fall 2014 to determine any potential improvement in soil quality.

## MATERIALS AND METHODS

This field research trial was conducted at the Penn State Berks Campus (Reading, PA), specifically at a location referred to as the "outdoor experimental plant and soil science research area." The test site is currently used to grow field corn (i.e., dent) on campus land that is rented to a local farmer, and therefore provided the necessary stover for the start of the trial in Fall 2012.

**Experimental Design.** The treatments (Table 1) were randomized and arranged in a split-plot design, with __ replications. The main plots were stover removal, and the sub-plots were MC amounts (Table 2). Each individual plot was 4 rows wide at 30-inch spacing (10 feet in width) and 25 feet in length, with a 5 foot buffer row in between replications (Table 2).

**Fall 2012 – Stover Removal.** Stover was mechanically removed on 6 December 2012 by Penn State Department of Plant Science (formerly Department of Agronomy) staff.

**Fall 2012 – Soil Sampling.** Prior to the application of MC, soil samples were obtained on 20 December with a 0.75 inch diameter soil probe at two different depths of 0 to 2 inches and at 2 to 8 inches. For each depth, 20 samples were randomly collected from each replication, mixed thoroughly, and four pint-size samples were retained for a standard laboratory analysis at Penn State Ag Analytical Services Laboratory (University Park, PA). This soil sampling data will serve as the "baseline" for soils information to be compared with soils data obtained for each depth in each individual test plot in Fall 2013 and Fall 2014. Note, 20 additional soil samples were obtained at the 0 to 8 inch depth randomly obtained from the entire test site for soil textural class determination.

**Fall 2012 – MC Application.** The MC was obtained directly from a production house (*Agaricus bisporus* - "white button mushroom) of Giorgi Mushroom Company (Reading, PA) and immediately transported to the field test site. The MC was surface-applied with a tractor on 20 December 2012 and hand-raked evenly across the test plots according to the amounts dictated by the treatment list (Tables 1 and 2). The MC amount per plot was calculated from a standard compost analysis (Penn State Ag Analytical Services Laboratory, University Park, PA) that revealed the bulk density of 458 lbs/cubic yard on a wet volume basis. The MC was allowed to remain evenly on the surface area of the plot and not incorporated into the soil.

**Spring 2013 – Corn Planting.** All individual plots were seeded with 'dent' corn on 25 April 2013 according to standard procedures (i.e., no-till) conducted by staff from Penn State's Department of Plant Science. A standard preemergence herbicide program (3 quarts Lumax product/acre plus 32 fl oz Roundup product/acre) was applied on 26 April 2013 with a 25-gallon sprayer calibrated to deliver 43.5 gal water-carrier per acre through three flat-fan (air induction) nozzles, spaced 20 inches apart with a 20 inch boom height.

## RESULTS

**Fall 2012 – Stover Removal.** Stover removal was successfully completed on 6 December 2012 (Figures 1 and 2). The amount of dry matter removed for the 100% corn stover removal plots averaged 4,180.7 lbs, and 3,382.6 lbs for the 70% corn stover removal plots.

**Fall 2012 – Soil Sampling.** The soil texture was determined to be a silt loam, with 21.4% sand, 51.6% silt, and 27% clay. The baseline soil audit results are listed in Table 3.

**Fall 2012 – MC Application.** The MC successfully applied and evenly distributed on the surface of the test plots (Figures 3 and 4).

**Spring 2013 – Corn Planting.** The corn was successfully planted and is currently growing at a standard or normal rate for Southeastern Pennsylvania (Figures 5 and 6).

## SUMMARY

At the conclusion of the harvest in Fall 2013 and soil sampling audit also in Fall 2013, all data (i.e., yield, soil information, other data) will be subjected to analysis of variance and treatment means compared using Fisher's least significance difference test at $P < 0.05$. Refer to Table 1 for a complete list of all treatments to be evaluated in this field research project.

Expected outcomes for this research project include a recommendation and/or program to Pennsylvania farmers for removing stover and using fresh mushroom compost in corn cropping systems, which will result in improved yield as well as improved soil quality (i.e., efficient use of N, P and K; improve organic matter status in soils; improve soil moisture retention during environmental drought stresses, potentially decrease slug pest infestation, etc.).

**Table 1.** Treatment list.

| | | | "x" Indicates Timing of Field Trial Activity | | | |
|---|---|---|---|---|---|---|
| | | | Stover Removal and Application of Fresh MC[3] | | Plant and Harvest[4] | |
| No. | Stover Removal[1] | Fresh MC per Acre[2] | Fall 2012 | Fall 2013 | Spring/Fall 2013 | Spring/Fall 2014 |
| 1. | 100% | 0 | x | x | x | x |
| 2. | 100% | 5 | x | x | x | x |
| 3. | 100% | 10 | x | x | x | x |
| 4. | 100% | 20 | x | x | x | x |
| 5. | 70% | 0 | x | x | x | x |
| 6. | 70% | 5 | x | x | x | x |
| 7. | 70% | 10 | x | x | x | x |
| 8. | 70% | 20 | x | x | x | x |
| 9. | 0% | 0 | x | x | x | x |
| 10. | 0% | 5 | x | x | x | x |
| 11. | 0% | 10 | x | x | x | x |
| 12. | 0% | 20 | x | x | x | x |
| 13. | 100% | 20 | x | -- | x | x |
| 14. | 100% | 40 | x | -- | x | x |
| 15. | 70% | 20 | x | -- | x | x |
| 16. | 70% | 40 | x | -- | x | x |
| 17. | 0% | 20 | x | -- | x | x |
| 18. | 0% | 40 | x | -- | x | x |

[1]Percent stover to be removed per test plot.
[2]Fresh mushroom compost (tons per acre) to be surface-applied per test plot.
[3]Timing of stover removal and application of fresh mushroom compost.
[4]Corn crop to be planted in the spring (i.e., May) and harvested in the fall (i.e., October).

**Table 2.** Experimental plot design.

| Rep I | | | | | | Rep II | | | | | | Rep III | | | | | | Rep IV | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 6 | 1 | 2 | 3 | 4 | 3 | 6 | 1 | 4 | 5 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 1 | 5 | 6 | 2 | 4 | 3 |
| 3 | 4 | 5 | 6 | 1 | 2 | 1 | 5 | 6 | 2 | 4 | 3 | 1 | 2 | 3 | 4 | 5 | 6 | 4 | 2 | 3 | 5 | 1 | 6 |
| 1 | 2 | 3 | 4 | 5 | 6 | 4 | 2 | 3 | 5 | 1 | 6 | 5 | 6 | 1 | 2 | 3 | 4 | 3 | 6 | 1 | 4 | 5 | 2 |
| 100% | | 70% | | 0% | | 100% | | 0% | | 70% | | 70% | | 100% | | 0% | | 0% | | 100% | | 70% | |

**Whole Plot:** 100% Stover Removal.
70% Stover Removal.
0% Stover Removal.

**Sub-Plot:**
1) 0 tons Fresh Mushroom Compost/Acre; apply Fall 2012 and Fall 2013.
2) 5 tons Fresh Mushroom Compost/Acre; apply Fall 2012 and Fall 2013.
3) 10 tons Fresh Mushroom Compost/Acre; apply Fall 2012 and Fall 2013.
4) 20 tons Fresh Mushroom Compost/Acre; apply Fall 2012 and Fall 2013.
5) 20 tons Fresh Mushroom Compost/Acre; apply Fall 2012 only.
6) 40 tons Fresh Mushroom Compost/Acre; apply Fall 2012 only.

***Total Area:*** 240’ x 85’ (20,400 sq ft or 0.48 acre); 5’ alleys in-between rows.

***Individual Sub-Plot Size:*** 10’ x 25’ (4 rows of corn at 30” spacing).

**Figure 1.** Stover being removed with Hess hay stacker.

**Figure 2.** Stover removed, next to treatment without stover removed.

**Table 3.** Soil audit results.

| | Sampling | Sample | | | | | | CEC | ------ % Saturation of CEC ------ | | | | Salts | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rep | Depth | ID # | soil pH | P (ppm) | K (ppm) | Mg (ppm) | Ca (ppm) | meq/100g | K | Mg | Ca | % OM | mmhos/cm | Zn (ppm) | Cu (ppm) | S (ppm) |
| rep I | 0 - 5 cm | 1a | 6.8 | 124 | 275 | 221 | 1540 | 10.2 | 6.9 | 18 | 74.1 | 4.2 | 0.17 | 12.5 | 9.1 | 13.6 |
| | | 1b | 6.7 | 122 | 273 | 242 | 1552 | 12.5 | 5.6 | 16.2 | 62.2 | 4.3 | 0.22 | 12.1 | 8.7 | 15.3 |
| | | 1c | 6.6 | 133 | 266 | 223 | 1487 | 12.8 | 5.3 | 14.5 | 58.2 | 4.6 | 0.2 | 12.2 | 8.7 | 14.1 |
| | | 1d | 6.8 | 111 | 261 | 217 | 1582 | 10.4 | 6.4 | 17.4 | 76.1 | 4.6 | 0.2 | 12.1 | 9.4 | 13.4 |
| rep II | 0 - 5 cm | 2a | 6.7 | 112 | 245 | 193 | 1470 | 11.8 | 5.3 | 13.6 | 62.4 | 4.3 | 0.17 | 10.5 | 9.1 | 12.7 |
| | | 2b | 6.8 | 108 | 271 | 218 | 1568 | 10.4 | 6.7 | 17.6 | 75.7 | 4.6 | 0.17 | 11.6 | 9.4 | 13.9 |
| | | 2c | 6.8 | 113 | 263 | 221 | 1639 | 10.7 | 6.3 | 17.2 | 76.5 | 4.7 | 0.16 | 12.5 | 9.6 | 13.5 |
| | | 2d | 6.8 | 111 | 262 | 205 | 1627 | 10.5 | 6.4 | 16.2 | 77.4 | 4.7 | 0.2 | 12.2 | 9.1 | 13.2 |
| rep III | 0 - 5 cm | 3a | 6.8 | 121 | 262 | 222 | 1544 | 10.2 | 6.6 | 18.1 | 75.4 | 4.6 | 0.21 | 13.6 | 9.8 | 13.6 |
| | | 3b | 6.8 | 110 | 243 | 197 | 1466 | 9.6 | 6.5 | 17.1 | 76.4 | 4.4 | 0.18 | 10.7 | 8.9 | 12.8 |
| | | 3c | 6.8 | 140 | 300 | 252 | 1522 | 10.5 | 7.3 | 20 | 72.6 | 4.6 | 0.25 | 14.9 | 9.8 | 14 |
| | | 3d | 6.9 | 121 | 263 | 228 | 1601 | 10.6 | 6.4 | 18 | 75.7 | 4.9 | 0.23 | 13.3 | 9.4 | 13.3 |
| rep IV | 0 - 5 cm | 4a | 7 | 127 | 308 | 261 | 1599 | 11 | 7.2 | 19.8 | 73 | 4.7 | 0.12 | 16.5 | 11 | 13.2 |
| | | 4b | 6.9 | 121 | 267 | 220 | 1600 | 10.5 | 6.5 | 17.4 | 76.1 | 4.5 | 0.17 | 12.4 | 9.6 | 13.3 |
| | | 4c | 7 | 99 | 251 | 205 | 1523 | 10 | 6.5 | 17.1 | 76.4 | 4.5 | 0.18 | 13.1 | 9.9 | 13.4 |
| | | 4d | 6.8 | 117 | 272 | 236 | 1573 | 10.5 | 6.6 | 18.7 | 74.7 | 4.7 | 0.19 | 12.6 | 9.5 | 14.8 |
| | | **AVERAGE:** | **6.8** | **118** | **268** | **223** | **1556** | **10.8** | **6.4** | **17.3** | **72.7** | **4.6** | **0.19** | **12.7** | **9.4** | **13.6** |

| | Sampling | Sample | | | | | | CEC | ------ % Saturation of CEC ------ | | | | Salts | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rep | Depth | ID # | soil pH | P (ppm) | K (ppm) | Mg (ppm) | Ca (ppm) | meq/100g | K | Mg | Ca | % OM | mmhos/cm | Zn (ppm) | Cu (ppm) | S (ppm) |
| rep I | 5 - 20 cm | 1e | 6.9 | 47 | 178 | 125 | 1271 | 7.9 | 5.8 | 13.3 | 80.9 | 2.8 | 0.13 | 4.9 | 7.5 | 10.2 |
| | | 1f | 6.9 | 48 | 164 | 126 | 1274 | 7.8 | 5.4 | 13.4 | 81.2 | 2.6 | 0.13 | 5.5 | 7.3 | 10 |
| | | 1g | 6.9 | 50 | 170 | 124 | 1242 | 7.7 | 5.7 | 13.5 | 80.9 | 2.4 | 0.13 | 5.4 | 7.3 | 10.1 |
| | | 1h | 6.8 | 54 | 235 | 138 | 1281 | 8.2 | 7.4 | 14.1 | 78.5 | 3.2 | 0.16 | 6.1 | 8.4 | 11.1 |
| rep II | 5 - 20 cm | 2e | 6.9 | 60 | 235 | 164 | 1577 | 9.9 | 6.1 | 13.9 | 80 | 3.6 | 0.15 | 7.4 | 7.7 | 11.2 |
| | | 2f | 6.9 | 56 | 203 | 140 | 1380 | 8.6 | 6.1 | 13.6 | 80.4 | 3.2 | 0.13 | 6 | 7.8 | 11.2 |
| | | 2g | 7 | 61 | 214 | 151 | 1547 | 9.5 | 5.8 | 13.2 | 81.1 | 3.2 | 0.14 | 6.2 | 8.1 | 11.1 |
| | | 2h | 7 | 54 | 182 | 125 | 1312 | 8.1 | 5.8 | 12.9 | 81.3 | 2.5 | 0.13 | 5 | 7.5 | 10.1 |
| rep III | 5 - 20 cm | 3e | 6.9 | 63 | 215 | 137 | 1346 | 8.4 | 6.5 | 13.6 | 79.9 | 2.9 | 0.12 | 6.1 | 8 | 10.5 |
| | | 3f | 7 | 55 | 192 | 139 | 1435 | 8.8 | 5.6 | 13.1 | 81.3 | 2.8 | 0.13 | 5.5 | 7.7 | 10.6 |
| | | 3g | 6.9 | 61 | 231 | 140 | 1311 | 8.3 | 7.1 | 14 | 78.8 | 3 | 0.1 | 6 | 7.4 | 12 |
| | | 3h | 6.9 | 61 | 234 | 142 | 1363 | 8.6 | 7 | 13.8 | 79.3 | 3.3 | 0.13 | 6.7 | 7.8 | 11.3 |
| rep IV | 5 - 20 cm | 4e | 6.9 | 69 | 242 | 141 | 1340 | 8.5 | 7.3 | 13.8 | 78.9 | 3.2 | 0.11 | 6.7 | 8.1 | 11.3 |
| | | 4f | 6.9 | 71 | 226 | 155 | 1463 | 9.2 | 6.3 | 14.1 | 79.6 | 3.4 | 0.11 | 7.4 | 8.1 | 11.5 |
| | | 4g | 6.9 | 58 | 227 | 136 | 1324 | 8.3 | 7 | 13.6 | 79.4 | 3 | 0.14 | 5.6 | 7.7 | 10.6 |
| | | 4h | 6.7 | 63 | 231 | 127 | 1226 | 10 | 5.9 | 10.6 | 61.4 | 3.1 | 0.14 | 6.4 | 8.3 | 11.4 |
| | | **AVERAGE:** | **6.9** | **58** | **211** | **138** | **1356** | **8.6** | **6.3** | **13.4** | **78.9** | **3.0** | **0.13** | **6.1** | **7.8** | **10.9** |

**Figure 3.** Example of fresh mushroom compost applied to a test plot.

**Figure 4.** Another example of fresh mushroom compost applied to test plots.

**Figure 5.** Example of a corn planting activity in test plot, 25 April 2013.

**Figure 6.** Example of corn growing in test plot with fresh mushroom compost applied to the surface (first week of July 2013).