Effect of Organic Manures Fortified with Plant Growth-Promoting Rhizobacteria on Controlling Some Soil-Borne Diseases and Growth of Wheat Plants

Nemat M. Awad and Azza Sh. Turky
Agricultural Microbiology Department, National Research Centre, Cairo, Egypt.

The addition of organic composites fortified with high effective antagonistic plant growth-promoting rhizobacteria (PGPR) to control soil-born diseases in wheat plants were evaluated. The three composites, sugar beet haulms (SBH), flax shivers (FS) and rice straw (RS) as well as FYM were fortified with highly effective antagonistic PGPR (P. fluorescens and B. subtilis) to control Fusarium graminearum. Plants receiving SBH compost followed by the infection with F. graminearum had an average mortality of 13.3% compared to 63.3% for plants receiving pathogen alone. Plant mortality averaged between 33.3 and 36.7% for plant receiving FS and RS composites, respectively. The addition of FYM did not significantly reduce plant mortality compared with the RS, FS composites and non-amended control. Numbers of both antagonists, Pseudomonas spp. and Bacillus spp., were the highest in the rhizosphere of wheat plants grown in soil receiving compost enriched with the mixture of antagonistic bacteria, especially in SBH compost. In the FYM, however, both populations had been declined below the detected limits the 84 days after planting period. Wheat plants grown on infested soil amended with compost enriched with PGPR had high dry weights of shoots and roots as well as R/S ratio compared to those grown on soil infested with F. graminearum. The lowest plant dry weights were associated with plants grown in soil amended with FYM compared to other treatments amended with compost. SBH, FS and RS composites significantly stimulated the accumulation of N and K in wheat shoots compared to control soil.

Keywords: Plant growth-promoting rhizobacteria (PGPR), P. fluorescens and B. subtilis, Wheat plants, F. graminearum, Sugar beet haulms (SBH), Flax shivers (FS), Rice straw (RS) composites.

It is well known that plant growth-promoting rhizobacteria (PGPR) inspire plant growth and/or trim down the incidence of some soil-born diseases (Attia et al., 2004). PGPR fulfill many norms, i.e., aggressive colonization, plant growth stimulation and biocontrol (Lucy et al., 2004 and Preston, 2004). Some PGPR might be designated as biofertilizers and/or plant growth promotion dominates (Awad et al., 2005). Their modes of action perform nitrogen fixation, phosphate
solubilization and production of phytohormones such as auxin and cytokinin and volatile growth stimulants such as ethylene and 2, 3-butanediol (Ryu et al., 2003).

These PGPR, which mostly belong to *Pseudomonas* spp. and *Bacillus* spp., are antagonists of recognized root pathogens. Some conceptual uncertainty was created by the early theory that PGPR might enhance plant growth by excluding so-called deleterious rhizobacteria, which are thought to inhibit plant growth without causing root invasion and classical disease. In retrospect, the evidence for the existence of deleterious rhizobacteria in nature is not convincing (Kloepper, 2003). In addition, biocontrol agents that colonize composts include bacteria like *Bacillus*, *Enterobacter*, *Flavobacterium* and *Pseudomonas* actinomycetes like *Streptomycetes* and fungi like *Trichoderma* and *Gliocladium* (Hoitink et al., 1991). The concentration and availability of nutrients (carbohydrates in lignocellulosic substances, chitin, lipids, etc.) within the soil organic matter play a critical role in regulating activity of the microbial community as well as the activity of biological control agents (Hoitink et al., 1997).

Organic matter might suppress plant pathogens through stimulating activities and enhancing antagonists, leading to a decrease in viable pathogens and reduce the need for fungicides (Gamliel & Stapleton, 1993). Diseases caused by soil borne pathogens, including *Rhizoctonia solani* (Stephens et al., 1981), *Phytophthora cinnamomii*, *Phytophthora cactorum*, *Pythium ultimum* and *Fusarium* spp. (Hoitink et al., 1991) have been reported to be effectively controlled by soil amendments.

The objective of this study was to evaluate the efficiency of applying organic compost that is fortified with highly effective antagonistic PGPR on growth and soil-borne diseases of wheat plants infested with damping-off fungus.

**Material and Methods**

**Microbial antagonists**

*Plant growth-promoting rhizobacteria (PGPR) strains*

PGPR strains, i.e., *P. fluorescens* (PF), *P. putida* (PP), *Bacillus subtilis* (BS), *Bacillus megaterium* (BM) were tested against some phytopathogenic microorganisms. Strains were obtained from cultural collection of Agricultural Microbiology Dept., NRC and grown on nutrient broth until reaching a suspension with approximately $10^8$ CFU ml$^{-1}$, before being used to fortify compost.

*Phytopathogenic microorganisms*

High virulent strains of the pathogenic fungi, *Fusarium graminearum* (F), *Sclerotium rolfsii* (SC) and *Rhizoctonia solani* (RH) were isolated from an infected wheat filed soil. Root samples were washed with water, sterilized in *Egypt. J. Soil. Sci.* 47, No. 1 (2007)
70% ethanol for 30 sec, before being plated onto potato dextrose agar (PDA) medium in Petri dishes. Dishes were incubated under ambient laboratory conditions (20 to 23°) for 10 days, after which each pathogen was transferred to PDA containing 200 mg of ampicillin per liter. After 2 weeks, inoculum was obtained by flooding the colony with 10 ml of sterile double-distilled water, and the mycelia plus spores were scraped off using an inoculating loop. The spore suspension was diluted with sterile double-distilled water to the desired concentration as determined using a hemacytometer. The inoculum contained $10^5$ spore ml$^{-1}$.

**Preparation of composts**

Three plant residue (approximately 100 kg) composts were prepared:

1. SBH compost from sugar beet haulms.
2. FS compost from flax shivers.
3. RS compost from rice straw.

These residues were dried for two weeks on greenhouse benches then ground. Each ground residue was heaped after being mixed with chicken manure as 5% fresh weight. Adequate moisture and aeration were ensured throughout the composting period. The composting time was extended between 40 to 45 days then samples were taken for conducting chemical analyses (Table 1).

**TABLE 1. Chemical analyses of composts and farmyard manure.**

<table>
<thead>
<tr>
<th>Constituents</th>
<th>*SBH compost (%)</th>
<th>FS compost (%)</th>
<th>RS compost (%)</th>
<th>FYM (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic matter</td>
<td>56.20</td>
<td>54.60</td>
<td>53.00</td>
<td>36.20</td>
</tr>
<tr>
<td>Organic C (%)</td>
<td>32.60</td>
<td>31.70</td>
<td>30.70</td>
<td>25.60</td>
</tr>
<tr>
<td>Total N (%)</td>
<td>1.74</td>
<td>1.65</td>
<td>1.81</td>
<td>0.71</td>
</tr>
<tr>
<td>C/N ratio</td>
<td>18.73</td>
<td>19.19</td>
<td>16.96</td>
<td>36.13</td>
</tr>
<tr>
<td>Total P (%)</td>
<td>0.90</td>
<td>0.60</td>
<td>0.47</td>
<td>0.50</td>
</tr>
<tr>
<td>Available P (%)</td>
<td>0.012</td>
<td>0.01</td>
<td>0.015</td>
<td>0.008</td>
</tr>
<tr>
<td>Total K (%)</td>
<td>0.80</td>
<td>0.60</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>pH (1:5 H$_2$O)</td>
<td>7.60</td>
<td>6.60</td>
<td>7.90</td>
<td>8.00</td>
</tr>
</tbody>
</table>

* Sugar beet haulms (SBH), flax shivers (FS), rice straw (RS).

**Evaluation of antagonistic effect**

1) **Bacterial capability to colonize plant roots**

Eight pre-germinated wheat seeds coated with each strain of PGPR were placed on Petri dishes containing water-agar (7g agar in 1L D.W.) and the ability of bacteria to colonize roots was estimated according to Misaghi (1990). After 5 days, radical apex was isolated and placed into tubes containing solution of MgSO$_4$ (10%) and the bacterial suspension obtained was diluted to $10^5$ and 0.1 ml of these dilutions were seeded on Petri dishes containing specific medium (King's medium for *Pseudomonas* and potato starch medium for *Bacillus*) and incubated for 24 hr at 28° and CFU were counted. Results correspond to the mean of all experiments, which repeated at least four times. Data was statistically analyzed using ANOVA and Duncan Multiple Test.

2) *Inhibition of mycelial growth*

Antagonism between antagonistic bacteria and the pathogenic fungi was measured in Petri dishes containing PDA medium. A streak of each antagonistic microorganism and a disc (5 mm in diameter) of each pathogenic fungus were placed on opposite sides of Petri dishes. Three replicates for each treatment were incubated in the dark at 20° and the zone of inhibition was determined after 1 week of growth.

*Acts of PGPR against damping-off of wheat*

Two antagonistic bacterial strains were selected for controlling *Fusarium graminearum* *in vitro*. Seeds of wheat were surface disinfected and coated with antagonists following the method described by Kim *et al.* (1997). Seeds were surface sterilized by placing in a 2.5% sodium hypochlorite solution for 5 min followed by rinsing in 1:29 mixture of hydrogen peroxide: distilled water for 30 min and dried under sterile conditions. The PGPR strains grown in nutrient agar slants were scraped from agar surface with 20 ml of 1% sterile carboxymethylcellulose (CMC) suspension. Five grams of surface sterilized seeds were steeped in this bacterial suspension for 1 hr and dried overnight in sterile Petri dishes. The treated seeds were examined to give approximately $10^7$ CFU/seed for individual treatments. Seeds treated with only 1% CMC served as control. *Fusarium graminearum* was grown on PDB slants for 7 days in a growth chamber at 20° and conidia were harvested by pouring few milliliters of sterile water into the tube. Surface colony was scraped off into a tube; the conidial suspension was vortexed for 30 sec and filtered through cheesecloth to remove mycelia debris. Spore concentration was counted using a hemocytometer and adjusted to $10^6$ conidia ml$^{-1}$.

1) *Disease suppression*

Sandy soil (collected from Falouga, El-Tahreer province of 0.18% total N, 6 mg kg$^{-1}$ available P, and pH 7.6) was sterilized by autoclaving at 120° for 30 min on three consecutive days and packed in pots (8 cm in diameter and 12 cm height). An inoculum of *Fusarium graminearum* (at rate of 10 ml pot$^{-1}$) prepared as described above was first applied on the surface of the sandy soil and 25 g of the same soil was placed above. The coated seeds of wheat with either PGPR strain and control were planted in pots (5 seeds pot$^{-1}$) and covered with 10 g of the same soil. After sowing, each pot received 100 ml tap water. Pots were maintained in the greenhouse and watered for 21 days. Control plants were not inoculated with pathogen or PGPR strains. After 21 days, the number of plants showing disease symptoms such as wilting, drooping of leaves and/or root discoloration were determined.

2) *Greenhouse evaluation*

In a greenhouse experiment, a completely randomized block design was applied in four replicates. The treatments were as follows:
ORGANIC MANURES FORTIFIED WITH PLANT GROWTH-PROMOTING

1) Untreated soil fertilized with NPK.
2) Soil infested with the pathogen and fertilized with NPK.
3) Soil infested with the pathogen and amended with sugar beet haulms (SBH) compost.
4) Soil infested with the pathogen and amended with flax shivers (FS) compost.
5) Soil infested with the pathogen and amended with rice straw (RS) compost.
6) Soil infested with the pathogen and amended with FYM.

A recent cultivated sandy soil collected from Falouga, El-Tahreer province of 0.18% total N, 6 mg kg\(^{-1}\) available P, and pH 7.6 was amended with one of the three composts. Each of the three composts as well as FYM was fortified with highly effective antagonistic PGPR (at rate 10% v/w). Bio-fortified composts were incubated for three days before being mixed with soil and packed into plastic pots. The soil mixture was air dried and sieved to 2 mm before being mixed with the composts. Unamended control fertilized with recommended doses of mineral fertilizers (NPK). Ammonium sulphate, superphosphate and potassium sulphate were added at the rates of 100, 200 and 150 kg acre\(^{-1}\), respectively. Nitrogen fertilizer was added in three equal doses after 21, 35 and 60 days of sowing to all treatments. Each compost was added at use rate of 500g pot\(^{-1}\) (representing the recommended doses of 20 ton acre\(^{-1}\)) and mixed with soil before sowing. The treated soils were packed in pots of 25 kg each (40 cm in diameter and 40 cm in depth). After 48 hr, the pots received 10 ml of \(F. graminearum\) inoculum of \(10^5\) spores per ml was added to the seeding cavity of each block. Seeds of wheat coated as described above (10 seeds pot\(^{-1}\)) were sown in pots. Each pot received 150 ml of tap water and watered twice weekly with 200 ml pot\(^{-1}\) of tap water.

Rhizosphere samples were collected after 3, 14, 28, 56 and 84 days of sowing. Samples were collected arbitrarily from four replicate pots, diluted to 10\(^{-5}\) and 1-ml aliquots were plated onto each of both replicate plates of King's medium and potato starch medium to determine \(Pseudomonas\) spp. and \(Bacillus\) spp. numbers, respectively. Colonies were enumerated after 3 days of incubation at room temperature. Plant mortality (expressed as a percentage of dead plants) was recorded per 10 plants of each treatment 37 days after sowing. Sixty days after sowing, plants were harvested. Shoots and roots were oven-dried at 70 ° for 48 hr, weighed and R/S ratio was determined. Dried shoots were ground to pass through a 0.5-mm sieve and saved for determination of mineral nutrients. Macronutrients (N, P and K) and micronutrients (Ca, Mg, Mn, Zn and Cu) contents in plants were determined according to Kalra & Maynard (1991).

Data were analyzed using Statistical Analysis Software (SAS Institute Inc., Cary, NC). One-way ANOVA was used to detect significant differences among mean effects of amendments observed. Means were compared with Tukey's adjustment for multiple comparisons.

Results and Discussion

Evaluation of antagonistic effects

1) Bacterial capability to colonize roots

The use of bacteria to exert an appropriate biological control of *Fusarium* and other soil born fungi relies on their ability to colonize roots efficiently; otherwise, their biocontrol character would be of non-sense. The ability of colonized roots was highly variable among rhizobacteria, being a reflection for their ability to compete for ecological niches in the rhizosphere (Misaghi, 1990). The analysis of results from this assay showed that no significant differences were observed among the four bacterial antagonists although there were less than 10% of the initial CFU could be recovered. Figure one indicates that the introduced bacteria were able to colonize and multiply along the roots of wheat plants. However, BM strain showed the lowest ability in root colonization than other strains.

Root colonization studies confirmed the colonization of introduced organisms along the roots of the plants. Betelho *et al.* (1998) reported that a rifampicin resistant mutant strain derived from a broad spectrum antifungal, plant growth promoting strain of fluorescent *Pseudomonas* had colonized the endorhizosphere of maize.

![Bar chart showing colonization of wheat roots by plant growth promoting rhizobacteria (PGPR).](image)

**Fig. 1.** Colonization of wheat roots by plant growth promoting rhizobacteria (PGPR).
(PF=*P. fluorescens*, PP=*P. putida*, BS=*B. subtilis*, BM=*B. megaterium*)

2) Inhibition of mycelial growth

All the studied PGPR strains were antagonistic against all test fungi pathogens (*Fusarium graminearum, Sclerotium rolfsi* and *Rhizoctonia solani*) (Table 2). However, no single organism was specified for all the pathogenic fungi. *P. fluorescens* (PF) showed the maximum inhibition in most cases,
followed by *B. subtilis* (BS). The results generally showed that PF and BS were more efficient in inhibiting *Fusarium* and *Sclerotium in vitro*.

*In vitro* inhibition of three phytopathogenic, fungi growth was carried out by confronting the antagonistic microorganism and the pathogen simultaneously under the same conditions. A marked inhibition of fungi occurred in the presence of PGPR strains. Fungal pathogen control through PGPR had been reported by Dowling & O’Gara (1994). The reduction of inhibition zones might be involved in the mechanism of antagonism. In this respect, hydrolytic enzymes such as chitinase and other enzymes such as glucanase or proteases, might act against the fungal cell-wall, antibiotic production also being probably involved (Dwivedi & Johri, 2003). Also, fungal pathogen control through siderophore and antibiotic producing *Pseudomonas* has been reported by Dileep Kumar *et al* (2001). The work reported here and that of others indicated that PGPR produces a factor such as an enzyme and/or antibiotic that might be is released into culture medium and inhibits phytopathogenic fungi mycoparasitism, synergistic competition (Paulitz & Belanger 2001).

**TABLE 2. In vitro antibiosis of plant growth-promoting rhizobacterin against pathogenic fungi of wheat (n=3).**

<table>
<thead>
<tr>
<th>Pathogenic fungi</th>
<th>Zone of inhibition by the respective isolate (in cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
</tr>
<tr>
<td><em>Fusarium graminearum,</em></td>
<td>0.0</td>
</tr>
<tr>
<td><em>Sclerotium rolfs</em></td>
<td>0.0</td>
</tr>
<tr>
<td><em>Rhizoctonia solani</em></td>
<td>0.0</td>
</tr>
</tbody>
</table>

PF=P. *fluorescens*, PP=P. *putida*, BS= *B. subtilis*, BM= *B. megaterium*

**Acts of PGPR against damping-off of wheat**

1) Disease suppression

Disease suppression, *i.e.*, improvement of the healthy seedling percentage compared with control infested with pathogen, ranged between 3.9 to 53%. Bacterization reduced the number of plants showing wilt symptoms (Table 3). PF showed the best result (p<0.05) and was able to protect 53% of plants against disease.

Several lines of experimental evidence have shown that treated seeds with bacterial or fungal antagonists were effective in protecting germinating embryos and seedlings from the damaging action of root pathogens (Paulitz & Belanger, 2001). Therefore, *P. fluorescens* and *P. putida* have been reported as successful biocontrol agents *Fusarium* spp. (Dileep Kumar, 1999). Although the basic mechanisms behind pathogen inhibition are not clearly defined yet. Specific mechanisms involved in pathogen suppression by PGPR vary and include antibiotic production, substrate competition and induced systemic resistance in

the host (Van Loon et al., 1998). Fluorescent pseudomonades are known to suppress soil borne fungal pathogens by producing antifungal metabolites and by sequestering iron in the rhizosphere through the release of iron-chelating siderophores, rendering it unavailable to other organisms (Dwivedi & Johri, 2003). Recent reports by Ryu et al. (2004) have identified several volatile organic compounds produced by a variety of bacteria that promote plant growth and induce systemic resistance in Arabidopsis (Arabidopsis thaliana).

The effectiveness of PF and BS were particularly consistent and provided statistically the best control, compared to other treatments. PF and BS seed treatments, generally, controlled wheat damping-off better than all other PGPR strains. Here, it seems reasonable to state that PF and BS antagonisms were more effective as biocontrol agents towards wilt root caused by Fusarium than all other PGPR strains used.

### TABLE 3. Effects of seed bacterization on development of disease syndrome of Fusarium graminearum on wheat plants. N=30.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Control</th>
<th>Fungus alone</th>
<th>PF</th>
<th>PP</th>
<th>BS</th>
<th>BM</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of plant showing symptoms</td>
<td>0.0 (100)</td>
<td>26.0 (^b)</td>
<td>12.0 (^a) (53.0)</td>
<td>20.0 (^a) (23.1)</td>
<td>13.0 (^a) (30.8)</td>
<td>19.0 (^a) (26.9)</td>
</tr>
</tbody>
</table>

Values give within the parentheses show the percentage decrease over the fungus alone (Fungus only – inoculated/fungus only \(\times 100\)). \(^a\)Values are statistically significant as compared to the fungus alone \((p<0.05)\).

2) **Greenhouse evaluation**

**Mortality**

Sugar beet haulms (SBH) compost incorporation into soil resulted in a significant \((P<0.05)\) reduction in plant mortality relative to non-amended soil (Fig. 2). Plants receiving SBH compost followed by the infection with *F. graminearum* had an average mortality of 13.3% compared to 63.3% for plants receiving sole pathogen. Flax shivers (FS) compost and rice straw (RS) compost also reduced plant mortality, but to a lesser extent than SBH compost (Fig. 2). Plant mortality averaged between 33.3 and 36.7% for RS and FS composts, respectively. The addition of FYM did not significantly reduce plant mortality compared with RS, FS composts and non-amended control (Fig. 2).

The natural presence of specific antagonists in compost is unpredictable which is the reason that some authors appeal for the controlled enrichment of compost with effective microbial antagonists (Rijckeboer et al., 2002 and Postma et al., 2003). The addition of the two bacterial antagonists improved the disease suppressive effect of the compost depending on the product type. This means *Egypt. J. Soil. Sci.* 47, No. 1 (2007)
that, in general, enrichment of compost with antagonists increases the reliability of beneficial effects of compost and increase disease suppressiveness.

![Figure 2](image-url)

**Fig. 2.** Effect of incorporation of different composted materials enriched with PF and BS on mortality of wheat plants caused by *F. graminearum*.

**Population dynamics of the antagonists**

Numbers of both antagonists (*Pseudomonas* spp. and *Bacillus* spp.) were high in the rhizosphere of wheat plants grown in soil compost enriched with the mixture of antagonistic bacteria, especially in SB compost (Table 4). The counts of these two bacterial strains in the other compost products were significantly lower than in the SB compost. Nevertheless, the counts of two strains were reasonably high after 84 days of sowing, $10^4$-$10^5$ CFU of *Bacillus* spp. and $10^3$ to $10^4$ CFU of *Pseudomonas* spp. In the FYM, however, both populations had been declined below the detected limits after the 84 days planting period. Both organisms survived at high levels ($10^4$ and $10^5$ CFU) in the composts, which is apparently conducive to both pathogen and introduced antagonist. It is surprising to notice similar trends in survival, since both organisms have different biological properties. The antagonist populations faded out only in the FYM, which apparently has acquired a hostile environment not only for the pathogens, but for the introduced antagonists as well. In addition, low numbers of pseudomonades and bacilli were present in FYM compared to the FS and RS compost.

**Plant dry weight**

In the absence of *F. graminearum* (untreated treatment), the dry weight of plant (shoot and root) and R/S ratio were significantly higher compared with other treatments (Table 5). However, *F. graminearum* significantly reducing all the plant measurements, which is in accordance with the fact that it is a major pathogen of wheat and is the most destructive at the seedling stage. *F. graminearum* inoculation reduced wheat growth and this effect was suppressed by all the compost treatments. Wheat plants grown on infested soil amended with compost enriched with PGPR had high dry weights of shoots and roots as well as R/S ratio compared to those grown on soil infested with *F. graminearum*.

However, wheat seeds grown in soil fertilized with NPK significantly increased dry weights of wheat plant compared to soil compost fortified with PGPR and infested with *F. graminearum* (Table 5). The lowest biomass was associated with plants grown in soil amended with FYM compared to other treatments amended with compost.

**TABLE 4. Population dynamics of the antagonists *Pseudomonas* spp. and *Bacillus* spp. in the rhizosphere of wheat plants (Log CFU/g dry roots).**

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Time in days</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>14</td>
<td>28</td>
<td>56</td>
</tr>
<tr>
<td><em>Pseudomonas</em> spp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SBH compost</td>
<td>4.2</td>
<td>5</td>
<td>4.7</td>
<td>4.8</td>
<td>4.7</td>
</tr>
<tr>
<td>FS compost</td>
<td>4.5</td>
<td>5.2</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>RS compost</td>
<td>4.5</td>
<td>5.1</td>
<td>4.1</td>
<td>4.1</td>
<td>3.7</td>
</tr>
<tr>
<td>FYM</td>
<td>4.5</td>
<td>3.8</td>
<td>4.2</td>
<td>3.7</td>
<td>3</td>
</tr>
<tr>
<td><em>Bacillus</em> spp.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SBH compost</td>
<td>6.2</td>
<td>6</td>
<td>5.7</td>
<td>5</td>
<td>4.8</td>
</tr>
<tr>
<td>FS compost</td>
<td>4.8</td>
<td>6.3</td>
<td>6.2</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>RS compost</td>
<td>6</td>
<td>0.2</td>
<td>5.8</td>
<td>5.2</td>
<td>4.8</td>
</tr>
<tr>
<td>FYM</td>
<td>6</td>
<td>4.8</td>
<td>4.9</td>
<td>4.5</td>
<td>4</td>
</tr>
</tbody>
</table>

Sugar beet haulms (SBH) compost, flax shivers (FS) compost, rice straw (RS) compost.

**TABLE 5. Effect of compost enriched with *P. fluorescens* (PF) and *Bacillus subtilis* (BS) on dry weights of shoots, roots and R/S ratio of wheat grown in pot infested with *F. graminearum*.**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Dry weigh (g plant⁻¹)</th>
<th>R/S ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shoot</td>
<td>Root</td>
</tr>
<tr>
<td>Untreated (NPK)</td>
<td>2.58a</td>
<td>1.36a</td>
</tr>
<tr>
<td><em>F. graminearum</em> (FG)</td>
<td>1.50c</td>
<td>0.41c</td>
</tr>
<tr>
<td>FG + SBH compost</td>
<td>1.87b</td>
<td>0.69b</td>
</tr>
<tr>
<td>FG + FS compost</td>
<td>1.69b</td>
<td>0.63b</td>
</tr>
<tr>
<td>FG + RS compost</td>
<td>1.67bc</td>
<td>0.59bc</td>
</tr>
<tr>
<td>FG + FYM</td>
<td>1.59c</td>
<td>0.53bc</td>
</tr>
</tbody>
</table>

Different letters in each column indicate significant differences at P<0.05.
Sugar beet haulms (SBH) compost, flax shivers (FS) compost, rice straw (RS) compost.

*Plant nutrient content*

Table 6 shows the accumulation of macro- and micro-nutrients in wheat plants. SBH, FS and RS composts significantly stimulated the accumulation of N.

and K in plant shoots compared to unamended control. The accumulation of Ca was depressed by FYM and in turn, it was stimulated by SB and FS composts. Mg accumulation was significantly stimulated by FS and RS composts and slightly decreased by FYM. The accumulations of P, Mn, Zn and Cu were not affected by any compost or FYM amended under study.

**TABLE 6. Effect of composts on nutrient accumulation in wheat plants.**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>Mn</th>
<th>Zn</th>
<th>Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated (NPK)</td>
<td>15.2(0.73)</td>
<td>2.3(0.16)</td>
<td>17.8(0.96)</td>
<td>22.8(0.58)</td>
<td>4.9(0.23)</td>
<td>105.0(18.1)</td>
<td>44.2(5.47)</td>
<td>12.7(2.47)</td>
</tr>
<tr>
<td><em>F. oxysporum</em> (FO)</td>
<td>9.4(0.31)</td>
<td>2.1(0.13)</td>
<td>14.3(0.82)</td>
<td>18.4(0.44)</td>
<td>3.5(0.15)</td>
<td>72.0(11.1)</td>
<td>31.7(3.74)</td>
<td>7.2(1.09)</td>
</tr>
<tr>
<td>FO <em>SBIC</em></td>
<td>31.3(1.51)</td>
<td>2.9(0.21)</td>
<td>35.5(1.91)</td>
<td>28.5(0.73)</td>
<td>5.9(0.28)</td>
<td>131.3(33.7)</td>
<td>38.9(4.38)</td>
<td>10.0(1.95)</td>
</tr>
<tr>
<td>FO <em>FS</em></td>
<td>30.3(1.09)</td>
<td>2.6(0.19)</td>
<td>33.8(1.80)</td>
<td>29.3(0.75)</td>
<td>5.6(0.30)</td>
<td>91.0(15.7)</td>
<td>42.1(4.75)</td>
<td>11.0(2.14)</td>
</tr>
<tr>
<td>FO <em>RSC</em></td>
<td>22.5(1.09)</td>
<td>2.7(0.20)</td>
<td>31.4(1.69)</td>
<td>23.3(0.75)</td>
<td>4.9(0.23)</td>
<td>80.0(13.8)</td>
<td>34.2(4.23)</td>
<td>9.5(1.85)</td>
</tr>
<tr>
<td>FO <em>FYM</em></td>
<td>11.3(0.55)</td>
<td>2.3(0.16)</td>
<td>17.8(0.95)</td>
<td>20.3(0.52)</td>
<td>4.1(0.19)</td>
<td>102.0(17.6)</td>
<td>52.2(5.89)</td>
<td>14.0(2.73)</td>
</tr>
</tbody>
</table>

*Values are means of four replicates. These values are predictions from analysis of the deviance. The predictions are fitted values formed on the scale of the response variable. Numbers in parentheses are standard errors. Standard errors are approximate since the model is not linear.*

**Conclusion**

Biological control is becoming an important component of plant disease management. Although there is a little information on the biocontrol of damping-off of wheat, these indicate that the prospects for the biological control of damping-off and related soil-borne diseases of wheat appears to be promising. Gained results indicated that incorporation of sugar beet haulms (SBH) compost or flax shivers (FS) compost enriched with mixture of *P. fluorescens* (PF) and *Bacillus subtilis* (BS) significantly reduced damping-off of wheat and might be considered as a potential biocontrol agent of this disease. In addition, compost might provide better conditions for a larger number of bacteria which, in turn, will be in a position to have an antagonistic effect on the spermosphere and rhizosphere.

The use of improved bio-organic amendments for increase soil fertility and to control soil borne plant disease could provide several advantages to growers. First, the cost of purchase of off-farm inputs might be reduced if local sources of organic amendments are grown and used, because transportation is the greatest expense associated with this type of fertilization. Second, the need for pesticides for plant disease control might be reduced, thus providing both an economic and environments benefit. Third, cleaner produced commodities could be sold at a premium.

References


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تأثير السماد العضوي المخصب بتربة البعوضة المحفزة للنمو على مقاومة بعض فطريات التربة المعرضة لنباتات القمح

نعت مصطفى عوض وعزاء شاكر تركى
قسم الميكروبولوجيا الزراعية - المركز القومي للبحوث - القاهرة - مصر.

تم تقسيم بعض الكائنات الحية الدقيقة المحفزة للنمو ذات القدرات الهائلة في مقاومة فطريات التربة المعرضة لنباتات القمح في وجود 2 أنواع من الأمدودة العضوية (الكمبوست) المنتجة من عروش بنجر السكر وساس الكتان وثلاث الأرز بالإضافة إلى السماد البلدي المخصب بتربة البعوضة فايريسونس فالوريست وباسيد ساجنا.

وأظهرت النتائج في التربة المسددة بالكمبوست المنتج من عروش بنجر السكر المخصب بتربة البعوضة تحت الدراسة أن أعلى نسب في نباتات القمح المخزنة بين 13.2% مقارنة ب 0.7% في النباتات النامية في التربة المصادبة بالفطر الممرض فقط، وقد تراوح جود نسبة النباتات المخزنة بين 32.3% في التربة المسددة بالكمبوست المنتج من ساس الكتان، وثلاث الأرز على الترتيب. بينما لم تظهر فروق معينة بإضافة السماد البلدي المخصب بتربة البعوضة المقاومة الفطرية للتمور والكمبوست الم++]= المختصر من ساس الكتان أو قرش الأزر.

وأدى تسميد التربة بالكمبوست المخصب بتربة البعوضة والبابوا إلى زيادة أعداد هذه الكائنات في ريزوسفير نباتات القمح خاصة في التربة المسددة بالكمبوست المنتج من عروش بنجر السكر، بينما انخفضت أعدادها إذا أجريت مسير 82 يوم من الزراعة في ريزوسفير نباتات القمح المسددة بالسماد البلدي. ومن ناحية أخرى أدى إضافة الأمدودة العضوية المخصبة بتربة البعوضة المقاومة الفطرية للتمور إلى زيادة جودية في الوزن الجاف لنباتات القمح وكذلك في نسبة النباتات المخزنة بالفطر الممرض، كذلك كان بإضافة الأمدودة العضوية المخصبة بتربة البعوضة تراك الديازومين والبوزاتيوس في المجموعة ذات الفطر البري في نباتات القمح مقارنة بالنباتات غير المسدة.