Control of soil-borne pathogens with strategic use of animal manures

Background

Root-infecting fungi cause significant damage to soybeans and corn. *Fusarium graminearum* is a major stalk rot pathogen of corn. *Helminthosporium pedicellatum*, a native soil-borne fungus, causes root rot of corn. Neither of these fungi is controlled well by plant breeding for resistance or crop rotation. Brown stem rot caused by *Phialophora gregata* is the most important disease of soybean in Iowa. Again, resistance is not completely successful, and rotation of at least four years to another crop is needed to obtain satisfactory control.

Phytophthora root rot and brown stem rot of soybeans can be especially devastating under wet soil conditions. Another root rot, *Rhizoctonia*, affects the lower stem area, causing wilting and death during the plant’s reproductive stages. This fungus can be managed only with ridge tillage and stimulation of secondary root development above stem lesions.

Organic amendments such as green manures (a cover crop that is plowed into the soil) and straws have been studied extensively for their potential to control soil-borne pathogens. Results have varied. While animal manures have been recognized in many treatises on biological control of crop plant diseases, little data exists to support their use. Prior to this project, hardly any information existed on how manures affect root diseases or on how manures may be used strategically.

Animal manures and organic amendments increase the biological activity in soils and create small niches for the possible production of antibiotic types of compounds. They also encourage development of organisms that destroy fungal cells and prey on the fungi. This increased biological activity creates greater competition for the substrates, and usually the pathogen “loses out.” Manures also introduce carbohydrate and nitrogenous substrates, which can stimulate germination of fungal spores normally under the influence of soil fungistasis (a condition under which fungal spores will not germinate in soil). If no plant roots are present when the fungus germinates, it will likely die. After one to two weeks, fungistasis returns to the soil and and root exudates of a host plant may be insufficient to induce germination of the pathogen spores. Because amendments can act in various ways, understanding of how each causes the demise or inactivity of a pathogen is needed.

Because some of manure’s soil-conditioning traits may relate to disease control, strategic application may provide some measure of disease control. Although manure application on land slated for soybeans may be unconventional, it may be necessary in cases where land available for manure disposal is limited. Thus, the objectives of this research were

1. to determine the influence of animal wastes on the survival of soil-borne plant pathogens and the activity of their antagonists in soil,
2. to evaluate and optimize any beneficial effects of animal wastes on soil fungistasis and on the inhibition of propagule (reproductive agent) germination, and
3. to develop manure field-application systems for optimal plant disease control.

Approach and methods

Laboratory/greenhouse experiments: Liquid chicken manure was furnished by the ISU Poultry Science Research Unit. Liquid hog manure was obtained from two hog confinement sources. Analyses were performed by the Analytical Services Laboratory of the Civil...
and Construction Engineering Department at ISU.

Two topsoils, a loam and a clay loam, were collected at the end of the growing season or early in the spring when herbicide carry-over was minimal. One had been cropped to corn and the other to a corn-soybean rotation for a number of years prior to this project. Manures were kneaded and mixed into soils in specific weight ratios. All experiments were replicated.

**Fungistasis:** The fungistasis phenomenon was tested with conidia (reproductive spores) of several fungi—*Phialophora gregata*, *Fusarium moniliforme*, *Helminthosporium pedicellatum*, *Thielaviopsis basicola*, and the sclerotia (resting bodies of fungi from which fruiting bodies may develop) of *Rhizoctonia solani*—via several protocols.

**Survival of pathogens in manured soils:** A suitable medium was developed for enumerating *H. pedicellatum* spores from soil. Two experiments with similar protocols were used to determine *H. pedicellatum* propagule survival in soils amended with both hog and chicken manures. Using three replications, investigators conducted the experiment for six months, adjusting moisture weekly and before every sampling for *H. pedicellatum* populations.

An isolate of *F. graminearum* from a crown-rotted corn plant was infested into sterile soils and allowed to incubate at room temperature for about one month; chicken and hog manures were then kneaded into the soils at various rates. These experiments were monitored for five months; sampling protocols were the same as those for *H. pedicellatum*. Investigators then enumerated *Phialophora gregata* from soil. Samples were taken five times over a one-month period. In addition, investigators tested *P. gregata*’s survival in infected soybean stems.

**Activity of pathogens in manured soils:** Because the fungus *R. solani* produces sclerotia, the most effective analysis method involves baiting. Investigators found that live soybean stem pieces were most efficient as baits. Soils were either infested or left uninoculated, and in one of two experiments, soils were amended with manures at four rates or left unmanured. In the other experiment, soils were re-infested until *R. solani* activity became limiting. To test *P. gregata*, stems of infected soybeans were mixed into soil before manures were applied. To test *Phytophthora sojae*, investigators used a loam soil highly infested with *P. sojae*, then added manures at two rates. Following incubation, soybeans were planted. Emergence and post-emergence killing of the plants was recorded weekly.

Conidia of *H. pedicellatum* and *F. graminearum* were mass-produced on media and soil was added immediately, followed by two weeks of incubation. Manures were then added, moisture-adjusted, and, after incubation, corn kernels planted. Roots were observed for lesions after two weeks. One corn plant per pot was allowed to grow for three more weeks; various effects of the fungi on the roots were then rated.

**Field experiments:** Field experiments were conducted in 1992 and 1993 on crop land naturally infested with *P. sojae* and *P. gregata*. In the 1992 experiments, liquid chicken manure and hog manure were evenly distributed into the furrows of corn and soybean plots at two rates during May. Unfertilized plots served as a control. Manures were analyzed for nutrient content prior to application. Commercial fertilizer was added later to bring totals of all fertilizer applied on corn plots to a 180-60-60 ratio of nitrogen (N), phosphorus (P), and potassium (K). Additional fertilizer was also applied to soybean fertilizer control plots to balance them with the estimated amount of fertilizer added to the manured plots, based on nutrient analysis of the manure. Seedling emergence was quantified and the numbers of dead and wilted plants were recorded. In the fall, soybean plants were rated for stem rot, and corn was rated for stalk rot.

In 1993 experiments, manure was applied in spring and fall. One experiment each was established for corn and soybeans. Application of chicken and hog manures was the same.
as in 1992; inorganic fertilizers were applied to control plots. Again, seedling emergence was counted, and the numbers of dead and wilted plants in the soybean experiment were recorded. As in 1992, soybean plants were rated for stem rot and corn for stalk rot.

Findings

Fungistasis: In the laboratory and greenhouse experiments, manure applications to soil immediately annulled fungistasis and then eventually enhanced it. This could increase or reduce disease levels, depending on planting time. Planting crops soon after manure application could result in greater seedling and root disease problems, while a several-week interval between manure applications and planting could reduce disease potential. Manures had minor detrimental effects on survival of plant pathogens, and incorporation of manures into soil will not have an immediate great effect on the survival of soil-borne fungal pathogens. Addition of manures to a Rhizoctonia solani soil system enhanced soil suppressiveness.

Pathogen survival in manured soils: Propagule populations of H. pedicellatum initially increased significantly after the fungus was added to soil, indicating spore germination. Chicken manure at the higher rate produced the greatest reproduction; the higher rate of hog manure produced the lowest. However, after four months, H. pedicellatum propagules in the soil were no different in any of the soils, manured or unmanured.

Initial populations of F. graminearum propagules increased slightly when infested soil was blended into test soils. The manures had little if any effect on the survival of the propagules; subsequent enumeration revealed that manure does not appreciably affect the soil survival of F. graminearum.

The spores of P. gregata, which causes brown stem rot of soybean, are not known to survive as spores in soil; however, spores produced from soybean residue are supposedly responsible for infecting plant roots. High rates of chicken and hog manures accelerated the loss of viable P. gregata propagules in the soil.

Pathogen activity in manured soils: Manures did not influence the activity of indigenous R. solani. Where the soil was re-infested, previously manured soils showed a greater inhibition of R. solani activity than soils with no history of manure application. The development of soils suppressive to R. solani depended on the presence of R. solani in sufficient quantity to induce development of antagonists to the organism. Manures seem to make soils more suppressive.

Activity of P. gregata could be monitored only by the incidence of plant infection. High rates of hog manure inhibited infection by P. gregata, but low rates increased infection. With chicken manure, the high rate of manure increased infection, but the low rates had little effect or decreased infection by the pathogen.

The phytophthora root rot pathogen P. sojae was very active in these experiments. Post-emergence killing of soybean by P. sojae was most severe where hog manures were applied to the soils, and the high level of hog manure was related to the highest plant death, with the greatest plant loss occurring when planting was done soon after manure incorporation. Chicken manure does not pose the same problem as hog manure.

In experiments with H. pedicellatum and F. graminearum, lesions developed on young
corn seedlings. There appeared to be a slight trend toward less disease with a higher rate of hog manure added to soil.

Field experiments—corn: In 1992, plants receiving a high rate of chicken manure yielded greater than their respective control plot plants. Spring manure applications had no effect on initial plant stand. Major pathogens isolated from roots were *F. graminearum*, *H. pedicellatum*, *F. moniliforme*, and *Macrophomina phaseolina*. Although stalk rot was very slight, there was more in plots receiving high rates of hog and chicken manure than in the control plots.

In 1993, manure was applied both in spring and fall. Due to extremely wet weather, yields were less than half those of 1992. Stalk rot was greater when manure was applied than when inorganic fertilizers were employed. In general, there were no unusual findings with manure treatments and corn disease problems. Manure applications to corn increase fine root development.

Field experiments—soybeans: The soybean field experiments differed in that comparisons were made where the adjacent plot to a manured field was a fertilizer control that received the inorganic fertilizer equivalent of the manure plot. In 1992, soybean yield was very good. Hog manure treatments were associated with a decrease in initial plant stand in comparison to the unfertilized control. This difference was greater when the final plant stand was determined. Phytophthora root rot was the primary reason for loss of stand.

The extremely wet weather of 1993 severely affected the development of soybeans. The manures were applied in the fall and the spring, but none of the fertilizer treatments significantly affected yield. Variability in plant stands was great, with some stand loss, but the incidence of Phytophthora root rot was virtually nonexistent due to low temperatures. Application of manures to soybeans had few beneficial effects. While prolonged use of animal manures may result in a more biologically active soil, one with greater fungistasis, short-term use of manures for disease control in soybeans appears to be fruitless at present.

Recommendations: Phytophthora root rot of soybean was much more severe following hog manure application to the soil in both field and greenhouse experiments. Thus great care must be taken if manures are applied to soils slated for soybean production. Fall applications of manures can result in greater Phytophthora root rot. Since the effects on soybean are related to manure concentration, applications to soybean fields may be best accomplished via broadcasting, injecting between rows, or using very dilute solutions. Hog manures stimulated more Phytophthora root rot than chicken manures.

Applying manures before planting soybeans resulted in decreased crop stands and yields. Soybeans also had fewer nitrogen-fixing nodules following manure applications, and fine root necrosis (cell death) was greater with manure applications in soybeans, possibly because of greater Phytophthora root rot. In 1992, there was less brown stem rot of soybeans in soil amended with manures; in 1993, which was very wet, brown stem rot increased with manure applications to the soil. In those soil series where Phytophthora root rot can be a problem, it is not advisable to apply manures to the soil before soybean culture.

Manures are good nutrient sources for corn. No beneficial disease control effects were demonstrated with corn following manure applications. Pathogen survival was not affected greatly, and there was greater stalk rot in manured soils than in soils amended with inorganic fertilizers. This is probably an effect of the manure on plant vigor and the carbohydrate-photosynthesize pool in plants, and not on the pathogens per se.

Implications

Although animal production is one component of a sustainable agriculture system, manure usage and disposal poses challenges. This study has indicated that root diseases of corn are not greatly affected by manures over the short term. Prolonged use of manures, how-
ever, would likely increase the general biological activity of the soil, increase fungistasis, and encourage soil suppression of pathogens. Farmers who attempt to incorporate manures into soil before planting soybeans may face greater disease problems.

Manure application methods also affect the potential for disease problems in soybeans. It is likely that areas of soil having high concentrations of hog manure will have poor stands and greater Phytophthora root rot than areas with no manures.

This study did not address the long-term benefits of manure application. Future research should focus on how animal manure affects development of suppressive soils and soils with elevated levels of soil fungistasis—in particular, long-term effects from repeated application of manures over many years. The specific stimulatory activities of manures toward certain pathogens—for example, Phytophthora root rot of soybean, and Rhizoctonia development—need to be investigated. Timing of manure applications also warrants investigation in terms of how it affects disease suppression or enhancement.

Information from this project has been used by the Leopold Center’s Manure Management interdisciplinary research issue team, of which this investigator is a member (see p. 35).