BIOLOGICAL PESTICIDES AS PART OF AN IPM STRATEGY

All farming systems, whether they be organic or non-organic, use pesticides. In today's non-organic farming environment that is dealing with pesticide resistance development to synthetic pesticides in both fungal pathogens and insect pests, as well as environmental and social constraints on the use of synthetic pesticides, the role and development of biopesticides should be explored in-depth to determine efficacy and economic potential.

The term "biopesticide" likely means different things to people of varied agricultural backgrounds. The term itself is a contraction of "biological pesticide", which includes several types of pest management through predatory, parasitic, or chemical relationships. Biopesticides may include substances such as biochemical pesticides [bio-derived], microbial pesticides [bacteria, fungi, viruses], or substances produced by plants that contain added genetic materials [GM crops]. Generally, biopesticides are made of living things, come from living things, or they occur naturally. They should be considered as important components of integrated pest management [IPM] programs, and are receiving increased attention as substitutes for or supplements to synthetic chemical protectants that are used against biological pests. Biopesticides tend to pose fewer risks than conventional pesticides and therefore generally require a less rigorous approval process prior to their registration for use.

An article titled "Biological pesticides may pull integrated pest management out of a bog" by John Hart appeared in the Nov. 1, 2017 online edition of Southeast Farm Press. The lead sentence in that article states "Biological pesticides can play a key role in a successful integrated pest management program and can be useful in increasing sustainability on the farm." Also in that article, David Epstein, senior entomologist with USDA's Office of Pest Management Policy, states "IPM includes everything. You can use biopesticides in an IPM program. IPM is not limited to one approach. It takes everything into consideration. IPM is applicable across all farming systems. It is a philosophy of pest control formed on principles of ecology."

Several "biological insecticides" are presently labeled for use on commodity crops such as soybean. These insecticides do not poison the pest; rather they kill by causing a disease, as in the case of *Bacillus thuringiensis* (*Bt*) [e.g. Agree, IRAC code 11A] and *Helicoverpa zea nucleopolyhedrovirus* (HzNPV) [e.g. Heligen , IRAC code 31], or a physiological dysfunction [e.g. Dimilin, IRAC code 15]. These products are particularly suited to use in pest management operations because they have little or no effect on natural enemies of the pest or beneficial insects. Because of their mode of action [MOA], use of these compounds does not result in a quick kill. Thus, it may be several days after application before the insect is killed. However, little or no feeding by the pest will occur during this period. These products target many of the lepidopteran insect pests that plague soybean–e.g. loopers, green cloverworm, saltmarsh caterpillar, velvetbean caterpillar, and armyworms (*Bt* insecticides), and corn earworm and tobacco budworm (HzNPV)–and are labeled for use on soybeans. They perform best when applied to small, newly-hatched larvae.

In an Aug. 19, 2020 DTN article titled "Bt Bean Targets SCN", author Emily Unglesbee announces that the US-EPA has granted BASF a registration for a *Bt* soybean trait [currently known as GMB151] that will target the soybean cyst nematode [SCN]. This is a promising development for the soybean industry because of SCN's increasing ability to infest soybean varieties that have the predominant resistance trait derived from PI 88788. The BASF trait expresses a new novel *Bt* protein Cry14Ab-1, which damages the gut of the SCN when they ingest it. It appears to have no activity on any other soybean pest species, or on non-target organisms. This new trait is intended to be bred into soybean varieties that already possess resistance traits derived from PI 88788 and Peking in order to enhance overall SCN management, and will result in the first *Bt* soybean varieties brought to the U.S. market.

The development and use of *Bt* crops [particularly corn and cotton] has created a debate about their effects on the micro-environment in which they are grown. Of particular interest is their effect on non-target soil invertebrates that are recognized for their contributions to the availability of nutrients to plants, their activity on soil organic matter, and their overall enhancement of soil health properties. Thus, it is particularly relevant that these organisms are protected when *Bt* crops are grown on soils that they inhabit. This effect was analyzed in an article titled "The effect of *Bt* crops on soil invertebrates: a systematic review and quantitative meta-analysis" that is authored by Krogh, Kostov, and Damgaard. Major points from the article follow.

- To provide protection against certain crop pests, crop breeders have developed transgenic *Bt*-crops that have been genetically modified by inserting a gene from *Bacillus thuriengensis* [a naturally-occurring soil bacterium] into the modified plant's genome so that it expresses a Cry protein that is toxic to a targeted pest organism.
- Soil invertebrates are exposed to field-grown *Bt* crops in the soil rhizosphere through roots and their exudates, and organic matter resulting from those crops. There is an ongoing debate about the ecological effects of these *Bt* crops on these soil invertebrates because of their soil exposure when *Bt* crops are grown.
- The results presented in the above study analyze the effect of *Bt* crops [types Cry1Ab, Cry1Ac, Cry3Bb1, and Cry3Aa] on soil invertebrates that include Protista [primarily microscopic unicellular organisms], nematodes, Collembola [springtails and allies that are decomposers], mites, enchytraeids [miniature version of an earthworm], and earthworms in soil where these crops are grown compared to those populations in soil where non-*Bt* or conventional crops are grown.
- Results from 22 field studies conducted across a range of environmental conditions [36 locations in 10 countries] were selected and used in the meta-analysis to quantify the effect of *Bt* crops on soil invertebrates. Corn and cotton were the crops used in a large majority of the studies.
- **This meta-analysis did not find any significant effects of field-grown *Bt* crops on non-target soil invertebrates.**

The results of this meta-analysis indicate that current genetically modified *Bt* crops have no impact on soil invertebrates. Even though the above-mentioned *Bt* trait that is forthcoming in soybean for activity against SCN expresses a new *Bt* protein that was not included in the above study, the results from this cited study indicate that it is not likely to adversely affect non-target microbes and invertebrates in the soil. This is an encouraging point for the development of this new *Bt* trait in soybean.

BASF has released the biofungicide Serifel that is based on viable spores of the bacterium *Bacillus amyloiquefaceins* strain MBI 600. It has no crop rotation restriction, no preharvest interval [PHI], and a very short re-entry interval of only 4 hours. It is a FRAC Code 44 [microbial disrupters of pathogen cell membranes] preventive fungicide that is designed to be used in a program with conventional fungicides. It is labeled for problematic soil-borne diseases that plague Midsouth soybean producers.

Vive Crop Protection has received EPA registration for AZterknot fungicide that can be used on commodity crops that include soybeans. It is a premix of a traditional synthetic fungicide, azoxystrobin [FRAC code 11], and a biological fungicide [FRAC code P05] that is extracted from giant knotweed, *Reynoutria sachalinensis*. This premix of synthetic and biological fungicides is labeled for both specific soil and foliar diseases that affect soybeans.

Summit Agro USA is marketing Regev HBX hybrid fungicide, which contains tea tree oil [FRAC code BM 01 fungicide, a botanical ingredient], plus the conventional fungicide difenoconazole [FRAC code 3]. This fungicide product combines botanical and conventional chemistries to deliver broad-spectrum preventive, anti-sporulant, and curative control of targeted diseases through eight mechanisms of activity. Consult the Regev HBX label for the numerous targeted soybean diseases, and the list of application instructions and use restrictions. Also remember to follow appropriate resistance management strategies when using this product.

The following are summaries of two studies that present promising results toward the future use of biopesticides–in this case, arbuscular mycorrhizal fungi (AMF)–to control soil-borne pathogens that are major pests of soybeans. Results from both studies appear in the journal Plant Disease, and both are authored by Pawlowski and Hartman at the Univ. of Illinois. The following narrative is a summary of the conduct of and findings from those studies.

The first study yielded results that are reported in an article titled "Reduction of Sudden Death Syndrome (SDS) Foliar Symptoms and *Fusarium virguliforme* DNA in Roots Inoculated with *Rhizophagus intraradices*".

- There is increasing interest in incorporating AMF into agricultural production systems because of the benefits they provide, including activity against pathogens and pests.
- This study was conducted to determine whether or not soybean plants co-inoculated with *F. virguliforme* [pathogen that causes SDS] and the AMF species *Rhizophagus intraradices* showed reduced SDS foliar symptoms and reduced pathogen presence in soybean roots.
- Six different soybean genotypes that are susceptible to *F. virguliforme* were inoculated with *F. virguliforme* alone or in combination with *R. intraradices* in a greenhouse experiment.
- Plants were subsequently evaluated for foliar disease symptoms at 14, 17, and 21 days after planting using a 1 to 8 foliar disease rating scale.
- At 21 days after inoculation, dry weight of roots from plants was recorded, and roots were assayed for *F. virguliforme* DNA presence.
- There were visible differences in foliar symptoms and root mass between the AMF and non-AMF treatments.
- Area under the disease progress curve [AUDPC] values were 45% lower in plants inoculated with AMF compared to the non-AMF control.
- Average weight of roots of plants inoculated with AMF was 58% greater than that of the non-AMF control plants.
- Quantity of *F. virguliforme* DNA was 28% lower in plants inoculated with AMF vs. the non-AMF control plants.
- Nutrient concentrations in roots of AMF-inoculated plants were greater than those in roots of the non-AMF control plants.
- The authors suggested two major mechanisms that may have resulted in the AMF-mediated protection against the SDS pathogen. 1) AMF associations may have resulted in an overall increase in plant growth, thus allowing for compensation for SDS damage. 2) The reduction in SDS severity in AMF-inoculated plants could be related to increased nutrient uptake by roots of those plants.
- The authors concluded that this study showed that inoculating soybean plants with the AMF *R. intraradices* reduced both SDS severity and *F. virguliforme* DNA in soybean roots while increasing soybean growth and nutrient uptake by AMF-inoculated plants. They inferred that susceptible soybean genotypes will benefit from the positive effects of the AMF used in their study. Furthermore, they surmised that *R. intraradices* and possibly other AMF species could become routine inputs for the management of SDS in soybean.

The second study provides results that are reported in an article titled "Impact of Arbuscular Mycorrhizal Species on *Heterodera glycines*". Important points from that article follow.

- Soybean cyst nematode [SCN] is the leading cause of soybean yield losses in the U.S. Current effective control measures depend mainly on planting seed of resistant varieties and rotating soybeans with nonhost crops such as corn. However, approximately 95% of SCN-resistant varieties contain resistance genes from PI 88788, and the SCN has become or is becoming more virulent to varieties with this source of resistance. Thus, there is a need to find complementary strategies to control SCN virulence on soybeans and protect yield.
- The goal of the study was to evaluate the impact of AMF on SCN cyst production, SCN juveniles in soybean roots, and SCN egg hatching. This was done under the objectives of 1) compare SCN cyst production on soybeans inoculated with multiple species of AMF to those not inoculated (Expt. 1), 2) compare SCN juvenile populations at 7 and 28 days after AMF inoculation on soybean roots with

or without the AMF *Funneliformis mosseae* [Expt. 2], and 3) determine if *F. mosseae* spores or spore exudates impact SCN egg hatching (Expt. 3).

- All studies were conducted using an SCN-susceptible variety grown in a greenhouse.
- **Expt. 1 results**. All species of AMF had lower cyst numbers than the non-inoculated control, and the fewest cysts were produced on plants inoculated with *F. mosseae*.
- **Expt. 2 results.** At 7 days after planting, plants inoculated with *F. mosseae* had a lower number of juveniles than the non-AMF control plants. The AMF-inoculated plants also had a much fewer number of cysts vs. the non-AMF plants.
- **Expt. 3 results.** By day 6 after incubation, the number of SCN juveniles on inoculated plants was lower by 27% and 62% for spores and exudates, respectively, compared to the control without *F. mosseae*.
- These results indicate that 1) AMF can disrupt SCN reproduction, 2) SCN suppression occurred early in the interaction between the fungi and SCN, and 3) AMF spores and spore exudates had a direct effect on SCN by reducing egg hatching. The spore exudates suppressed egg hatching more than the presence of spores alone.
- The authors concluded that increasing the predictability, efficiency, and deliverability of AMF to soybean fields with high populations of SCN could provide a complementary tool for a more sustainable and effective management of SCN.

The below questions arise from the above cited research.

- Will the AMF that acted as biopesticides in these studies be potential candidates for a biopesticide product or products that can provide protection against the targeted pathogens in a field setting?
- If such AMF products prove effective in a production field, can their production be commercially scaled so that they will be available in quantities for use on a considerable acreage of pathogen-infested fields?
- Can these products be soil-applied, or must they be applied as a seed treatment?
- If they can be soil-applied, will they need rainfall to effect infiltration into the soybean root zone to achieve maximum effectiveness?
- How long will their effectiveness last once in the root zone?
- Will they be effective only when used as a supplement to synthetic pesticide seed treatments for control of the targeted pathogens?

These questions certainly are not meant to cast aspersion on the significance of the findings in the above cited studies. In fact, the findings from these studies are most significant. Rather, they are meant to encourage further work with these identified AMF that acted as biopesticides in the controlled environment studies cited above. This is needed to determine if they will in fact be effective in a production setting against these two very significant soybean pests/pathogens.

Currently, Pancho/Votivo (*Bacillus firmus*) and Clariva Complete Beans (*Pasteuria nishizawae)* seed treatment products for soybeans contain biological nematicides (shown in parentheses). However, Bissonnette and Tylka (ISU Extension and Outreach) in their publication titled "Seed Treatments for Soybean Cyst Nematode" state that "Nematode-protectant seed treatments are intended to supplement current SCN management strategies, and therefore should be used in coordination with growing varieties with SCN resistance genes and rotation to nonhost crops". In fact, a nematicide seed treatment product should never be used instead of using a resistant variety; rather, use it on a resistant variety. This supports the accepted dogma that current nematicide seed treatments will not replace proven management practices that should be used to manage SCN in soil at infested sites. Thus, there is no supposition that any AMF or other potentially forthcoming biopesticide products will replace the accepted practices for nematode control and/or management. However, the identification and development of additional complementary control measures that could result from the AMF results shown above could certainly change current recommendations. This is especially so since this would be a biopesticide vs. a chemical pesticide.

See the article on this website for additional information about using seed treatments for soybean planting seed.

An article titled "Biopesticides–An eco-friendly approach to plant protection and crop yield" from Ingevity Corp. provides a summary of the status of the myriad biopesticide products that are currently on the market or that could be forthcoming. The article provides insight into the myriad bioinsecticides, biofungicides, and antibiotics and signal molecules that show current and future promise for use in IPM programs to manage insect and fungal pests.

All sectors [both public and private] of the U.S. agricultural support system should be working diligently to ensure that all available tools for IPM are available and/or effective for use in all crops. Since it appears that efficacious biopesticides can be one of those tools, they should be available to producers of both organic and commodity crops. This will support the long-term sustainability of the large commodity crop production sector in the U.S. It is obvious that these tools are especially needed where resistance to synthetic pesticides has developed and is continuing to develop in the insect pests and disease pathogens that adversely affect soybean production.

Biological pesticides can and should play a role in IPM, and they can and should be an integral part of an IPM program, especially where resistance to synthetic pesticides has developed. IPM is applicable across all farming systems. However, until biopesticides are thoroughly evaluated for efficacy against pests that affect commodity crops such as soybean, producers will not fully utilize them if they have little or no information about their performance when used as a component of their IPM strategies. Plus, the cost of these products should be weighed against their potential effectiveness as a component of an IPM program.

Finding answers to questions regarding the use of biopesticides as a component of IPM for commodity crops such as soybean should receive increased attention from pesticide scientists. Since soybean producers depend on private companies to develop and label biopesticide products for use on commodity crops, the initial development and efficacy data to support the effectiveness of any new products that enter the market must come from the private sector. According to the information in the above article from Ingevity Corp., the myriad private companies that supply pesticide products to producers are increasing their efforts in this area of pesticide science.

A summary of important points regarding the use of biopesticides to manage crop pests follows.

- Pest suppression is a critical part of crop production in order to maintain plant health and crop yield.
- Environmental safety and resistance development to currently used synthetic pesticides are two major concerns that have increased the interest in using biopesticides as part of an IPM strategy in crop production.
- Biopesticides contain active ingredients that have biological origins.
- Present and forthcoming biopesticides can be used to aid in the management of insects, bacterial and fungal pathogens, and plant-parasitic nematodes.
- Biopesticides are now or should be viewed as important components of IPM strategies.
- The biggest hurdles to overcome for significant adoption of biopesticides are the knowledge gaps regarding their use and efficacy against targeted pests.
- Biopesticide use will likely play a significant role in insecticide resistance management by tempering the resistance issues that are associated with continued use of synthetic pesticides.
- Biopesticides may have special storage, handling, and mixing requirements, or tank-mix restrictions. Thus, referring to the manufacturer's label is imperative when using these products.
- It is likely that pests can develop resistance to biopesticides just as they have and do to synthetic pesticides.
- There is a critical need for productive collaborations among pesticide industry scientists and researchers, public researchers and extension scientists, extension educators, and growers to address the inclusion and use of efficacious biopesticides in IPM strategies to foster a more sustainable crop production system.
- Research results will help develop effective

biopesticide formulations and their effective use strategies, while educating growers about these effective strategies will foster and promote their use.

Not all biological crop additives are biopesticides. For instance, Corteva Agriscience has developed Utrisha N that is a naturally occurring bacteria that enters plant leaves through the stomata, and colonizes within the plant to help fix nitrogen from the air. It is intended for use in multiple crops, including soybean.

MAY 2023 UPDATE

Biotalys and Syngenta Crop Protection are collaborating to research, develop, and commercialize biocontrol products to manage and control pests in crops. These solutions will be focused on protein-based biocontrol agents to target specific crop pests. The collaboration will explore innovative and effective biological solutions that should limit the impact of pest control on the environment and biodiversity.

This collaboration will make use of the Biotalys AGROBODY Foundry platform to target specific plant pests with novel modes of action. Currently, such products are in the developmental phase, but hopefully these early efforts will lead to discoveries that can be used by producers to effectively supplant their use of a significant portion of the chemical pesticides that are now applied. Such discoveries also should counter the resistance to the modes of action of currently used chemical pesticides that is occurring in the myriad soybean pests.

DEC. 2023 UPDATE

The Crop Protection Network published a web book titled "Biopesticides for Crop Disease Management" to provide farmers and practitioners a source of information about the use of natural products for pest control in crop plants. The key objective of this publication is to increase the understanding of how biopesticides can be used to provide an additional, eco-friendly tool to supplement control of pests by synthetic pesticides. The authors of the publication are crop protection experts from leading universities and institutions across North America, including Arkansas and Kentucky.

Composed by Larry G. Heatherly, Updated Dec. 2024, larryh91746@gmail.com