Update on Soybean Inoculant Research

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Introduction

Soybean (*Glycine max* L. (Merr.) is a member of the Leguminosae family of plants. An important characteristic of this family of plants is their ability to live in a symbiotic (mutually beneficial) relationship with specific bacteria — *Bradyrhizobium japonicum* in the case of soybean. *B. japonicum* is specific to soybeans and will not fix nitrogen in any other legume. Likewise, the rhizobial species that fix nitrogen on alfalfa or other legumes will not nodulate and fix nitrogen on soybean. While the air is 79% di-nitrogen (N_2), the non-nodulated soybean plant is unable to utilize this nitrogen source. The soybean plant provides nutrients (carbohydrates and minerals) and a protective growing environment for the rhizobia, in turn, the rhizobia "fix" atmospheric nitrogen into forms that can be used by the soybean plant. Therefore, for this relationship to exist and benefit both the plant and the rhizobia, effective nitrogen-fixing bacteria must be present in the soil in relatively high numbers at the time of planting. It is essential to establish the specific rhizobia in the field soil on which soybean has never been grown to ensure nitrogen fixation. This process is known as "inoculation."

The rhizobial bacteria attach to, and then colonize, the soybean root on new root hairs immediately behind the growing root tip. At about 10-14 days after colonization, the nodule will be visible. Not to be confused with SCN, the nodule is a wart-like structure on the soybean root containing a colony of *B. japonicum*. The nodule grows very rapidly, and at about three weeks of age N_2 fixation begins. Functional nodules have a pink or red interior, although this red pigmentation (leghaemoglobin) does not indicate efficiency of fixation. At about four weeks of age, the nodule will reach its full size and will continue to fix nitrogen until it reaches 6 to 7 weeks of age, at which time they begin to senesce (become dark/black in color). Peak nitrogen fixation is reached by the soybean plant during late flowering-pod fill (R2-R5). Nodule growth and nitrogen fixation are influenced by a number of biotic and abiotic factors including soil moisture, soil temperature, soil pH, diseases, and in some instances, micronutrient availability. Soil fertility/nitrogen availability, pesticide use, and inoculant quality also impact the efficiency of nitrogen fixation.

When Should Inoculants be Used?

Inoculation is usually not necessary if a well-nodulated soybean crop has been grown in the field within the past 3-5 years. During the past 10 years, several studies have been conducted in Indiana and other Eastern Corn Belt states to evaluate the need to inoculate soybeans grown in fields having a corn-soybean rotation. At two of the Indiana sites, soybean had not been gown for at least 15 years. In one case, inoculation gave a 12 bushel per acre yield response (75 vs. 63) while the other gave no yield response to inoculation. The field that did not respond to inoculation was located down slope from a field where soybeans were grown regularly in rotation with corn. Most likely, water and/or wind moved enough soil to transport an adequate number of bacteria to provide good nodulation.

Over the past 15 years several samples of soybean plants that exhibited severe nitrogen deficiency (very light green color) and a total absence of nodules have been received by the Purdue Plant and Pest Diagnostic Laboratory. In all cases, the fields from which the plants were taken had no prior history of soybean production. In another case, plants adjacent to a road were normal in height, but heights declined as you moved away from the road. The plants in the area of the field the greatest distance from the road were extremely short with a very light green color and had no nodules. In this case, the soil pH was 6.5 near the road and declined gradually reaching a low of 4.5 in the area of the field farthest from the road. Dust from the road prior to paving provided the liming effect in the area nearest the road.

And finally, when land is removed from the Conservation Reserve Program and placed back into production, the first soybean crop grown in this field should be inoculated since soybeans have not been grown in the field in more than 10 years.

How Have Inoculants and Soybean Production Changed?

Historically, the carrier for the inoculant has been non-sterile peat powder applied to the seed at time of planting. During the last 15 years, a number of improvements have been made in the manufacture of inoculants. These improvements include the use of sterile carriers, the addition of stickers to the sterile peat products, the introduction of liquid carriers, the use of a concentrated frozen product, the introduction of new strains of the organism, preinoculants, and recently, the introduction of inoculants also having extended biofertilizer and biopesticidal activities. All of these improvements have resulted in products that are more concentrated with a longer shelf life. Most of the modern products will provide at least 1 million bacterial cells per seed when used at the manufacturers recommended rate. In spite of these large numbers of bacterial cells per seed, each nodule may be the product of a different serological group of rhizobia. It is very difficult to replace the indigenous population of rhizobia already in the soil with an introduced strain, even if it is superior in terms of nitrogen fixation efficiency.

During the past 10 to 15 years, production technologies and the complexion of agriculture have undergone many changes on Indiana farms. Included among these changes are: (a) the increased use of no-till in the production of soybeans, (b) an increase in the use of narrow rows, (c) earlier planting of soybeans, (d) an increase in seeding rates with the narrow rows, (e) a conversion of continuous corn acreage to rotational corn-soybeans, (f) improved planting equipment, (g) an increase in grain yield, and (h) larger farms.

The changes in soybean production in Indiana coupled with the improvements in soybean inoculants suggest that the use of inoculants in the production of soybeans should be re-evaluated. Evidence gathered from inoculant studies over the past 15 years in Indiana indicates that soybean yields can be improved by the use of inoculants when soybeans are grown in a soybean-corn rotation.

The inoculants in these trials included liquid products, concentrated frozen prep, sterile peat-based products, and a new strain of the *B. japonicum* both as a liquid and as a sterile peat product and more recently inoculants with added protectors and promoters. At no time were all of these products included at a single trial, but were included in the trials as they became available. All indications are that the new, improved products all perform equally well when evaluated over time and locations. The average yield response, when compared to a non-inoculated control, was 1 bushel or more per acre for this period. The cost for the products ranged from $1.50 to $3.25 per acre when used as a seed applied product at the manufacturers' recommended rates.

How Should I Use Inoculants?

Most soybean inoculants are seed applied. Inoculants can also be soil applied, but it is important to maintain the recommended concentration per 1000 linear feet of row to be effective. If a row spacing less than 30 inches is used, the cost increases accordingly and usually is not cost effective.

Concentrated liquid inoculants are becoming more popular with the increased use of bulk soybean seed. Bulk seed is usually transferred from the bulk container to the planter or drill using an auger. The liquid inoculant may be metered onto the seed at the base of the auger and is thoroughly mixed with the seed by the time the seed reaches the planter of drill box. The manufacturers of the liquid inoculants provide specific instructions related to calibration of the delivery auger and the metering of the inoculant onto the seed. Liquid inoculants can also be used as a seed box treatment. Place about 3 inches of seed in the bottom of the planter or drill box and apply the appropriate volume of the inoculant onto the seed and thoroughly mix. Continue filling the box by placing layers of about 6 inches of seed, adding the appropriate quantity of inoculant, and mixing until the box is full.

In previous years, the most commonly used inoculants utilized powdered peat as the carrying medium. The newer products on the market use a peat medium that is sterile and therefore contains a much higher number of cells per ounce. Many of these products also contain a sticker that permits the inoculant to adhere much better to the seed, and some with a safener to help protect the rhizobial cells against toxic pesticides. The method of application will vary depending on the product being used. The products with the built-in sticking agents may be applied directly to the seed in the planter or drill box. This is best accomplished by placing a 3-inch layer of seed in the bottom of the box, adding the appropriate quantity of the inoculant onto the seed, and thoroughly mixing to get good coverage. Continue filling the box by placing 6-inch layers of seed, the appropriate quantity of inoculant, and mixing until the box is full. Peat-based inoculants can be applied on-seed in the hopper box as mentioned, or now there are affordable systems to apply these products to bulk handled seeds such as via augers.

Some of the companies selling peat-based products recommend that the seed be dampened with non-chlorinated water prior to adding the inoculant to promote adherence of the inoculant to the seed. Other products will have a recommendation that the inoculant is mixed with water to form

a pastem and then the paste is added to the seed and mixed well. For best results when using any of these products, read and follow the instructions printed on the containers.

Inoculants are living organisms that are killed by desiccation, direct sunlight, heat, and contact with caustic fertilizers/pesticides. The inoculant should be stored according to the manufacturers' instructions to preserve its viability, and used within the expiration date. Once the seeds have been inoculated, they should be planted soon, ideally within two hours. The rhizobia begin to die as the inoculant begins to dry. In general, inoculants CANNOT be mixed with fungicides and applied together to the soybean seed. The one exception to this is ApronMaxxRTA fungicide.

There are also several new products in the marketplace where the dealer (or farmer) pre-inoculates the seeds. Various shelf life periods are claimed for these products (some preinoculants can also be co-treated with ApronMaxx), but in most cases the grower takes delivery of seed ready to plant, reducing the need for on-farm treatment.