Utilizing Inoculants in a Corn-Soybean Rotation

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EXPERT REVIEWED

Soybean (*Glycine max* L. (Merr.) is a member of the Leguminosae family of plants. An important characteristic of members of this plant family is their ability to live in a symbiotic (mutually beneficial) relationship with specific bacteria — in the case of soybean, *Bradyrhizobium japonicum*, a rhizobial species.

While the air is 79 percent di-nitrogen (N_2), soybean plants without *B. japonicum* are 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 ammonia (NH_3), which can then be used by the soybean plant. *B. japonicum* is specific to soybean and will not fix nitrogen in any other legume. Likewise, the rhizobial species that fix nitrogen for alfalfa or other legumes will not nodulate and fix nitrogen on soybean.

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Figure 1. *Soybean cyst nematodes are pests that cause small, white to yellow cysts to appear on soybean plant roots.*

For this relationship to exist and benefit both soybean and *B. japonicum*, effective nitrogen-fixing bacteria must be present in the soil in relatively high numbers at planting time. In field soil where soybean has never been grown, it is essential to first establish the specific rhizobia to ensure nitrogen fixation. Rhizobia are established through a process called, "inoculation."

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Figure 2. *Rhizobial nodules created by* B. japonicum *form on roots, helping soybean plants fix nitrogen.*

When present in the soil, rhizobial bacteria attach to, then colonize the soybean root on new root hairs immediately behind the growing root tip. Within 10 to 14 days after colonization, the bacteria will form a visible nodule. Not to be confused with soybean cyst nematode (SCN), which are white to yellow (Figure 1), the *B. japonicum* nodule (Figure 2) is a wart-like structure on the soybean root that contains a *B. japonicum* colony. The *B. japonicum* nodule grows very rapidly and begins fixing nitrogen at the V2-V3 soybean growth stage.

Functional nodules have a pink or red interior (Figure 3). This red pigmentation (leghaemoglobin), however, does not indicate fixation efficiency. After about four weeks, nodules will reach their full size and will continue to fix nitrogen until they are 6 to 7 weeks old, at which time they begin to senesce (become dark/black in color). The soybean plant reaches peak nitrogen fixation during the beginning seed/pod fill crop growth stage (R5/R6 soybean).

A number of biotic and abiotic factors influence nodule growth and nitrogen fixation, including soil moisture, soil temperature, soil pH, diseases, and in some instances, micronutrient availability. Soil fertility/nitrogen availability, pesticide use, and inoculant quality also affect the efficiency of nitrogen fixation.

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Figure 3. *Functioning rhizobial nodules have a pink or red interior caused by leghaemoglobin. The color isn't an indicator of fixation efficiency.*

When Should Inoculants Be Used?

Traditional thinking suggests that inoculation is usually unnecessary if a well-nodulated soybean crop has been grown in the field within the past three to five years. For example, inoculate the first soybean crop in fields removed from the Conservation Reserve Program (CRP) and placed back into production, since soybean has not been grown in the field in more than ten years.

Several studies conducted over the past decade in Indiana and other Eastern Corn Belt states have evaluated the need to inoculate soybeans grown in fields with a corn-soybean rotation. These experiments have had variable results among states, suggesting that regional differences may exist.

In Indiana, inoculation experiments have generally been conducted in traditional corn-soybean rotation systems. However, Purdue Extension conducted research in two experimental sites where soybean had not been grown for at least 15 years. At one of these sites, inoculated soybean had a yield of 75 bushels per acre while the uninoculated soybean yielded 63 bushels per acre. The other experiment site showed no yield response to inoculation. The unresponsive field was located downslope from a field where soybean was grown regularly in rotation with corn, so it is likely that water and/or wind moved soil containing enough bacteria to provide adequate nodulation.

The Purdue University Plant and Pest Diagnostic Laboratory routinely receives soybean plant samples that exhibit severe nitrogen deficiency symptoms (very light green color) and a total absence of nodules. In virtually all cases, the fields from which the plants were taken had no history of soybean production.

How Have Inoculants and Soybean Production Changed?

Historically, the carrier for inoculant has been nonsterile peat powder applied to the seed at planting. Recently, a number of improvements have been made in inoculant manufacturing, including the use of sterile carriers, the addition of stickers, the introduction of liquid carriers, the use of concentrated frozen products, the introduction of new organism strains, the use of preinoculants, and (more recently) the introduction of inoculants with extended biofertilizer and biopesticidal properties.

All of these improvements have resulted in more concentrated products that have a longer shelf life. Most modern products provide anywhere from 500,000 to over 1 million rhizobia cells per seed when used according to manufacturer recommendations. Despite the 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 rhizobia population with an introduced strain, even if it is superior in terms of nitrogen fixation efficiency.

Soybean production practices on Indiana farms also have undergone many changes, including:

1. The increased use of no-till
2. The greater use of narrow rows
3. Earlier planting
4. Higher seeding rates with narrow rows
5. Improved planting equipment
6. Increased grain yields
7. Larger farms

These changes in Indiana soybean production, coupled with soybean inoculant improvements, suggest that inoculant use should be re-evaluated.

New Inoculant Research in Corn-Soybean Rotations

Evidence gathered from recent inoculant studies in Indiana indicates that yields can be improved by using inoculants when growing soybeans in a soybean-corn rotation. Table 1 presents a summary of the soybean yield response to inoculation since 1993. The annual summaries may include multiple sites and multiple products. More than two-thirds of these sites were no-till fields.

Table 1. *Soybean yield response to inoculants in Indiana when planted in fields with a native population of Bradyrhizobium japonicum.*

Year	Number of Commercially Available Inoculants Compared	Average Yield Response Above Control	Control Group Yield
1993	-	1.9 bu/acre	-
1994	-	2.4 bu/acre	-
1996	-	0.0 bu/acre	-
1997	3 products, 3 locations	1.4 bu/acre	44.7 bu/acre
1998	2 products, 1 location	0.3 bu/acre	66.6 bu/acre
1999	2 products, 1 location	2.0 bu/acre	41.6 bu/acre
2000	3 products, 1 location	0.5 bu/acre	62.1 bu/acre
2001	2 products, 3 locations	1.5 bu/acre	60.3 bu/acre
2002	5 products, 2 locations	0.0 bu/acre	65.7 bu/acre
2003	3 products, 1 location	0.7 bu/acre	37.5 bu/acre
2004	4 products, 2 locations	0.3 bu/acre	50.0 bu/acre
Average	3 products, 2 locations	1.0 bu/acre	53.6 bu/acre

The data in Table 1 include liquid products, concentrated frozen prep, sterile peat-based products, and a new strain of *B. japonicum* as both a liquid and sterile peat product. No single trial included all these products. All indications are that the new products all perform equally well when evaluated over time and locations. The average yield response, when compared to an uninoculated control, was equal to 1 bushel per acre for the 10-year period. When used as seed-applied products, inoculant costs ranged from $1.50 to $2.75 per acre.

How Should I Use Inoculants?

Most soybean inoculants are seed applied. Inoculants also can be soil applied, but it is important to maintain the recommended concentration per 1,000 linear feet of row to be effective. If row spacing is less than 30 inches, the cost increases accordingly and may not be cost effective.

Powdered Peat Inoculants

The most common carrying medium for inoculants is powdered peat. Newer products use sterile peat media that contain a much higher number of *B. japonicum* cells per ounce than older, nonsterile products. Many newer products also contain stickers, substances that permit the inoculant to adhere more readily to the seed. And some include safeners to protect rhizobia cells against toxic pesticides.

Application methods vary with the product being used. Products containing sticking agents may be applied directly to seeds in the planter or drill box. This is best accomplished by placing a three-inch layer of seed in the bottom of the box, adding the appropriate amount of inoculant onto the seed, and thoroughly mixing to get good coverage. Repeat this process by adding three-inch layers of seed, inoculant, and mixing until the box is full.

Peat-based inoculants can be applied on-seed in the hopper box in a manner similar to that described above for products containing sticking agents. However, there are affordable systems that apply these products to bulk handled seeds using augers. The manufacturers of some peat-based products recommend dampening the seed with water before adding the inoculant to promote adherence of the inoculant to the seed. Other products recommend mixing the inoculant with water to form a paste, then mixing the paste with the seed. For best results with any of these products, read and follow label directions.

Liquid Inoculants

As bulk soybean seed use increases, so does the popularity of liquid inoculants. Usually, bulk seed is transferred from a bulk container to the planter or drill using an auger or other metering device. Liquid inoculants are metered onto the seed at the base of the auger and thoroughly mixed with the seed by the time it reaches the planter or drill box. Liquid inoculant manufacturers provide specific instructions for calibrating the delivery auger and metering the inoculant.

Liquid inoculants also can be used as a seed box treatment. Place about three inches of seed in the bottom of the planter or drill box, apply the appropriate amount of inoculant onto the seed, and mix thoroughly. Repeat this process by adding three-inch layers of seed, the proper amount of inoculant, and mixing until the box is full.

Inoculant Care

Inoculants are living organisms that are killed by desiccation, direct sunlight, heat, and contact with caustic fertilizers and pesticides. Inoculants should be stored according to the manufacturer's instructions to preserve their viability, and used before the expiration date.

Ideally, seeds should be planted within two hours of inoculation. If you wait too long to plant, the rhizobia begin dying as the inoculant dries.

In general, inoculants *cannot* be mixed with fungicides and applied together to the soybean seed. The exception to this is ApronMaxxRTA® fungicide.

There are also new products that allow dealers or farmers to pre-inoculate seeds. These products have various shelf life claims (some pre-inoculants can also be co-treated with pesticides), but essentially, growers take delivery of seed ready to plant, reducing the need for on-farm treatment.

Conclusions

Purdue Extension research suggests that inoculant use may be a viable method of increasing soybean yield. Over the last decade, our results have shown that using inoculant results in an average yield increase of 1.0 bushel per acre.

We would not recommend that growers routinely apply inoculant to every acre in the first year of use. Instead, we would suggest that growers initiate a replicated, side-by-side strip trial on their farm to test efficacy. If a yield increase is shown, growers can continue to incorporate this technology into their current production system.

If you have questions about how to set up a replicated strip trial, please contact your local Purdue Extension Educator. For contact information in your county, visit www.ces.purdue.edu/counties.html.

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