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Soybean Inoculation -- When Is It Necessary?

This NebGuide discusses when soybean seed should be inoculated and why, and provides recommendations on inoculant types to use.

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Soybeans can obtain up to half of their nitrogen needs from the air when nitrogen-fixing rhizobia bacteria are present in the soil. Nitrogen fixation is a result of the symbiotic (beneficial to both) relationship of rhizobia and plants. Establishing rhizobia (inoculation) in a field that has never grown soybeans is needed to insure nitrogen fixation. Reinoculation may be necessary in fields with a past history of soybeans.



Nodules are very apparent on carefully dug soybeans. Nodule rhizobia convert atmospheric nitrogen to forms that can be used by the plant.

The relationship between rhizobia and plants is unique to legumes. When infected by rhizobia, the plants form special structures called nodules that enclose the rhizobia colonies. The plant provides carbohydrates and mineral nutrients to the rhizobia; the rhizobia in turn provide nitrogen to the plant.

The rhizobia species that inoculates soybeans is not native to Nebraska soils and nodulates only soybeans. It is different from those that fix nitrogen in alfalfa and other legumes. This means the rhizobia inoculant for soybeans cannot be used for alfalfa and other legumes, and vice versa.

When to Inoculate

Recently, a field in Indiana that had not grown soybeans for at least 15 years had no yield response to inoculation because rhizobia were present. In contrast, a field near Clay Center, Nebraska that never had

soybeans had an established rhizobia population. The rhizobia had apparently been carried in by either machinery or wind and water erosion. But, it is not a good policy to wait 15 years or more before reinoculating. A rhizobia population can be drastically reduced before that time. Likewise, do not forget to inoculate fields where soybeans will be grown for the first time. Within the same section of land near Clay Center just mentioned, another field without a soybean history had no rhizobia population at all.

Soybeans grown on soils without a rhizobia population will use available soil nitrogen. If soil nitrogen levels are low due to soil type, heavy spring rains, etc., nitrogen deficiency symptoms will be evident. These symptoms are characterized by lighter green leaves in parts of fields planted with the same variety.

A guideline for most soils is to inoculate if there has not been a well-nodulated soybean crop grown on the field within the past 3 to 5 years. The degree of nodulation can be determined by carefully digging random plants throughout the field two weeks after emergence and examining the root systems. A well-nodulated plant should have around 5 to 7 nodules on the primary root. If plants have fewer nodules, monitor the field carefully to determine if the nodule numbers increase. If they do not, and nitrogen deficiency symptoms develop, apply 50 to 60 lbs. of nitrogen to supplement soil nitrogen reserves. Apply this nitrogen at or soon after flowering. **On sandy soils (greater than 90% sand), rhizobia survival from one season to the next is very low. With these soils, inoculate every year. Don't hesitate to inoculate on any soil if soybeans are to be grown for the first time!** If in doubt, inoculate; it's cheap insurance.

How to Inoculate

Two types of inoculants are used most often--seed-applied and soil-applied. The seed-applied inoculant is most effective when mixed with water to form a slurry which is used to coat the seed. This should be done several hours to a day before planting. Less acceptable methods of using this type of inoculant are either layering it with the seed in the planter box, or mixing seed, water, and inoculum in the planter box. Soil-applied inoculants can be applied into the seed furrow at planting with either the herbicide or insecticide boxes. The soil-applied inoculant is easier to apply than the seed-applied type, but it is more expensive on a per acre basis.

Table I. Soil- vs. seed-applied inoculants for soybeans.*

Inoculant Treatment	Soybean Yield (bu/a)				
	"New" Soybean Ground ¹		---"Old" Soybean Ground ² ---		
	A ³	B ⁴	C ⁴	D ⁵	E ³
None	31.2	15.4	58.4	51	39
Seed-applied	38.7	40.5	56.8	50	39
Soil-applied	46.1	64.7	59.2	52	39

*Compiled from several research reports from several locations.
¹New soybean ground has never had soybean grown on it.
²Old soybean ground has had soybeans grown on it.
³Two-years data.
⁴One-year data.
⁵One-year -- two locations.

Although the cost spread between the two may be extreme, there is a place for soil-applied inoculants. In fields without a history of soybean production ("new" soybean ground), soil-applied inoculants have been shown to increase yields (*Table I*). Also, seed-applied inoculants were better than no inoculant at all on these new soils. Although the advantage shown in *Table I* may not always be as good as it looks, use soil-applied inoculants on new soybean ground.

On "old" soybean ground (where soybeans have been grown), neither type of inoculant increased soybean yield. This lack of inoculant response has often been reported by researchers and growers. The "resident population" of rhizobia in these fields is more competitive for nodule sites than the introduced rhizobia. Only 5 to 10% of nodules formed on plants in old soybean ground come from the introduced strains. It's still cheap insurance to inoculate these fields, however.

Pre-inoculated seed is often considered an option to farmer-applied inoculants like those mentioned before. Although larger numbers of rhizobia may be applied to the seed with pre-inoculation, their numbers at planting can be severely reduced, resulting in poor nodulation. This reduction in numbers may be the result of many factors, including storage conditions, handling, or simply normal degradation between pre-inoculation and planting. Therefore, pre-inoculation may be convenient for the grower, but its variable nodulation in the field makes its use a questionable practice.

Store and handle inoculants according to the manufacturer's instructions. Inoculants are living products; high temperatures, sunlight, and other adverse conditions can reduce rhizobia viability and performance. To insure best results, never use an inoculant after its expiration date.

Special Considerations

Two possible problems exist when using inoculants. First, seed treatment with certain fungicides reduces rhizobia survival and nodulation (*Table II*). Only the Thiram had no adverse effect on rhizobia survival and nodule counts. Even with Thiram-treated seed, however, it is important to plant as soon as possible after inoculation. If seed treated with a fungicide other than Thiram is planted in a field with no history of soybeans, use soil-applied inoculant. No information is available yet on the compatibility of the fungicide Apron to soybean rhizobia. This is a systemic for phytophthora root rot control. On new ground it would be safest (and probably more productive) to use soil-applied inoculant with any seed treatment.

Table II. Effect of chemical seed treatment on rhizobia and nodule counts on soybeans planted one hour after treatment.

Fungicide	Rhizobia Count/Seed (x 1000)	Taproot Nodules/ Plant
None	400	6.8
Thiram	410	6.6
Carboxin	350	4.5
Captan	330	0.4
PCNB	90	0.6

(Curley and Burton, Agron. J. 67:807-808.)

The second problem is that rhizobia do not function below pH 5.0 and molybdenum deficiencies can occur below pH 6.0. Molybdenum is important in the nitrogen fixation process. One alternative for soils

with a pH range of between 5.0 and 6.0 is to use inoculant supplemented with molybdenum (*Table III*). Liming, however, is the best long-term solution to this problem if soybeans are to be grown regularly.

Table III. Effect of inoculants with and without molybdenum (Mo) at different pH levels on a field with a history of soybeans, Brownstown, IL.

Treatment	Soil pH			
	4.9	6.5	7.1	7.9
	-----bu/a-----			
None	24	36	35	35
Inoculum	26	33	32	34
Inoculum + Mo	34	35	32	33

(Johnson and Boone, Illinois Research 18(4):3-4)

Recommendations

Soybeans planted on soils other than sands that have had a well-nodulated crop within the past three to five years usually do not respond to inoculation, although inoculation is cheap insurance in these cases. This is if the pH is above 6.0. Inoculate sandy soils every year. Fields with no history of soybeans require inoculation. Soil-applied inoculants are better than seed-applied inoculants in these fields.

Many fungicides used for seed treatment are harmful to rhizobia. They should never be used with seed-applied inoculants or preinoculated seed. However, Thiram is compatible with rhizobia. But, to maintain maximum rhizobia numbers, plant Thiram-treated seed soon after inoculation.

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