NO-TILL AND NITROGEN FIXING INOCULANTS

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Nitrogen fixation is the utilization of the free gaseous nitrogen in the air by soil bacteria to produce a form of nitrogen that plants can use. Nitrogen fixing Inoculants provide the 'Rhizobia' bacteria necessary for this process in legume plants. The name for the Rhizobia that are necessary for soybeans is Bradyrhizobium japonicum. These Rhizobia bacteria form a symbiotic relationship with the soybean plant in which the bacteria supply 'fixed' (useable) nitrogen to the plant while the plant provides photosynthates (sugars) to the bacteria as a source of energy. This process occurs in the nodules located on the soybean roots.

The specifics of this process has been known for slightly more than 100 years, and 'Inoculants' for legumes have been available almost as long. Inoculation is the application of Rhizobia bacteria (Inoculant) directly onto legume seed or into the furrow while planting the seed. If all goes well, the Rhizobia bacteria in the Inoculant infects the developing soybean root and forms nodules on the root where the bacteria proliferate and start 'fixing' nitrogen. Inoculants should be used when there is reason to believe that soil populations of the necessary Rhizobia bacteria are low. This situation will exist when cleared land is brought into production, the legume has not been grown on the soil for several years (more than 4), when the pH is low, or after severe drought or flooding.

'No-till' or 'conservation tillage' is used for soybean production in many areas. These reduced tillage practices save moisture, soil, and fuel; but these same practices can generate problems involving planting in cool, wet soil (disease and emergence problems), soil compaction, and weed control.

RECOMMENDATIONS:

The question Inoculant manufacturers often are asked is how Inoculation fits into the no-till picture. Very generally, our answer is that Inoculation is needed and that our standard rules for Inoculation apply: Remember that Inoculants (be they in the granular form, or the liquid or humus seed-applied form) are biological and thus must be treated differently than are chemicals or fertilizer. Specifically, some things to do in this regard are:

a. store in a cool place.
b. check expiration dates and package labels -- especially with regard to getting the proper Inoculant for the specific legume being planted.
c. check manufacturer's compatibility recommendations with regard to mixing with pesticides like fungicides; and use the suggested application rates and techniques.
d. Remember the general rule that 'in-furrow' Inoculants will have a greater

chance of success in stress conditions and thus are the first choice, followed by double rates of Inoculants using a liquid product as the sticker for a humus-based product, with the third choice being a single rate of a liquid or humus-based product. All these methods work equally well in optimum planting and growing conditions -- though 'optimum' is seldom seen.

PROBLEMS:

Since much of no-till ground is in areas of low annual precipitation, and since such areas are considered stress areas for biological N-fixing Inoculants, potential problems are abundant:

Examples:

1. The general no-till suggestion is to plant soybeans early and shallow. This can place a seed-applied Inoculant close to the soil surface exposed to the sun and drying winds. Also, early-planted soils often are more moist soils that can easily be compacted. Compaction not only makes it difficult for the soybean to emerge, but also it makes it difficult for air to get to the nodule and thus provide the gaseous nitrogen needed for the Nitrogen Fixation process. Further, it has been observed in some cases that compaction can result in decreased nodule number.

2. Often seed treatment fungicides are recommended for early plantings and thus fungicide/Inoculant compatibilities can be a problem – i.e. just as fungicides kill biological disease organisms in the soil, they can kill the Rhizobia bacteria in the Inoculant or in the soil. The level of toxicity depends on the active ingredient in the fungicide, and on the formulation of the active ingredient.

3. In some areas, pH can be a problem. Especially in areas where wheat has been continuously grown for a long time. The pH optimum for growing wheat may be below or close to 6.0 while the optimum for soybeans is closer to 6.5. A low pH kills the Rhizobia bacteria in the Inoculant and/or prevents the bacteria from surviving and growing in the soil.

4. Many no-till farmers use starter fertilizer with soybeans because of low initial nitrogen levels. If too much nitrogen is used, the soybean roots may not pick up the Rhizobia early when the bacteria are readily available; and then when the soil N is totally depleted by normal plant growth, the Inoculant Rhizobia bacteria are dead or not available. Also, direct contact between starter fertilizer and the Inoculant bacteria can kill the bacteria in some cases (usually because of low pH fertilizer.)

5. Drought! Drought shuts down plant growth as everyone knows. One of the initial things a soybean plant does in a drought stress is to redirect photosynthate from the nodule to the root tips -- most likely to help the

roots grow and explore for more water. When the Rhizobia bacteria in the nodule don't receive the photosynthate energy source from the plant, they stop fixing nitrogen.

There is not a lot a farmer can do about drought and some of these other factors, but it is important to understand their effect on the soybean plant and on the process of Nitrogen Fixation. Inoculants are not super fertilizers or magic bullets but rather just provide the living bacteria (Rhizobia) to soybean roots so that the plant can use the free nitrogen in the air. Both the bacteria and the soybean plant must be in good health for this symbiotic process to develop and work efficiently.

The Nitrogen Fixation process will not be initiated if: a) the plant does not have all the macro and micro nutrients needed besides nitrogen, b) the soil is compacted, c) a fungicide toxic to Rhizobia is mixed directly with the Inoculant, d) the pH is too low, or e) the Inoculant bacteria are not alive as the soybean root starts to grow. Consequently the plant will be starved for nitrogen. Therefore, use Inoculants wisely remembering that the Rhizobia bacteria in these Inoculants are biological, living entities that needed to be treated as such.

BENEFITS:

Properly nodulated legumes can leave from 50 to 300 pounds of nitrogen in the soil for the succeeding crops. [Table I] The exact amount depends on effectiveness of the Nitrogen Fixation process, type of legume, length of time the legume is grown, soil nutrient levels, moisture levels, and nitrogen already available in the soil. A general rule of thumb for the amount of nitrogen left by soybeans for the next year's crop is one lb. of nitrogen for every bushel of soybeans harvested.

TABLE I

NITROGEN FIXED BY LEGUMES

Type of Legume	lb. N fixed/acre/year
Alfalfa	110 – 300
Red Clover	75 – 170
Pea	70 – 135
Soybean	55 – 100
Vetch	80 – 140

[From: Soil Microbiology by Dr. Martin Alexander]

TYPES OF INOCULANT (WHAT TO USE?):

Table II shows the forms of Inoculant available to the Farmer along with the advantages and disadvantages of each.

TABLE II

FORM OF INOCULANT	ADVANTAGES	DISADVANTAGES
Humus based:		
1. Granular in-furrow	No treatment of seed is required. Granular herbicide or insecticide equipment can be used	Requires more Inoculant material. Produced and sold in 40 pound bags.
2. Seed applied Humus based:	Good bacterial survival. Can be sterilized to eliminate background contamination and/or made with extra adhesives.	Can have high level of contamination. Can adversely affect seed flow in planter
Water based:		
1. 'Ready to Use' - seed applied	No background contamination. Good seed coverage	Lots of volume to ship and store.
2. 'Concentrates' (frozen)	Little background contamination. High concentration	Higher shipping costs. Special storage required.

The goal of any Nitrogen Fixing Inoculant is to provide the proper specific strains of Rhizobia in large numbers. An important secondary goal is to produce an Inoculant which coats the seed well or can be introduced into the soil in a precise manner via methods that are convenient and efficient. Thus, Inoculants are like different types of equipment or different formulations of fertilizer. Certain types of equipment work best for certain crops, and different types of fertilizers (bulk, anhydrous ammonia, liquid slurry, dry starter, etc.) work best according to the crop and management scheme. Similarly, different Inoculant carriers or forms work best with different types of seed, soil, or planting equipment.

EVALUATION:

After using Inoculants, it is good to evaluate the resultant nodulation. The late vegetative stage is a good time to dig up a few soybean plants to look at the root structure and to evaluate nodulation. Use a garden spade or shovel rather than jerking the plant out of the ground. Soaking the plants in a bucket of water will help remove excess soil clods without removing nodules.

On crops such as soybean that have been planted in the Spring, there should be from 5 to 15 spherical shaped nodules located on or around the taproot. The total root system may have up to 50 or more nodules. For alfalfa and clovers that have been growing for a year or two, the nodules will appear on the lateral roots and be long and slender in shape. When evaluating nodules, keep in mind you are looking for overall nodule mass not just quantity. For example, 4 large nodules with a weight of 50 grams will be as effective as 10 small nodules with a weight of 50 grams.

Next, slice open a few nodules and check the color. Nodules actively 'fixing' free atmospheric nitrogen to usable ammonia will range in color from pink to bright red. If the nodules are white, they are ineffective or may not be developed yet to a stage at which they can fix nitrogen. To check if white nodules are immature or ineffective, examine the plant roots again a week later. This will usually give enough time for young nodules to mature into pink or red colored N-fixing nodules. If nodules are green and soft, they are past their prime and have already contributed to the plant's nitrogen economy. In soybeans, this 'green' stage will be observed in August and September after the plants are well into the pod filling stage of growth.

The final evaluation, of course, is yield.

SUMMARY:

There are several specific factors that adversely affect Rhizobial survival in the soil:

1. Acid or alkaline soils
2. Very wet or very dry soils
3. Soil treatment or seed treatment chemicals
4. High soil temperatures
5. Soils low in organic matter

Keep these things in mind as well as the fact that Nitrogen Fixing Inoculants for legumes contain a biological living entity that must remain alive in order to be effective. Biological Inoculants have requirements necessary for successful use that chemicals and fertilizers don't have. There are specific and important rules for handling Nitrogen Fixing Inoculants that must be followed for the Inoculant to work.

On the positive side of the ledger, when you successfully establish Rhizobia bacteria in your soils, you can harvest the benefits of higher legume yields with lower inputs, fertilizer savings, and residual soil nitrogen for succeeding non-legume crops.