Nodulation and Nitrogen Fixation in Soybean

Key Points

- Most of the nitrogen (N) requirement for soybean is supplied through the N fixation process, which is a result of a beneficial relationship between the plant and soil bacteria.
- Soybean seed should be inoculated with the appropriate bacteria to facilitate nodulation.
- Healthy and active nodules are pink to red on the inside and 2-4 mm in diameter.
- Light green, stunted soybean plants at the beginning of reproductive growth stages may indicate poor nodulation or other deficiency or environmental stress.

About 5 lbs of nitrogen (N) is needed to produce a bushel of soybeans. Anywhere from 50-75% of this comes from N fixation, the process by which atmospheric N is converted to a form usable by the soybean plant. N fixation is critical to producing higher yields in soybean. In order for this process to take place, soil bacteria called *Bradyrhizobia japonicum* need to be available in the soil or must be applied to soybean seed. The bacteria act by invading the soybean plant root hairs and multiplying to form nodules on the roots. These nodules house the N-fixing bacteria and are usually visible by plant emergence.

How Nodules Function

When a soybean seed germinates, the bacteria invade the root hairs and multiply forming a nodule, which houses the bacteria. Bacteria have a symbiotic relationship with the plant; the plant provides them with carbohydrates while the bacteria provide N fixation for the plant. Nodule formation can be seen within a week of emergence, but active fixation usually begins within 10-14 days later, around V2-V3 growth stages, at which point they can supply most of the plant’s N requirements. An individual nodule remains active for 6-7 weeks before beginning to break down. New nodules continue to form throughout much of the plant’s life, until ceasing during pod fill stages. Fixation production increases to its peak around the R5.5 growth stage, after which nodules decline and fixation decreases.

Evaluating Nodule Presence and Activity

If nodules fail to form, soybean plants will become N deficient and significant yield reductions can occur. It is important to evaluate soybean plants to see if nodules are present and actively fixing N. Being able to diagnose nodulation failure early can permit time for remedial action to reduce potential yield and income loss.

Michigan State University recommends checking roots at 5-6 weeks post planting when nodules should be large and active. Choose at least 10 plants from representative areas in each field to sample. Using a shovel to remove as much of the root system from the ground as possible, dig up the plants and immerse the roots in water to remove the soil. There should be 8-20 large (2-4 mm diameter) active nodules per plant prior to flowering. If sampling is done earlier and there are less than 5 nodules per plant, resample in a week. When split open, nodules are pink to red when actively fixing N although this is not a sign of efficient ammonium production. Small, white nodules have yet to fix N (immature) and green, brown, or mushy nodules are not fixing N. Inactive nodules may result from stresses such as flooding or the soybean nodule fly maggot. Nodules on the tap root are usually a result of this season’s inoculation, while those appearing on lateral roots generally result from bacteria present in the soil or from soil applied inoculants.

Conditions Resulting in Poor Nodulation

Poor nodulation and reduced N fixation are possible in these conditions:

- New soybean fields are likely to have low populations of the appropriate soil bacteria.
- Fields containing high levels of residual soil N from a previous forage legume, manure, or fertilizer application will likely have poor nodulation because nitrate in the soil reduces nodule formation and activity, thus inhibiting or delaying bacterial fixation.
- Soil compaction and cool soil conditions resulting from no-till practices can reduce nodulation.
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- Extremely dry or wet conditions following soybean planting.
  - Coarse-textured soils may have inadequate moisture levels to sustain bacteria.
  - Flooded or saturated soil conditions can cause oxygen deprivation. Nodules may form and die due to flooding (3 or more days saturation can cause nodule rotting and death).  
- Plants that have been weakened by hail damage, root diseases, or IDC (iron deficiency chlorosis).
- Fields that have soil at a pH level below 5.7 or above 7.3.

What is Inoculation and When Might it be Needed?

If soils do not carry adequate numbers of *Bradyrhizobium* bacteria for N fixation, they can be added as either a liquid or granular peat inoculant, or a peat-based powder. Inoculants can be seed applied or applied in-furrow. The viability of inoculants will depend on storage time and storage conditions. An expiration date should be listed for commercial inoculants, but they can be killed by direct sunlight or excessive heat prior to the shelf life’s end. Results from 13 years of North Dakota State University research show an average 2.1 bu/acre yield advantage with inoculation as compared to an untreated check.

Inoculants can have a positive impact in many growing situations including the following:

- If no soybean crop has been grown in the field for 3-5 years and if soil pH has not been maintained above 6.0.
- Field never planted to soybean should be double inoculated with both a seed applied inoculant and a soil applied inoculant.
- Fields with sandy soil (low organic matter soils) need to be inoculated every year.
- Fields that were flooded the previous season may need to be inoculated due to the anaerobic conditions reducing the level of *Bradyrhizobium* bacteria in the soil.

Sometimes the conditions in first-year soybean fields or fields with a high residual N can result in inoculation failure. With first-year soybean planting, inoculant can be applied to the seed and in-furrow to the soil. Another method to encourage nodulation in first-time soybean fields is to consider planting a soybean crop for two consecutive years, inoculating both years.

Conditions most likely to cause inoculation failure:

- Planting a soybean crop into a field for the first time.
- Soil pH levels below 5.5 and above 8.0.
- Residual soil nitrogen levels greater than 40 pounds per acre.
- Flooding.
- Improper inoculant application to the seed or poor quality inoculant resulting from improper storage.

Nitrogen Application Considerations

In general, applications of N fertilizer to soybean should be avoided. A greater supply of N available in the soil from fertilizer results in reduced N fixation by the nodules. As the N soil supply increases, nodule number and activity level decline proportionately. Soybean planted in fields with excessive residual nitrate should be closely monitored. If nodulation has been severely inhibited and N deficiency symptoms appear, additional N during pod fill may be helpful. Research has shown conflicting results regarding late-season N applications, with the greatest success occurring when N was applied via irrigation system in high-yield situations.

Sources:

Individual results may vary.