SCIENCE FOR SUCCESS

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Soybean Inoculation and Nitrogen Fixation

Key Takeaways

- Soybeans have the greatest nitrogen (N) requirement per bushel among row crops
- Biological N-fixation generally provides 40-70% of total soybean N requirement
- Inoculum (*Bradyrhizobium japonicum*) may be necessary in fields not recently planted with soybean
- Well-nodulated roots with active nodules are foundational for soybean growth and yield potential

Why Nitrogen Matters

Although the atmosphere has 78% N_2 gas, plants cannot use it directly. Instead, they must get N from the soil. Soybean is a legume that forms a symbiotic relationship with a specific bacteria called *Bradyrhizobium japonicum* to transform the atmospheric N_2 into plant-available N in the soil. These bacteria need to be introduced through inoculation because they are not naturally occurring in US soils.

N-fixing bacteria colonize root hairs to form nodules. If nodulation and N-fixation fail, a 50-bu soybean crop would require 100-175 lbs N per acre in addition to the supply of N in the soil.

Fun Facts

40-70% | N-fixation generally provides 40-70% of total N for soybeans[1]

3-4x | Soybean crops require three to four times more N per bushel than cereal crops such as corn, wheat, or rice.

Nodulation on a soybean root

Need to Know

N-fixing bacteria can be introduced through seed or in-furrow inoculation in the form of powders, liquids, or granular.

Bacteria are alive and should not be exposed to high temperatures or direct sunlight.

Even when soybean seeds are inoculated with the right bacteria and method of application, satisfactory nodulation is not guaranteed.

Learn More

Science for Success Videos

Soybean Growth Stages

[1]Almeida, Luiz Felipe A., et al. (2023). Soybean yield response to nitrogen and sulfur fertilization in the United States: contribution of soil N and N fixation processes. *European Journal of Agronomy*, 145. doi:10.1016/j.eja.2023.126791

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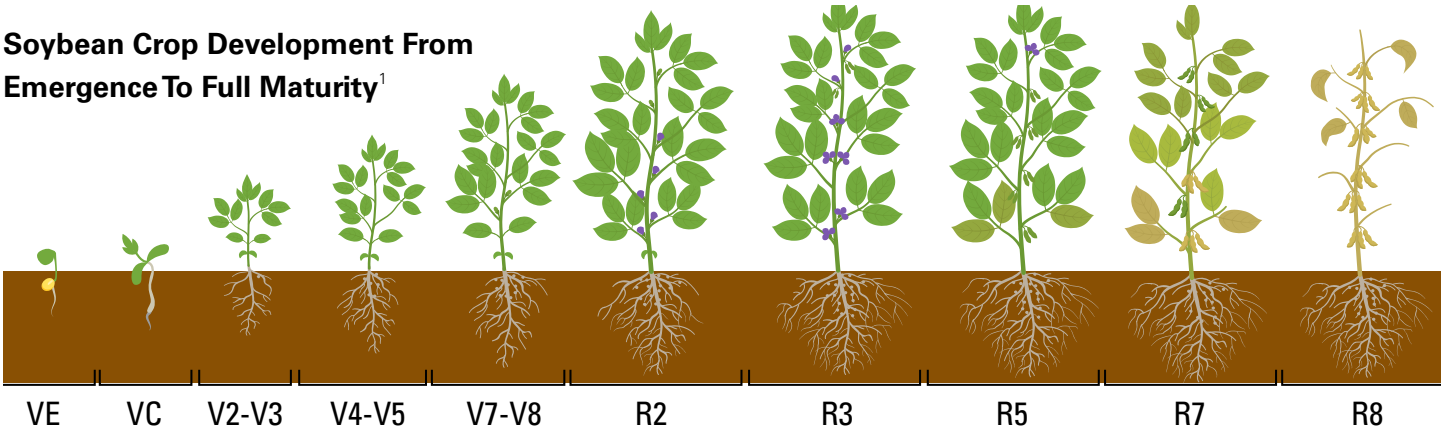
Soybean Crop Development From Emergence To Full Maturity[1]



Factors That May Compromise Nodulation and N-fixation:

- Low or high temperatures
- Low or high soil pH
- High salinity
- Dry or excessive water conditions
- Nutrient deficiency
- High soil N level

The formation of nodules can be observed as early as V1 to V2 growth stage a few weeks after the N-fixing bacteria have infected root hairs. Nodule development takes about 30 days to start fixing N_2 from the atmosphere. Fixation from the mature nodule will continue for the following 20 to 30 days. Active N-fixation is usually present by V3 to V4 and continues through reproductive stages, peaking between R5 to R6 (Below: Cross section of an active N-fixing nodule; pink interior). The number of nodules per root and the nodule size will increase as the plant develops. The N-fixing bacteria will infect new roots, develop new nodules, and fix more atmospheric N. In soybean rotational systems, an adequate level of N-fixing bacteria can survive in the soil for several years until the next soybean crop.

Determining Successful Nodulation and N-fixation

1. Scout for the presence of nodules after V3 to V4 stage.
2. Carefully dig up plants in several locations of the field to avoid removing nodules.
3. Wash the roots in a bucket of water.

Successful Nodulation

The plant has several active (pink) nodules and can fulfill soybean N requirements for an average yield (50 bushels per acre).

Unsuccessful Nodulation

- Nodules are present, but they are green or white, which means they are not fixing N
- No nodules are present and the plants show yellowing from N deficiency

Cross section of an active N-fixing nodule; pink interior

Soybean plants showing signs of Nitrogen deficiency (left) vs. adequate Nitrogen (right)

What Now?

1. Additional soil inoculation will have no effect after planting if nodules are not already present
2. A rescue N application may be warranted (contact your local Extension office for recommended rates)
3. Inoculate with *Bradyrhizobium japonicum* the next time soybean is planted in the same field

[1]Development stages defined by Fehr and Caviness (1977). "V" stands for Vegetative stage. VE: emergence; VC: cotyledons fully expanded; V2: fully developed trifoliate leaf at node above the unifoliate leaf; V3: fully developed trifoliate leaf at node above the first trifoliate leaf; V4-V5: third trifoliate leaf fully expanded; V7-V8: sixth trifoliate leaf fully expanded; R3 (beginning of pod setting): a pod of 3/16 inch long at one of the four uppermost nodes on the main stem with a fully developed leaf; R5: (beginning of seed filling) a seed 1/8 inch diameter in a pod at one of the four uppermost nodes on the main stem with a fully developed leaf; R7 (physiological maturity): one "normal" seed-filled pod on a plant will have matured to a brown pod color; R8 full maturity: 95% of the plant's pods will have matured to a final brown color.

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