



Why Inoculate or Double Inoculate?

WHAT YOU'LL LEARN

- Effective nodulation is essential for nitrogen fixation, particularly on soils where soybeans have not been planted recently.
- Seed-applied inoculant can be profitable on fields with a history of soybean planting.
- Double inoculation can help quickly establish high populations of rhizobia bacteria to ensure optimal nodulation and soybean performance.

BIOLOGICAL NITROGEN FIXATION

Effective nodulation of soybean and other leguminous crops is the key factor in the complex process of nitrogen (N) fixation. The success of N fixation is highly dependent on the presence of high populations of the specific bacteria for each crop in the soil near crop roots or applied to seed.

Bradyrhizobia japonicum is the rhizobia bacteria associated with soybean. About 70% of the total N requirement for soybean is generated by the symbiotic process of N fixation. A large percentage of this N is fixed during soybean reproductive stages, which is the period of greatest N demand. The bacteria receive a signal (flavonoids) from soybean roots and return a signal (lipo-chitooligosaccharide - LCO) back to a plant to initiate N fixation. The bacteria enter soybean roots causing a nodule to develop. Around the V2 to V3 soybean growth stage, viable nodules begin to fix N. A plant can have 8 to 10 healthy nodules at the V3 to V4 growth stage, with the maximum number of nodules typically occurring by the R5.5 growth stage.^{1,2} Viable nodules have a pink to red interior color (Figure 2). Nodules that are green, brown, or mushy are not fixing N. New nodules are formed into the pod-filling growth stage.

WHY INOCULATE?

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

- Field has no previous history of soybean production (Figure 1).
- Soil pH is below 6.0. Greater response from inoculants can be expected in fields with a pH below 6.0.

- Fields that have been flooded for several days can have anaerobic conditions that inhibit rhizobia.
- Compaction and cool soil temperatures can reduce nodulation.
- Sandy soils with low organic matter (less than 1%) generally have very low populations of rhizobia bacteria and need to be inoculated every year.²



Figure 1. Well-nodulated plant (left) versus poorly-nodulated plant (right). Photo courtesy of Stu Duncan, Kansas State University.

Several universities throughout the Midwest have found a long-term average yield advantage for a soybean seed-applied inoculant on fields with a history of soybean planting.^{3,4,5} The 11-year average yield advantage in Ohio State University inoculant testing was 1.94 bu/acre when using inoculants versus no inoculation, over an 11-year period in fields with a corn/soybean rotation, with excellent drainage, fertility, and pH.³ Inoculant product improvements, custom application, and better compatibility with multiple seed-applied products have contributed to performance advantages.³

MULTI-ACTION INOCULANTS

Applying several microbial products to soybean seed can have distinct advantages for soybean performance. Adequate availability of phosphate is essential for N fixation. *Penicillium bilaii* is a soil fungus that is a phosphate solubilizer that can be used in conjunction with *Bradyrhizobia japonicum*. Used together, these products can provide increased phosphate availability, more



Figure 2. Root nodules and a dissected, pink nodule (insert).

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Why Inoculate or Double Inoculate?



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fixed N, better root and shoot growth, and improved yield potential. Some products include nod factor compounds (LCO). These compounds are a bacterial signal to the plant to initiate the nodulation process to promote early plant vigor, under stress or normal conditions, which helps support productive nodulation.

DOUBLE INOCULATION

Land that will be planted to soybean for the first time, or that has been in the Conservation Reserve Program (CRP), pasture, or not been planted to soybean in several years may require a special inoculation plan. Double inoculation combines seed-applied inoculants with a sequential in-furrow application of a granular or liquid inoculant to quickly establish high populations of rhizobia bacteria to ensure optimal nodulation and soybean performance. Recommended rates for in-furrow products are based on soybean row width (Table 1).

NODULATION FAILURE

The following conditions are most likely to cause poor nodulation and reduce N fixation:⁶

- Planting soybeans in a field for the first time.
- Soil pH below 5.5 and above 8.0.
- Residual N levels greater than 40 lbs/acre.
- Anaerobic conditions in flooded soils that are saturated for at least three days can cause nodules to rot, turn brown, and die.
- Fields with low soil rhizobia bacteria populations and/or fields with a high residual of soil N from a previous forage legume, such as alfalfa, clover, or other crop, or due to manure application.
- Hail damage, root diseases, or iron deficiency chlorosis symptoms early in the season.
- Soil compaction can limit root growth and root hair development reducing rhizobia colonization of roots and nodule development.
- Improper application of fungicide and inoculant to seed. Product suppliers publish compatibility guides for inoculant products for use with other products.
- Poor quality inoculant due to improper storage.

Symptoms of inadequate nodulation include yellowing and stunting of soybean plants. These same symptoms can be caused by soybean cyst nematode, other nutrient

Table 1. Recommended in-furrow rates.

Row width	Cell-Tech® Liquid (based on 1 oz/1,000 ft of row)	TagTeam® Granular (based on 1.5 to 6 oz/1,000 ft of row)
	Rate oz/acre	Rate lb/acre
30	8.5 to 17	1.6 to 6.5
20	13 to 26	2.5 to 9.8
15	17.5 to 35	3.3 to 13.1
7.5	35 to 70	7 to 28

Contact your brand representative for product recommendations.

deficiencies, or environmental conditions such as drought, compaction, or excessive rainfall. If poor nodulation is suspected, the best way to identify the problem is to dig up plants in the affected areas, wash the roots, and count the root nodules. If fewer than 7 nodules are found per plant, the plants will probably be nitrogen deficient. Count only nodules that are pink or red when split open.⁶

Fields new to soybean should always be double inoculated. Follow the inoculant expiration date and proper storage conditions to preserve the inoculant's viability. Avoid exposing inoculants to direct sunlight or excessive heat.

SUMMARY

Inoculants can have a positive impact in many growing situations such as fields with no previous history of soybean, soil pH below 6.0, compaction and cool soil temperatures, and sandy soils with low organic matter. Applying several microbial products to soybean seed can have distinct advantages for soybean performance. Double inoculation combines seed-applied inoculants with a sequential in-furrow application of a granular or liquid inoculant to quickly establish high populations of rhizobia.

Sources: ¹Pedersen, P. 2004. When do we need to inoculate our soybean seeds? Integrated Crop Management. Iowa State University. ²Pedersen, P. 2003. Soybean seed inoculation. Integrated Crop Management. Iowa State University. ³Beuerlein, J. 2009. Soybean inoculation; its science, use and performance. Ohio State University. <http://agcrops.osu.edu>. ⁴Thelen, K., Schultz, T. 2011. Soybean seed applied inoculation. Soybean Management and Research Technology. Michigan State University. ⁵Conley, S.P., and Christmas, E.P. 2005. Utilizing inoculants in a corn-soybean rotation SPS-100-W. Purdue University. ⁶Stanton, M. 2014. Identifying and responding to soybean inoculation failures. Michigan State University. <http://msue.anr.msu.edu>. 150727134522

Performance may vary, from location to location and from year to year, as local growing, soil and weather conditions may vary. Growers should evaluate data from multiple locations and years whenever possible and should consider the impacts of these conditions on the grower's fields. ALWAYS READ AND FOLLOW PESTICIDE LABEL DIRECTIONS. Cell-Tech®, Monsanto BioAg & Design™ and TagTeam® are trademarks of Monsanto Technology LLC. All other trademarks are the property of their respective owners. ©2018 Monsanto Company All Rights Reserved. 150727134522 032318CAM

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