Soybean Soil Fertility

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Soybean has a need, as do most crops, for the 14 mineral nutrients: nitrogen (N), phosphorus (P), potassium (K), sulfur (S), calcium (Ca), magnesium (Mg), zinc (Zn), manganese (Mn), copper (Cu), iron (Fe), boron (B), chloride (Cl), nickel (Ni) and molybdenum (Mo). Of these, North Dakota soils provide adequate amounts except for nitrogen, phosphorus, potassium, sulfur and iron.

Nitrogen Fixation

Although the atmosphere is 78 percent nitrogen gas, plants cannot use it directly. Plants can use only ammonium-N or nitrate-N. Soybean is a legume and normally should provide itself N through a symbiotic relationship with N-fixing bacteria of the species *Bradyrhizobium japonicum*. In this symbiotic relationship, carbohydrates and minerals are supplied to the bacteria, and the bacteria transform nitrogen gas from the atmosphere into ammonium-N for use by the plant. This process also is called N_2 fixation.

The process of soybean infection by N-fixing bacteria and symbiotic N fixation is a complex process between the bacteria and the plant. The right species of N-fixing bacteria must be present in the soil either through residual populations from inoculation of previous soybean crops or through inoculation of the seed or seed zone at planting.

N-fixing bacteria are attracted to the roots by chemical signals from the soybean root. Once in contact with the root hairs, a root compound binds the bacteria to the root hair cell wall. The bacteria release a chemical that causes curling and cracking of the root hair, allowing the bacteria to invade the interior of the cells and begin to change the plant cell structure to form nodules. The bacteria live in compartments called "bacteroids;" a nodule may have up to 10,000 bacteroids. Each bacteroid is bathed in nutrients from the host plant, and the bacteroid takes N_2 gas from the soil air and converts it to ammonium-N using the enzyme nitrogenase. Nitrogenase consists of one Fe-Mo (iron-molybdenum)-based protein and two Fe (iron)-based proteins. Fe and Mo deficiencies, therefore, are a problem for N fixation in certain soybean-growing areas.

N fixation by nitrogenase must take place in an environment without oxygen. However, bacteria and roots have to respire, which requires oxygen. To get around this problem, nodules use the same strategy humans do in oxygen transfer in our blood. The transfer compound is leghemoglobin (closely related to our hemoglobin). It results in a pink-red color of active nodule interiors. N fixation is very energy intensive and does not come without cost to the soybean plant. Ten pounds of carbohydrate are needed for each pound of N produced.

Some researchers refer to carbohydrate movement in soybean plants as the "source-sink" relationship. Early in the growing season, the source of carbohydrates is leaves and the main sink is the nodule, in addition to the growing points of the plant. After flowering, the activity of nodules decreases rapidly and eventually stops due to lack of nutrient supply. The plant changes the sink from the nodules to the seed. Nodules disintegrate and bacteria are released once again into the soil.

These environmental conditions limit N fixation:

Cold and heat – A temperature of 60 to 80 F is ideal, while levels above or below this reduce bacterial activity.

N levels too high – When that occurs, nodule number and activity decrease. Roots do not attract bacteria or allow infection, so N fixation is limited or nonexistent.

Drought – Poor plant growth does not allow the plants to sustain nodules and plant growth, therefore nodule activity is sacrificed.

Excessive wetness – If soil pores are filled with water, not air, no N is available to fix.

Compaction – Compaction has been shown to affect nodulation of soybean plants more than N fertilization. If no air is available, no N-gas is available to fix.

In the soil, competition is possible between *Bradyrhizobium japonicum* bacteria found in inoculum and native strains of Rhizobium bacteria, which are less efficient than bacteria in inoculum. Nodules from initial inoculation tend to be on the main tap root near the surface, while native strains tend to grow on the branches away from the seed zone. Native strains are sometimes much better at infecting roots and can limit inoculation effectiveness. Native strains also siphon off nutrients from the host, lowering the N-fixing ability of more efficient strains.

Using Inoculants

Inoculation is the application of specific bacteria (Rhizobia) to the soybean seed prior to planting. Brands of inoculants can be purchased in various formulations, including liquids, frozen prep, peat-based, dry powder-based and granular.

Proper storage is critical. Make certain the inoculant is fresh and has been stored in a manner recommended by the manufacturer. Inoculation ahead of seeding is possible, but check with the manufacturer to see if the shelf life of the product will allow it. Some seed treatments are toxic to inoculum. For example, Captan and PCNB are very toxic to inoculum. Vitavax is relatively safe up to 24 hours before seeding. Thiram produces effects in between these two groups. Planter box treatments using dry materials or auger treatments with liquids, fresh or frozen are all acceptable if they give good coverage of all seed. Granular treatments applied separately in a band at seeding also work well but are more expensive than planter box or auger treatments.

Follow product instructions and get uniform coverage on the seed. Use the high side of the application rate, especially for new growers and first-time fields. For first-time inoculum use, the granular form is most foolproof, particularly if the granular applicator is calibrated before use. On Conservation Rerserve Program breakout or previously flooded lands, we highly recommend growers inoculate soybean seed. Plant seed as soon as possible after inoculation (four hours for liquids and 24 hours for dry material). Always keep the inoculant and inoculated seed out of the sun in a cool place by tarping the truck or keeping it in a shaded area.

Nutrients

Nitrogen Recommendations for Soybean

Nitrogen is not recommended for soybean, even first-year soybean. Elevated soil nitrate may increase the likelihood and severity of iron-deficiency chlorosis. The economics of late-season N application also is not justified.

Phosphorus

Soybean reacts better to broadcast applications of P than to banded applications with or near the seed. Soybean plants appear to prefer their entire rooting zone bathed in nutrients rather than having nutrients concentrated in a small area of the root zone. Several recent studies confirm that broadcast application of P is better than banded P.

If soil test levels are low to very low, then a separate application of broadcast P is justified. However, if soil test levels are medium or higher, the level of response of soybean to P fertilizer is small, not justifying a separate P application. Soybean roots are excellent scavengers of P at medium or higher soil test levels. At medium or higher soil test levels, front-loading the crop prior to soybean or applying more to the crop following soybean would be better than applying P to that soybean crop. The most common fertilizer application in the central soybean belt is applying extra P to the previous corn crop and allowing soybean plants to scavenge what is left. The practice has been successful for more than 40 years.

Even though a broadcast application of P may result in several more bushels of soybeans than a banded application, some producers will elect to apply P with the seed. **NO** fertilizer of any kind is recommended with soybean seed in a 15-inch row or wider. However, using a double-disk drill with 6-inch spacings, up to 10 pounds of N/acre may be applied to soybean as a P fertilizer (do not use urea). With air seeders, risk to soybean plants with fertilizer spread across the seed zone will be decreased. Even though applying up to 10 pounds of N/acre with a 6-inch row spacing is possible, dry weather at planting will increase the risk of injury. Therefore, the prudent action for the producer is not to push rates too hard toward the limit because of the variability within fields in both sand and soil water content. Sandier textures and low available soil-water soils may show more stand injury than other areas of the field. Again, the best recommendation for P application is to broadcast it.

Potassium

Testing the soil for K is important. After many years of soybean production, some soils may have been mined of K. Sandier-textured soils in the beach ridges west or east of the Red River Valley have been low in K for many years. Some sandier hilltops in the glacial till plain or in residual materials west of the Missouri River also may be lower in K. Some limited soil testing based on general landscape will show whether K is needed in these areas. Generally, coarser-textured soils are more at risk for K deficiency than heavier soils. However, with continuous soybean production, even heavy soils may be at risk. Potassium either should be broadcast or banded, with the seed and fertilizer separated. Do not apply potassium fertilizers with the seed.

Sulfur

Deficiencies are most possible on sandier hilltops and eroded areas with low organic matter. The risk of S deficiency is increased after wet falls and/or above-normal snowmelt and early spring rains. Coarser-textured, low-organic matter soils are then at risk and should receive a S application under those climatic circumstances.

Soil pH

Soybean grows best around a pH of 6.5. Lowering the pH from 8 to 6.5 usually is not an option because of the cost of amendments and the formation of salt if the application is successful. However, low pH levels have been found in North Dakota. Sampling by landscape position reveals much better pH information than composite testing. Application of ground limestone or sugarbeet lime would be justified if the soil pH is lower than 6.

Zinc

Soybean is usually not sensitive to low soil zinc levels in North Dakota and grow well at zinc test levels much lower than sensitive crops such as dry beans and corn. In a recent North Dakota study with 10 locations, nine varieties with and without zinc revealed no significant differences, even at soil test levels as low as 0.2 parts per million.

Iron

Soybean plants are susceptible to low soil iron availability. Iron-deficiency chlorosis (IDC) is expressed as yellowing in between veins on younger leaves. Iron chlorosis is not seen until the first trifoliolate leaf emerges because before that time, iron from the seed is translocated to new growth. At emergence of the first true leaves, iron becomes an immobile nutrient and the plant must rely on soil availability to supply iron needs. This yellowing is called "chlorosis."

Iron deficiency chlorosis in this region is different than chlorosis historically reported in the central soybean growing belt. High soil carbonates, increased solubility of bicarbonate caused by soil wetness, and the presence of high levels of soluble salts have been shown to influence the presence and severity of iron chlorosis in soybean in North Dakota and northwestern Minnesota. Cold temperatures also aggravate the problem in some spring seasons. Application of harsh contact herbicides and systemic residual herbicides postemergence are discouraged on severely stressed soybean plants.

Application of iron-EDDHA chelate appears to be most helpful in correcting chlorosis. New formulations may be cost effective. An iron-EDDHA seed-applied fertilizer also should be used in conjunction with an IDC-tolerant variety.

Recent research in North Dakota and Minnesota has shown that in fields susceptible to IDC, seeding an oat cover crop at the same time as glyphosate-resistant soybeans decreases the IDC effect. The oat plants serve to dry the soil and take up some residual soil nitrate. In a dry spring, the oat plants should be killed earlier, and in a wet spring, they should remain until the five-leaf stage if practical.

To combat chlorosis, plant the most iron chlorosis-tolerant varieties available in your maturity range. See *www.yellowsoybeans.com* for the latest updates on varietal screening in our area.

Nutrient recommendations for soybean.

	Soil test P, ppm (Olsen)					Soil test K, ppm				
Yield potential	VL 0-3	L 4-7	M 8-11	H 12-15	VH 16+	VL 0-40	L 41-80	M 81-120	H 121-160	VH 160+
bu/a	lb P_2O_5/acre					lb K_2O/acre				
30	35	20	10	0	0	55	35	10	0	0
40	50	30	10	0	0	75	45	15	0	0
50	60	35	10	0	0	90	55	20	0	0
60	70	40	10	0	0	110	65	20	0	0

Olsen P recommendation = (1.55- 0.14 STP)YP.

Potassium recommendations = (2.2-0.0183 STK)YP.

The abbreviations used in the equation are as follows:

YP = yield potential.
STP = soil test phosphorus.
STK = soil test potassium.
ppm = parts per million.