UNIVERSITY OF MINNESOTA EXTENSION

NUTRIENT MANAGEMENT

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Fertilizing Soybean in Minnesota

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Soybean is an important crop in Minnesota and provides a significant return for many farms. The fertilizer needs of the crop are often neglected while attention is mostly directed at fertilizing other crops in the rotation. Soybean crop yields will decrease when it lacks essential nutrients. Therefore, it's important to develop a profitable fertilizer program to maximize crop yields. This publication covers fertilizer guidelines that are a key component of profitable production.

NITROGEN CONSIDERATIONS

Soybean is a legume, and, if properly inoculated, can use the nitrogen gas (N_2) in the atmosphere for plant growth via fixation in the nodules. The amount of fixation that takes place is related to the amount of nitrate-nitrogen (NO_3-N) in the soil. In general, the amount of N fixed increases as the amount of NO_3-N in the soil decreases. When soil NO3-N is high, the amount of N fixed in the nodules is small. If soil NO3-N is low, N fixation quickly increases to meet the greater N demand.

Manure is an excellent source of phosphorus (P), potassium (K), all secondary nutrients, and micronutrients. However, producers have been concerned about the effect of N in the manure on nodule development. During the 1990s, research conducted at 10 sites throughout Minnesota evaluated the effect of manure application on soybean production. That research effort produced several conclusions about the use of manure for soybeans. The soybean crop removed a greater amount of N when compared to corn, leading to the conclusion that the rate of manure applied should be limited to the amount of N removed by this crop. The results of the study also showed that if manure-N was applied at rates to supply less N than was removed, nodulation quickly resumed in mid-season and the final N removal was similar for both manured and non-manured fields.

The application of manure to soybean fields had a consistent positive effect on grain yield. This management practice also increased vegetative growth, which led to more lodging of some varieties. The increased vegetative growth also provided a more favorable environment for white mold growth and development. The effect of manure on production was the same for several soybean varieties. Therefore, decisions about variety selection should not be changed when manure is used.

In recent years, some scientific speculation has questioned the ability of the soybean nodule to supply adequate amounts of N late in the growing season, a situation that could limit soybean yields. This speculation leads to suggestions, by some, for in-season fertilizer N application for the crop. Previously, University of Minnesota research was conducted at many locations throughout the state's soybean growing areas to evaluate the effect of in-season application of various N sources during the growing season on soybean yield. Results of the study were conclusive: In-season application of fertilizer-N had no effect on soybean yield.

The effect of nitrogen fertilizer use on soybean yield at one site is summarized in **Table 1**. Foliar application of nitrogen during the growing season can decrease yields (see **Table 2**). In-season application of fertilizer-N is **not recommended** for soybean production in Minnesota.

Nitrogen fertilizer use for soybean production in the Red River Valley deserves special consideration. Research in the region has shown that use of fertilizer N may increase yields where producers have (1) experienced problems getting good nodulation and (2) the amount of NO_3-N to a depth of 24 inches is less than 75 lbs./acre. The use of some N in a fertilizer program (50 to 75 lbs. per acre) could be beneficial for some soybean fields in the Red River Valley. Soybean growers in northwestern Minnesota are advised to measure carryover NO_3-N before they decide to apply fertilizer N. In fields where iron deficiency chlorosis occurs, additional N may worsen the problem. In these cases, additional N is not recommended.

Table 1. Soybean yield as affected by nitrogen source, time, and method of application (N rate = 75 lbs. per acre)

N-SOURCE	APPLICATION		
	TIME	METHOD	YIELD
			bu/acre
None	--	--	52.4
Amm. Sulfate	Pre-plant	Broadcast	54.2
Amm. Sulfate	Early	Broadcast	54.3
Amm. Sulfate	Early	Knife	52.5
Amm. Sulfate	Pod fill	Broadcast	53.2
Urea	Early	Knife	51.5
Urea	Pod fill	Broadcast	52.4

Table 2. Yield of irrigated soybeans as affected by time and method of application of urea fertilizer (N rate = 75 lbs. per acre)

APPLICATION TIME	APPLICATION METHOD	YIELD
		bu/acre
None	--	45.1
Early bloom	Broadcast	42.3
Early bloom	Foliar	42.4
Pod set	Foliar	31.8

Table 3. Soybean grain yield response to applied P fertilizer based on soil test category

BRAY-P1 OR OLSEN SOIL TEST P CATEGORY	PROBABILITY P FERTILIZER WILL INCREASE SOYBEAN GRAIN YIELD	EXPECTED YIELD WITHOUT P FERTILIZER
	----------------%----------------	
Very Low	40	90
Low	49	91
Medium	23	98
High	23	99
Very High	15	99

PHOSPHATE AND POTASH USE

The use of phosphate fertilizer can substantially increase soybean yield if soil test values for phosphorus are in the Low and Very Low ranges. The probability in which P application should increase the yield of soybean and the magnitude of the expected increase in grain yield is shown in **Table 3**. The probability of a response to P fertilizer in the Low and Very Low ranges has been found to be less for soybean than corn. This difference can be attributed to the prevalence of iron deficiency chlorosis in sites summarized in **Table 3**, which limited the potential for P fertilizer to increase yield. The reduction in soybean grain yield in the Very Low and Low soil P classes is such that P application is warranted despite the lower probability that a yield response will occur compared to corn. Phosphate fertilizer guidelines for soybean production are listed in **Table 4**. The guidelines for potash use are listed in **Table 5**.

Table 4. Phosphate fertilizer guidelines for soybean production in Minnesota

	Phosphorus (P) Soil Test (ppm)				
YIELD	BRAY: 0-5	6-10	11-15	16-20	21+
GOAL	OLSEN: 0-3	4-7	8-11	12-15	16+
----bu./ac----	--------------lbs. P_2O_5 / acre to apply*--------------				
< 30	50	30	0	0	0
30-39	60	40	0	0	0
40-49	70	50	0	0	0
50-59	80	60	0	0	0
60-69	90	70	0	0	0
70+	100	80	0	0	0

*Use the following equations to calculate phosphate fertilizer guidelines for specific yield and specific soil test values for P:

$P_2O_{5\ Recommended}$ = [1.752 - (0.0991) (Bray P, ppm)](Yield Goal)

$P_2O_{5\ Recommended}$ = [1.752 - (0.1321) (Olsen P, ppm)](Yield Goal)

No phosphate fertilizer is recommended if the soil test for P is greater than 10 ppm (Bray) or 7 ppm (Olsen).

Table 5. Potash fertilizer guidelines for soybean production in Minnesota

YIELD GOAL	Potassium (K) Soil Test (ppm)				
	0-50	51-100	101-150	151-200	200+
--bu./ac--	--------------lbs. K_2O / acre to apply*--------------				
< 30	55	35	20	15	0
30-39	65	50	30	20	0
40-49	80	60	40	25	0
50-59	100	75	50	30	0
60-69	110	85	60	35	0
70+	120	95	70	40	0

*Use the following equation to calculate potash fertilizer guidelines for specific yield goals and specific soil test values for K:

$K_2O_{\ Recommended}$ = [2.0 - (0.0088) (K Soil Test, ppm)](Yield Goal)

The recommended rates of phosphate and potash are not adjusted for placement. A summary of research in Minnesota and neighboring states leads to the conclusion that neither banded nor broadcast placement is consistently superior if adequate rates of phosphate and/or potash are applied. If moisture is adequate, soybean yields have usually been slightly higher if the recommended rates of phosphate and/or potash are broadcast and incorporated before planting.

The use of air seeders for planting soybeans is increasing in popularity. There are several options for placement of seed and fertilizer with this seeding method. One option involves mixing fertilizer and soybean seed in the same band. The soybean seed is very sensitive to salt injury. Therefore, placement of fertilizer in contact with soybean seed is a risky practice. Results of trials have shown that placement of any fertilizer in contact with the seed when both are in a narrow band reduces stand establishment. Any method of application that places at least one-inch of soil between fertilizer and seed is satisfactory.

No-till planting of soybeans raises special questions with respect to phosphate and potash fertilization. Phosphorus and potassium are not mobile in soils. Therefore, broadcast applications in no-till systems can be questioned. A substitute would be to band phosphate and/or potash fertilizers below the soil surface, then plant on top of the band. Results of research conducted at the West-Central Research and Outreach Center in Morris show that yield responses to phosphate fertilization in no-till production systems are the same for both banded and broadcast applications. The fertilizer incorporation that takes place in the planting operation seems to be adequate in many no-till planting systems.

REMOVAL-BASED MANAGEMENT OF P AND K

Table 6. Expected removal of phosphate and potash in harvested soybean grain at 13% moisture

	Median	Range
	-----lbs. per bushel-----	
Phosphate (P_2O_5)	0.69	0.62 to 0.74
Potash (K_2O)	1.10	1.04 to 1.15

Many growers would prefer to maintain soil test values for P and K in the Medium to High range to reduce the risk of yield loss due to insufficient P or K. This is especially true if they own, rather than rent, the land. There is justified concern that soil test levels for either P or K will drop substantially if low rates of phosphate or potash fertilizers are applied year after year and soils are not tested frequently enough to make adjustments for decreasing soil test values. In these circumstances, application of P and K based on crop removal may be warranted. Average removal of P and K for corn is listed in **Table 6**. High rates of P or K applied for maintenance will commonly result in a lower return in crop value per pound of nutrient applied. **The most economical use of P and K fertilizer is to only apply what is needed year-to-year.** It has not been shown that the build-and-maintain method is superior to the sufficiency approach for P and K management.

Strict crop removal of P and K may not provide sufficient nutrients for soils that test Very Low or Low for either nutrient. Extra P can be applied to build some soils to the Medium or High soil test category. A general rule of thumb is that 16-18 lbs. P_2O_5 and 7-10 lbs. K_2O are required to increase the Bray-P1 or ammonium acetate K tests by 1 ppm, respectively. However, the exact amount of P or K needed to build the soil test greatly depends on soil chemical properties. The rates of fertilizer suggested in Tables 4 and 5 should slowly build soils to the medium category beyond which removal rates of P or K can be used to maintain or slowly build soil test values to near critical soil test values.

For soils in western Minnesota where the Olsen P test is used, aggressively building soil test P values will not be cost effective due to the reaction of ortho-phosphate with calcium. Under these circumstances, applying only what the crop needs to maximize yield potential is recommended.

Table 7. Example P fertilizer guidelines for the use of crop removal when utilizing commercial P fertilizer sources (non-manure)

Bray-P1 test	Suggested Rate Ranges
(PPM)	
0-10	**See Table 4**
10-20	**100% Crop Removal**
20-30	**25-50% Crop Removal**
30-40	**0-20% Crop Removal**
40+	**No Fertilizer P recommended**

Excessive building of P increases the risk for P loss to the environment. The maintenance-based strategy for P application is outlined in **Table 7** indicated the STP range which is optimal for crop removal-based maintenance is within the Medium to High STP categories. This strategy suggests drawing STP down using P application based on partial crop removal in order to maintain STP in a more profitable, optimal zone. Soil test P ranges are not given for the Olsen P test as it may not be possible to build and maintain some high pH soils. The example in **Table 7** could be used for K. However, research has demonstrated increased seasonal variability in the soil K test. Collecting samples at the same time is critical to best evaluate maintenance-based strategies for K.

Yield data collected from combines equipped with yield monitors makes it easy to calculate nutrient removal by the crop on a yearly basis. Using the previous years' yield map to generate a P or K application map is not recommended due to potential high cost of fertilizer P and K, low probability of a profitable return on investment in Medium and High P testing soils, and general uncertainty as to the exact removal of nutrients per bushel of corn produced. A long-term average yield should be used in these circumstances. Recent long-term research has shown that P and K will build over time in the top six inches of soil when exact removal of the nutrients was applied.

Soil tests will decrease over time when no fertilizer is applied. Research in Minnesota has shown that soil test levels for phosphorus and potassium do not decrease rapidly if no fertilizer is applied. Long-term trends indicate the Bray-P1 test will decrease by 1-2 ppm per year. It is possible that soil test decreases can be greater due to extremely high starting P or K levels or due to some environmental factors. Having multiple sampling in the same area of a field over time is important when evaluating trends in soil test values over time.

P AND K APPLICATION TIMING

Timing of the phosphate application can be an important consideration when fertilizing soybeans. Many farmers who wish to save on fertilizer application costs apply P or K for the soybean crop ahead of a preceding crop. While it is okay to apply P or K directly ahead of the soybean crop, research has demonstrated that soybean is less sensitive to application timing within a two-year cropping system and will provide maximum yield as long at the rate of P or K applied to the preceding crop is sufficient for both crops in the rotation. An exception is situations where P can be quickly tied up. Soybean grown on soils with a pH of 8.0 or greater is more likely to respond to an application of P directly ahead of the soybean crop.

If phosphate is recommended and applied to soybean for fields having a pH of 7.4 or higher, the fertilizer should be applied in the spring before planting. This practice will reduce the time interval for contact between soil and fertilizer. This reduces tie-up of phosphorus and the soybean plant will make more efficient use of the applied phosphate. For more acidic soils (pH <7.4) the timing of P application is less important for soybean and more important for corn. Application of P ahead of corn for a two-year corn-soybean rotation can be effective at maintaining high yield levels for both crops as long as the correct amount of fertilizer is applied.

TIMING OF K APPLICATION AND THE IMPACT OF CHLORIDE ON SOYBEAN PRODUCTION

Potassium fertilizer is commonly applied as potassium chloride (KCl), which contains roughly 50% Cl^- by weight. High levels of chloride in the soil are known to reduce soybean grain yield in the southern United States. Recent research has shown a tendency to build chloride in some Minnesota soils, which can potentially reduce soybean grain yield. The potential for yield reductions due to Cl^- is tied to seasonal rainfall with a reduced impact occurring in years with above-normal rainfall.

Soybean varieties can vary in tolerance to high Cl^- in the soil but little is known about Cl^- tolerance of northern soybean varieties. Research in Minnesota has found that soybean grain yield tends to be higher when KCl fertilizer is applied ahead of corn in areas of western Minnesota. No long-term impact of K application timing in the rotation in central and eastern Minnesota has been found. However, small reductions in yield have been found in most areas of Minnesota on irrigated and non-irrigated soil when greater than 100 lbs of KCl were applied directly to the soybean crop. If K is needed for soybean production particularly on soils where Cl^- can build, no more than 100 lbs. of KCl fertilizer should be applied per acre in the fall or spring directly ahead of the soybean crop, with the remainder of fertilizer applied ahead of a rotational crop like corn or hard red spring wheat.

IMPACT OF CATION EXCHANGE ON SOYBEAN K GUIDELINES

Potassium fertilizer guidelines for soybean were revised based on recent research on medium- and fine-textured soils in Minnesota. Currently, these guideline rates are not adjusted based on a soil's ability to hold potassium on cation exchange sites of clays. Coarse-textured soils, such as sands and loamy sands, have very little clay and low cation exchange capacity (CEC). Potassium can leach on low CEC soils, potentially wasting K fertilizer and reducing the economic return on fertilizer costs. Research in Minnesota is ongoing to determine if K guidelines need to vary based on soil CEC. Recent research on sandy soils with a CEC around 5 meq per 100 grams showed sandy soils needed less potassium fertilizer than medium- and fine-textured soils with the same soil test K level and had a lower critical soil test level. Due to the K leaching potential and a lower critical level of low CEC soils, building soil test K greater than 120 ppm is not recommended. Until more research data are available, K fertilizer could be applied on low CEC soils using the equation below. However, use of this equation will reduce K fertilizer application rates on low CEC soils and should be done on a trial basis to ensure K is not limiting yield on irrigated soybean grown on low CEC sandy soils.

$K_2O_{\text{Recommended}}$ = [2.0 - 0.0146 (Soil Test K, ppm)] (expected yield)

SOYBEAN SULFUR NEEDS

Several research studies have evaluated the use of sulfur (S) for soybean in Minnesota. Soybean may respond to sulfur application by increasing plant growth but yields were almost never increased and in some circumstances were decreased. Sulfur is only suggested under the following circumstances:

- Fields with a history of reduced yield for crops susceptible to deficiency such as alfalfa and corn, soil organic matter in the top six inches is 2.0% or less, and no or very low rates of sulfur were previously applied on the field for many years.
- Irrigated and very sandy soils where the amount of sulfate applied through the irrigation water is low.

Under these limited circumstances, an application of 10-15 lbs. of S as sulfate may be warranted. In most cases, sulfate sulfur carried over from a previous application or mineralized from the soil will be enough for achieving maximum yield.

Application of sulfur in excess of soybean needs has been shown to increase sulfur containing amino acids cysteine and methionine but has not been shown to increase total protein concentration unless soybean grain yield is impacted by a deficiency of sulfur.

IRON DEFICIENCY CHLOROSIS

Frequently, soybeans grown on fields with a pH of 7.4 or greater turn yellow, and, in some cases, die. This condition is described as iron deficiency chlorosis (IDC). There is no deficiency or shortage of iron in the soil. Because of soil and/or environmental conditions, the soybean plant is not able to absorb or take up the amount of iron that is needed for normal growth and development.

There is no easy solution to the iron chlorosis problem. There are several management practices that can be used to reduce the severity.

Careful variety selection is of major importance. The University of Minnesota publication "Varietal Trials for Farm Crops" has chlorosis scores for many varieties. The majority of the companies that market soybean seed also provide chlorosis scores for their varieties.

Damage can be reduced if stress on the soybean plant is at a minimum. There are several factors that can stress soybean plants. Some that are easy to identify are: 1) use of some post-emergence herbicides, 2) soils with a high "salt" content, 3) root damage from excessively deep cultivation, 4) soil compaction, and 5) seedling diseases. It is important to eliminate or manage, as much as possible, the factors that place stress on the soybean plant. In addition, nitrate carried over from previous crops has been found to increase the presence of chlorosis, especially in less tolerant varieties.

Current research has shown that application of EDDHA-Fe chelates that contain most of the chelate in the ortho-ortho form may increase yields with an application of 1-3 lbs. of active ingredient per acre directly on the soybean seed at planting. Additionally, an oat companion crop seeded prior to planting at a rate of 1.5 bushels per acre and killed at 10 inches height has been shown to benefit soybean by reducing IDC for severely affected field areas.

It is recommended that growers in IDC-affected areas: 1) plant a tolerant variety, and 2) consider using either or both in-furrow EDDHA-Fe and an oat companion crop. Additional information on managing IDC can be found in University of Minnesota publication "Managing Iron Deficiency Chlorosis in Soybean".

OTHER POSSIBLE NUTRIENT NEEDS

Research has shown a link between glyphosate-tolerant soybeans and possible deficiencies of manganese and other micronutrients. Research trials conducted at several locations in Minnesota have shown that the soybean crop does not respond to the application of magnesium, zinc, or copper. Therefore, additions of these nutrients to a fertilizer program are not recommended.

BORON USE: In recent years, plant tissue analysis has been used to identify hidden nutrient deficiencies and help decide whether to apply in-season foliar nutrients. One nutrient consistently noted as potentially deficient in crops is boron (B). Soybean has a low tolerance to boron application and toxicity symptoms can show up with broadcast application rates as low as two lbs. B per acre. Research has not shown a positive benefit to boron applied to soybean. In fact, boron is more likely to reduce yield in soybean if application rates are too high.

MANGANESE USE: Soybean has been shown to respond to manganese (Mn) application in some areas of the U.S. where soils have been traditionally low in Mn. In Minnesota, research has not demonstrated a widespread need for Mn application. Recent data has indicated that soybean may respond to Mn when grown on soils with a pH greater than 7.4 and a DTPA soil Mn test, from a 0-6" soil depth, of 10 ppm or less. In these cases, an application of 10 lbs. Mn broadcast per acre may be warranted. Foliar application of Mn has not been tested and should be done on a trial basis. Research on more acidic soils with DTPA Mn soil tests of 10 ppm or less did not show a consistent benefit to Mn application to soybean.

Additional information about nutrient management in all crops can be found in the related publications listed below.

Additional Publications

FO-00794-Sulfur for Minnesota Soils
FO-00792-Phosphorus for Minnesota Soils
FO-00723-Boron for Minnesota Soils
FO-00725-Magnesium for Crop Production in Minnesota
FO-06288-Understanding Phosphorus Fertilizer
FO-06794-Potassium for Crop Production
FO-00720-Zinc for Crop Production
FO-5956—Lime Needs in Minnesota
FO-08670 Managing Iron Deficiency Chlorosis in Soybean

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