University of Idaho Extension

CIS 1189

Southern Idaho Fertilizer Guide

Beans

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Introduction

Fertility requirements for beans are relatively low compared with those of other irrigated Idaho crops due to the bean plant's ability to fix nitrogen (N) and its relatively short growing season. However, because a bean crop yielding 2,800 pounds per acre will typically take up 140 pounds of nitrogen (N), 37 pounds of phosphorus (P_2O_5), 43 pounds of potassium (K_2O), and 24 pounds of sulfur (S), providing optimal levels of nutrients is critical for achieving competitive bean seed yields. Also, because of their poor root systems, beans are more prone than other crops to react to micronutrient deficiencies and toxicities in soils.

This publication provides general fertilizer recommendations for commercial dry and garden bean production under southern Idaho conditions. All the recommendations were estimated using information from Idaho bean growers, from the previous University of Idaho bean fertilizer guide, and from fertilizer guides produced by universities in other bean-producing regions in the U.S. with climates and soils comparable to Idaho's. The recommendations assume no other external factors such as diseases, insects, etc., limit plant growth.

Use these recommendations as a baseline for your nutrient management program. The guidelines are designed to meet the needs of a typical bean field in Idaho; however, you should make adjustments if your crop's response is insufficient or deficiencies are evident.

Soil sampling

Effective soil sampling and soil testing are critical for establishing a cost-effective nutrient management plan. A soil sample that is representative of your field will provide important information on how to manage that field, while having a soil sample from just one spot in your field will provide information only on how to fertilize that spot.

For soil sampling a production field, we recommend collecting a minimum of one sample per acre, if possible. The samples from the field should be combined into one mixed composite sample. If your field has variations in crop growth, soil color, topography, etc., sample these areas separately if you plan to manage them differently from the rest of the field. Soil probes and soil augers are useful tools for extracting soil samples from the field.

To account for the typical depth of the bean root system, collect separate 1-foot and 2-foot soil samples at each sampling location. Soils from the 1-foot depth should be analyzed for soil pH, electrical conductivity (EC or soluble salts), ammonium-nitrogen (NH_4-N), nitrate-nitrogen (NO_3-N), Olsen phosphorus (P), potassium (K), sulfur (S), zinc (Zn), iron (Fe), and boron (B). Samples from the 2-foot depth should be analyzed for ammonium-N, nitrate-N, S, and B. Additional tests that may be included for the 1-foot-depth sample include copper (Cu), calcium (Ca), magnesium (Mg), and sodium (Na).

Ideally, you should sample your soils and submit them for analysis between 2 and 4 weeks prior to planting. Yearly soil testing is recommended for all nutrients, but it is most critical for ammonium and nitrate.

Store your soil samples in quart- or gallon-sized plastic bags in a refrigerator for no longer than a week prior to submitting them to a soil-testing lab. For more information on soil sampling, refer to *Soil Sampling*, University of Idaho Extension Bulletin 704.

Nitrogen management

Bean plants require nitrogen (N) for production of chlorophyll and proteins. Plants that do not receive enough N have limited growth and bean seed production. Nitrogen deficiency symptoms include yellowing of mature lower leaves and stunted growth. Excessive N, on the other hand, can cause delayed maturity, excessive vegetative growth, stem breakage, lodging, greater susceptibility to diseases, and inhibition of N fixation.

Nitrogen fertilizer rates

Although beans are legumes capable of fixing N, they still require N from other sources in order to produce optimal crop yields. The N fertilizer recommendations in table 1 reflect appropriate broadcast N fertilizer rates for a typical, well-managed commercial bean field in southern Idaho, with realistic yield goals ranging from 1,800 to 3,000 pounds of beans per acre. The recommended N rates are based on soil test inorganic N (ammonium and nitrate) in the top 2 feet and take into account average levels of N mineralization observed in a typical southern Idaho bean field.

Use the values in table 1 as a guideline. N requirements will vary based on bean variety, soil salinity, soil texture, geographical location, climate, irrigation, depth to hardpan, organic matter content, microbial activity, and other factors. Long-term monitoring of soil nitrate and ammonium concentrations and bean yield is recommended to determine optimal N requirements for specific fields.

Table 1. Total N broadcast fertilizer application rates for irrigated dry beans in southern Idaho based on soil test N (NO_3-N + NH_4-N) and realistic yield goals.

Soil test N	Realistic yield goal (lb/acre)			
(0-24")[a]	< 1800	2200	2600	> 3000
(ppm)	(lb N/acre)	(lb N/acre)	(lb N/acre)	(lb N/acre)
0	90	110	130	150
5	70	90	110	130
10	50	70	90	110
15	30	50	70	90
20	10	30	50	70
25	0	10	30	50
30	0	0	10	30
35	0	0	0	10
> 40	0	0	0	0

Notes:
- If banding fertilizer, reduce application rates by one-third to one-half.
- Following alfalfa, reduce N rates by 50 lb N per acre for alfalfa killed and incorporated the previous fall.
- Following small grains or grain corn, increase N rates by 15 lb N per acre per ton of straw residue returned to the soil up to a total 50 lb N per acre.

[a] When soil test values for the second foot are not available, multiply values from the first foot (0-12 inches) by 2.

Nitrogen fertilizer timing

A successful N fertility program for commercial bean production will generally include both pre-plant and in-season N fertilizer applications. Because nodules for N fixation are not formed and fully functional until approximately 20 days after seedling emergence, applying a portion of N fertilizer prior to planting can help to ensure successful establishment. We recommend a pre-plant application of up to 20 pounds N per acre, based on soil test N. Research has shown that N rates higher than this do not further improve seedling vigor.

Nitrogen use by the plant is greatest during seed formation; therefore in-season N fertilizer applications are a critical and necessary step toward achieving maximum bean yields. In-season N fertilizer applications must be carefully timed with bean seed production in the plant. The initial in-season N application can be side-dressed prior to the flowering stage, while subsequent applications can be made through an irrigation system. To preserve bean seed quality, all N applications need to be completed before top pod fill begins.

Nitrogen fertilizer placement

Pre-plant nitrogen fertilizer applications may be either surface broadcast or banded. Broadcast N fertilizer applications are most effective when followed by timely incorporation; otherwise, N losses of up to 50% due to volatilization (conversion of ammonium to ammonia gas) may occur.

Banding is generally considered to be a more efficient use of N fertilizer than broadcasting because the fertilizer is placed closer to the seed and is less likely to be lost through leaching or volatilization prior to being taken up by the plant. For this reason, N application rates listed in table 1 should be decreased by one-third to one-half for band applications. Optimally, the fertilizer band should be placed 2 inches below and 2 inches to the side of the seed row. To avoid seed damage, banding N rates should not exceed 20 pounds N per acre.

Inoculation with nitrogen-fixing bacteria

Bean plants are in the legume family and are therefore capable of symbiotically fixing atmospheric nitrogen gas (N_2). Nodules on the bean roots contain *Rhizobium phaseoli* bacteria that can convert nitrogen gas to a form of N the plant can use. A study from Kimberly, Idaho, showed that the N_2 fixation contributed up to 80 pounds N per acre, or 40 to 50% of the N in the bean plants at maturity.

A variety of factors can affect the ability of the bean plant to fix N. Several studies have shown that N fixation in bean plants decreases as N levels in the soil increase. Also, bean plants will slough off N-fixing nodules under adverse weather conditions (too hot, too cold, too wet, too dry, etc.).

Bean growers are often interested in applying *Rhizobium phaseoli* inoculum either to seed or soil to ensure effective N fixation by bean plants. In most cases, application of inoculums is not necessary because most soils that have had a history of bean production already contain sufficient populations. However, you may want to consider applying inoculum if:

- You have noticed few or no nodules on bean roots from previous bean crops
- This is the first time growing beans on a field in 5 or more years

- You are growing organic beans and have limited N sources

Varietal and market class effects

While 50% of the 2010 Idaho dry bean commercial crop acreage was pinto beans, the remaining 50% was divided among small red, pink, navy, great northern, and other bean classes. Beans vary widely in nitrogen needs, depending both on market class and on variety. For example, one study from USDA ARS in Kimberly, Idaho, showed that among 14 garden and dry bean varieties, the N fixation potential varied as much as six fold among the different varieties. In this study, the varieties with the greatest biomass had the greater potential for N use, and the greatest ability to fix N. We recommend working with your seed dealer for advice on how to change N application rates and other fertilizer application rates to account for potential varietal differences among both dry and garden beans.

Cropping history effects

Alfalfa. Reduce the recommended rates in table 1 by approximately 50 pounds per acre if alfalfa was killed and incorporated the previous fall season. Because excessive N in the soil can delay maturity in the bean plant, consider waiting at least 1 year before following alfalfa with beans, especially for soils with high soil nitrate levels (40 ppm or greater).

Small grains and grain corn. Following small grains or grain corn, increase the N rates in table 1 by 15 pounds N per acre per ton of straw residue returned to the soil up to a total of 50 pounds N per acre. To minimize microbial immobilization of fertilizer N, the best time to apply N following small grains is in the spring or in the fall after soil temperatures drop below 50°F.

Other crops. The majority of residues from potatoes, beans, and onions are decomposed in the soil by spring planting, and therefore no adjustments in the N recommendation are required. Fertilizer N remaining in the soil should be reflected in the soil test.

Phosphorus management

Dry beans need phosphorus (P) for energy, sugar, and nucleic acid production. Signs of P deficiency include stunted growth, dark green leaves that appear purplish, brown dead leaf tips, and delayed maturity. Purplish, dark-green leaves are more commonly noticed in younger plants due to the bean plant's greater need for P during early stages of growth and because cool, wet spring soils can limit P movement to roots. In southern Idaho, these symptoms become less severe as soil temperatures increase.

Plant-available P in the soil is determined using extraction methods specific to soil pH categories. The Olsen, or sodium bicarbonate, method is recommended for soils containing calcium carbonates (pH > 6.5), while the Bray I method is recommended for acidic soils (pH < 6.5). Confirm with your soil testing lab which P extraction method will be used in the analysis of your soil sample as P recommendations vary based on extraction method used.

Phosphorus fertilizer rates

Recommended broadcast P fertilizer rates are based on soil test P values and percentage free lime in the soil (table 2). The lime adjustment accounts for the reduced availability of P resulting from P precipitation by free lime.

Table 2. Phosphorus broadcast fertilizer application rates for irrigated dry beans in southern Idaho based on soil test P and percentage free lime in the soil.

Soil P test (0-12")		Percentage free lime			
Olsen P	Bray P	0%	4%	8%	12%
(ppm)	(ppm)	(lb P_2O_5/acre)			
0	0	160	200	240	280
5	7	120	160	200	220
10	14	80	120	160	200
15	22	40	80	120	160
20	29	0	40	60	80
25	37	0	0	0	40
> 30	44	0	0	0	0

Note: If banding fertilizer, reduce application rates by 50%.

Phosphorus fertilizer placement

Banding P is more efficient than broadcasting because P does not readily move in the soil. This is especially true in cool, wet, or compacted soils. Band-applied P also tends to be more soluble for a longer time than broadcast and incorporated P fertilizers.

If P is broadcast prior to planting, incorporate it to a depth of 4 to 6 inches to place it in the root zone. If P is banded prior to or during planting, decrease the rates in table 2 by 50% and place the band 2 inches below and 2 inches to the side of the seed row. Liquid ammonium phosphate (10-34-0) is an ideal P (and N) source for banded applications. Again, it is important to avoid contact with the seed because beans are sensitive to fertilizer salts.

Potassium management

Potassium is important for a variety of processes, including water and energy movement, photosynthesis, protein formation, and sugar movement in the bean plant. Stem strength has also been associated with K levels. Proper K levels in a bean plant may improve a plant's disease resistance and cold hardiness.

Signs of deficiencies can include white, yellow, or brown streaks or spots on only the outer edges of older leaves. Early stages of K deficiencies may be difficult to diagnose because a reduction in growth rate may be the only sign. Sandy soils are more likely to have lower

K levels, and therefore K deficiencies are more likely in sandy soils.

Approximately 50% of the K used by beans is removed from the field at harvest; therefore, it is important to avoid depleting the soil of K reserves. Soil K levels in southern Idaho are seldom low enough to limit bean production. Beans grown in rotation with other common Idaho crops such as corn, wheat, potatoes, or sugar beets will generally have sufficient K to meet their requirements. Recommended K application rates for optimal yields are listed in table 3.

Table 3. Potassium fertilizer application rates for irrigated dry beans in southern Idaho based on soil test K (Olsen or acetate).

Soil test K (0-12")	Application rate
(ppm)	(lb K_2O/acre)
0	200
60	100
90	50
> 120	0

Sulfur management

Sulfur (S) is important in beans because it is used in protein and chlorophyll synthesis, and it assists the plants with utilizing P and other nutrients. Sulfur is also essential for nodulations and N fixation.

Signs of sulfur deficiency are usually seen in younger leaves as opposed to older leaves. They include the yellowing and stunting of growth common in deficiencies of other nutrients such as N. While beans are more susceptible to S deficiencies than other Idaho crops, S deficiencies are still rare due to sufficient S in most irrigation water, industrial emissions, and dairy manure applications. Areas that are susceptible to S deficiencies include sandy soils, soils low in organic matter, and areas receiving irrigation water that is low in S.

If a soil sample from the first 2 feet contains less than 6 ppm S and irrigation water is known to be low in S, then beans may respond to fertilizer applications of 20 to 30 pounds S per acre. Sulfur may be applied with other fertilizers (ammonium sulfate, potassium sulfate, etc.) or as elemental S, which is commonly applied to Idaho soils as a soil-acidifying agent.

Foliar fertilization

Foliar fertilization is a fertilizer application method that can be used to remedy in-season micronutrient deficiencies. Effective transport of the nutrient into the plant can be achieved when you follow the following tips:

- Add a spreader sticker or surfactant to the fertilizer solution to maximize adhesion to the leaf surface.
- Spray the leaves to get them wet.
- Apply micronutrient foliar fertilizers before July 15 in Idaho to minimize yield losses.

Although foliar fertilization may eliminate visual deficiency symptoms, bean yields may not be affected. Plants are more effective at taking up nutrients through the roots than through leaves; therefore, pre-plant applications are generally more effective than foliar applications.

Zinc management

Zinc (Zn) plays an important role in internode elongation, flowering, and seed setting. Dry beans crops are particularly sensitive to Zn deficiencies. Zinc deficiencies can show up as bronzing, browning, interveinal chlorosis, mottling, trifoliate curling, and death of leaf tissue. Deficiency symptoms are most likely seen in leaves mid-plant. Zinc deficiencies can delay maturity, decrease yields, and lead to increased frost damage. Late-maturing varieties appear to be more susceptible to Zn deficiencies than early maturing varieties.

Zinc deficiencies in beans are more prevalent than deficiencies of any other micronutrient. A study conducted in 58 bean fields in southern Idaho showed that Zn was the only micronutrient in the plant tissue that was not at adequate concentrations for optimal yields.

Soil conditions common to Zn deficiencies in beans include exposed subsoils, sandy soils, compacted soils, soils with high lime contents, soils with heavy straw residues, and soils that have received excessive applications of P fertilizer. Research by the USDA Agricultural Research Service in Kimberly, Idaho, has also shown a greater potential for Zn deficiencies following both fallow and sugar beets due to the reduction of mycorrhizal colonization in these soils. (Sugar beets are a non-host for mycorrhizae, and the availability of Zn and other plant nutrients is aided by mycorrhizal associations).

Soil tests can be used to avoid Zn deficiencies in beans. Recommendations for preplant application of Zn fertilizers, based on soil test Zn levels, are listed in table 4.

Zinc can be applied to the soil as Zn salts such as Zn-sulfate or Zn-chelate. Manure applications can also help to resolve Zn deficiencies in beans. Pre-plant applications of Zn are preferable to foliar applications, as the applications are cheaper, easier, and will provide Zn to the plant roots throughout the season as needed. While Zn availability is limited in alkaline soils (soil pH greater than 7.5), the use of chelated Zn fertilizers allows Zn to enter the plant roots without reacting with carbonates and other soil compounds.

While less common and more labor intensive than soil testing, plant tissue analysis can be useful for identifying Zn deficiencies during the growing season. Zinc tissue levels should be greater than 30 ppm in plant tops at the bloom stage.

Deficiencies of Zn detected during the season can be treated with foliar sprays of zinc sulfate, zinc chelate, or ammoniated zinc solutions. Foliar applications of zinc in the first 6 weeks of growth have been effective in preventing Zn deficiencies. Zinc sulfate can be applied as a foliar spray (3 to 4 pounds per 100 gallons of water) at between 10 and 40 gallons per acre to correct a zinc deficiency.

Table 4. Zinc fertilizer application rates for irrigated dry beans in southern Idaho based on soil test Zn (DTPA).

Soil test Zn (0-12")	Application method: Broadcast	Application method: Banding
(ppm)	(lb Zn/acre)	(lb Zn/acre)
0.0–0.5	10	5
0.5–1.0	8	4
1.0–1.5	6	3
1.5–2.0	4	2
> 2.0	0	0

Iron management

Iron (Fe) is important in the bean plant for chlorophyll production. Iron deficiencies often appear as interveinal chlorosis in new leaves on the upper portion of the plant. As the deficiency progresses, whole leaves can appear yellowish-white. Like P, Fe is less available for plant use during cool, wet spring conditions. Also like P, Fe deficiencies will fade with warmer weather. Iron deficiencies are more likely in highly calcareous soils, in soils with a pH of 7.5 or greater, in soils with low levels of organic matter, following sugar beets, or under high nitrate (NO_3-N) soil test levels.

Fe deficiencies may be corrected with pre-plant applications of Fe-chelate or Fe-sulfate fertilizers. Recommendations for preplant application of Fe fertilizers, based on soil test Fe levels, are listed in table 5. Iron deficiencies may also be corrected through foliar spraying with 1 to 2% ferrous sulfate solution at the rate of 20 to 30 gallons per acre.

Market-class selection can be a useful management tool for avoiding Fe deficiencies. For example, small-seeded bean varieties (black and navy) are more susceptible than medium-sized seeds (pinto, great northern, pink, and small reds). To avoid Fe deficiencies in beans, select varieties developed on alkaline soils in the western U.S. as these varieties are more tolerant to Fe deficiencies than those developed on acidic soils.

Table 5. Iron fertilizer application rates for irrigated dry beans in southern Idaho based on soil test Fe (DTPA).

Soil test Fe (0-12")	Fertilizer rate
(ppm)	(lb Fe/acre)
0–2.5	4
2.5–5.0	2
> 5.0	0

Manganese management

Although manganese (Mn) deficiencies are very rare in Idaho, beans do have a relatively high requirement for manganese compared with other crops. Soils that are well-drained, alkaline, and low in organic matter are especially susceptible to Mn deficiencies. Recommendations for preplant application of Mn fertilizers, based on soil test Mn levels, are listed in table 6. Like deficiencies of Fe and Zn, Mn deficiencies can be corrected with preplant applications of Mn chelated fertilizer or Mn sulfate fertilizer or with foliar Mn applications.

Table 6. Manganese fertilizer application rates for irrigated dry beans in southern Idaho based on soil test Mn (DTPA).

Soil test Mn (0-12")	Fertilizer rate
(ppm)	(lb Mn/acre)
0–0.5	20
0.5–1.0	10
> 1.0	0

Boron and arsenic management

Beans are far more susceptible to boron (B) toxicities than B deficiencies, which have not been documented in Idaho. Beans have a soil test tolerance limit for B of 0.50 ppm, compared to 5.0 ppm for alfalfa and 1.0 ppm for wheat. Boron toxicity symptoms include yellowing of leaf tips, yellow between the veins, and progressive scorching or death of leaf margins. Toxic levels of B in bean plant tissue are 100 ppm or greater; sufficient levels are between 20 and 50 ppm. Soil testing for B is recommended at least once every 5 years to confirm that B levels are not high enough to cause B toxicity issues.

Beans are very sensitive to residual soil arsenic (As), generally derived from historic applications of lead arsenate insecticides. Because As residues are inorganic and non-mobile, they don't decompose in the way that organic pesticides do, and they can remain in the soil for a very long time. High As concentrations are common at the sites of old fruit orchards.

High amounts of fertilizer P can reduce the effects of As by competing with As for uptake by the plant, but this generally only lessens the effect. Deep plowing can also help push As away from the root zone in the soil profile, but it is costly.

Soil properties

In addition to managing nutrients, selecting fields with the appropriate soil type is very important for bean production. Dry beans are one of the most sensitive crops to soluble salts, and they prefer soils that are very low in salts.

Saline soils can affect bean plant germination and emergence. Salt-affected plants may have stunted growth with thick, dark-green leaves that appear burned around the edges. Dry beans show crop injury and yield reduction in soils with electrical conductivity (EC) greater than 2.0 deciSiemens per meter (dS/m), with the potential for severe yield losses in soils with EC greater than 3.5 dS/m. (EC is a common measurement used to indicate soil salinity levels.) Optimal EC for beans is between 0 and 1.0 dS/m.

While sodium issues, which differ from saline issues, are relatively uncommon in Idaho, sodium adsorption ratios (SAR) greater than 4 may also trigger yield losses. For information on how to most effectively manage a saline or sodic soil, refer to *Managing Salt-Affected Soils for Crop Production*, Pacific Northwest Extension Publication 601.

In addition to salt sensitivity, beans are sensitive to soil types that are poorly aerated, which do not allow for penetration of the bean plant's poorly developed root system. For example, beans are not tolerant of crusting, compaction, hardpans, or flooding. Clayey soil textures are also challenging for the bean root system.

Beans also struggle on extremely sandy soils, in which the shallow bean roots cannot adequately access water and nutrients for growth.

Cultural practices

Irrigation

Irrigating beans and other crops in amounts exceeding evapotranspiration rates has been shown to increase nitrate leaching potential and irrigation costs. Such losses can potentially reduce yields while increasing negative health and environmental impacts. Information on managing irrigation can be found in the publication *Irrigation Scheduling*, Pacific Northwest Extension Publication 288.

Use of manure and compost

Due to the expansion of the dairy industry in southern Idaho, dairy manures and composts are widely available for use in the region's bean and other crop fields. Dairy manures and composts are effective sources of P and K for plants, with an estimated 70% of P and 90% of K in the manure or compost available to plants shortly after application and incorporation. The plant availability of N in manure or compost, however, is an estimated 0 to 30%, depending on their stage of decomposition, straw content, and ammonium concentration, the length of time since the last application, and how quickly the material was incorporated into the soil. Because dairy manure and compost are relatively low in N, supplementation with other N sources may be necessary to meet the N requirements of the plant. To estimate N, P, and K availability from manures and composts, refer to *Estimating Plant-Available Nitrogen from Manure*, Oregon State University EM 8954-E.

Research has shown that manure applications can increase bean yields. In a study conducted in Kimberly, Idaho, soil organic matter and zinc tissue concentrations were both significantly higher on manure-treated plots than control plots, suggesting that manure applications improved Zn uptake, which improved yields.

When possible, we recommend that growers have their manure and compost tested prior to application, as nutrient concentrations can vary drastically from one pile to the next. Manures and composts should be tested for total N, ammonium-N, total P, and total K. Additional testing for soluble salts (also referred to as electrical conductivity or EC) and micronutrients may also be necessary. For an updated list of certified manure testing laboratories, refer to http://www2.mda.state.mn.us/webapp/lis/manurelabs.jsp.

Fertilization of organic bean crops

Organic growers in southern Idaho often include beans in their crop rotations. One of the benefits of growing organic beans is their relatively low nutrient requirement, as locating organic nutrient sources can be challenging. In general, the most common nutrient sources for organic crops in Idaho are dairy compost (see preceding section) and green manures.

Common green manures include perennial legumes (alfalfa), annual legumes (Austrian peas, hairy vetch), and annual non-legumes (wheat, barley, canola, mustard, radish). Other nutrient options include other animal manures and composts, fish emulsions, canola meal, soybean meal, kelp, and feather meal. Any raw (non-composted) animal manure must be applied a minimum of 120 days prior to bean harvest.

Rock phosphate is an allowable P source for organic production. However, rock phosphate does not easily dissolve in the alkaline soils of southern Idaho; therefore, it is not generally considered an effective P source for most fields in our region.

One of the most plant-available N sources for organic crop production is Chilean nitrate (sodium nitrate or nitrate of soda), although applications are limited to 20% of a crop's total N requirement. However, several countries do not consider Chilean nitrate to be an acceptable material for organic crop production. As of January 2012, Chilean nitrate was under evaluation by the USDA's National Organic Program to be allowed to remain on the "allowable materials list." For the latest information on allowable nutrient sources and products for certified organic crop production, refer to the Organic Materials Review Institute website at: https://www.omri.org/. Contact your organic certifier to confirm that your fertilizer sources are organic.

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Further Information

Idaho Nutrient Management Website, University of Idaho Extension. www.extension.uidaho.edu/nutrient/ crop_nutrient/beans.html

Organic Materials Review Institute Website. http://www.omri.org

Estimating Plant-Available Nitrogen from Manure, Oregon State University EM 8954-E. http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/20528/em8954-e.pdf

Irrigation Scheduling, Pacific Northwest Extension Publication PNW 288. http://ir.library.oregonstate.edu/ jspui/bitstream/1957/15998/1/pnw288.pdf

Managing Salt-Affected Soils for Crop Production, Pacific Northwest Extension Publication PNW 601-E. http://extension.oregonstate.edu/catalog/pdf/PNW/PNW601-e.pdf

Monitoring Soil Nutrients Using a Management Unit Approach, Pacific Northwest Extension Publication PNW 570. http://extension.oregonstate.edu/catalog/pdf/PNW/PNW570-E.pdf

Soil Sampling, University of Idaho Extension Bulletin 704. http://www.cals.uidaho.edu/edcomm/pdf/EXT/EXT0704.pdf

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Published June 2012