BUL 935

Southern Idaho Fertilizer Guide: Sugar Beets

Olga S. Walsh
David Tarkalson
Amber Moore
Greg Dean
David Elison
Jeffrey Stark
Oliver Neher
Bradford Brown

Contents

This paper updates *Southern Idaho Fertilizer Guide: Sugar Beets*, University of Idaho Extension Publication CIS 1174, https://www.extension.uidaho.edu/publishing/pdf/CIS/CIS1174.pdf.

University *of* Idaho Extension

Introduction

SUGAR BEETS ARE ONE OF THE MAJOR RAW MATERIALS for sugar manufactured in the United States. Idaho—one of eleven U.S. sugar beet–producing states—ranks second nationally in production of sugar beets. The sugar beet industry contributes 1.7% of the Idaho gross state product. Idaho growers plant sugar beets on about 170,000 acres annually, with a ten-year average of 169,000 acres. Oregon growers increased their sugar beet acreage from 7,800 in 2015 to 10,700 in 2016. Since most Oregon sugar beets grown in the eastern part of the state experience conditions close to those in Idaho, the current guide is applicable for both Idaho and Oregon sugar beet recommendations.

Three Idaho sugar beet factories in Nampa, Twin Falls, and Paul process 12,000, 6,800, and 17,000 tons of sugar beets, respectively, per day. Currently, typical sugar beet yield across the state is about 35 tons per acre. In 2015, growers produced a record 38 tons per acre sugar beet yield, up from 37.5 tons per acre in 2014. Record yields of 41.4 tons per acre were achieved by Idaho sugar beet growers in 2016. According to the Joint Finance-Appropriations Economic Outlook & Revenue Assessment Committee, sugar beets are typically the fourth most profitable crop grown in Idaho after potatoes, wheat, and hay, in terms of cash receipts. Sugar beet profits are based on three key factors: beet yield, sucrose content, and sucrose recovery efficiency. Nutrients, especially nitrogen (N), can affect all three factors.

Optimizing beet sugar yields can be a challenge. Nitrogen deficits in the soil can reduce sugar beet root and sugar yields. Excess N in the soil can reduce sucrose content while lowering sucrose recovery due to higher nitrate impurities. Although easier to manage than N, maintaining adequate amounts of phosphorus (P), potassium (K), sulfur (S), and micronutrients is also critical for achieving optimum sugar yields. Figure 1 shows in-season nutrient uptake by sugar beets.

In the past, N recommendations have been traditionally made using a standard 8 lbs per historical expected ton

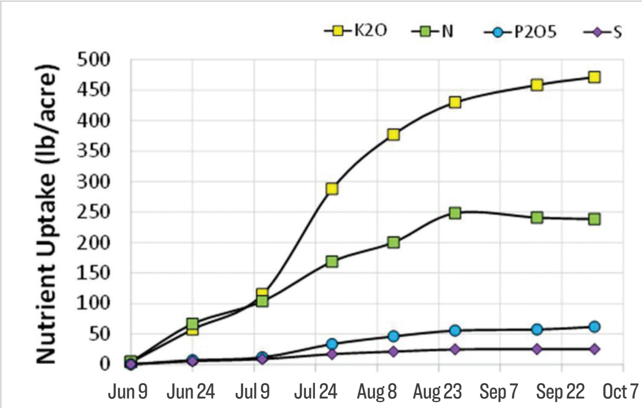

Figure 1. Nutrient uptake of sugar beets throughout the growing season (Amber Moore, unpublished data).

(five-year average) of sugar beets. This standard was established through systematic N response trials across Idaho. Based on the most current information available, this guide contains updated recommendations for fertilizer applications needed to achieve optimum sugar beet yields, information on farming practices that impacts nutrient availability. It also provides suggestions on how to improve nutrient use efficiency and lower input costs for a sugar beet cropping system.

Soil Sampling

An accurate, representative soil sample is important for developing a fertilizer recommendation. Details on effective soil sampling practices, including number of subsamples, sampling equipment, and sampling location selection, can be found in *Soil Sampling*, University of Idaho Extension Bulletin 704.

It should be noted that sugar beets can extend roots to a soil depth of 5 ft or greater. For this reason, soil samples should be retrieved in 1-ft increments to a depth of 3 ft, unless a restrictive layer inhibits moisture below that level. For accurate results, soil sampling is best done 2–4 weeks prior to preplant fertilizer applications. Residual nitrate levels can be accessed through grid- or zone-based soil sampling.

Grid soil sampling should be used if the field history is unknown, if the fields have historically high fertility, if they have a history of manure applications, or if several fields have been combined into one. *Zone soil sampling* should be used if the yield monitor information or remote imagery shows a pattern relationship with the landscape, or the field has no history of manure use.

To observe long-term changes in soil fertility, soils should be sampled and tested at the same time every year.

Nitrogen Fertilization

Sugar beet seeds contain adequate N reserves to sustain the plant through germination and emergence. Once the seedling reaches cotyledon stage, N in the soil is accessed by plant roots for leaf (canopy) development. Adequate N is needed at this stage for optimum seedling growth and canopy development to maximize light interception. However, once the sugar beet root and the canopy have developed, continued uptake of N from the soil can stimulate excessive canopy growth at the expense of the sugars stored in the root. In other words, higher sucrose content in beet roots is normally related to low-available N during late growth.

Because of their expansive root systems, sugar beets have a tendency towards luxury N consumption. Excessive N fertilizer, especially later in the growing season, can divert photosynthate sugars normally used for beet root growth and sucrose accumulation to unnecessary top growth, and result in increased nitrate concentration, salts, and other impurities in the beet. Unfortunately, growers often wrongly associate a vigorous sugar beet canopy with high yields, thus tempting growers to apply N in excess for optimal sugar production amounts. Brei nitrate concentrations are directly related to excessive soil N.

Impurities, such as N, stored in the sugar beet root, hinder sugar extraction, which decreases the quantity of recovered sugar from the harvested beet and increases sugar extraction costs. Brei nitrate concentrations, or concentrations of remaining nitrate impurities in the beet root, should not exceed 200 ppm to optimize sugar content in the beet (Figure 2). The figure below shows that sugar content tends to decrease by 0.5% for every 100 ppm of brei nitrate.

As reported by the Amalgamated Sugar Company (TASCO), the use of new glyphosate-resistant varieties and more stringent nutrient regulations resulted in decreased overall brei nitrate content in sugar beets (Figure 3).

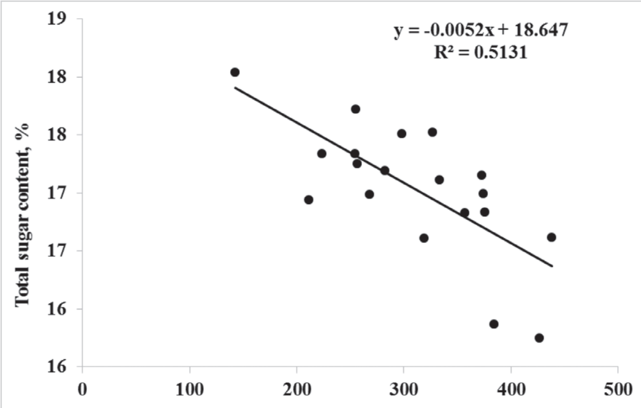

Figure 2. Relationship between brei nitrate and sugar content in sugar beets, 1998–2016 (TASCO).

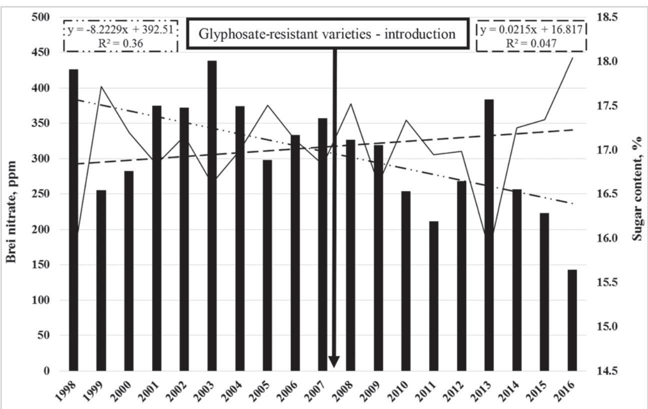

Figure 3. Relationship between brei nitrate (columns) and sugar content (solid line) in sugar beets, 1998–2016 (TASCO). The trends are shown in dash lines (---) for brei nitrate, and dash-dots for sugar content (–··–).

Nitrogen Losses

Excessive N application also can be associated with N losses, including leaching, runoff, denitrification, volatilization, plant loss, and immobilization. For detailed information on reducing N losses and improving N fertilizer use efficiency, please review *Improving Nitrogen-Use Efficiency in Idaho Crop Production*, University of Idaho Extension, Bulletin 899.

Nitrate leaching—the movement of nitrates into groundwater and waterways—not only poses serious environmental and health risks, but also represents an economic loss to growers.

Common N fertilizer sources for sugar beet production are chemical fertilizers [urea, ammonium sulfate, mono-ammonium phosphate (MAP), urea ammonium nitrate (UAN)], and organic fertilizers (manure and composts). Organic N fertilizers must be converted, or mineralized, by microbes to nitrate and ammonium. Chemical N fertilizers comprised mostly of urea, or nitrate and ammonium, represent plant-available forms of N. Research by Stanford et al. (1977) has shown that between 15% and 22% of soil organic N in southern Idaho soils would be converted to plant-available forms over a typical growing season for sugar beets.

Yields and Fertilizer Rates

The N fertilizer recommendations in Table 1 reflect appropriate fertilizer rates for a typical commercial sugar beet field in southern Idaho. These values take into account average levels of N use efficiency, N mineralization, and soil N variability observed in growers' fields. The recommended N rates are based on yield goal and soil test inorganic N in the top 3 feet. To avoid overfertilization, select a realistic yield goal by averaging the three best beet yield years out of five years of sugar beets produced on a given field.

The values in Table 1 should serve only as a guideline and not as an absolute recommendation, since N requirements will vary based on factors such as geographical location, climate, soil type, soil organics matter content, microbial activity, water table height, irrigation type, and so on. Long-term monitoring of soil nitrate and ammonium concentrations, beet sugar content, brei nitrate concentrations, and beet tonnage is recommended to determine optimal N requirements for any given field.

Collaborative research conducted by the United States Department of Agriculture-Agricultural Research Service and TASCO in 2005–10 has shown that, on heavier-textured soils (sandy loams to clays), it is recommended to apply no more than 6 lbs N per ton of beet (Table 1). In most cases, an N requirement of 4.5–5.5 lbs N/ton will be optimum. On coarse-textured soils (loamy sands to sands) and/or underfurrow irrigation, up to 7 lbs N per ton of beet may be required (Table 1 recommendation + 1 lb N per ton of beet.) Adjusted sprinkler irrigation timing that reduces water leaching could result in a lowered requirement on these soils (i.e., 6–6.5 lbs N per ton of beet).

Previous research has shown that the sucrose percentage was comparable for furrow- and sprinkler-irrigated sugar beets. Higher N rates were associated with a decrease in the sucrose percentage for both furrow and sprinkler irrigation (Carter et al., 1971).

Table 1. Nitrogen requirements for sugar beets grown under southern Idaho conditions. Recommendations are based on applying 6 lbs N per ton of beet based on the most recent research data on soils textures ranging from clays to sandy loams. For sandier soil textures ranging from loamy sands to sands, add 1 lb N per ton of beet on top of the table-recommended amount. The calculated values were determined as follows: (Yield Goal x 6) – [(N ppm 1st foot + N ppm 2nd foot + N ppm 3rd foot) x 4].

Soil test	Realistic yield goal (beet tons/acre)								
N[1] (ppm)	25	30	35	40	45	50	55	60	65
	N application rate (lb N/acre)								
0	150	180	210	240	270	300	330	360	390
5	130	160	190	220	250	280	310	340	370
10	110	140	170	200	230	260	290	320	350
15	90	120	150	180	210	240	270	300	330
20	70	100	130	160	190	220	250	280	310
25	50	80	110	140	170	200	230	260	290
30	30	60	90	120	150	180	210	240	270
35	10	40	70	100	130	160	190	220	250
40	0	20	50	80	110	140	170	200	230
45	0	0	30	60	90	120	150	180	210
50	0	0	0	40	70	100	130	160	190
55	0	0	0	20	50	80	110	140	170
60	0	0	0	0	30	60	90	120	150
65	0	0	0	0	0	40	70	100	130
70	0	0	0	0	0	20	50	80	110
75	0	0	0	0	0	0	30	60	90
80	0	0	0	0	0	0	10	40	70
90	0	0	0	0	0	0	0	0	30
95	0	0	0	0	0	0	0	0	10
100	0	0	0	0	0	0	0	0	0

[1]Soil test N = Sum of nitrate-N (NO_3-N) and ammonium-N (NH_4-N) in the first, second, and third 3 ft of the soil. When soil test values are not available for 2nd and/or 3rd foot of soil, multiply the first foot by 2 and add the value to the 1st foot.

Nitrogen Fertilizer Timing

To maximize N use efficiency and to minimize N leaching and losses, the most efficient and effective time to apply N fertilizer is in the spring, prior to planting. Smith et al. (1973) found that nitrogen uptake by beets and total uptake by beets and tops were greater for spring applications than for fall applications, while the total percentage of N in the beets was not affected. Also, ammonium derived from fall-applied urea, especially at rates of 200 lb N/acre or greater, may be slow to convert to nitrate via nitrification over the winter, as cold temperatures and dry conditions inhibit the nitrification process. Excessive concentrations of ammonium in the soil can be toxic to germinating seedlings.

Splitting N fertilization between preplant and in-season applications has been shown in some cases to increase beet tonnage, sugar content, and economic returns, especially on sandy soils. Split applications may also limit loss of applied N to the environment and increase N use efficiency. However, applying N to beets grown on most soils other than sands after the 4-6 true leaf stage will likely cause excessive nitrate accumulation later in the season, which can lower sugar content and increase impurities, as described above. Numerous studies have shown that for all soils except sands, the early application of N to sugar beets is most favorable. The lag time for conversion of ammonia fertilizers limits sugar beet canopy formation and development at critical growth stages early in the growing season. Thus, regardless of N application timing, N needs to be tailored to be available to sugar beet plants by the 4-6 true leaf growth stage.

Cropping History

Knowing the crop history is important so that nutrient availability from crop residue and prior fertilization practices may be taken into account when determining the fertilizer recommendation. Factors to consider are as follows: manure or compost application timing before crop uptake, irrigation methods, other fertilization practices, previous crops, date of residue plow down for grain and green manure crops, and disease, weed, and insect pressure.

Small Grains

Following small grains (or grain corn), the N recommendation is increased by 15 lb N/acre per ton of straw residue returned to the soil up to a total of 50 lb N/acre. The optimum practice is to apply N fertilizer in the early fall, incorporate fertilizer with the small-grain residue, disk, and rollerharrow, and irrigate the field to facilitate decomposition during favorable temperatures and before the soil cools as it nears the winter months.

Summer Fields

Small grain residues incorporated in summer in fields with adequate soil moisture should partially decompose by late fall, leaving less residue affecting N immobilization during the sugar beet growing season.

Poor Straw Residue Distribution

Poor straw residue distribution behind larger grain combines (with wider headers) can leave chaff rows that can reduce available N. The position of chaff rows are frequently evident the following season if applied N fertilizers don't completely mask their effects. These chaff rows make it difficult to uniformly apply fertilizer to equally satisfy the N requirements of sugar beets in and between the chaff rows. For more information on wheat residues and N, refer to *Wheat Straw Management and Nitrogen Fertilizer Requirements*, University of Idaho Extension Publication, CIS 825.

Following Alfalfa

Including alfalfa in a rotation will significantly reduce the need for fertilizer N application for the following crop. The N recommendation in Table 1 should be reduced 80–100 lb per acre for alfalfa killed and incorporated the previous fall, depending on the alfalfa growth at the time of its killing. It is recommended to delay sugar beet planting for at least one month following spring-terminated alfalfa to allow for adequate green manure decomposition. Poor sugar beet stands are often observed with planting sugar beets immediately following alfalfa due to the difficulty of achieving a good seedbed uniformity and the factor of alfalfa persistence, even after plowing under.

Other Crops

The majority of residues from potatoes, beans, and onions is decomposed in the soil by spring planting, and therefore no adjustment in the N recommendation is required. Fertilizer N remaining in the soil should be reflected in the soil test. Soil testing in spring prior to planting sugar beets is highly recommended to determine the soil residual N level.

Cultural Practices

Irrigation

Irrigating sugar beets and other crops in amounts exceeding evapotranspiration rates has been shown to increase nitrate leaching potential and irrigation costs. On shallow, coarse soils with perched water tables, such losses can potentially reduce yields while increasing negative health and environmental impacts.

Information on managing irrigation for optimal sugar beet production can be found in the publications *Sugar Beet Irrigation Management—Using Watermark Moisture Censors*, University of Idaho Extension Publication CIS 1140, and Irrigation Scheduling–PNW 288.

Tillage Method

Traditionally, moldboard plowing has been the most common method of tillage in sugar beets. However, glyphosate-resistant sugar beets, introduced to the market in 2008, have motivated some growers to switch to strip-tillage when planting into small-grain or alfalfa residues because intensive plowing and cultivation are no longer needed for weed control. As previously mentioned, N fertilizer rates need to be increased 15 lb N/acre per ton of small-grain residue to compensate for immobilization of plant-available N.

Preliminary results from Agricultural Research Service Kimberly indicate that tillage method (moldboard plow, chisel plow, or strip tillage) had no significant effect on beet tonnage or sugar content during the first year of implementation. However, if sugar beets are grown in rotation with other no-till or strip-till crops, long-term effects of conservation tillage may improve crop production in sugar beets. Research from Montana, North Dakota, and Nebraska illustrates that over 6–12 years, organic matter, N content, and wheat yields were significantly higher in no-till and/or minimum-tilled soils compared to tilled soils.

Broadcasting Fertilizers

Broadcasting fertilizers into a minimum-till system with surface residues can cause ammonia volatilization of urea N and stratification of P and K. To avoid these issues, use subsurface fertilizer applications in strip-till systems. Strip-tillage equipment can often be outfitted to shank or band N during tillage. Finally, when feasible, increase soil nutrient levels prior to strip tillage. For more information, refer to *Nutrient Management in No-till and Minimum Till Systems*—Montana State University Extension Publication, EB0182.

Tillage Timing

A study by Tarkalson et al. (2015) found that sucrose and beet yields were not different between fall and spring tillage timings. This suggests sugar beet growers have flexibility in timing their tillage practices. The findings were true for both conventional and strip-tillage systems. However, there are times when strip tilling in the spring must be delayed due to high soil moisture, especially during a cool wet spring.

If residues of small grains are fully incorporated into the soil, early incorporation will reduce immobilization of fertilizer N applications. For example, Smith et al. (1973) found in a study near Kimberly, Idaho, that plowing straw into the ground in September increased the sucrose percentage and yield and decreased impurities in comparison to November plowing. Early incorporation provides additional time and heat units for the residues to decompose before the sugar beets are fertilized. Greater decomposition of incorporated residues reduces the potential for N immobilization. Residues incorporated late may require additional N fertilizer to satisfy sugar beet N requirements. The effects from the seasonal timing of strip tillage have yet to be fully determined.

Cattle Manure Applications

The overlap between sugar beet field production and the dairy industry in southwestern and south-central Idaho has created the opportunity for sugar beet growers to work with dairy manure as a potentially beneficial soil amendment. Please note that interactions between animal manures, soils, and crops are complex, and therefore further evaluation may be needed. The nutrient content of manure is highly variable and needs to be taken into account when making manure application recommendations. A crop consultant, company agronomist, or University of Idaho Extension faculty member may be able to give further guidance.

Fields with Cattle Manure Application History

Primary concerns for sugar beet production in fields that have a history of cattle manure applications are late-season release of N and soil salinity. The late-season release of N from organic N compounds in the manure can lower sugar content due to increased top growth and decreased sugar storage. Soluble salts (commonly measured as soil EC [electrical conductivity]) can increase beet EC levels, which are an indication of impurities. As mentioned previously, impurities impair the sugar extraction process.

Recent findings from a study conducted at Kimberly, Idaho, in sugar beets grown on manured and fertilizer-treated soil have linked a direct correlation between increasing soil test P above 40 ppm (Olsen method), decreasing beet sugar content, and increasing brei nitrate content. Increasing soil test P and mineralizable N pools were also well correlated, suggesting that manured soils with high Olsen P levels also have similarly large pools of mineralizable N. For southern Idaho fields that have a history of stockpile dairy manure applications, it is recommended that sugar beet growers keep Olsen P soil test levels below 40 ppm (first foot depth) for sugar beet production, to avoid sugar content losses related to potentially excessive late-season releases of mineralizable N. This recommendation does not apply to regions beyond southern Idaho. This recommendation should also not be applied to fields that do not have a history of cattle manure applications, as this relationship between P and N is specific to cattle manure.

In the same study, direct correlations were found between soil EC above 2.0 dS/m, decreasing beet sugar content, and increasing beet EC levels. Soluble salts (commonly measured as soil EC) can increase beet EC levels, which is an indication of impurities. Beet impurities impair the sugar extraction process. To avoid sugar content loss and impurity issues caused by soil salinity issues, we recommend that sugar beet growers in southern Idaho avoid planting beets into fields that have soil EC levels above 2.0 dS/m (first foot). This recommendation applies to both manured and nonmanured field conditions.

Applying Cattle Manure to Sugar Beet Production Fields

Recommendations for cattle manure and compost application rates are found in Table 2. In a recent study, these applications rates and application timings within the crop rotation produced an optimal crop yield and quality response to manure applications, assuming that mineralizable N and soil EC levels are relatively low.

Finally, it should be noted that lagoon waters applied to sugar beets have considerably less organic N in comparison to composts and manures, since the majority of N is ammonium-N, which generally is as plant-available as conventional N fertilizers that are applied through the irrigation system.

Crop Sensors

Remote Sensors

While preplant soil NO_3 tests typically provide a reasonably accurate estimate of the optimal N rate for sugar beets, relatively low test reliability has been noted under certain conditions, including water stress or soils with high leaching potential. Petiole NO_3 levels have been used as an effective indicator of sugar beet N status, but in-season NO_3 concentrations are not well related to sugar beet yield and quality. Remote sensors such as GreenSeeker 505 handheld sensor (Trimble Navigation Ltd., Sunnyvale, California) or the Crop Circle sensors (Holland Scientific, Lincoln, Nebraska) utilize the optical characteristics of plants and their associated health properties and vigor. Remote crop sensors offer an additional resource for adjusting N fertilizer recommendations based on site-specific and crop-specific conditions.

Remote crop sensor readings collected throughout the growing season have shown potential for an accurate estimation of sugar beet root yields and recoverable sugar. Recent work by Bu et al. (2017) in North Dakota has shown that either of these instruments might be used to manage an N fertilization in sugar beets early in the growing season (V6), if N stress is detected. They also found that later in the season (V12–V14 growth stages), the sensor measurements could be used to estimate the sugar beet root yield and recoverable sugar content for logistical purposes. Thus, using remote sensors in combination with traditional soil tests could allow for more efficient N management based on estimated sugar beet yield potential. Furthermore, remote sensor measurements collected on the day of a sugar beet harvest

Table 2. General guidelines for cattle manure applications to irrigated sugar beet production fields. First-foot preplant soil test levels should be below 40 ppm Olsen P and 2.0 dS/m soil electrical conductivity (EC) to prevent sugar content loss and beet impurity issues.

Cattle manure application timing and crop rotation	Cattle Manure (40%-60% moisture content)	Cattle Compost or Dry Stacked Cattle Manure (20%-30% moisture content)
Applied before sugar beet crop	5–10 ton/acre	1–5 ton /acre
Applied before wheat, corn, or alfalfa crop	10–40 ton/acre	5–15 ton/acre
Applied before bean, barley, or potato crop	5–20 ton/acre	5–10 ton/acre

could be used to define N management zones for the subsequent growing season by measuring the amount of residual N returned to the system as sugar beet foliage. For more information on the use of crop sensors for developing N fertilizer recommendations for Idaho crops, please refer to *Nitrogen Management in Field Crops with Reference Strips and Crop Sensors*, University of Idaho Extension Bulletin 896 (see Further Reading section).

Phosphorus Fertilization

Phosphorus is needed by sugar beets for energy transfer in the plant and to support cell walls (phospholipids). Phosphorus binds strongly to aluminum in acidic soils, to calcium (free lime) in alkaline soils, and to aluminum oxides and iron oxides in all soils. For this reason, P does not move long distances to the roots with the soil water flow as N does. To ensure contact between the root and P in the soil, P must be placed in the same location as the largest portion of the root system, which is typically the upper 0–12 in of the soil profile.

Broadcast applications of P fertilizer should be incorporated into the soil to get the P into the root zone. Broadcast applications of P are often needed to ensure that the bulk soil P concentration is sufficient.

Sugar beets are unique in that they do not develop an extensive fibrous root system to explore the topsoil until several weeks after emergence. Therefore, banded P fertilizer applications on low P soils are also important to ensure that sufficient soluble P is in a position for root interception early in the season when the root architecture is dominantly focused downward and poorly developed.

Band placement should be directly below the seed, with at least 2–5 in between the fertilizer band and the seed to avoid salt toxicity and seed burn. Deeper placement of P ensures that the roots will grow directly into the band and that the plant will have access to the P early in the season with minimal salt toxicity risk. While sugar beets are very salt tolerant, they are unusually susceptible to salt damage at emergence and early seedling stages. Band-applied P also tends to be more soluble for a longer time than broadcasted and incorporated P fertilizers. Liquid ammonium phosphate (10-34-0) is an ideal P (and N) source for banding applications.

Plant-available P in the soil is determined using extraction methods specific to soil pH categories.

- For soils containing calcium carbonates (pH>5.5), use the Olsen or sodium bicarbonate method.
- For acidic soils (pH <6.5), use of the Bray-I method is ideal.

Confirm with your soil testing lab which P extraction method will be used in the analysis of your soil sample, as P recommendations will vary based on the extraction method used.

Recommended broadcast P fertilizer rates are based on soil test P values and percent free lime in the soil (Table 3). The lime adjustment is made to account for the reduced P availability resulting from P precipitation by free lime. When band-applying P, reduce P application rates by approximately 50%.

A recent Idaho study demonstrated the need for high P fertilizer application rates (>205 lbs P_2O_5/acre) to maximize yields, particularly on soils with low P levels. Research confirmed that current University of Idaho and TASCO P fertilizer recommendations are valid and growers can continue using them as the base for P fertilizer management in sugar beets.

Table 3. Phosphorus requirements for sugar beets grown under southern Idaho conditions.

Olsen P[1] (pH > 6.5)	Bray-I P[1] (pH > 6.5)	Percent Free Lime			
		0	4	6	12
ppm	ppm	Application rate, lb P_2O_5 per acre			
0	0	280	320	360	400
5	7	200	240	280	320
10	14	120	160	200	240
15	22	40	80	120	160
20	29	0	0	40	80
25+	37+	0	0	0	0

[1]Soil test P (ppm) in the top 0–12-in depth of soil.

Potassium Fertilization

Potassium (K) has been shown to greatly improve early vigor and growth of sugar beets, particularly when producing optimum yield. Potassium also affects sugar content, as sugar produced within the plant depends upon K for movement to the storage root. Between 240 and 540 lbs K_2O/acre are removed at harvest through tops and roots, and therefore must be replaced to maintain optimum yields. Recommendations for K application rates for optimal sugar yield are listed in Table 4.

Sulfur Fertilization

Sulfur (S) is a constituent of several amino acids and therefore is essential for protein synthesis. Sulfur is usually not deficient in the major sugar beet–growing regions of Idaho that are irrigated with Snake River water. Application of S is sometimes needed in areas where soil S levels are below 10 ppm, especially on sandy soils with low organic matter, and where S concentrations in the irrigation water are naturally low. Broadcast applications of 30–40 lb S/acre should be applied to soils testing less than 10 ppm at the 0–12-in soil depth.

Sulfur can be applied as a sulfate source or as elemental S. Sulfate-S is readily available for plant uptake, but is susceptible to leaching. Elemental S, however, needs to be oxidized to sulfate-S before being taken up by the plant roots. When applying elemental S, there is often a significant time lag in the conversion to sulfate-S due to the initially low activity of S-oxidizing bacteria. This is particularly true for cold, wet soil conditions that further slow the oxidation process. Elemental S applications are commonly made to potatoes grown the year prior to sugar beets and it is reasonable to assume that a portion of this S will oxidize during the sugar beet growing season. Where ammonium sulfate (21-0-0) or potassium sulfate (0-0-52) is used in the rotation, sulfur should not be limiting for sugar beets.

Table 4. Potassium requirements for sugar beets grown under southern Idaho conditions.

Soil test K[1] ($NaHCO_3$/ Olsen method)	Soil test K[1] (Acetate method)	Sugar beet yield goal (beet tons per acre)				
		20	25	30	35	40
ppm	ppm	Application rate, lb K_2O per acre				
40	47	210	240	270	300	330
60	70	150	180	210	240	270
80	93	90	120	150	180	210
100	117	30	60	90	120	150
120	140	0	0	30	60	90
140	163	0	0	0	0	30
160	187	0	0	0	0	0

[1]Soil test K for the top 0–12-in depth of soil.

Micronutrients

In general, yield responses to additions of micronutrients have not been widely observed. However, in soils where zinc concentrations are below 1.0 ppm at the 0–12-in soil depths, or where land leveling has exposed white, high lime subsoil, apply zinc fertilizer at a rate that will supply 10 lbs of water-soluble zinc per acre or the equivalent. It is possible that other micronutrient fertilizers will provide a yield response if soil test values are low. However, very little research is available to establish the critical values and documented deficiencies are rare. It is unlikely that sugar beets would respond to calcium or magnesium due to the deep exploration of the taproot in a subsoil typically rich in these essential nutrients.

Glyphosate-Resistant Varieties

The introduction of glyphosate-resistant sugar beets in 2008 has raised concerns from growers on the possible effects that this may have on nutrient uptake. Manganese, zinc, and iron deficiencies in glyphosate-resistant soybeans and corn have been documented in the midwestern states. Suspected causes of the deficiencies include the binding of soil micronutrients to glyphosate and gene alterations that reduce manganese uptake by the roots.

While micronutrient deficiencies in glyphosate-resistant sugar beet cropping systems have not been identified or thoroughly researched at this time, growers should still be aware of this phenomena.

If you notice *interveinal chlorosis in the leaves*, a visible sign of manganese deficiency, submit chlorotic leaf blades to a plant tissue–testing lab to be analyzed for manganese concentrations. Leaf blade manganese deficiency symptoms have been observed with leaf blade concentrations within the 4–20 ppm range, while sufficiency levels range from 25–360 ppm. Glyphosate-induced deficiencies in corn and soybeans have been managed with applications of the deficient micronutrient.

Considering the use of N, P, and other macronutrients, preliminary data from a limited number of grower fields in Michigan and Minnesota showed no difference in nutrient uptake or yields between conventional and glyphosate-resistant sugar beets. While this information is helpful, more information on glyphosate-resistant beets grown under Idaho conditions is needed.

The fertilizer recommendations in this guide are based on relationships established through research by the University of Idaho, TASCO, the USDA-ARS Northwest Irrigation and Soils Research Laboratory, and the Cooperative Fertilizer Evaluation Project (a cooperative research program comprised of producers, agronomists, consultants, and the University of Idaho). Results and experience indicate that these recommendations will produce above-average yields if other factors do not limit production.

Further Reading

Note: All University of Idaho Extension and PNW publications listed here can either be downloaded for free at the URL listed, or you can order them from UI Extension Publishing by phone (208) 885-7982 or e-mail calspubs@uidaho.edu.

Brown, B. *Wheat Straw Management and Nitrogen Fertilizer Requirements*. University of Idaho Extension Publication, CIS 825 (1988). (out of print)

Bu H., L. K. Sharma, A. Denton, and D. W. Franzen. "Comparison of Satellite Imagery and Ground-Based Active Optical Sensors as Yield Predictors in Sugar Beet, Spring Wheat, Corn, and Sunflower." *Agronomy Journal* 109, no. 9 (2017): 299-308.

Carter, J. N., C. H. Pair, and S. M. Bosma. "Effect of Irrigation Method and Leaching of Nitrate-Nitrogen on Sucrose Production by Sugarbeets." In Proc. 22nd Ann. Pac. NW Fert. Conf., 13–20. Bozeman, MT, 1971. https://eprints.nwisrl.ars.usda.gov/987.

Cooke, D.A., and R.K. Scott, eds. *The Sugar Beet Crop*. London: Chapman & Hall, 1993.

Dinkins, P.D., C. Jones, and K. McVay. *Nutrient Management in No-till and Minimum Till Systems*. Montana State University Extension Publication, EB 0182 (2008, revised 2014). http://landresources.montana.edu/soilfertility/documents/PDF/pub/No-tillNutMgtEB0182.pdf.

Draycott, A.P., ed. *Sugar Beet*. Suffolk, UK: Blackwell, 2006.

Gehl R., and T. Boring. "In-Season Prediction of Sugarbeet Yield, Quality, and Nitrogen Status Using an Active Sensor." *Agronomy Journal* 103, no. 4 (2011): 1012–18.

Mahler, R. L. *Fertilizer Placement*. University of Idaho Extension Publication, CIS 757 (2001). https://www.extension.uidaho.edu/publishing/pdf/CIS/CIS0757.pdf.

Mahler, R. L. *Fertilizer Primer: Terminology, Calculations, and Application*. University of Idaho Extension Publication, CIS 863 (2002). https://www.extension.uidaho.edu/publishing/pdf/CIS/CIS0863.pdf.

Mahler, R.L., and T.A. Tindell. *Soil Sampling*. University of Idaho Extension Publication, BUL 704 (revised) (1997). Out of print, but updated version pending as Walsh, O.S., R.L. Mahler, and T.A. Tindall. "Soil Testing to Guide Fertilizer Management" (in review, University of Idaho Extension Publishing, 2017).

Reddy, S., J. Neufeld, J. Gallian, H. Neibling, J. Ellsworth, and S. Gortsema. *Sugarbeet Irrigation Management—Using Watermark Moisture Sensors*. University of Idaho Extension Publication, CIS 1140 (2007). https://www.extension.uidaho.edu/publishing/pdf/CIS/CIS1140.pdf.

Smith, J. H., C. L. Douglas, and M. J. Lebaron. "Influence of Straw Application Rates, Plowing Dates, and Nitrogen Applications on Yield and Composition of Sugar Beets." *Agronomy Journal* 65 (1973): 797–800.

Staben, M. L., J. W. Ellsworth, D. M. Sullivan, D. Horneck, B. D. Brown, and R. G. Stevens. *Monitoring Soil Nutrients Using a Management Unit Approach*. University of Idaho Extension, Oregon State University Extension, and Washington State University Extension Publication, PNW 570-E (2003). https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/pnw570.pdf.

Stanford, G., J. N. Carter, D. T. Westermann, and J. J. Meisinger. "Residual Nitrate and Mineralizeable Soil Nitrogen in Relation to Nitrogen Uptake by Irrigated Sugar Beets." *Agronomy Journal* 69 (1977): 303–8.

Tarkalson D., D. Bjorneberg, and A. Moore. "Fall and Spring Tillage Effects on Sugarbeet Production." *Journal of Sugar Beet Research* 52 (2015): vols. 3–4.

Trimmer, W., and H. Hansen. *Irrigation Scheduling*. University of Idaho Cooperative Extension, Oregon State University Extension Service, and Washington State University Cooperative Extension Publication, PNW 288 (1994). http://irrigation.wsu.edu/Content/Fact-Sheets/pnw288.pdf.

Walsh, O. S. *Nitrogen Management in Field Crops with Reference Strips and Crop Sensors*. University of Idaho Extension Bulletin, 896 (2015). https://www.extension.uidaho.edu/publishing/pdf/BUL/BUL896.pdf.

Walsh, O. S., and K. M. Belmont. *Improving Nitrogen-Use Efficiency in Idaho Crop Production*. University of Idaho Extension Bulletin, 899 (2015). https://www.extension.uidaho.edu/publishing/pdf/BUL/BUL0899.pdf.

About the Authors

Olga Walsh, Systems Agronomist, University of Idaho Parma Research & Extension Center; **David Tarkalson**, Research Soil Scientist, USDA-ARS; **Amber Moore**, Assistant Professor and Soil Fertility Specialist, Oregon State University Extension Service; **Greg Dean**, Manager, Sugarbeet Quality Improvement Department, TASCO, **David Elison**, Senior Research Agronomist, TASCO; **Jeffrey Stark**, Professor and Superintendent, University of Idaho Aberdeen Research & Extension Center; **Oliver Neher**, Manager of Plant Health, TASCO; and **Bradford Brown**, Soil and Crop Management Specialist (retired), University of Idaho Parma Research & Extension Center.

BUL 935 | Published August 2019 | © 2019 by the University of Idaho