Science Societies

Considerations for increasing sugar accumulation in sugarbeet production

By Michael Larkin

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Photo by Jacob Ryan Osland.

Sugarbeet growers are paid for sugarbeet tons delivered to the factory and for the extractable sugar content found in those beets. The focus of this article will be on agronomic principles that lead to higher extractable sugar. There are several factors that influence sugar development in sugarbeets. Among the most important factors are variety selection, nutrition, and harvest management. Weather, environmental conditions, soil chemical properties, and pest management also influence sugar development. What can we as crop advisers do to ensure the best possible outcome for sugar accumulation in the sugarbeet crop?

Nature manufactures “sugar” or sucrose daily through the process of photosynthesis. It’s a simple, yet complex miracle that happens all around us. Plants use chlorophyll to absorb energy from sunlight and combine carbon dioxide from the atmosphere and water from the soil to create a hydrated (water) carbon molecule known as a “carbohydrate.” A small, but extremely important side benefit of photosynthesis is the release of oxygen (O_2) back to the atmosphere.

The general formula for a carbohydrate is $(CH_2O)n$. The “n” simply means that CH_2O is repeated a certain number of times, usually three or more (a single CH_2O does not exist).

Although humans have created artificial sweeteners in the laboratory, none rival what photosynthesis creates naturally. So let's discuss a little more chemistry before we approach agronomy.

Simple sugars, also known as *monosaccharides*, include glucose, fructose, and galactose. They bond with each other and themselves to make more complex carbohydrates known as disaccharides and polysaccharides:

Disaccharides

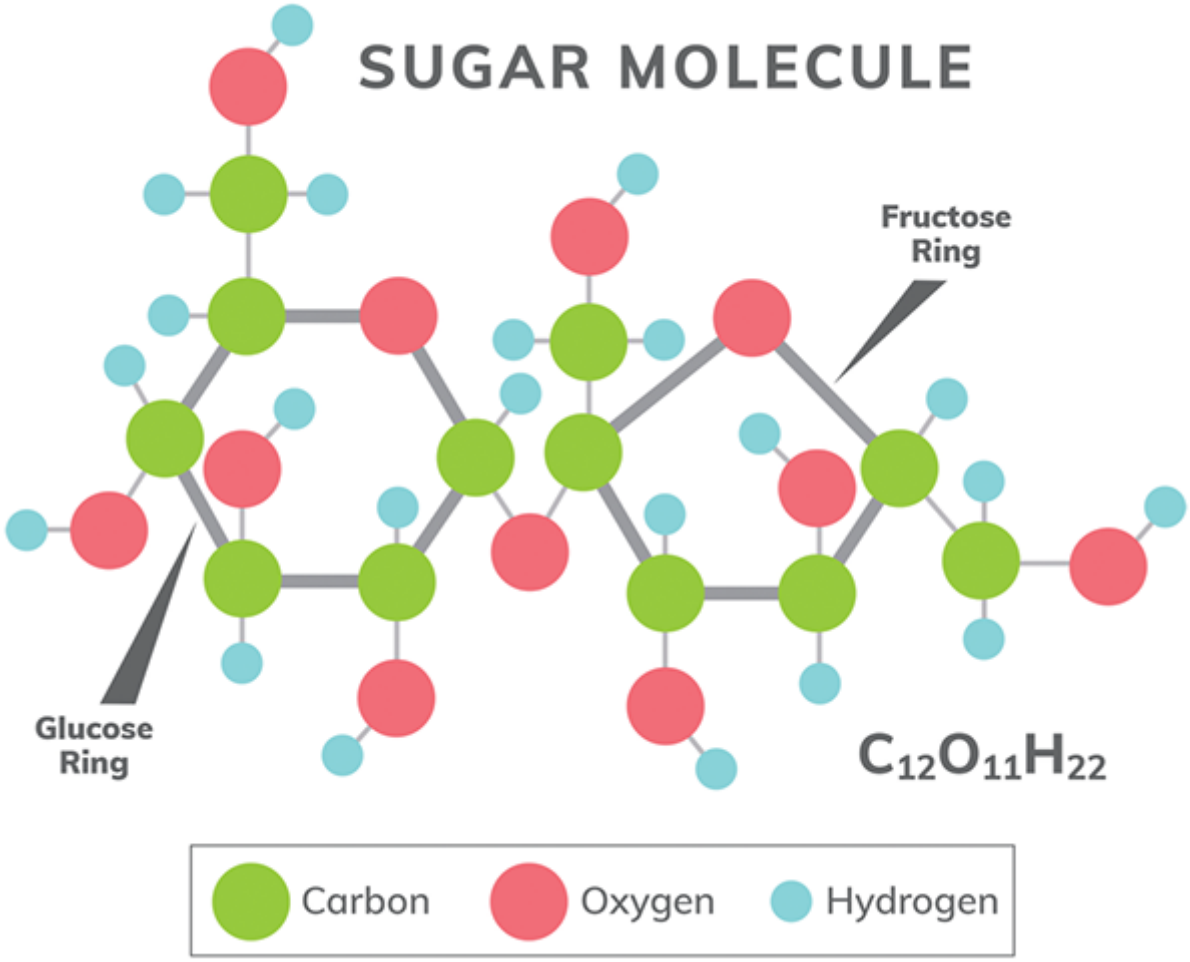
Sucrose (table sugar) = glucose + fructose

Lactose (milk sugar) = glucose + galactose

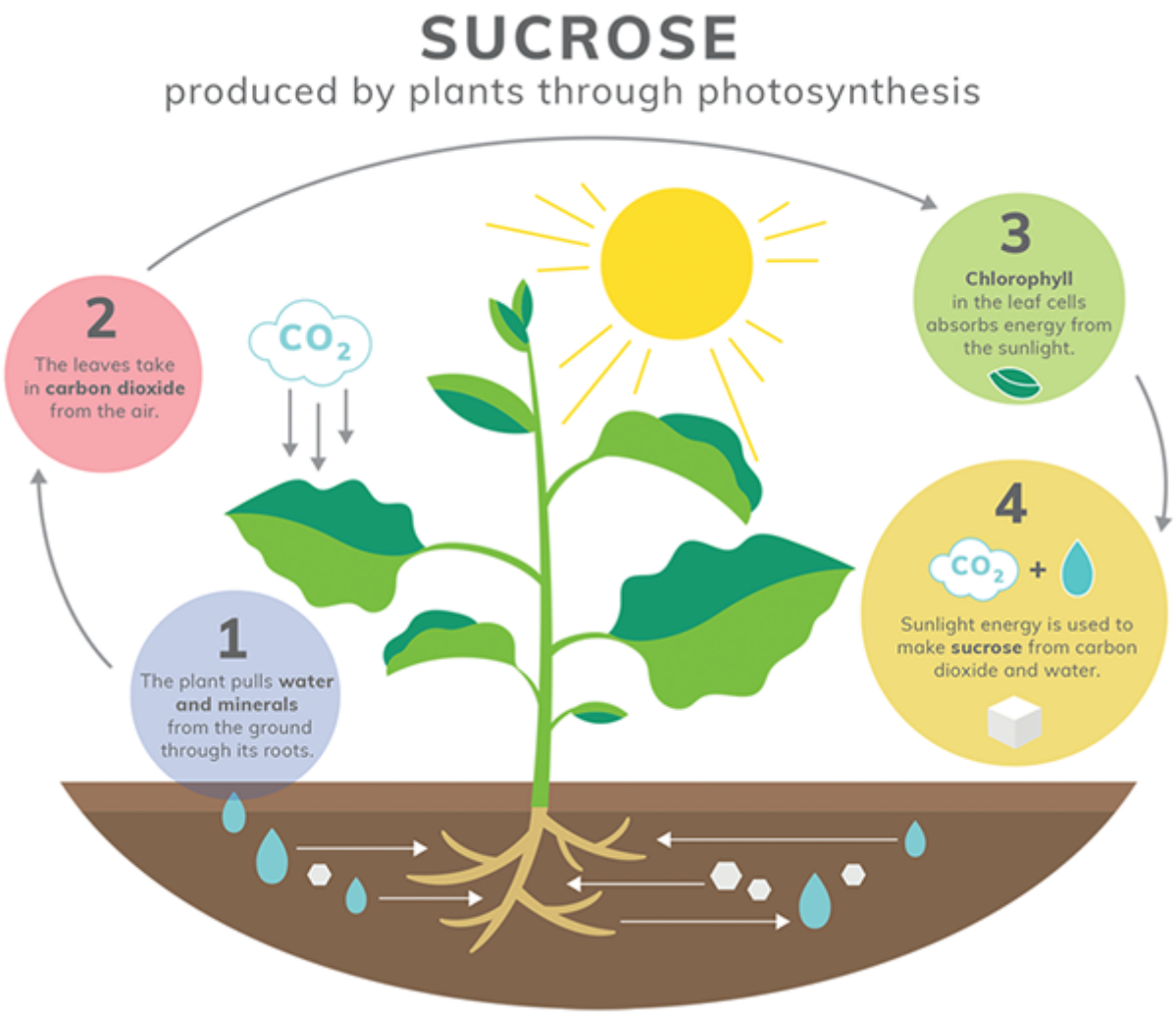
Maltose (malt sugar) = glucose + glucose

Polysaccharides

Starch (glucose polymer—more than 10 monosaccharides linked together)



Sugar's chemical structure contains just two molecules: one molecule of glucose bound to one molecule of fructose. Illustration courtesy of The Sugar Association.



All green plants make sugar through photosynthesis, the process plants use to transform the sun's energy into food. Illustration courtesy of The Sugar Association.

Although many fruits, nuts, and vegetables contain sucrose, the sugar we use as table sugar or granulated sugar, a natural sweetener, comes primarily from sugarbeet and sugarcane, which contain sucrose at 16 and 14%, respectively. They are the most efficient crops for us to grow and harvest sucrose.

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There are several factors that influence sugar development in sugarbeets. Among the most important factors are variety selection, nutrition, and harvest management. Weather, environmental conditions, soil chemical properties, and pest management also influence sugar development. Some years are more favorable than others. So what can we as crop advisers do to ensure the best possible outcome for sugar accumulation in the sugarbeet crop?

There are three areas of focus which need attention: (1) nutrition, (2) leaf health, and (3) water management. All three impact photosynthesis, yield, and quality. Let's briefly review each.

Nutrition

There are 17 essential plant nutrients. A balanced and sufficient supply of each is necessary for optimum growth. All play important, unique, and critical roles, but we will specifically mention only a few.

Nitrogen (N)

This nutrient is key for achieving optimum yields. When it is limiting, growth suffers. However, research has clearly shown that excess nitrogen depresses sugar development and interferes with sugar recovery in the factory. Nitrogen recommendations vary depending on the growing district but typically range from 6 to 8 lb N/ton of expected yield. Individual growing conditions and practices may warrant adjustment.

Most growing districts recommend a preplant soil test to account for residual soil N. This residual soil N is subtracted from the total N requirement to determine N to be applied in preplant and in-season applications. Split application of N generally leads to greater

uptake and utilization efficiency. It is important to have sufficient N early in the season to close the canopy quickly and to maximize photosynthetic light capture.

Petiole monitoring is recommended, and in-season applications should be adjusted accordingly. Late-season N applications are discouraged, and most growing districts have a cutoff date for N application that usually precedes harvest by six to eight weeks. This late-season N depletion, coupled with cooling temperatures, triggers greater sugar accumulation in the roots.

There may be times when it appears N applications have fallen short, and a grower believes yield (tonnage) may be impacted negatively. However, be cautious with rescue N treatments late in the season. In such cases, a 5 to 10 lb N/ac water-run application or a foliar application of 1 to 2 lb N/ac may be considered and should be applied no less than three to four weeks prior to harvest.

Should a grower increase tons (yield) or should a grower increase percent sugar? **Growers face this dilemma every season they grow sugarbeets. Let's look at some simple math:**

Increasing Tons, Holding Sugar Constant		
Tons/Acre	% Sugar	Gross Sugar/Acre
40.0000	0.17	6.8000
40.4000	0.17	6.8680
40.8040	0.17	6.9367
41.2120	0.17	7.0060
41.6242	0.17	7.0761
42.0404	0.17	7.1469
42.4608	0.17	7.2183
42.8854	0.17	7.2905
43.3143	0.17	7.3634
43.7474	0.17	7.4371
44.1849	0.17	7.5114

Increasing Sugar, Holding Tons Constant		
Tons/Acre	% Sugar	Gross Sugar/Acre
40	0.1700	6.8000
40	0.1717	6.8680
40	0.1734	6.9367
40	0.1752	7.0060
40	0.1769	7.0761
40	0.1787	7.1469
40	0.1805	7.2183
40	0.1823	7.2905
40	0.1841	7.3634
40	0.1859	7.4371
40	0.1878	7.5114

On the left, you see what happens if we increase tons by 1% while holding percent sugar constant at 17% compared with the previous line. On the right, you see what happens if we increase percent sugar by 1% while holding tons constant compared with the previous line. You will note the gross sugar/acre remains identical in both scenarios. This data does not consider other factors that impact recoverable sugar (i.e., purity, nitrates, amino-N, etc.).

Generally, increasing sugar content is preferable because it is more efficient (less tons to harvest, haul, and process). Frequently, more tons are easier to obtain. However, more tons at the expense of lower sugar content may not be the most profitable approach.

It is vital that a grower manages both production and quality to achieve the greatest economic benefit.

Phosphorus (P)



Photo courtesy of Adobe Stock/DiedovStock.

Phosphorus is linked to a plant's ability to use and store energy (carbohydrates), including the process of photosynthesis. It serves as a catalyst for many key biochemical reactions in plants. A steady supply of phosphorus is needed all season long.

Synthesis of sucrose occurs in the cytosol. Phosphorylated (containing P) forms of

glucose and fructose are important precursors for building sucrose. Glucose-1-phosphate and fructose-6-phosphate contain the two hexose units needed to yield disaccharide sucrose, but the combination of those units is indirect because energy must be provided to activate the glucose unit. This energy is provided by uridine triphosphate.

Want to build sugar? You need phosphorus. Sugarbeet roots contain 2.2 lb P_2O_5/ton, and the tops contain 4.0 lb P_2O_5/ton. Combined that is just over 6 lb P_2O_5/ton.

Potassium (K)

Among many roles, one of potassium's roles in plant nutrition is associated directly with translocation of sugars. It is generally recognized that K^+ plays an important role in both the release of sucrose from mesophyll cells and the uptake of sucrose into the phloem. Potassium deficiency results in reduced rates of net photosynthesis and translocation.



Photo by Marco Verch (***https://foto.wuestenigel.com/the-pile-of-sugar-beet/****) and reprinted here under a Creative Commons 2.0 license (* ***https://creativecommons.org/lice***

nses/by/2.0/).

Sulfur (S)

Sulfur is required for synthesis of proteins. It is important in the nitrate-reductase process, during which nitrate-nitrogen is converted to amino acids. Sulfur deficiency decreases photosynthesis and has a pronounced retarding effect on plant growth.

Magnesium (Mg)

Magnesium is the central molecule of chlorophyll. Chlorophyll drives photosynthesis.

Boron (B)

Boron plays an essential role in the development and growth of new cells; assists in translocation of sugars, starches, nitrogen, and phosphorus; and regulates carbohydrate metabolism.

As you can see, N, P, K, S, Mg, and B all have direct roles in photosynthesis and/or sugar development and translocation. Each of these nutrients is important in sugarbeet production. Particular attention to these nutrients will increase both yield and quality.

See **www.yara.co.uk/crop-nutrition/sugar-beet/nutrient-deficiencies-sugar-beet/** to identify and diagnose if your sugarbeet is suffering from nutrient deficiencies and learn more about the symptoms and causes and how to control or correct the deficiency.

Leaf Health

Maximizing photosynthesis requires healthy leaves and sufficient canopy to intercept all available light. Crops with leaves compromised by physical or chemical damage or impacted by disease will not reach their full yield potential.

Two diseases of sugarbeet that are of particular concern include Cercospora leaf spot and powdery mildew. More information on both diseases may be found here: **http://msuextension.org/publications/AgandNaturalResources/mt201710AG.pdf**.

Water Management

In nearly all crops, there is a direct correlation of evapotranspiration (consumptive water use) to yield. Higher evapotranspiration leads to higher yields. Indeed, when water is not limiting, and when the soils are not saturated, then crops conduct photosynthesis most efficiently, and other factors such as temperature and nutrition may become the limiting factors to increased production.

Sugarbeets, once established, tolerate excess salinity and moisture deficits. However, severe salinity or moisture deficit will reduce photosynthetic capacity, leading to reduced yields. Generally, growers should not allow soil moisture depletion to fall below 50% available moisture for optimum production in sugarbeets.

Although some literature suggests moisture deficit in sugarbeet production can increase sucrose content, severe moisture deficit can negatively impact yield. Thus, growers must weigh the perceived benefit of increased sugar content against the loss of potential yield.

For more on water management in sugarbeet, see **https://bit.ly/3R47EHb**.



Sugarbeet leaf showing powdery mildew symptoms. Photo by Gerald Holmes, Strawberry Center, Cal Poly San Luis Obispo, Bugwood.org.



Sugarbeet leaf displaying symptoms of infection with Cercospora leaf spot. Photo by Howard F. Schwartz, Colorado State University, Bugwood.org.

Concluding Thoughts

What can you do to increase yield and quality (sugar recovery) in sugarbeet production? Focus on nutrition, leaf health, and water management. Those are the factors over which you and the grower have some level of control.

Nitrogen management will likely have the greatest impact on both yield and quality, but each of the other mentioned nutrients also have a direct role in photosynthesis and/or translocation of sugars, so don't ignore them.

Some additional resources are found in the following links.

Resources

Water Management for Sugarbeet and Dry Bean: **www.ksre.k-state.edu/irrigate/oow/p05/Yonts1.pdf**

FAO of the United Nations—Sugarbeets: **www.fao.org/land-water/databases-and-software/crop-information/sugarbeet/en/**

Water Management in Sugarbeet: **https://rd.springer.com/article/10.1007/s12355-010-0038-0**

Sugarbeet Agronomy 101: **https://waterquality.montana.edu/farm-ranch/irrigation/other_crops/sugarbeet.html**

North Dakota State University Sugarbeet Production Guide: **https://www.ndsu.edu/agriculture/ag-hub/publications/2022-sugarbeet-production-guide**

Management Guidelines for Improving Sugarbeet Quality: **www.michigansugar.com/wp-content/uploads/2020/03/2020-Michigan-Sugar-Grower-Guide.pdf**

Nitrogen and Potassium Effects on Sugarbeet Quality: **https://bit.ly/3UmMoPT**

University of Idaho Nutrient Management: **www.uidaho.edu/extension/nutrient-management**

Southern Idaho Fertilizer Guide—Sugarbeets: **https://bit.ly/3BG7Ir8**

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