COLORADO SOIL HEALTH FUNDAMENTALS

PRIMER 10: COMMODITY CROPS

PRIMER 10 SUMMARY

The goal of the Colorado Soil Health Primer series is to demonstrate the core principles related to soil health management as practiced and researched within the boundaries of the State of Colorado. Colorado scientists studying the effects of management practices and the state's farmers and ranchers implementing and measuring the changes on the land participated in this project.

This series is not about instructing the exact tactics a farmer or rancher would need to improve soil health. The individual tactics and strategies must change from property to property — or even field to field – depending on the goals of the land manager, and the available natural and financial resources. This series will give readers the resources to understand and evaluate practical and proven ideas to explore and adapt into a new or existing operation.

This primer is focused on the production of commodity crops. Though commodity crops are second to livestock in dollar value of gross sales, they represent a significant share of the agricultural economy in Colorado. The STAR program is collecting data to document which soil health management tactics help commodity growers spend less on inputs, and which tactics can help maintain or increase yields.

	Industry Description	Total Output	Total Employment
Production	Beef cattle ranching and farming (including feedlots and dual-purpose ranching and farming)	$3,544,801,937	18,829
	Grain farming	$1,080,580,122	3,645
	Dairy cattle and milk production	$776,889,068	1,553
	All other crop farming	$382,047,275	11,260
	Greenhouse, nursery, and floriculture production	$357,485,678	3,542
	Animal production, except cattle and poultry and eggs	$356,714,469	2,593
	Vegetable and melon farming	$327,471,418	2,692
	Poultry and egg production	$168,110,868	268
	Commercial logging	$53,593,797	917
	Fruit farming	$48,686,354	537
	Sugarcane and sugar beet farming	$36,791,989	234
	Commercial hunting & trapping	$24,684,400	881
	Oilseed farming	$21,331,077	23
	Forestry, forest products, and timber tract production	$21,180,361	242
	Tree nut farming	$80,425	2

▲ A glance at how commodity crops rank with specialty vegetables and livestock production in the state. *Source: USDA*

By the numbers, here is a look at Colorado's providers:

- 39,000: Farm operations
- 31.8 million: Acres in production (including livestock)
- 1.4 million: Corn (acres)
- 2.2 million: Wheat (acres)
- 495,000: Sorghum (acres)
- 465,000: Millet (acres)
- 53,000: Sunflowers (acres)
- 53,000: Potatoes (acres)
- 52,000: Barley (acres)
- 24,300: Sugar Beets (acres)
- 11,500: Peaches (tons)

—USDA State Agriculture Overview for 2021

COMMON TERMS

Cover Crops: The act of keeping the ground covered and maintaining living roots are two principles of soil management, and cover crops are a key tool to help farmers transition and measure the gains.

Pasture: Fields for grazing, wildlife passage or soil remediation are common across the state of Colorado.

Soil Biology: The life in the soil, from the smallest microbes to earthworms and dung beetles. The biology is responsible for helping break down organic matter and turning it into available nutrients for your crops.

Soil Chemistry: The ratios of elements in the soil are important and go beyond N-P-K.

Soil Health: The concept of maximizing an ecosystem's ability to feed soil microorganisms, leading to efficient nutrient cycling and turnover, which creates more nutrient availability for plants, increases soil water storage, and improves ecosystem sustainability and resiliency.

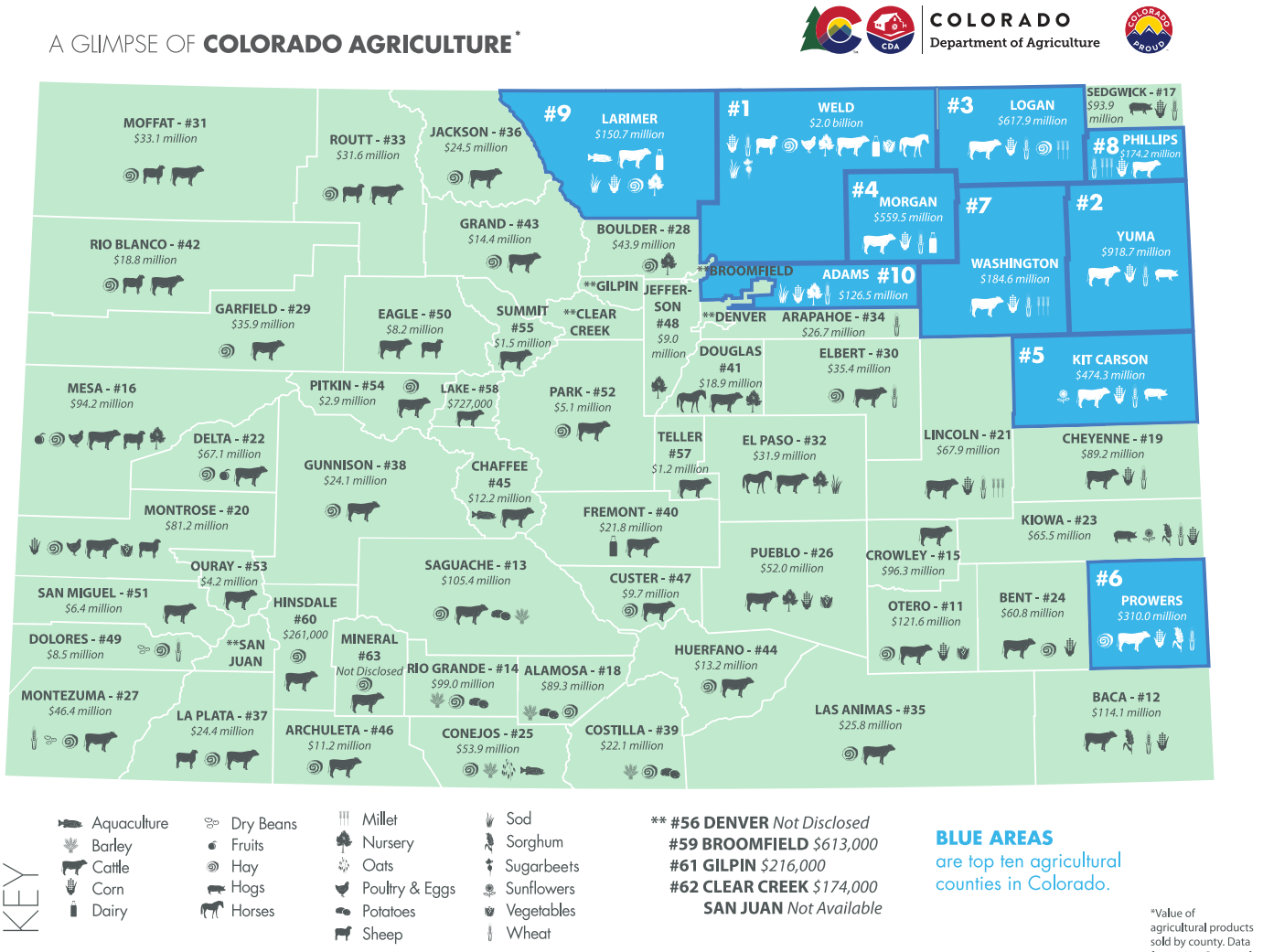
Soil Testing: The process of quantifying certain attributes of soil, including macro- and micro-nutrients, soil organic matter, cation exchange capacity, soil biology, water and/or air.

NRCS: The Natural Resources Conservation Service.

Source: Jim Ippolito & Megan Machmuller, Colorado State University

USDA-NRCS Soil Management Principles

1. Limit disturbance
2. Keep soil covered
3. Strive for biodiversity
4. Maintain living roots
5. Integrate animals



▲ This map shows the breakdown of the type of agriculture that thrives in Colorado. *Source: Colorado Department of Agriculture*

In the STAR program, a focus on soil health in commodity crop systems aims to help measure and track the impacts of soil management on yields and expenses, including inputs and water.

For commodity growers, finding ways to use tactics to build soil health, including biology, balanced chemistry and a thriving ecosystem, can be especially challenging. In the past, many thought, "more is better." Yet, with an increase in fertilizer and input costs since 2020, tactics like cover cropping and using more biological inputs are becoming increasingly attractive and can help decrease expense lines on the budget sheets.

The yield of a crop depends on efficient crop growth, since what the farmer is interested in is plant matter of some kind — roots, stalks, leaves, or seeds and fruit. All plants (all species and varieties) have a built-in genetic potential to grow plant matter. But in order for the plant to produce as much as its genetic potential allows, the environmental conditions in which it grows need to be optimal. If any environmental factor is not ideal, it becomes a limiting factor in crop production. Some limiting factors are beyond the farmer's control, while others can be adjusted. The STAR program helps producers implement management strategies to overcome as many limiting factors as possible.

Wheat & Small Grains

Third generation farmer Roy Pfaltzgraff uses a rotation and soil testing system to help him manage his cash crops and ensure effective and efficient growth. He farms about 1,900 acres of small grains and beans in the northeast corner of the state, and says that testing for soil organic matter can help farmers focus on soil improvements for specific crops.

"We have used soil testing from 1985, we changed to the Haney test in 2018. Our organic matter averages around 2.5 percent where the neighboring land is around 0.5 to 1 percent. We have better soil quality in our fields than the adjoining pastures that have never been broke out of sod."

For Pfaltzgraff, field testing helps him plan out his crop rotations.

"When we first got the Haney results we were seeing things that didn't make sense, so I had my father create a table of what crops had been in which fields since 2000. With that information, we have been able to tie soil health improvement to specific crops. Using that we have been able to improve soil health significantly, the worst field's Haney score was around 5 and using rotation in the last 5 years have moved it to 11.5 which is similar to our other fields."

With a production value estimated at around half a billion dollars on 2.2 million acres, wheat germination and diseases are a big issue in the Plains region where Pfaltzgraff farms. With an average production rate of 37 bushels an acre bringing in $6.70 a bushel, this crop can net around $250 an acre.

Certain diseases, like scab (Fusarium head blight, a fungal plant pathogen), can cause low germination rates, and may be due to wet conditions. Smuts and bunts, other important fungal diseases of grasses, can also be a problem. Cool and moist weather conditions tend to favor fungal diseases and growth. Stinking smut (also called common bunt), which caused the loss of 25 percent of the Kansas wheat crop in 1890, germinates in favorable weather, growing root-like threads called hyphae that penetrate into the tissue of young wheat seedlings, eventually replacing the seeds with fungal tissue called telliospores, which then spread onto the soil and other grains during harvest.

The development of chemical seed treatments all but eliminated the spread of these fungal diseases. These treatments are called "systemic" because they move systemically through the seedling to provide protection against fungal infiltration. The current winter wheat varieties that are grown on the High Plains are susceptible to Stinking Smut and Loose Smut.

Early fall seedings of winter wheat can also help to eliminate this problem, when the soil temperature is above 68 degrees. While this can reduce potential infestation, there are several other wheat diseases and insect pests that actually favor early plantings.

Nathan Raymer and his family farm about 5,000 acres of wheat, millet, and milo in the New Raymer area, which is situated in the northeastern plains. They've tried growing corn but in their semi-arid region, small grains just make more sense.

"We've done corn a little bit, but we are in such a limited rainfall area," Raymer said. "We have 100-bushel corn potential, but year-in, year-out, we're looking at probably more realistically 40 bushel corn. With input prices right now it doesn't make as much sense as, say, milo, which has less input costs, or the millet, which is a lot lower input costs."

Raymer notes that wheat stem sawfly—what some call the "WSS"—is the biggest pest they see in their operation.

"It saws its way in and makes a cocoon in the bottom of the stem

▼ More than 2 million acres of wheat are grown annually in Colorado. *Source: Colorado Department of Agriculture and Travis Harvey*

CHEMICAL BALANCE

OUT OF BALANCE	IN BALANCE
Calcium less than 65%of CEC.	Calcium 75%-85% of CEC.
Magnesium over 20% of CEC.	Magnesium 12-18% of CEC.
Potassium less than 3% of CEC or more than 5%.	Potassium 3-5% of CEC.
Phosphorus less than 20 ppm (P1).	Phosphorus 25-50ppm (P1).
Sulfur less than 20ppm.	Sulfur over 25ppm.
N:S ratio over 15:1 in plants.	N:S ratio 10:1 in plants.
pH less than 6.0, over 7.0.	pH 6.5-6.8.
Low OM (organic matter).	Medium to high OM.
Low trace elements.	Adequate trace elements.

SYMPTOMS:	IN BALANCE
1. Hollow stems (alfalfa), difficult to establish, short-lived standards.	1. Solid stems (alfalfa), easy-to-establish), long-lived stands.
2. Poor dry-down of crops.	2. Good dry-down & keeping quality.
3. Low sugar content in plant.	3. High sugar content.
4. Mineral imbalance in feed.	4. Good mineral balance.
5. Crops show nutrient deficiency.	5. Crops show no nutrient deficiencies.
6. Herd health problems.	6. Healthy animals.
7. Crops stressed by weather.	7. High yield; low weather stress.
8. Weed problems.	8. Few weeds.

▲ The typical symptoms in commodity crops as related to soil mineral deficiencies. *Source: Acres U.S.A.*

and all the wheat falls over," Raymer explained. "That's basically our biggest pest we're fighting at the moment. With the WSS we are planting semi-solid stem and solid stem varieties to try to get in front of the sawfly. We are primarily no-till on all our ground. We do wheat, millet, fallow rotation, and the goal ultimately is to never work the ground."

Like Raymer, NRCS State Agronomist Christine Newton notes that the wheat stem sawfly is one of the biggest issues on wheat acreage.

"Right now, with wheat prices being so high, the wheat stem sawfly is what comes to mind as the most damaging economic pest on cropland in the eastern plains of Colorado. The WSS is so damaging in Colorado because wheat is a staple crop and prices are high right now. Also dry weather favors WSS. Colorado State University estimates the economic damage of WSS to be 33 million dollars statewide," Newton said.

In Colorado there are several kinds of aphids and small bugs that infest small grains, including the destructive Russian wheat aphid (RWA), and the greenbug. To combat these pests, the state soil health program recommends working to balance soil chemistry and growing a biodiverse field that attracts beneficial insects.

Pfaltzgraff uses a variety of practices to manage his small grains and fight pests on his acreage.

"We have both released beneficial insects and done our part to attract beneficial insects," Pfaltzgraff said. "We have released both puncture vine stem and seed weevils, but they say it takes a while to see the difference. They are super tiny so finding them after release is a challenge. I don't know if they can handle the heat and drought problems we are having this year."

He also focuses on raising the sugar levels of his crops. "We spray sugar water on crops to attract beneficials in corn and other crops," he advised. "So far it has let us stay below economic threshold for chemical treatments. The biggest thing is we try to keep our brix levels up in plants so the plants have a natural immunity to most insects."

In Colorado, most small grain producers grow barley, millet, and sorghum. Barley is planted on around 52,000 acres in the state, millet on 465,000 acres, and sorghum on about 495,000 acres.

The destructive aphids inject their saliva into the plant and suck out the sap. Yield losses can be significant if the infestation is not dealt with swiftly, decimating up to 50 percent of the total crop or more. Over the years, biological controls and resistant seed varieties have helped farmers gain control of this pest, but newer resistant pest species have put the farmers on the defensive yet again.

Most severe spring infestations are caused by overwintering wingless aphids. The winged varieties appear in April and May and flights peak in July around the wheat producing regions of the state. Winter wheat and barley may become infested, but not corn, millet, or sorghum. RWA can survive the winter in most areas of Colorado.

Planting as late as possible in the season is one strategy based in biology to control the aphid, as well as focusing on producing a stress-free crop. Infestations often occur on stressed fields or stands, and cause more damage to stressed plants. Having a healthy plant is therefore a boon not only to a producer's pocketbook, but to the overall the health of the operation. Controlling volunteer grains is important, as these are the most likely source of infestation for a new crop in the fall.

Greenbugs are an important vector of the barley yellow dwarf virus, and other aphids are also vectors of this and other viruses that may cause economic damage to a field.

Recommended practices involve using an integrated pest management (IPM) system and due diligence. NRCS

State Agronomist Christine Newton noted that "Some of the IPM techniques would be increasing the diversity of your crop rotation, avoid planting wheat into existing wheat stubble, delayed wheat planting, using semi solid stem variety, plant wheat into larger blocks to minimize the effects of infestations along field edges, swathing and using a stripper header at harvest when infestation does occur."

Corn

Corn, commonly called maize in much of the world, is America's most important agricultural crop, with the United States producing nearly half the world's corn. It is a member of a large plant family,the grasses, to which other important crops such as wheat, oats, barley, and rice also belong.

A corn plant is a marvel of energy production and storage, capturing the sun's energy during photosynthesis and converting it into food molecules. In only three or four months, a single kernel of corn grows into a plant seven to 12 feet tall and produces 600 to a thousand kernels similar to the one that was planted.

Corn is the largest crop in Colorado, as it is in many other states, with more than a million acres in production and a 2021 crop eclipsing 148 million bushels.

For corn, optimal growing temperature limits are about 41°F and 87°F, and in much of the state, the land, weather and geography prevent corn growth; however, as you go east, the conditions become much more conducive to growing corn.

Nitrogen is the commonly applied fertilizer, but many organic and soil health farmers are avoiding costly nitrogen treatments by incorporating cover crops. As the saying goes, "Why pay for nitrogen when you can grow it?"

For agronomist Gary Zimmer, that means helping farmers incorporate cover crops and corn residue back into their field. But this approach can also make a no-till practice especially challenging.

Shallowly incorporating residues breaks up the soil crust, which is essential if you want your soil to be healthy, and it improves water infiltration as well. Without proper residue decay, insects and diseases are going to be

▼ This chart will help farmers understand how to better feed their corn plant, and what to plant during the different periods in the plant's growth cycle. *Source: Acres U.S.A.*

Nutrient	Growing Pattern	Leaf Translocation	Peak Time of Availability
Nitrogen	Throughout season, with two peaks	Yes, during grain development	Tassel to silk through grain fill
Phosphorus	Steady accumulation until maturity	Yes, during grain fill (more than N)	Early tassel and early dent
Potassium	86 percent accumulated by silking	Very little	Early tassel
Calcium	Vegetative growth (86 percent before blister stage)	No	Early tassel
Magnesium	Throughout growing season	Very little	Steady supply all season
Sulfur	Throughout growing season	Very little	Steady supply all season
Boron	Throughout season,with two peaks	Very little	Steady supply all season
Copper	Steady accumulation throughout season	No	Steady supply all season
Iron	Two distinct times (70% accumulation by blister stage)	Very little	Early through blister stage

bigger problems.

"On many no-till farms, field inspections show volumes of residual corn residues from two years prior," Zimmer said. "I certainly don't think you need to bury the residues out of sight in order to speed breakdown. Running a vertical tillage machine, rotavator, sharp disk, or chopping them or running an aerator-type tool over them does wonders. If you have high carbon residues, such as straw or corn stalks, the use of some nitrogen or manure is essential to speed breakdown of those residues. For corn stalks, spraying on five to ten gallons of 28 percent nitrogen with a molasses-type product or humic acid and possibly adding stubble digesting organisms before shallowly working them in, works great. You could also bulk spread ammonium sulfate at up to 200 pounds per acre in place of the liquid nitrogen mix."

A more careful fertilizer program, along with a more resilient root system, will help corn farmers in variable weather years, and help offset weed and pest pressures. Crop rotations and genetics are currently being used most commonly to combat weeds and pest pressure in corn crops, said Ron Meyer, Colorado State University Extension Agronomist, who noted that although weed pressure is an important issue, certain pests are more economically damaging to the crop.

"The most damaging pest is corn rootworm," Meyer said. "Corn rootworm has worked its way through some of the GMO [genetically modified organism] technology. As a result, companies have introduced newer generations of corn rootworm GMO traits which seem to be working currently. Corn rootworm will eat brace roots and cause severe lodging. Some older GMO traits are not very effective controlling this pest."

While organic farmers will avoid GMOs, organic control strategies can be difficult if the soil conditions are favorable to pests and weeds.

Corn rootworm larvae feed on root hairs and small roots while the adult worms feed on larger roots. The most successful cultural practices involve crop rotation, as the hatched larvae cannot move more than 10 to 20 inches in search of food, and without corn roots they die. The rootworm beetles rarely lay their eggs anywhere but in corn.

Disease and pest pressure, for a farmer focused on soil health, originates in a plant weakened by poor soil nutrition. Here's a guide published in Modern Corn Production in 1975 on the nutrient deficiency symptoms in corn (exact deficiencies may be difficult to identify because there may be more than one):

- **Nitrogen**—lower leaves yellow at tip and center, later dying; rest of plant pale yellowish green; slow growth; stalks slender; ears small, not filled at tip.
- **Phosphorus**—leaves dark green, turning reddish-purple beginning at tips of upper leaves (in young plant; purple leaves in older plant usually from other causes [drought, barren stalk]); slow growth; stalk size small; ears small, misshaped, often twisted from missing rows of kernels, not filled at tip.
- **Potassium**—lower leaves yellow at tip and edges, later dying; stalk weak; ears small, poorly filled at tip, kernels loose.
- **Magnesium**—lower leaves streaked by yellow between the veins, sometimes with rows of dead spots; upper leaves may become reddish-purple at tip and edges.
- **Calcium**—in young plant, leaf tips stick together (do not unfold), giving a ladder-like appearance.
- **Sulfur**—yellow streaks between veins and stunted growth, especially in young plant.
- **Iron**—upper leaves pale green to nearly white between veins (along entire leaf).
- **Copper**—young leaves yellow as they emerge, becoming pale streaked between veins, edges may later die; youngest leaves twisted and dried; stalk soft and limp.
- **Boron**—leaves brittle with small dead spots or streaks; top of growing plant with bushy appearance because stalk does not lengthen; tassels and ears reduced or do not emerge.
- **Manganese**—leaves olive green, may become streaked; stalk may be thin and limber.
- **Zinc**—leaves with wide whitish bands between edge and midrib (edges remain green or turn purplish) which may later die, youngest leaves may be white; plant short because of little stalk growth.

Soybeans

Improved soil health within a soybean crop system can help prevent insect and disease pressure and maximize the plant's ability to fix nitrogen, which is a valuable mineral for a corn crop in rotation. Soybeans are a legume crop, which means they need abundant available calcium, sulfur, and certain trace elements. Soybeans like well-drained, healthy soils, which can be a challenge in the clay-rich, rocky environment in Colorado. Yet, many farmers do include beans in their rotation, for all the reasons listed above. Plus, there is still a growing market for soybeans.

Soybean farmers, when they inspect their fields, are looking at their nodules for a healthy soybean crop, as they are the nitrogen-fixing tools on the plant. Synthetic fertilizers can help create a nitrogen-rich environment, but when other micronutrients are not in balance, that nitrogen can be tied up and become unavailable to the crop.

Molybdenum, for example, is an extremely important micronutrient for nodule formation and formation of complete proteins in the plant. Foliar feeding and feeding close to the roots are important tactics to deliver fertilizer at the right time to the plant. Most often, any pest pressure is coming to a plant already weakened by poor soil nutrition.

Here's a quick guide to potential soil mineral deficiencies in soybean crops, as published in *Modern Soybean Production* in 1983:

▲ Soybeans need well-drained, healthy soils to thrive. *Source: Colorado Department of Agriculture and Travis Harvey*

- **Nitrogen**—Pale green or yellowish leaves. Seldom a problem if root nodule bacteria are present. Can be due to a molybdenum deficiency.
- **Phosphorus**—Plants stunted; leaves blue-green and sometimes cupped.
- **Potassium**—Irregular yellow border around leaves.
- **Calcium**—Few nitrogen-fixing root nodules, causing nitrogen deficiency symptoms.
- **Magnesium**—Leaves turning yellow or brown between veins; leaf tip curled down.
- **Sulfur**—Slow growth; leaves becoming yellowish.
- **Iron**—Slow growth; new leaves yellow or brown between veins.
- **Manganese**—Leaves light green to white between veins.
- **Molybdenum**—Reduced growth; leaves with nitrogen deficiency symptoms.
- **Zinc**—Plants stunted; lower leaves turning yellow to brown to gray and dropping off; young plants with pale green leaves. Few flowers and pods; pods mature slowly.

Potatoes & Sugar Beets

Potatoes and beets are a small but important crop in Colorado, and are challenging for soil management due to the amount of soil disturbance required during harvest.

Jim Ippolito, a research scientist at Colorado State University, talked about the challenge: "Those crops you will never get away from tilling," he said, "so, in those systems, you have to look at a whole systems approach, as you have a major disturbance. How do you get around that? It's challenging and those crops are going on in the Western U.S. We have ideas and you have to scratch your heads with those crops. The systems can be a real pain in the neck relatively speaking. Brendon Rockey is doing them with beneficial plants and organisms; if I wanted to be a producer, I'd want to make it as simple as possible."

On Rockey's farm near Center, Colorado, he and his team produce a biodiverse blend of plants that help attract beneficial insects, help store the nutrients he needs for a strong potato crop, and protect his soil from the challenging weather they experience at high elevation.

"I've seen it snow a foot in June," he said. Yet, the systems he has employed help him trap the needed moisture from those snows, as well as create a more resilient root system.

Rockey's farms are a few hundred of the 53,000 acres planted in potatoes across the state that feed up to 17.5 million people each year. He doesn't have any trouble with the primary pest, the Colorado potato beetle (CPB), which defoliates the crop and is resilient to most commercial pesticides. He credits that to the strong plants he is growing, which are "too much trouble."

While named after our state, the bug has been found on four continents, from South America to western Asia. Female beetles lay masses of eggs

on the underside of potato leaves, or other nearby nightshade plants, like tomatoes and eggplants. Depending on food availability, three or more generations can cycle through the landscape. The hatched larvae and adults both feed on the leaves above ground, with the intermediate stage of pupa developing underground nearby. They overwinter in the soil, so they can began eating foliage immediately in the summer, and the bugs develop resistance to pesticide at a swift rate.

Colorado's San Luis Valley, where Rockey farms, is a hub of potato farming.

At 7,600 feet in elevation, the valley has moderate temperatures, a lot of sun, and low humidity, great conditions to grow potatoes. This climate helps keep CPB pressure low and the area has its own potato packing facility. Most farmers need to use irrigation for a good crop.

The Colorado Certified Potato Growers Association provides high quality seed and vigorously monitors fields for pests and disease. Colorado State University provides seed certification and services to maintain the highest quality of seed potato in the state.

Potatoes in Colorado have an estimated yield of 400 hundredweight (CWT) an acre, at a market price of $10.40/CWT, for a gross of $4,160 an acre.

Sugar beets are produced on around 24,000 acres in production annually. Once a booming industry before the advent of cheap corn syrup in the 1960s, especially in the Weld County area, the sugar beet crop is making a comeback in the state with more than a million tons of sugar beets produced a year in recent years.

Weed pressure in the sugar beet industry is an important issue that must be addressed to produce a good crop. Embracing at least some STAR soil health management tactics will help tackle the weed problem, though there are unfortunately no silver bullets.

Sugar beets are also a crop that requires significant amounts of irrigation water, which, in Colorado means finding the water rights to do so. In 2019, market price for sugar beets was around $38 per ton, and at around 6 tons an acre, grosses around $230 an acre.

"Sunflowers are drought tolerant and can thrive in heat."

Sunflowers

Sunflowers in Colorado have an estimated yield of 935 pounds an acre, at a market price of $27.50/CWT, for a gross of $257 an acre. Sunflowers are planted on 53,000 acres in the state. The value of production is around $13 million as reported to the USDA in 2021, and the yield varies from year to year, between 45-65 million pounds of seed.

Sunflowers are drought-tolerant and can thrive in heat, and as such are a resilient crop in today's current climate. Sunflowers provide seed for oilseed, confection, and birdseed markets. The largest oil processing plant in the state uses 30 million pounds of seed from 120-150 farms a year. Another local mill crushes the seed to make a livestock feed, extracting seven to ten thousand gallons of oil a day. The markets for sunflower are unique and varied compared to other crops, and producers must follow the quality guidelines of a specific market.

Colorado State University is working on increasing sunflower seed production and resiliency through hybrid sunflower trials. CSU has found that crop rotation and plant diversity can address many pest issues. Sunflower head moth and the red seed weevil are a couple of the most voracious pests of the sunflower. Sunflower head moth adults emerge about mid-July and are present until mid-August, living for around 10 days total. As their emergence is staggered, they are present for around 8 weeks in the season. Within about a week after emergence, the females lay eggs on the bract heads at twilight. The larvae develop through five stages and are present until September, feeding on pollen and ultimately seed. When mature, they drop to the ground to spin cocoons in the ground where they spend the winter, only to pupate in June or July and start the cycle again the next year.

Generally insecticides are thought to be warranted when moths are at or exceed the Economic Injury Level (EIL), which is the density of insects expected to cause damage equal to the cost of controls. The red sunflower seed weevil is a small pest of 1/8-inch or so width that are red brown in color. The EIL for oilseed sunflowers is 4 to 6 adults per head, and for confection sunflowers it is one adult per head. It is considered the most seed damaging pest. The market that a farmer is growing for dictates the EIL.

Pheromone trapping helps determine the presence of the moth, but not the density. The best time to treat for this pest, according to North Dakota State University, is the R5.1 growth stage, or right when pollen is beginning to shed. This is the time when most moth eggs have hatched and larvae are present, before the seed heads have formed. It is recommended to apply insecticide early in the morning or late in the day to minimize chemical exposure to pollinators.

Mechanical control can be a very effective and ecologically sustainable method of control as well, although a farmer in a soil health program would need to be conscious and cautious of destroying the humus layer, fungal networks, microbial colonies, and organic residue with any deep tillage. Deep tillage of sunflower stalks in the fall has been shown to reduce moth emergence by 80 percent in trials in Manitoba, Canada. Delaying planting to late May or June will also reduce moth numbers.

The use of insecticides may reduce the effectiveness of an important ecological method of pest control: natural predators and pollinators. A diverse population of beneficial insects

can help keep the pests below the EIL, keeping crops and the ecosystem healthy and in balance.

Cannabis

Cannabis is a relatively new crop that was legalized for medical reasons in 2000 via Amendment 20 to the Colorado Constitution, and was subsequently legalized for industrial use (as hemp) and recreation use (as marijuana for adults over the age of 21) purposes in Colorado in November 2012, via Amendment 64.

In 2019 the industry surpassed $1.7 billion in marijuana medical and retail sales and by 2021, sales numbers had climbed to $2.2 billion in annual sales.

In 2013 Colorado Legislators directed the Colorado Department of Agriculture to assume responsibility for establishing registration and inspection regulations for hemp cultivation. Hemp is a different plant than marijuana, and plant cultivars have an extremely low presence of THC, the chemical in the cannabis family that creates states of intoxication. Hemp was a traditional US crop, first introduced in the 1600s to grow paper, rope, and fuels. Growing a field of hemp was even a requirement for farmers in the 1700s.

In 2021 the USDA approved Colorado's Hemp Plan, which commenced on January 2022. The state also established a "Hemp Center of Excellence" focused on aiding research and outreach, as well as educational efforts that will help boost Colorado's hemp industry. The overall market value of the hemp industry is valued at $5.3 billion, with revenues forecast to be around $15.2 billion by 2027, a growth rate of around 15.8%.

Hemp is therefore a relatively new agricultural industry in the state. Fiber, grain, and seed are all possible products, and fiber and grain utilize similar farming methods as traditional grain farming, and don't come with the same hassles and headaches that producing the oil, called CBD oil, may entail. Even so, producing hemp-based CBD oil products can offer the highest return on investment.

With an average yield of 2.5 to 3 tons of hemp fiber per acre and a hemp grain cost of production between $300 and $350 an acre, it may be possible to net a total of approximately $700 per acre planted in hemp—$250 to $300 an acre for hemp seed, and up to $480 an acre for the fiber. However, these price points are only possible with a fiber or grain mill within 30 or so miles of production, which is unusual in the state.

Thus, many farmers are growing for the oil market, which nets $2,500 to $75,000 an acre, dependent on growing conditions and the final CBD to THC ratio in the cannabis crop.

There are two ways to grow hemp for CBD: horticultural or agronomic, which translates to greenhouse production or field production. At scale, greenhouse production is not considered viable, and so most crop farmers stick to the growing methods they know in the field. Producers can plant up to 2,500 plants per acre, and collect about a pound of oil per plant. The highest yields of CBD can be in the 10 percent range, which sell for about $25 to $35 per pound, according to Bona Fide Seeds, grossing approximately $62,000 to $87,000 per acre. Soil health—primarily biology and chemistry management—is linked to a more resilient crop, and more consistent controls of THC and CBD levels.

Conclusion

No matter the cash crop in Colorado, yield volume and pest and weed controls are the primary reason to enact specific soil health management practices. In many crops, mineral imbalances in the soil weaken the plant's defense system, which attracts pests and creates an environment for diseases to thrive.

Balancing the chemistry, while practicing smart fertilization techniques, will help create adverse conditions for pests and weeds. Mechanical and synthetic controls are still common, but have also been linked to resistance among pests and weeds, so soil health management becomes the economic choice for farmers like Roy Pfaltzgraff and Brendon Rockey.

Produced by Acres U.S.A. for the Colorado Department of Agriculture's STAR program. Primers written and edited by Andrew French, Amy Kousch, Lauren Krizansky, Lydia Lazar, Paul Meyer, Ryan Slabaugh. Thanks to contributions from Jim Ippolito, Megan Machmuller, Ryan Taylor, and the many Colorado farmers and ranchers who provided us on-the-ground information.

Endnotes

AGMRC (2022). Sugarbeet Profile. https://www.agmrc.org/commodities-products/grains-oilseeds/sugarbeet-profile

alishabee (2021). The USDA Approves Colorado's New Hemp Plan, What Does That Mean for Other States?. https://cannabis.net/blog/news/the-usda-approves-colorados-new-hemp-plan-what-does-that-mean-for-other-states

Bona Fide Seeds (2019). How Much Can I Make? Hemp Farming Profit Per Acre. https://www.bonafideseeds.com/how-much-can-i-make-hemp-farming-profit-per-acre/

Brown, J. (2016). GMO seeds are sustaining Colorado's sugar beet farms, but new labels could damage already shrinking industry. Denver Post. https://www.denverpost.com/2016/11/06/gmo-seeds-boost-colorado-beet-farms-but-labels-could-damage-industry/

Chilvers, M., Nagelkirk, M., Byrne, J. (2020). Smuts and Bunts of Small Grains. Michigan State University. https://www.canr.msu.edu/news/smuts-and-bunts-of-small-grains

Colorado Department of Agriculture (2021). Hemp State Plan. https://www.ams.usda.gov/sites/default/files/media/COHempStatePlan.pdf

Colorado Department of Agriculture (2022a). Soil Health. https://ag.colorado.gov/soil-health

Colorado Department of Revenue (2019). Colorado marijuana industry continues to grow, revenue surpasses $1 billion to date. https://sbg.colorado.gov/news-article/colorado-marijuana-industry-continues-to-grow-revenue-surpasses-1-billion-to-date

Colorado Department of Revenue (2022a). Marijuana Sales Report. https://cdor.colorado.gov/data-and-reports/marijuana-data/marijuana-sales-reports

Colorado State University ((2022). About the Colorado Seed Lab. https://agsci.colostate.edu/seeds/seedlab/about-the-colorado-seed-lab/

Colorado State University (2020a+). Colorado Sunflower Report. https://webdoc.agsci.colostate.edu/csucrops/reports/sunflowers/sunflowerreport_2020.pdf

Colorado Wheat (2014). Wheat Disease Alert - Stinking Smut. https://coloradowheat.org/2014/07/wheat-disease-alert-stinking-smut/

History Colorado (2019). Collecting the History of Marijuana Legalization in Colorado. https://www.historycolorado.org/story/stuff-history/2019/04/19/collecting-history-marijuana-legalization-colorado

Knodel, J.J., Prasifka, J. R. (2019). Banded Sunflower Moth. NDSU. https://www.ag.ndsu.edu/publications/crops/banded-sunflower-moth

Luoping Zhang, Iemaan Rana, Rachel M. Shaffer, Emanuela Taioli, Lianne Sheppard (2019). Exposure to glyphosate-based herbicides and risk for non-Hodgkin lymphoma: A meta-analysis and supporting evidence. Mutation Research/Reviews in Mutation Research,Volume 781, pp. 186-206, ISSN 1383-5742. https://www.sciencedirect.com/science/article/abs/pii/S1383574218300887

Meyer, R.F. (2021). Sunflower Update. Colorado State Univerisity. https://www.hpj.com/archives/colorado-wheat-farmers-should-test-seed-for-germination/article_e6b2037d-cc58-583d-bfb5-02eef7cd5cdf.html

Ministry of Hemp (2019). History Of Hemp In The US. https://ministryofhemp.com/hemp/history/

Morgan, T. (2022). Drought Robs Colorado Farmer's Wheat, Now it May Be Too Dry to Plant Corn This Spring. AgWeb. https://www.agweb.com/news/crops/planting/drought-robs-colorado-farmers-wheat-now-it-may-be-too-dry-plant-corn-spring

Peairs, F. B. (2016). Russian Wheat Aphid. Colorado State University. https://extension.colostate.edu/topic-areas/insects/aphids-in-small-grains-5-568/

Peairs, F. B., Pilcher, S.D. (2013). Western Corn Rootwaorm - 5.570. Colorado State University. https://extension.colostate.edu/topic-areas/insects/western-corn-rootworm-5-570/

Reppenhagen, C. (2017). Colorado's sunflowers have sprouted into a $30 million industry. 9 News. https://www.9news.com/article/news/local/next/colorados-sunflowers-have-sprouted-into-a-30-million-industry/73-495286934

Sibley, G. (2012). 'Water Wrangling' for the West Slope. Post Independent. https://www.postindependent.com/news/water-wrangling-for-the-west-slope/

STAR (2022). About Star. https://starfreetool.com/about

Stovall, B. (2016). Plentiful Potatoes Grown In Colorado. Farm Flavor. https://farmflavor.com/colorado/colorado-crops-livestock/plentiful-potatoes-grown-in-colorado/

The Coloradoan (2018). Sugar beets making a comeback as Colorado cash crops. Denver Post. https://www.denverpost.com/2018/08/04/sugar-beets-colorado-cash-crops/

The Nature Conservancy (2021).The Southern High Plains Initiative. https://www.nature.org/en-us/about-us/where-we-work/priority-landscapes/southern-high-plains-initiative/

Tyne, M. (2022). Drought Robs Colorado Farmer's Wheat, Now it May Be Too Dry to Plant Corn This Spring. AgWeb. https://www.agweb.com/news/crops/planting/drought-robs-colorado-farmers-wheat-now-it-may-be-too-dry-plant-corn-spring

USDA (2022). 2021 STATE AGRICULTURE OVERVIEW, Colorado. https://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=COLORADO

USDA ARS (2016). Colorado Potato Beetle. USDA. https://www.ars.usda.gov/northeast-area/beltsville-md-barc/beltsville-agricultural-research-center/invasive-insect-biocontrol-behavior-laboratory/people/donald-c-weber/colorado-potato-beetle/

UWM ((2013). Colorado Potato Beetle (Family Chrysomelidae). https://uwm.edu/field-station/colorado-potato-beetle-family-chrysomelidae/

Walden, K. (2018). he 3 Distinct Agricultural Regions of Colorado. https://farmflavor.com/colorado/colorado-farm-to-table/3-distinct-agricultural-regions-colorado/

The STAR program was originally developed by Champaign County Soil and Water Conservation District (CCSWCD) in Illinois and is now also administered in four other states: Colorado, Indiana, Iowa, and Missouri. The Colorado STAR Plus program grew out of a stakeholder process launched by the Colorado Department of Agriculture and other partners in 2019 that was facilitated by the Colorado Collaborative for Healthy Soils, involved more than 250 stakeholders and resulted in passage of HB21-1181 and SB21-235, which authorized and funded the launch of a state soil health program based around STAR. This state stimulus funding and additional grant funding received from the Gates Family Foundation, Colorado Department of Public Health and the Environment, Colorado Water Conservation Board, NFWF, and NRCS have enabled the launch of the first round of the STAR Plus program.

Getting Involved with Colorado STAR

In the summer of 2021, legislation was passed in the Colorado House of Representatives funding the Agricultural Soil Health Program for 2022. The Colorado Soil Health Program is built around the framework of an Illinois program called STAR, which stands for Saving Tomorrow's Agriculture Resources. STAR was developed to be a free resource for farmers and ranchers, helping them evaluate their current land practices, and particularly focusing on nutrient and soil loss. The STAR program encourages best soil health practices, and rewards producers with recognition, a high rating, and a field sign. While the STAR rating system is a useful metric for farmers to measure their own conservation efforts, it is also a tool for consumers interested in a farmer's soil health practices.

The program was originally created in the Champaign County Soil & Water Conservation District in 2017, with the assistance of the Illinois Department of Agriculture, as a means to facilitate specific environmental and agricultural goals that were outlined in the state's Nutrient Loss Reduction Strategy. Colorado, as well as Iowa and Missouri, have adopted this program framework.

Best management practices for agricultural land use have been developed since the 1930s by the United States Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS). The STAR program utilizes these best practices, and also relies on a panel of experts, including university researchers and scientists, to establish appropriate ranking systems based on different resource factors. STAR Plus is an additional level of producer support that "facilitates capacity building by providing matching state funds towards the cost of these projects and activities within each district". This means that the state provides technical and financial assistance to producers over the course of three years, through grants and services like soil testing that are facilitated through the state's conservation districts.

Any farmer or rancher can visit the STAR website and fill out these forms in order to receive this rating. The first 100 participants in a year also receive a free soil test.

To participate, the only requirement is that the farmer or rancher fill out a form to the best of their knowledge, describing their farm practices in detail for a specific field chosen by the producer. The forms include questions about cropping practices, tillage regimes, fertilizer and nutrient applications, and other management practice information. The producer then receives a STAR rating from 1-5 that demonstrates their incorporation of the five principles of STAR: Soil Armor, Minimize Soil Disturbance, Plant Diversity, Continual Live Plant/Root, and Livestock Integration in their cropping system. Earning five stars in a field means that a farmer or rancher is implementing all five soil health principles on that field, while earning one star means that they are following only one.

COLORADO Department of Agriculture Conservation Services Division

ACRES USA

Colorado State University

SAVING TOMORROW'S S.T.A.R. AGRICULTURE RESOURCES