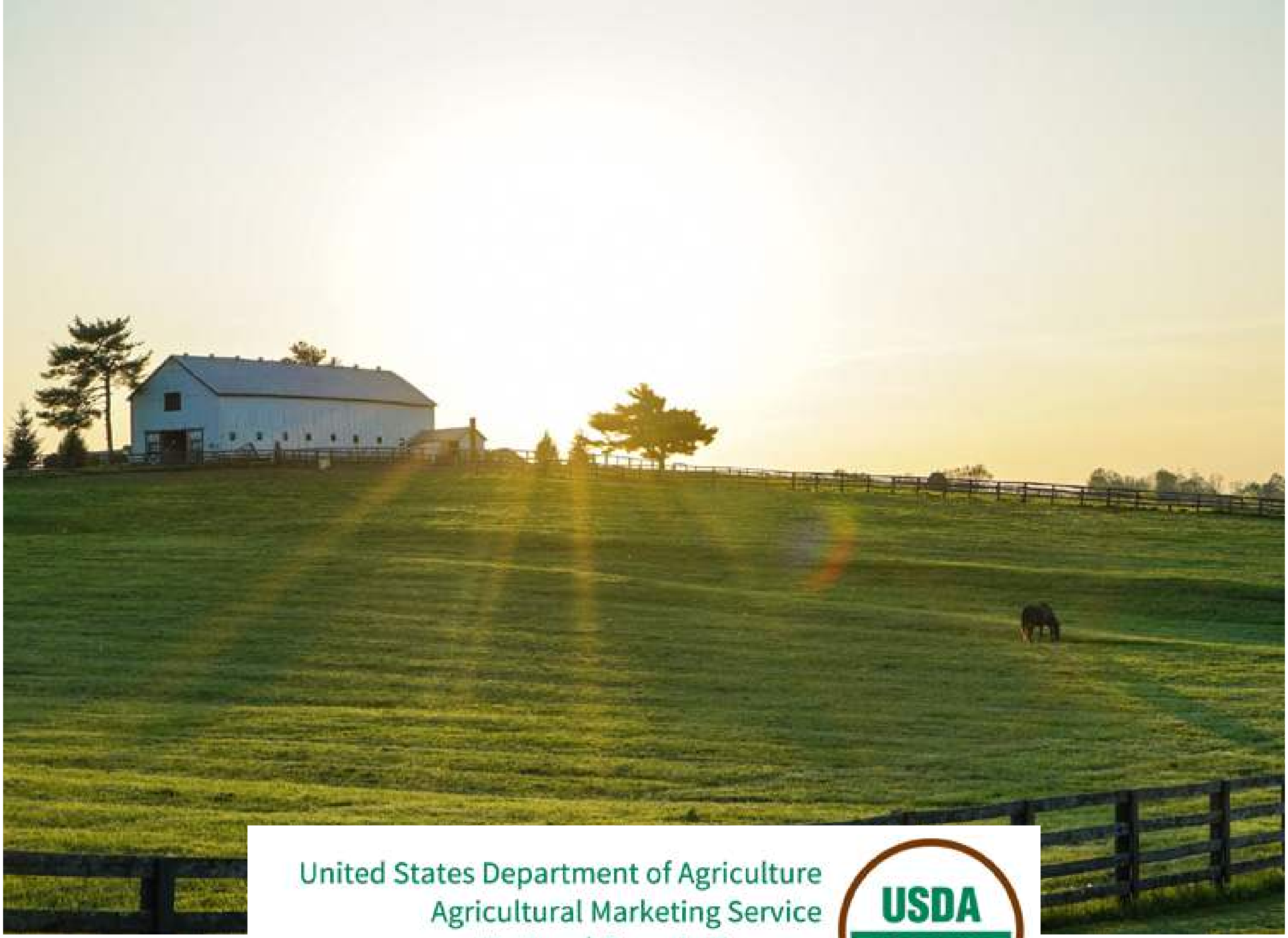
The Transition to Organic Partnership Program (TOPP)

ACRES USA®

Prepared for USDA Organic by Acres U.S.A.



United States Department of Agriculture
Agricultural Marketing Service
National Organic Program
Transition to Organic Partnership Program

USDA ORGANIC

Soil Balancing Basics for Organic Farming

All farmers, and particularly organic farmers, understand the importance of the soil for growing healthy crops and animals. Farmers who overuse the plow and neglect the necessary practices for returning fertility to the ground generally don't remain in business long. The question, then, is how to build and maintain that healthy soil.

Simple laboratory soil analysis methods became available in the early 20th century. This allowed scientists and farmers to begin to discern exactly how much of which minerals were in the soil. The predominant form of agriculture that arose from this knowledge emphasized the three primary macronutrients: nitrogen, phosphorus and potassium. For about a century — and certainly since synthetic sources for each became widely and inexpensively available after World War II — testing for N, P and K and amending based on deficits of these three minerals has been the mainstream approach.

But a separate analytical system has been in use since that same time by a smaller number of farmers that doesn't require yearly additions of commercially sold synthetical fertilizer, nor even on-farm-produced organic matter. This method — popularly known as soil balancing — leads to more fertile soils and healthier plants, and healthier plants are more resistant to insect pests and diseases.

In this paper we'll provide an introduction to soil balancing and how it can help organic farmers provide robust fertility to their plants.

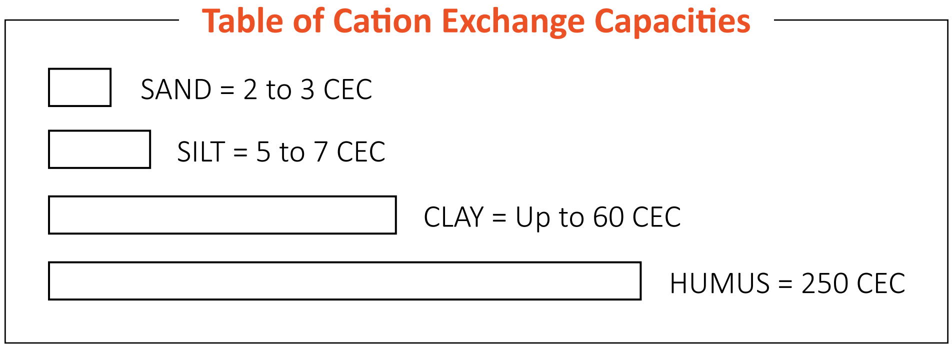
PHOTO COURTESY ACRES U.S.A.

PREREQUISITES: A SOIL TEST AND BIOLOGY

Soil balancing requires a soil test. There are many different methods of testing soil today (and of testing irrigation water, plant sap, soil biology, etc. — see the AcresUSA/TOPP paper "Soil and Plant Testing Basics for Organic Farming"), but the test used for soil balancing — the Mehlich 3 extraction method — is widely available and inexpensive.

The Mehlich 3 method uses a strong acid to determine both available and some unavailable nutrients. There are other extraction models — ammonium acetate, Morgan, modified Morgan, etc. — and each is useful in the proper circumstances, but the soil balancing methods developed in the early 20th century were first based on the Mehlich 3 extraction.

Also, just because we're talking about soil chemical balancing, we should never forget the importance of soil biology for farming. We've learned much in the past few decades about the vital importance of microbiology — whether in the human gut, the soil or plants. Microbes — bacteria, fungi, and others — receive signals from plants, mainly in the form of root exudates, and exchange those exudates for forms of minerals that are available (usable) to the plant. This will be the focus of a forthcoming white paper by AcresUSA and TOPP. In the current paper we will concentrate on ensuring the proper minerals — whether available or not — are in the soil. This is chemistry in support of biology, which in turn supports overall plant health.



SCHRIEFER, *AGRICULTURE IN TRANSITION*

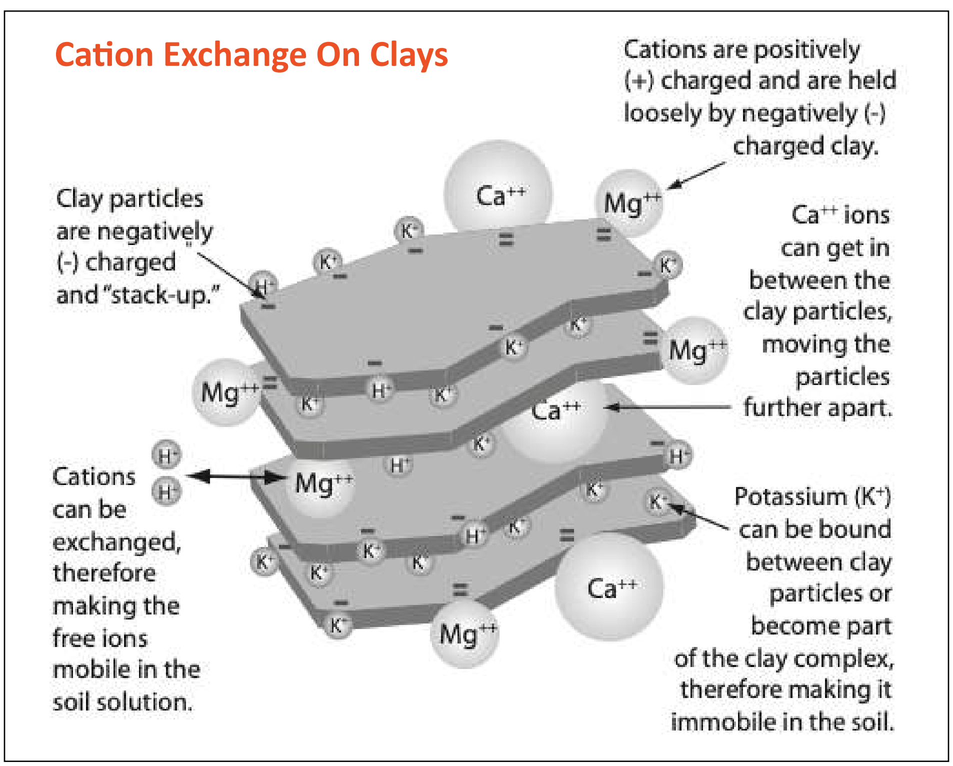
CATION EXCHANGE CAPACITY

Building a balanced soil begins with understanding Cation Exchange Capacity (CEC).

CEC is the soil's holding tank. A low CEC is like having a very small gas tank for your car — you can't drive very far without running out; a low CEC means your soil doesn't hold very many nutrients. Also, when you try to put too much gas in a small tank, you make a mess — excess nutrients in the soil means that much of what you apply gets washed away, plus you have an increased risk of plant disease.

Technically speaking, CEC is the ability of the soil to hold and release elements and compounds. Clay has a high CEC — it is able to hold onto nutrients better than sand, which has a low CEC. Organic matter has a very high CEC and is able to retain and give away nutrients even better than clay. CEC is called "cation" exchange capacity because it measures the ability of the negatively charged soil particles (clay, silt, sand and organic matter) to hold and release cations — positively charged nutrients, most importantly calcium, magnesium, potassium and sodium.

Nutrients are also in the soil in the form of rocks and liquids. We generally do not consider these for analysis, however, because minerals in rocks are not available to the plant until they're broken down by microbes over the course of centuries, and nutrients in liquid form are likely to simply leach out of the soil anytime there's rain.



ZIMMER, *ADVANCING BIOLOGICAL FARMING*

The fact that soil particles are negatively charged explains why positively charged ions are attracted to it. But how are these ions "exchanged"? Plant root exudates and soil microbes give off H+ ions (carbon dioxide, CO_2, actually, but this interacts with water in the soil and creates carbonic acid, H_2CO_3, which contains H+ ions). When two hydrogen ions get close enough to a calcium (Ca++) ion, for example, they together take the place of the calcium and displace it into the soil for the plant or the microbe to use.

In the early 20th century — after the advent of laboratory tests capable of measuring amounts of these cations, CEC, pH and other important metrics, but before the rise of the chemical industry after World War II that led to largescale farming with synthetic NPK fertilizers — soil scientists, notable Dr. William Albrecht at the University of Missouri, ran field tests and determined that the "ideal" soil is one in which the soil's CEC was "saturated" to approximately 65 percent calcium, 15 percent magnesium, 2 to 5 percent potassium, and 1 to 4 percent sodium (the rest is made up of trace minerals and hydrogen — H+). These levels produced soils that had good pH (6.4 to 6.5) and excellent structure and that grew high-quality crops.

A Well-Balanced Soil

Primary cations (as % of Cation Exchange Capacity

Calcium (Ca++) 60–80%	**Potassium (K+)** 2–5%
Magnesium (Mg++) 10–20%	**Sodium (Na+)** 1–4%

Primary anions

Phosphorus (P-)	Should equal K by weight – but phosphate (P_2O_5) should be twice the potash (K_2O)
Sulfur (S--)	Half of K, up to 300 ppm

Secondary elements

Iron (Fe+)	1/3 to 1/2 of K, min 50 ppm
Manganese (Mn+)	1/3 to 1/2 of Fe, min 25 ppm
Zinc (Zn+)	1/10 of P, 10<ppm<50
Copper (Cu+)	1/2 of Zn, 5<ppm<25
Boron (B+++ or B-)	1/1000 of Ca, 1<ppm<4
Chlorine (Cl-)	1–2 x Na, min 25 ppm

BASED ON *THE IDEAL SOIL V2.0*

CALCIUM AND MAGNESIUM

The two largest components of a balanced soil are calcium and magnesium, and the ratio between these two is the most important to keep in check. Conveniently, they are also often the least expensive imbalances to correct because the sources of Ca and Mg — lime, gypsum, dolomitic lime, etc. — are usually locally available.

In general, calcium loosens soil and magnesium tightens it. A soil that is high in calcium will tend to have more oxygen, will drain water better, and will support the decomposition of organic matter. High-magnesium soils are the opposite; if you dig up undigested crop residue from previous years, your soil is probably too high in magnesium relative to calcium. But too much calcium can interfere with the plant's ability to take up other important nutrients; again, it's the ratio — the balance — that is key.

The 65-15 goal stated above is an average; soils that are more compacted or that have more clay may need up to 80 percent calcium and 10 percent magnesium, whereas a sandy soil might need 60 and 20.

FIGURING OUT THE NUMBERS

With a simple soil test and the table of goals for a balanced soil, it only takes some simple math to determine how much of each element your soil has, how much it needs, and how much to add. Here are the basic steps:

1. Conduct your Mehlich 3 soil test. Ask for the results to come back in ppm (parts per million) of the element, rather than in pounds or in any other metric. If your results aren't in ppm, do that conversion (see *The Ideal Soil v2.0* for step-by-step procedures).
2. Based on the CEC of your soil (which should be provided in the soil test results), and the chart below (based on the elemental composition of each nutrient and its charge), determine how many ppm of each element your soil needs. The complete explanation for the math is in *The Ideal Soil v2.0* and other places. Here's an example:

All of the negative exchange sites on a soil with a CEC of 1.0 would be filled by:

Calcium	200 ppm	400 pounds/acre
Magnesium	120 ppm	240 pounds/acre
Potassium	390 ppm	780 pounds/acre
Sodium	230 ppm	460 pounds/acre

For a soil with a CEC of 12.5, and a desired calcium saturation of the ideal — 65 percent —

200 ppm x 0.65 x 12.5 = 1,625 ppm calcium required

Or, in a soil with a CEC of 8.2, and a desired magnesium of 15 percent,

120 ppm x 0.15 x 8.2 = 148 ppm magnesium required

3. Subtract the amount of each nutrient you have (provided on the soil test) from the required amount (calculated in Step 2). For example, for the calcium example, if your test says you have 1,300 ppm,

1,625 ppm required – 1,300 ppm on hand = 325 ppm to add

4. Convert the ppm you need into pounds per acre by multiplying by 2 (325 ppm would be 650 pounds per acre). Then determine which inputs you have easy access to and how much of that will supply the necessary amount. Many inputs come in different forms with differing elemental analyses. For example, here are the common options for calcium:

Calcium-containing amendments (by percentage)

	% calcium	% magnesium	% sulfur
Ag (high-calcium) lime	32-40	1-5	-
Dolomitic lime	22	13	-
Gypsum	22	-	16
Oyster shell	36	0.3	-

So, if we choose to supply 650 pounds of calcium via dolomitic lime, we would need to apply

650 pounds Ca / 0.22 = 2,955 pounds dolomitic lime

Be aware, though, that since dolomitic lime also contains magnesium, those 2,955 pounds would provide 384 pounds of magnesium — which your soil may or may not need.

5. Apply the required amendments and retest the next year.

APPLICATION TIPS AND DEALING WITH EXCESSES

Always err on the side of applying less — it's very difficult to lower levels of any mineral, and plant diseases and insect outbreaks are often associated with nutrient levels that are too high rather than too low. That said, sulfur application can be an effective treatment for high levels of many cations, and plants and soils generally need more sulfur.

Soil balancing works, but don't expect immediate, incredible results. It takes time for added nutrients to begin to make a difference. Remember that nature is forgiving — robust soil biology can make up for some level of chemical imbalance. Start with calcium and magnesium — they're inexpensive and readily available, and they make the greatest impact.

Agronomic recommendations are going to continue to become more and more precise — and complex — as new analytical methods are developed and the number of different inputs increases. Yet simple soil balancing will continue to work, just like it has for the past hundred years. It's a tried-and-true method, with easy-to-find, natural amendments that fit organic philosophies and practices.

Using sulfur to treat cation excesses

CONDITION	PRESCRIPTION	% S	% Ca	% Mg	% K_2O
High Ca, low Mg	Add magnesium sulfate (Epsom salt)	**14**	-	**10**	-
HighMg, low Ca	Add calcium sulfate (gypsum)	**16**	**22**	-	-
High Ca and/or Mg, low K	Add potassium sulfate	**17.5**	-	-	**51**
High or adequate Ca, Mg and K, high pH	Add 90% agricultural sulfur	**90**	-	-	-
High Na	Add sulfate sale of whichever major cation is deficient, or 90% ag sulfur				

This article was written by Acres U.S.A., in coordination with the Organic Crop Improvement Association (OCIA) International. OCIA is the TOPP administrator for the Plains Region. This article is supported through the United States Department of Agriculture (USDA) Transition to Organic Partnership Program (TOPP). TOPP is a program of the USDA Organic Transition Initiative and is administered by the USDA Agricultural Marketing Service (AMS) National Organic Program (NOP).

Recommended resources to learn more about balancing soil on organic farms:

The Ideal Soil v2.0
by Michael Astera

Advancing Biological Farming
by Gary Zimmer

Eco-Farm: An Acres U.S.A. Primer
by Charles Walters

Agriculture in Transition
by Don Schriefer

A Beginner's Plan for Small Farms

What if you grow, say, a variety of different vegetables on a relatively small amount of land (<1 to 10 acres)? Conducting leaf sap analysis for every different crop you grow could certainly help, but this is likely too expensive and time consuming.

Here's agronomist John Kempf's recommendation. Begin with the standard soil balancing method outlined in this paper, focusing on achieving a good balance of calcium and magnesium. Then conduct a simple soil mineral assay, also known as a mining assay or "total nutrient digestion" test. This is an inexpensive test that's been available for a long time but that is only now being recognized for its value. Modern organic farmers understand that the bacteria and fungi in the soil are able to receive signals from plants and can transform molecules from forms the plant can't use into bio-available forms, feeding those new molecules back to the plant in exchange for root-exudate sugars.

Given this knowledge, a soil mineral assay tells the grower the total mineral content of their soil, allowing them to know whether the nutrients their plants need — whether in available or unavailable form — are present. Microbes can't make unavailable nutrients available if the nutrients aren't there in the first place. A soil mineral assay tells the grower the total elemental composition of the macro- and micronutrients in the soil.

Add the elements the assay says are missing (per the chart on page 4). Finally, rely on biology to make whatever's unavailable available to your plants. This means everything from inoculating seeds with microbes to adding biology to the soil and feeding that biology with simple and complex sugars. Adding a general micronutrient source like kelp onto the seed treatment itself can also be incredibly effective, ensuring those needed minerals are where the plant needs them right from the start.

