NebGuide

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Research-Based Information That You Can Use

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Nutrient Management in Organic Farming

Sam E. Wortman, Assistant Professor–Environmental Horticulture
Charles S. Wortmann, Extension Soils Specialist
Ashley Linville Pine, Former M.S. Graduate Student
Charles A. Shapiro, Soils Specialist–Crop Nutrition
Ashley A. Thompson, Post-Doctoral Research Associate
Richard S. Little, Research Technologist

Compost (left) and cover crops (right) are potentially complementary components of a successful organic nutrient management plan.

This NebGuide addresses nutrient management in organic farming and considers sources, soil availability, and cycling of nutrients.

Maintaining or enhancing long-term soil productivity is a key provision of the National Organic Program (NOP) regulation § 205.203, which states that the producer must (a) select and implement practices "that maintain or improve the physical, chemical, and biological condition of soil and minimize soil erosion," (b) "manage crop nutrients and soil fertility through rotations, cover crops, and the application of plant and animal materials," and (c) "manage plant and animal material applications to maintain or improve soil organic matter," but minimize "contamination of crops, soil, or water by nutrients, pathogenic organisms, heavy metals, or residues of prohibited substances." Any soil-applied product, including composts or manures, must be produced in compliance with NOP regulations.

The National Organic Standards Board (NOSB) periodically revises the NOP list of allowed or prohibited substances by considering the need for the product and the impact it may have on human health and the environment. The Organic Materials Review Institute (OMRI) reviews manufacturer claims for specific products annually to determine whether they meet NOP requirements. OMRI maintains an extensive, up-to-date list of approved substances available at www.omri.org. When a specific fertilizer or amendment is not OMRI-listed, farmers should consult their third-party certifying agency prior to application to ensure compliance. The use of organic materials, biofertilizers, cover crops, and crop rotations according to National Organic Program standards are addressed in this NebGuide.

Nutrient management on organic farms should economically meet crop nutrient needs and avoid soil nutrient depletion, while maintaining or improving soil productivity without excessive nutrient losses. Soil nutrient availability is dependent on diverse soil chemical, physical, and biological properties, their interactions, and their interaction with the cropping system. While measurements can be made for many soil properties, crop performance is the best indicator of soil productivity. Farmers typically manage to minimize soil physical and chemical constraints to sustainable productivity through practices such as:

- Applying organic materials such as manure, compost, and biofertilizers to supply nutrients and maintain soil organic matter
- Growing cover crops to cycle soil nutrients and biologically fix atmospheric nitrogen
- Diversifying crop rotations for more efficient recovery and physiological use of

Soil and plant tissue analysis

Most crop essential soil nutrients are adequately supplied by agricultural soils in Nebraska. Application of nitrogen and phosphorus is most common for high crop productivity in Nebraska. Deficiencies of potassium, sulfur (with sandy soil), iron (with calcareous soil), and zinc can occur and require attention in some fields. Yield increases due to application of other nutrients are rare in Nebraska. Management to avoid acidic soil conditions (Nebraska Extension NebGuides G1503 and G1504) and soil aggregation, and to avoid compaction (NebGuide G896) are also important for ensuring sufficient nutrient availability to crops.

Soil sampling every four years is advised to test for soil organic matter, pH, and availabilities of phosphorus, potassium, and zinc, as well as other properties of interest. Soil sampling practices and methods, such as grid versus management zone sampling, are addressed in NebGuide G1740. Soil pH 6 is the desired minimum pH for most

Table 1. Critical soil test values for four diverse field crops common to Nebraska (based on soil samples taken to an 8-inch depth). Values are derived from EC155, *Nutrient Management for Agronomic Crops in Nebraska*

	Crop		
Soil property	Corn	Dry beans	Potato
P (ppm)	>16–24 [1]	>10 [2]	>25 [1]
K (ppm)	>125–150	>125	>125
SO_4-S (ppm)	>6–8 [3]	*	>8
Zn (ppm)	>0.8	>1.5	>1.0

1. Bray-1 P values; 2. Olsen-P values; dry bean production regions in Nebraska have high pH, calcareous soils where Olsen-P test is more appropriate (however, values can be multiplied by 1.5 to estimate Bray-1 values); 3. Only applicable for sandy soil with very low soil organic matter; * = not limiting in soils of typical production regions

organic cropping systems in Nebraska. Iron deficiency is commonly associated with calcareous soils with pH > 7.2. Alkaline soils on organic farms can be acidified over time by applying OMRI-approved mineral sulfur (e.g., sulfate of potash) or acidic mulches (e.g., pine needles).

Applying agricultural lime to raise soil pH is allowed in organic production. Beef feedlot manure has a liming effect, typically the equivalent of about 60 pounds of agricultural lime per ton of manure dry weight. However, most other manures and composts, and biological nitrogen fixation, have a net acidifying effect. Plant and soil testing laboratories commonly do recommend nutrient application rates, but Nebraska Extension EC155, *Nutrient Management for Agronomic Crops in Nebraska* is especially valuable for interpretation of soil test results and determination of nutrient and lime application rates.

Critical levels for soil nutrient availability represent thresholds above which no yield increase is expected due to application of the nutrient, although application of organic materials may have other positive effects on the crop. See *Table 1* for a sample of critical soil test values for several essential plant nutrients for common field crops in Nebraska. These values can be used as a starting point for making annual decisions about nutrient sources and application rates; however, developing a long-term nutrient management plan and proactive (instead of reactive) management of soil fertility is advised for organic farms.

Soil nitrate-nitrogen is highly variable throughout a field and over time is not always a reliable predictor of fertilizer need. Many farmers use a late-spring soil nitrate test to determine sidedress application rates in corn, but sidedress fertilizer applications are rare in organic farming. Crop nitrogen demand and annual removal should guide fertilizer or amendment application rates in organic farming, but rates can be reduced if nitrate is detected in

Table 2. A phosphorus (P) budget example for a four-year organic crop rotation where animal manure was applied to meet crop nitrogen demand, resulting in high phosphorus application and accumulation over time

Crop	Inputs	P content of inputs	Rate (dry)	Total P input	P content of crop*	Crop yield	Total P removed†	Total P balance
		%	tons/ac	lb/ac	%	lb/ac	lb/ac	lb/ac
Soybean	None				0.659	1,775	12	-12
Corn	Manure	0.6	15	180	0.317	5,850	19	161
Soybean	None				0.659	1,775	12	-12
Wheat	Manure	0.6	10	120	0.435	2,810	12	108
4-yr total								245

*Based on values from NRCS Plant Nutrient Content Database. All P values are for elemental P and not for P_2O_5; † Total P removed = (% P content of grain) x (grain yield)

soil samples taken to the rooting depth (2–4 feet for most crops; see EC155 for interpretation of deep soil nitrate values in agronomic crops) and when a legume is the preceding crop (see section below for further information).

In addition to increased productivity, using organic materials to fertilize crops can improve broader measures of soil "quality" or "health." Changes to soil physical and biological properties that may result from long-term organic nutrient management include reduced bulk density, increased aggregate size and stability, increased water infiltration, and increased water-holding capacity; increased microbial biomass, diversity, and respiration; and increased nitrogen mineralization potential, reduced soil erosion and soil crusting, and increased soil carbon sequestration (NebGuide G2283). Soil physical and biological tests are available at some soil testing labs. Other "soil health" do-it-yourself procedures also are available, including the USDA NRCS Soil Quality Test Kit (https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/health/assessment/?cid=nrcs142p2_053873).

Plant tissue analysis every three to five years to diagnose potential nutrient deficiencies of perennial crops, such as fruit tree crops, is advised. See New Mexico State University Cooperative Extension Service Guide A-123, *Sampling for Plant Tissue Analysis,* for crop-specific sampling techniques.

Nutrient sources

Manure

Manure application is often valuable to organic production. However, applying manure to meet all of the crop nitrogen demand can lead to excessive soil phosphorus because crops remove more nitrogen than phosphorus. The excessive soil phosphorus is not likely to be harmful to crops but contributes to phosphorus loss in runoff and erosion and contamination of water bodies. Therefore, manure nitrogen needs to be complemented by biological nitrogen fixation or other nitrogen sources in organic systems.

A nutrient budget can be a useful tool for long-term accounting of phosphorus addition via manure (or other fertilizer source) and removal via harvested crops (see example in *Table 2*). This approach to nutrient management can help to ensure organic farmers do not unsustainably mine inherent soil nutrient reserves, and on the other end of the extreme, do not build up soil nutrient levels of high risk for environmental contamination.

The National Organic Program restricts the use of manure on crops for human consumption. Raw manure must be applied more than 120 days before harvest if the edible portion of the crop will be in direct contact with soil, and 90 days before harvest if the edible portion of the crop will not be in direct contact with soil. These restrictions do not apply for composted manure and for crops not intended for human consumption; however, if the farm is Good Agricultural Practices (GAPs) certified (https://www.ams.usda.gov/services/auditing/gap-ghp), it is important to consult with the certification agency for recent guidelines prior to any manure applications.

Typical nutrient concentration estimates for different manure sources are available *(Table 3),* but actual nutrient content varies with the methods of manure storage and handling, livestock ration, animal maturity, and weather conditions. Thus, manure samples should be analyzed for nutrient content before application (NebGuide G1450). Manure application equipment should be calibrated to ensure the desired rate of nutrient application (NebGuide G1335).

Manure nitrogen is primarily in organic and ammonium forms. Ammonium-nitrogen is immediately available to the crop for uptake if it is not lost to volatilization as

Table 3. Typical nutrient content of different solid manure sources

Solid manure	Dry matter %	Nutrient composition			
		Ammonium-N	Organic-N	P_2O_5	K_2O
		(lb of nutrient per ton of manure)			
Beef (dirt lot)	67	2	22	23	30
Beef (paved lot)	29	5	9	9	13
Beef (bedded pack barn)	30	1	17	11	14
Swine (hoop barns)‡	40	6	20	15	18
Dairy (scraped earthen) lots)	46	—	14	11	16
Broiler (house litter)	69	15	60	27	33
Layer	41	18	19	55	32
Turkey (house litter)	70	—	44	15	30

Source: NebGuide G1335, *Determining Crop Available Nutrients from Manure*. Dashes indicate reliable numbers are not available for this manure.

Table 4. Estimated first-season availability (%) of manure ammonium-nitrogen

Ammonium-N			
	% ammonium-N (NH_4-N) available this year[1]		
Incorporation	Solid	Liquid (<50 °F)	Liquid (>50 °F)
Immediately	95%	95%	95%
1 day after	50%	70%	70%
2 days after	25%	55%	45%
3 days after	15%	45%	40%
7+ days after	0%	40%	0%
Organic N			
	% organic-N available this year[2]		
Source	Solid	Fresh liquid	Stored liquid
Beef/dairy	25%	—	35%
Poultry	30%	—	—
Swine	—	50%	35%
Compost	15%[3]	—	—

1. Applied preplant and incorporated via tillage or rainfall event greater than ½ inch; 2. Assumes spring-seeded crops; for fall-seeded crops, multiply values by 70 percent to account for delayed mineralization during cooler months; 3. This estimate is for composted feedlot manure but composts of lower carbon-to-nitrogen ratios are expected to have higher availability.

ammonia. Ammonium-nitrogen availability depends on if the manure is injected or surface-applied, the time before incorporation if surface-applied, temperature, and precipitation or irrigation events *(Table 4)*. Manure organic nitrogen must be mineralized to ammonium before it can be used by plants. Estimated organic nitrogen availability to the first crop following application varies with manure type, ranging from 25 percent for solid beef feedlot manure to 50 percent for fresh swine manure. Estimated nitrogen availability for second, third, and fourth crops after application are 15, 7, and 4 percent, respectively, of the total organic nitrogen applied

Instead of depending on manure to meet annual crop nitrogen demand, organic farmers should build diverse fertility strategies into their farm system plan. A conventional crop may receive the majority of nitrogen from mineral fertilizers applied prior to the growing season. However, an organic crop should receive nitrogen from a greater number of sources at a greater number of intervals to ensure regular mineralization of organic nitrogen. For example, 40 percent of nitrogen may be supplied by fall-applied manure followed by mineralization until nitrogen uptake by the following crop ceases; 20 percent may be available from a preceding summer legume cover crop; and 40 percent may be available from mineralization of soil organic matter and ammonium-nitrogen deposition from the air. Because the timing of nitrogen availability varies by crop and nutrient input, organic farmers must be proactive and plan crop rotations and nutrient inputs well in advance to synchronize nutrient availability with crop demand.

Compost

Composting processes organic waste into material of higher nutrient concentration, and reduces the bulk of organic materials through carbohydrate and water loss during decomposition (NebGuide G1315). Compost is often easier to handle than the bulk organic material, and the composting process kills some pathogens and weed seeds. Compost has less odor and fewer microbial pathogens, with less risk of microbial contamination of fresh produce than with raw manure. There are fewer NOP restrictions on the use of compost in edible crops, but composted animal manures must be applied to soil prior to planting to mitigate pathogen risks. For GAPs-certified growers, composts must meet Food Safety Modernization Act standards.

Nitrogen mineralization for finished composts with a carbon:nitrogen ratio (C:N) less than 20:1 occurs readily with much of the organic nitrogen released to the first crop following application. Composts with C:N greater than 30:1 will result in net immobilization of soil nitrogen with reduced nitrogen availability to the first crop following application. Nearly all of the nitrate and ammonium in the compost will be available to the plants the first season after application, but only 15 percent of the organic nitrogen in the compost may be available during that season if the C:N is high. Organic N availability estimates for years two through four are the same as for manure (15, 7, and 4 percent, respectively).

In addition to supplying nitrogen, compost is an important source of other macro- and micronutrients. As with other organic materials, compost application can improve soil organic matter content, cation exchange capacity, soil porosity, aggregate stability, and water-holding capacity, although the magnitude of improvements will depend on current soil organic matter levels (NebGuide G2283). Similarly, soil biological properties, including microbial biomass, microbial enzymatic activity, and nitrification potential are often increased following compost application. Despite the many benefits of compost, raw manure is still popular because of the added cost of composting and the nitrogen volatilization loss that occurs during composting.

Other products for nutrient supply

For organic production of agronomic crops, manure, compost, and nitrogen fixation are the main sources of added nutrients. However, other organic products are used to enhance nutrient availability for high-value crops *(Table 4)* with varying nutrient composition and mineralization rates. As with manure and compost, the nutrient mineralization rates of such products are largely driven by the C:N. Use of these products for lower value commodities is limited due to high purchase and shipping costs. Given the low nutritional content of compost, manure, and organic products on a mass basis (relative to fertilizer), economic feasibility of application decreases as distance from the source increases.

Biofertilizers

Biofertilizers are products designed to provide enhanced nutrient availability and uptake, stimulation of crop growth, biological nitrogen fixation, and protection against insect pests and disease. Depending on the purpose, biofertilizer products can be applied to soil, seeds, or foliar tissue. Evidence to support product claims is often limited or mixed. Recent research suggests biofertilizers may be most beneficial in soils of low to moderate soil organic matter and nutrient availability or with foliar application. In contrast, biofertilizer applications to soils of >3 percent organic matter rarely result in measurable crop or soil benefits. Introduced microorganisms often fail to compete and survive with already well-established and resilient microbial communities.

Several common categories of biofertilizers include nitrogen-fixers, phosphorus-solubilizers, phosphorus-absorbers, and humic acid. Nitrogen-fixers such as *Rhizobium* (in symbiosis with legumes), *Azospirillum*, and *Azotobacter* convert atmospheric nitrogen into ammonia. *Bacillus* and *Pseudomonas* are examples of microbes found in phosphorus-solubilizing biofertilizers that lower the soil pH to dissolve soil-bound phosphate for plant availability and may be most effective for calcareous soils. Arbuscular mycorrhizal fungi take up soil phosphorus, zinc, and copper and transfer these to plant roots, but these are typically abundant in Nebraska agricultural soils. Humic acid is important to plant growth but is already abundant in most soils. A soil with 3 percent organic matter may have as much as 10–15 tons of humic acid in the surface soil layer; thus, adding a few more ounces per acre is unlikely to enhance crop growth and yield.

While biofertilizers may be beneficial in some situations, it is important to note that biofertilizers, unlike chemical fertilizers, are not regulated. Product labels often lack detailed information about the ingredients. If they contain living organisms, the shelf life is often short. Given the number of products on the market with unproven claims of crop and soil benefits, growers are urged to include a non-treated check or control in the field when using biofertilizers to test the claims of soil or crop benefits and evaluate their cost-effectiveness. See the Nebraska Extension “Grower’s Guide to On-Farm Research” (http://cropwatch.unl.edu/nofrnzmag) for tips on conducting simple, but effective and scientifically valid, experiments on your own farm. Evaluations of many biofertilizers and other nontraditional soil additives are documented but others are too short lived to be evaluated well (http://extension.agron.iastate.edu/compendium/index.aspx).

Cover crops

Cover crops can improve soil physical properties, nutrient cycling, and soil microbial activity. In addition, cover crops can scavenge residual nitrogen mineralized from soil and organic amendments before it is lost to volatilization, runoff, or leaching. However, like other sources of organic nitrogen, nitrogen contained in cover crop biomass is not entirely available to the next crop. It is important to consider the C:N of the cover crop residue. Species with high C:N (>20:1; e.g., grasses) result in net immobilization of soil nitrogen in the short term, whereas nitrogen will be more readily available following decomposition of species with low C:N (<20:1; e.g., legumes).

Nitrogen fixation by legume cover crops can be especially useful for increasing soil nitrogen availability

Table 5. Nutrient analysis and approximate release speed (time required for mineralization of guaranteed nutrients) of common products for organic production

	% N	% P_2O_5	% K_2O	Release speed
Nitrogen				
Alfalfa meal	2	1	2	2–6 months
Blood meal	12	1	1	6–8 weeks
Cottonseed cake	7	2	1	12–16 weeks
Feather meal	13	0	0	6–9 months
Fish meal	10	5	0	6–8 weeks
Fish emulsion	5	1	1	<4 weeks
Soybean meal	7	2	1	8–12 weeks
Phosphate				
Bonemeal (raw)	4	20	0	8–12 weeks
Rock phosphate	0	20	0	6–12 months
Potassium				
Greensand	0	1	6	6–12 months
Kelp meal	1	0.1	4	2–6 months

and balancing the abundant phosphorus and potassium supplied through manure or compost application. Legume cover crops high in nitrogen, such as hairy vetch and field pea, can provide up to 150 pounds of plant-available nitrogen per acre to the following crop, depending on the amount of growth. However, the cover crop needs to be terminated early enough to avoid increased C:N as the plant matures, and to allow sufficient time for residue decomposition, mineralization of organic nitrogen, and soil water recharge (farmers in western Nebraska should carefully consider trade-offs between cover crop nitrogen contributions and soil water use during fallow periods). To this end, it is recommended that legume cover crops are terminated at the flowering stage and at least one to two weeks prior to planting.

When using cover crops in nitrogen management, it is important to consider the total nitrogen content of the cover crop residue. If a cover crop has 3 percent nitrogen concentration at the time of termination, the resulting soil input is 60 pounds of organic nitrogen per ton of dry matter. Subsequent ammonium-nitrogen release from that organic nitrogen is estimated to be 19 pounds of nitrogen per ton after four weeks and 28 pounds of nitrogen per ton after 10 weeks *(Table 5).* Thus, if a grower can produce 3 tons of dry matter per acre of a 3 percent nitrogen cover crop, approximately 84 pounds of plant-available nitrogen per acre could be mineralized within 10 weeks after termination. Combined with other organic amendments to meet plant phosphorus, potassium, and micronutrient demand, cover crops can be a sustainable and cost-effective nutrient source for organic production.

Table 6. Predicted ammonium-N (Am-N) release from cover crop residues with differing N content and C:N ratios

Cover crop residue total N		Predicted Am-N release	
		4 weeks	10 weeks
% N in DM	lb N/ton in DM	lb PAN/ton DM	
1	20	<0	0
1.5	30	3	9
2	40	7	14
2.5	50	12	20
3	60	19	28
3.5	70	28	37

Source: Pacific Northwest Extension PNW 636, *Estimating Plant-Available Nitrogen Release from Cover Crops.*

Crop rotation

Crop rotation can contribute to improved soil physical properties, pest management, nutrient availability, nutrient use efficiency, and crop yield. Legumes in the rotation (e.g., beans, alfalfa, or clover) can result in a nitrogen credit for subsequent crops due to biological nitrogen fixation and less nitrogen immobilization compared with a non-legume as the preceding crop *(Table 6).* However, the nitrogen credit for forage legumes is greater than for grain or vegetable legumes because most of the nitrogen (whether scavenged from the soil or biologically fixed) is removed during harvest of the grain.

In contrast, forage legumes contribute nitrogen from vegetative biomass, which can be comparable to cover crop nitrogen contribution if the forage has time to regrow between the last cutting and termination. Cereal and other non-legume crops in rotation can be useful for building soil organic matter–an important reservoir of nutrients in organic farming (G2283). Root architecture is important to sustainable crop rotation. Deep-rooted crops like alfalfa can scavenge immobile nutrients like phosphorus and leached nutrients like nitrate-nitrogen from deep soil layers, which may be released near the soil surface with decomposition of the crop residue for availability to subsequent crops in rotation.

Conclusions

Nutrient management on organic farms requires long-term planning and a diverse combination of cultural practices and inputs. There are an increasing number of commercially-available organic fertilizers and biofertilizers, but the most profitable organic farms typically source nutrients on or very near the farm by using organic wastes, scavenging residual soil nutrients, and biological fixation of

Table 7. Nitrogen credit to subsequent crop following legume

Legume	N Fertilizer Credit (lb/acre)	
	Medium and fine textured soils	Sandy soils
Soybean	45	35
Dry bean	25	25
Alfalfa (70–100% stand, >4 plants/ft^2)	150	100
Alfalfa (30–69% stand, 1.5–4 plants/ft^2)	120	70
Alfalfa (0–29% stand, <1.5 plants/ft^2)	90	40
Sweet clover and red clover	80% of credit allowed for alfalfa	

Source: Nebraska Extension EC117, *Fertilizer Suggestions for Corn*.

nitrogen. When off-farm or manufactured fertilizer inputs are necessary, it is essential to verify that the product is allowed in organic production by consulting the OMRI list or the certifying agency.

Resources

The cited Nebraska Extension publications are available at: http://extensionpubs.unl.edu/.

Flynn, R., S.T. Ball, and R.D. Baker. 2004. Sampling for Plant Tissue Analysis Guide A-123. New Mexico State University. http://aces.nmsu.edu/pubs/_a/A123.pdf

Sullivan, D.M., and N.D. Andrews. 2012. Estimating plant-available nitrogen release from cover crops. PNW 636: A Pacific Northwest Extension Publication. Oregon State University, Washington State University, University of Idaho. https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/pnw636.pdf\

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