CHAPTER 4

Soil Fertility

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Organic farmers have different approaches to supplying crop needs compared to conventional farmers who provide fertility by numerous synthetic fertilizers, (Table 4-1). However, even among organic producers, there can be different philosophies when it comes to supplying nutrients. Some believe it is important to keep fertility on-farm and avoid any external outputs. These producers gain nutrients for their crops from longer, diverse rotations with green manures and cover crops, and perhaps manure from their livestock. Other producers supplement organic practices with external amendments purchased from outside sources. Both viewpoints are valid and are based on a similar principle – to provide good nutrition for crops and develop healthy soils without environmental degradation.

PHOTO COURTESY OF JOHN DEERE

Figure 4-1. *Manure spreader.*

Compost manure, animal manures, and green manures are examples of commonly used organic fertilizers for short and long-term fertility management. Other soil amendments can be mineral-based such as rock powders and lime, or organically-based such as fish emulsions and kelp (Table 4-2). Mineral fertilizers and some of the organic-based amendments are slow-acting and require long-range planning. Once soil fertility and nutrient cycling have been established in organic rotations, some producers find that mineral amendments are rarely necessary. Instead, fertility is managed by conserving nutrients, using green manures and composts, by leaving stubble in the field, and keeping hay on the farm.

Adjusting pH

Soil pH affects nutrient availability (Figure 4-2). Even if nutrients are present, they may not be available for plant uptake. Overly acidic or alkaline soils need to be adjusted to proper levels for crops to grow adequately. With the exception of alfalfa, which requires a pH of 6.5 or more, most crops do well with a pH of 6.0. When soil is overly acidic, lime is applied to increase the pH of soil.

Liming is the practice of adding crushed limestone (calcium carbonate) to raise the pH and reduce the acidity of a soil. In organic systems, only natural sources like mined products are allowed to adjust pH. There are two main types of lime—calcitic lime (also called calcite) and dolomitic lime (also called dolomite). Both types not only correct soil pH, but also supply calcium (Ca^{++}) for plant nutrition. Soils in Minnesota generally have adequate calcium so the use of lime for the sole purpose of supplying calcium is not recommended. Dolomitic limestone also contains magnesium (Mg^{++}) in addition to calcium carbonate. Calcium hydroxide and calcium oxide are synthetic liming products and are not allowed in organic systems.

Prior to liming, a soil test is needed to assess both the pH and buffer pH to apply the correct source of lime, if any. Soil samples should be taken from a six- to eight-inch depth. Lime application rates will be dependent

Table 4-2. NOP allowed soil amendments (other than compost and manures).
Deficiencies must be documented with soil/tissue testing prior to amendments.

ALLOWED AMENDMENTS
Aquatic plant extracts (other than hydrolyzed)
Elemental sulfur
Humic acids (naturally occurring)
Magnesium sulfate
Soluble boron
Sulfates, carbonates, oxides, or silicates of zinc, copper, iron, manganese, molybdenum, selenium, and cobalt.
Liquid fish products
Lime (naturally occurring)

Table 4-1. Organic versus conventional fertilizers.
Adapted from Cogger, 2000.

ORGANIC FERTILIZERS	CONVENTIONAL FERTILIZERS
Naturally occurring with minimal processing	Manufactured or extracted with substantial processing
Nutrients are usually slow release	Nutrients are usually immediately available
Nutrients occur in low concentrations	Nutrients occur in high concentratrations
Nutrients can be long-lasting	Nutrients are not long-lasting
Examples include manure, rock phosphates, and fish meal	Examples include ammonium sulfate, processed urea, and potassium chloride
Usually not more than one plication per season	May require multiple applications apwithin a single season
Nutrients that are slow release will have less potential to cause environmental damage	Nutrients have more potential to cause environmental damage

Table 4-3. Approximate amounts of lime needed to raise pH to 6.0. *The SMP buffer pH is a quick procedure used by laboratories to determine how much lime to apply in soils with pHs less than 6.0. Refer to Figure 4-3 for map with Areas I and II. Adapted from Rehm et al., 2002.*

	Lime (tons/acre)	
SMP buffer pH	Area I	Area II
6.8	2.0	0
6.7	2.0	0
6.6	2.0	0
6.5	2.5	0
6.4	3.0	2.0
6.3	3.5	2.0
6.2	4.0	2.0
6.1	4.5	2.0
6.0	5.0	2.5
5.9	5.5	2.5
5.8	6.0	3.0
5.7	6.5	3.0
5.6	7.0	3.5

on recommendations in the soil test results, the quality of the lime (Effective Neutralizing Power, ENP), and the desired final pH (Table 4-3). Lime is not required in many soils (e.g., Western Minnesota) when the pH is 6.1 or higher because of the non-acidic subsoils (Figure 4-3).

Reducing risk: adjusting pH. For pH, take soil samples at six- to eight-inch depths. See Chapter 3 for more information. Follow liming recommendations and evenly apply. Verify liming materials and methods with certifier.

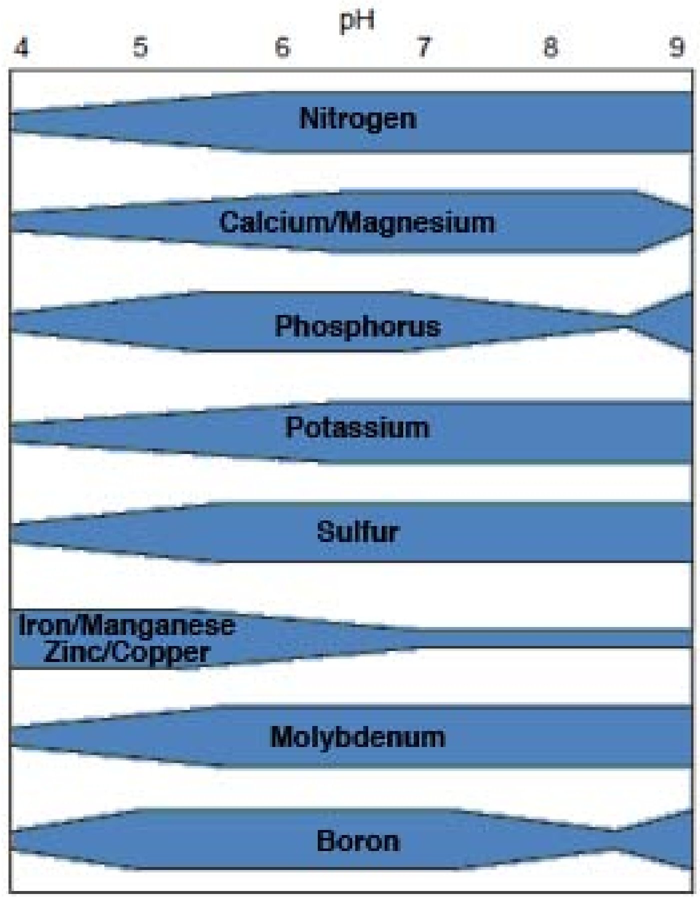

Figure 4-2. *Ranges of pH and nutrient availability. The wider the bar, the more that nutrient is available. Adapted from University of Minnesota Extension.*

Ca:Mg ratios

Some organic producers prefer calcitic limestone because they believe that dolomitic limestone is harmful to the soil because the magnesium in dolomitic limestone affects Ca:Mg ratios. However, considerable research has shown that insuring that the overall amounts of calcium and magnesium are sufficiently available is more important than ratios. In other words, it has not been possible to predict crop yields based on the Ca:Mg ratio. Therefore, both calcite and dolomitc limestone products should be acceptable and effective liming agents. In any case, producers should also consider that calcitic lime tends to be more expensive. Dolomitic lime can be slower acting and can supply magnesium, which can be deficient in Minnesota (see Table 3-9 from Chapter 3).

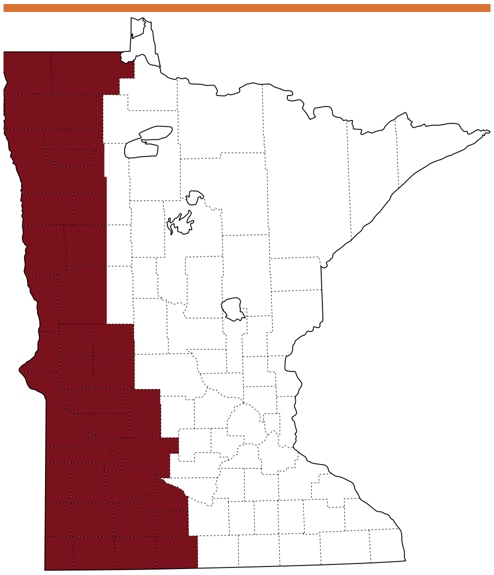

Figure 4-3. *Lime is not recommended when pH is 6.1 or above in the western part of the state (in red). Adapted from Rehm et al, 2002.*

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Figure 4-4. *Alfalfa green manure.*

Green manures

A green manure is a crop that is incorporated into the soil to add organic matter, nitrogen or other nutrients. Green manures can be legumes that fix nitrogen or non-legumes that scavenge nutrients. In organic systems, legumes are often used as green manures to add nitrogen. Green manures can have dual functions; in addition to providing fertility, they also function as winter cover crops and forages. Legumes used as green manures can provide a significant source of nitrogen for the next crop;

Gypsum

Gypsum ($CaSO_4$-$2H_2O$) is a naturally occurring soft mineral obtained from mining of sedimentary deposits. Gypsum is widely used in a number of building materials including plaster and wallboard for construction. Gypsum is also marketed to organic producers as a fertilizer and as a soil building agent. However, in the Upper Midwest, its value is limited. Gypsum is a good example of why producers need to understand the properties of soil amendments before purchase and application.

When applied to the soil, gypsum dissolves slowly into Ca^{++} and SO_4^{--} ions and both can be taken up and used in nutrition of plants. But, a response to Ca fertilization is unlikely in most Minnesota soils, because most soils have adequate levels of Ca. However, gypsum can be a valuable sulfur fertilizer on soils with a sandy texture. When, applied as a fertilizer, gypsum dissolves slowly so an immediate response should not be expected.

Although gypsum contains both calcium and sulfur, gypsum has no effect on soil pH. This is related to soil chemistry and the Ca^{++} and SO_4^{--} ions that are formed when gypsum is applied to the soil. Soil pH is changed from addition of $CaCO_3$ (lime) and S (elemental S), and neither Ca^{++} and SO_4^{--} ion affects pH.

Gypsum is effectively used in the western United States to condition and enhance structure of soils containing high amounts of sodium. Fortunately, few of these soils are found in the Upper Midwest. In addition, the diversified crop rotations practiced by organic farmers are effective at maintaining soil structure.

Table 4-4. The amount of nitrogen (nitrogen credit) available to subsequent crops in the first and second year after. *Adapted from Rehm, et al., 2008.*

	NITROGEN CREDIT (LBS/ACRE)	
PREVIOUS CROP	1st year	2nd year
Harvested alfalfa		
- 4 or more plants/ft$_2$	150	75
- 2-3 plants/ft$_2$	100	50
- 1 or less plants/ft$_2$	40	0
Red clover	75	35

Figure 4-6. *Sorghum-sudangrass can provide soil organic matter and can smother weeds.*

this is referred to as a nitrogen credit (Table 4-4). However, unlike grasses, legumes do not make considerable lasting contributions to soil organic matter. Thus, legumes and grasses/cereals mixes create a good compromise and are often grown together to increase nutrient availability and soil organic matter. Green manures can be one of the most sustainable ways to provide nitrogen and other nutrients. As opposed to manure or compost, they do not cause phosphorous loading and there is reduced leaching of nitrogen because nutrients are released slowly.

SPECIES SELECTION

Selection of green manures requires knowledge of the crop rotation. Typically, organic producers who use legume green manures follow them with a crop like corn because of its high fertility needs. Other considerations are ease of incorporation, weediness in the following crop, timing of incorporation, and possible allelopathic effects. Alfalfa, red clover, and hairy vetch are common legume green manures used by organic producers in the Midwest. Alfalfa is a long-lived perennial, red clover a short-lived perennial and hairy vetch is a winter annual. For more information on growing these crops, see the Winter Cover Crops chapter and Forages chapter.

In addition to legumes, grasses such as winter rye and sorghum-sudangrass are used for plowdown to add soil organic matter (Figure 4-6). These grasses can accumulate soil nitrogen and release it when they are incorporated. In low nitrogen soils, incorporation of a large amount of grass biomass into the soil can cause a temporary tie-up of nitrogen until the microorganisms break the herbage down.

Is your green manure fixing nitrogen?

To determine if a green manure crop is fixing nitrogen, take the following steps:

- ✔ Dig up a legume plant that is over 1 month old but not flowering
- ✔ Remove soil from roots
- ✔ Look for nodules, which will look like round or elongate whitish growths on the roots (Figure 4-5)
- ✔ Break open some of the nodules. Actively-fixing nodules appear pink or red.

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Figure 4-5. *Red clover root with pinkish, elongate nodules.*

Table 4-5. Factors that determine the amount of legume nitrogen available to the next crop.

FACTOR	EFFECT ON NITROGEN CREDIT
Stand condition (e.g. presence of weeds, density of stand)	Stand density is an important determinant. See Tables 4-2 & 4-3. Weeds will significantly reduce credit.
Stand age	Two or three year old stands of alfalfa will provide more N than first year alfalfa. See Table 4-6.
Stand height/herbage yield	If alfalfa height is taller than 8 inches, the nitrogen credit can be 40lb/ac greater than if the height is less than 8 inches. See Table 4-4.
Harvest management and number and/or removal of cuttings	Forage that has been cut once or not at all will usually provide a higher N contribution in the fall for use the following spring. See Figure 4-2. Removal of herbage will reduce nitrogen contribution.
Incorporation	Herbage left on the soil surface will provide less N (because some has been lost to the atmosphere) than if it had been incorporated.
Time of termination: spring vs. fall	Legume crops that are terminated in the spring before planting rather than the fall will provide more nitrogen in the year of incorporation though some nitrogen may be available to a crop in the 2nd year. The hazards to spring alfalfa termination are possible moisture shortages as well as potentially less accommodating seed beds.
Soil type	Nitrogen credits will be lower on sandy soils compared to medium or heavy textured soils. See Table 4-4.
Soil moisture	Determines when the nitrogen is available. Herbage will break down faster in moist soils.
Soil temperature	Determines when the nitrogen is available. Herbage will break down faster at higher temperatures.
Legume species	Nitrogen fixation rates vary by species.

PRODUCER PROFILE

Red clover seeded with a spring small grain can be used as a late fall plowdown to provide nutrients for subsequent crops. An organic producer from Clay County plants his small grains with underseeded red clover. After small grain harvest, he plows down the red clover in the fall (usually in October). The red clover green manure is the only nitrogen source he uses; no manure or soil amendments have been used for the past eight years. His organic inspector says his fields are the least weedy he has seen.

NITROGEN CREDITS

The amount of nitrogen that is provided by a legume green manure is influenced by many factors (Table 4-5). Legumes vary in nitrogen fixation and also the amount of nitrogen rich herbage they produce. Alfalfa generally will provide twice as much nitrogen as red clover. Soybean, though a legume, has a low credit (about 30 pounds/acre) as most of the fixed nitrogen is removed at harvest. Important management factors include stand density, harvest management, and timing of incorporation (Figure 4-7 and Tables 4-6). Environmental factors affecting nitrogen production and utilization include soil temperature and soil moisture.

In addition to the amount of nitrogen available from green manures, the timing of the release of nutrients is a critical component. Once legumes are worked into the soil, about half of their nitrogen is released in one month. Unfortunately, this may occur before the primary crop needs it most and the nitrogen can be lost (Figure 4-8).

Reducing risk: green manures. Choose a species adapted to your area and cropping system. Plant an appropriate crop to be grown after the green manure like corn or another grass to utilize nitrogen. To protect soil and minimize carbon loss, use the least intensive tillage method (i.e. chisel plowing vs. moldboard) that is still effective to terminate green manures.

PRODUCER PROFILE

A producer from Waseca County regularly grows red clover as part of his rotation. He uses it as a green manure for a subsequent corn crop. In the fall, he partially controls the red clover with chisel plowing and does another operation in the spring to complete the termination. He finds it difficult to control unless he does a fall operation. If conditions do not permit fall chisel plowing, in the spring he will use a spike tooth digger rather than a shovel digger, which causes compaction on his soil.

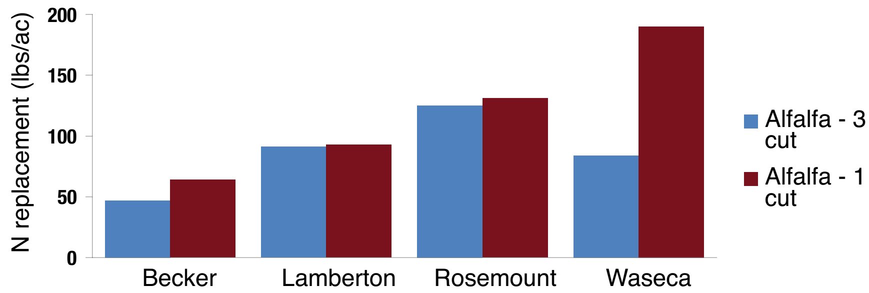

Figure 4-7. *N replacement values in lbs/acre for alfalfa that has been cut once or three times at four sites in Minnesota. Sheaffer, et al., 1989.*

Table 4-6. Nitrogen credits (pounds/acre) from alfalfa with varying stand heights and densities on different soils.
Adapted from Undersander, 2005.

Stand density (plants/ft^2)	CLAY/LOAM SOILS > 8″	CLAY/LOAM SOILS <8″	SANDY SOILS > 8″	SANDY SOILS <8″
> 4	190	150	140	100
1.5 to 4	160	120	110	70
< 1.5	130	60	80	40

(AMOUNT OF REGROWTH INCORPORATED)

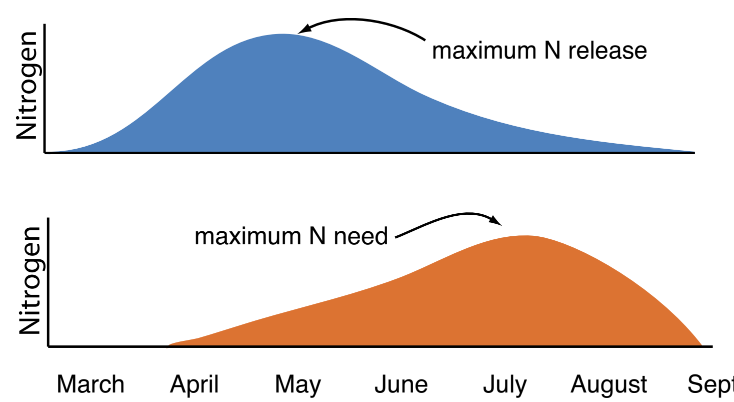

Figure 4-8. *Nitrogen rate of release from green manures relative to crop needs. The majority of nitrogen is released by June, while the crop needs are highest in July.*

Manure

NCRS, TIM MCCABE

Figure 4-10. *Liquid hog manure being spread on a field.*

Manure is a valuable resource on an organic farm. Its application can serve as a source of organic matter and plant nutrients. Livestock are inefficient in extracting nutrients from feed and some of the nutrients in feed are excreted into the manure. Most common manures in the Midwest are beef, dairy, hog, chicken, and turkey. Properly managed manure can add plant nutrients and improve soil quality. Raw manure is high in nutrients, especially readily available N. Nitrogen is the main nutrient considered in application rate, but P and K should be monitored over time as they quickly build up in soil. Timing of application is also important, as raw manure is best applied to row crops in the spring prior to planting. Fall application could cause leaching and risk of runoff,

A producer from Chippewa County plows his alfalfa in the second year. He finds he has to use moldboard plowing to control alfalfa.

Figure 4-9. *Close-up of a moldboard plow.*

Terminating green manure crops

Terminating a perennial green manure crop in preparation for another crop can be a source of risk. If the green manure is only partially controlled, it will compete with the next crop. There are two things to consider: when to terminate and how to terminate.

The time to terminate will be largely dependent on soil and climate conditions. For instance, if soil moisture and anticipated spring weather conditions do not allow the type of tillage needed for complete control of the legume, fall tillage is a common practice. However, fall termination can expose the soil to erosion. Red clover is more easily terminated than alfalfa. Some organic farmers are able to control red clover with chisel plowing. Many organic producers who use alfalfa have few options other than moldboard plowing for termination (Figure 4-9).

To terminate red clover, a producer from Lac Qui Parle suggests minimal straight point chisel tillage in the fall with more aggressive field cultivator seedbed preparation tillage in the spring as late as is possible depending on the subsequent corn crop.

but in some cases can be necessary to comply with NOP rules on manure application to certain crops. According to NOP rules, manure cannot be applied when the ground is frozen.

Manure from conventional operations is allowed under NOP rules, but the type of manure allowed may vary by certifier. Some will not allow conventional manure, some will allow conventional manure with restrictions, and some will allow conventional manure only if it has been composted. It is very important to verify the manure source and test the manure prior to use. Certifiers will also monitor levels of manure application, which should not be applied at excessive levels, which potentially lead to pollution problems of waterways and air quality. See Table 4-7 for NOP rules on manure and compost application.

MANURE TESTING

Animal manures vary widely in nutrient content and availability, depending on the animal source (Table 4-8). Since the nutrient content is so variable, testing is recommended. The Minnesota Department of Agriculture has a list of certified manure testing laboratories at http://www2.mda.state.mn.us/webapp/lis/manurelabs.jsp. Taking representative samples is critical for characterizing the manure nutrient content. Samples should be taken prior to application for the best estimate of nutrients. Mixing the manure before sampling will increase the chances of getting a more representative sample. A composite of at least 10 subsamples is best. Manure testing may be required to adhere to European or Canadian organic rules. Some manure from conventional operations, especially poultry litter, may be contaminated by heavy metals.

Table 4-7.

NOP MANURE & COMPOST RULES

1. No raw manure unless it is incorporated more than 120 days prior to harvest for crops for human consumption whose edible portion is in direct contact with the soil.

2. No raw manure unless it is incorporated more than 90 days prior to harvest for crops whose edible portion does not contact soil.

3. Compost can be applied at any time if produced according to requirements.

Table 4-8. Nutrient content of manures in the Midwest.

These values are estimates only. Adapted from Blanchet and Schmitt, 2007.

		LIQUID			SOLID		
		N	P	K	N	P	K
Livestock		lbs/1000 gallons			lbs/ton		
Swine	Farrowing	15	12	11	14	6	4
	Nursery	25	19	22	13	8	4
	Gestation	25	25	24	9	7	5
	Finishing	58	44	40	16	9	5
Dairy	Cows	31	15	19	10	3	6
	Heifers	32	14	28	10	3	7
Beef	Cows	20	16	24	7	4	7
	Finishing	29	18	26	11	7	11
Poultry	Broilers	63	40	29	46	53	36
	Layers	57	52	33	34	51	26
	Tom Turkeys	53	40	29	40	50	30
	Hen Turkeys	60	38	32	40	50	30

MANURE NUTRIENT AVAILABILITY

Manure nutrients vary in their availability to crops. Some nutrients are lost to the atmosphere and to leaching due to the application process (Table 4-9), while some nutrients are only available over the long-term. After manure testing to determine initial content, it will be helpful to consult with Table 4-9 that tells how application method and timing will affect availability. The amount of nutrients available post-application from manure will vary due to initial content, application method, and timing of application (Table 4-10).

Table 4-9. Percent nitrogen lost from original content based on application method, time of incorporation, and species.
Adapted from Blanchet and Schmitt, 2007.

	BROADCAST			INJECTION	
	No incorporation	Incorporated within 1-4 days	Incorporated within 12 hours	Sweep	Knife
Beef	40	20	5	5	10
Dairy	40	20	10	5	10
Swine	50	30	10	5	15
Poultry	30	20	5	NA	NA

The nitrogen in manures is in two forms: the organic form, which releases slowly; and the inorganic form (ammonium and nitrate), which are immediately available. Generally, the inorganic nitrogen will be depleted in the year of application, while a portion of the organic nitrogen is available over two to three years. Different types of manure have different proportions of the two types of nitrogen, which will be indicated on the manure analysis. Manure with a higher proportion of ammonium, like poultry manure, should be incorporated into the soil so that the nitrogen is not lost to the atmosphere. Timely incorporation also protects water sources from nutrient runoff.

Reducing risk: manure.

Check with your certifier about appropriate sources. Have manure tested for nutrient content prior to application. For maximum manure N use, apply manure before heavy-feeding crops like corn. Follow NOP rules on manure use and application. Apply manure two weeks to one month ahead of planting to synchronize nutrients to crop needs and to avoid problems with pests such as corn root worm and seed corn maggot. Be aware of potential environmental consequences of manure application such as excess phosphorus accumulation in the soil and loss of nutrients from during spreading.

Table 4-10. Percent nitrogen available over time based on application method, time of incorporation, and livestock.
Adapted from Blanchet and Schmitt, 2007.

		BROADCAST			INJECTION	
		No incorporation	Incorporated within 1-4 days	Incorporated within 12 hours	Sweep	Knife
Beef	Year 1	25	45	60	60	50
	Year 2	25	25	25	25	25
	Year 3	10	10	10	10	15
Dairy	Year 1	20	40	55	55	50
	Year 2	25	25	25	25	25
	Year 3	15	15	10	15	15
Swine	Year 1	35	55	75	80	70
	Year 2	15	15	15	15	15
	Year 3	0	0	0	0	0
Poultry	Year 1	45	55	70	NA	NA
	Year 2	25	25	25	NA	NA
	Year 3	0	0	0	NA	NA

Compost

Composting is the controlled decomposition of manure, crop residue, bedding, or other organic matter by microorganisms in the presence of oxygen. The goal of composting is to produce a nutrient stable product. There are numerous advantages to composting as compared to using raw manure that offset the storage and handling required to make the finished product. (Table 4-11). These include a high return of nutrients to the field; improvement of soil biological, physical, and chemical properties; slow and steady release of nutrients; easier handling; reduced weed seeds/insect larvae/pathogens; decreased crop disease/pest issues; and reduced odor.

KEN HAMMOND, ARS

Figure 4-11. ***Turning windrows is a necessary part of efficient composting.***

Compost quality depends on the source materials of organic matter, the conditions under which the compost is made, and the maturity when the compost is supplied (Table 4-12).

COMPOST APPLICATION

Mature compost is low in phytotoxins (chemicals harmful to plants) and is safe for application to any crop/growth stage. Compost alone may not be able to supply all the N for some crops. Incorporation of compost

Table 4-11. Advantages and disadvantages of compost as compared to manure.

ADVANTAGES
Slow release of nutrients
Spreads easier than manure
Fewer weed seeds
Less potential for runoff
Less pathogens
Fewer odors
Fewer NOP restrictions on time of application
DISADVANTAGES
More expensive than manure
May be more difficult to obtain
Lower nutrient content
Additional time and labor to produce own compost
Potential nutrient leaching during compost process

Heat-processed manure products

Heat-processed or dehydrated manure is another fertilizer source. Recently the NOP changed the rules for application of this product. Previously, the rules for applying heat-processed manure to organic fields were the same as for raw manure. Now this product can be applied without manure restrictions, similar to compost. However, heat-processed manure must reach a temperature of 165° F briefly or 150° F for at least one hour. In addition, it must be dried to a maximum moisture level of 12 percent. To verify these conditions, bacterial counts of no more than 1,000 fecal coliform per gram or three *Salmonella* per four grams should be found in the final product. Heat-processed manure will have nutrients available more quickly compared to compost, though there is greater potential for leaching.

Table 4-12. Compost nutrient content.
Adapted from Rosen and Bierman, 2005.

COMPOST	DRY MATTER	AVAILABLE N	TOTAL N	P_2O_5	K_2O
	%	------------------- lb/ton	--------------------		
Poultry	45	1	17	39	23
Dairy	45	<1	12	12	26
Mixed (poultry, dairy, swine)	43	<1	11	11	10

Table 4-13. Estimated compost nutrient availability over time.
Adapted from Rosen and Bierman, 2005.

	% N availability		
Compost type	1st year	2nd year	3rd year
Poultry	30	10	10
Dairy	14	10	10

is recommended for organic N to be broken down by microorganisms. As with manure, testing compost is important and there can be great variability in nutrient content Compost nutrient N, P_2O_5, and K_2O content is usually in the range of 1-1-1 to 2-1-2. For composted dairy manure, 5 to 20% of N is available the first year (Table 4-13).

MAKING COMPOST

Making good compost depends on a good C:N balance of the starting material (Table 4-14). Usually animal bedding such as straw mixed with raw manure is an excellent base. The combined values of C:N ratios of the total starting materials must be in the range of 25:1 to 40:1. Finished compost will be half of these ratios. To produce compost approved for organic production, materials must be maintained at certain temperatures for defined time periods (Table 4-15). Other factors that are important in making compost are the correct levels of moisture and aeration. Proper conditions during composting are particularly important, as this will minimize odors. The three primary techniques for producing compost include static piles, windrows and in-vessel. See the "For More Information" section at the end of this chapter for resources on composting.

Some organic producers use semi-composted manure due to the difficulty in following the NOP composting rules. The benefits of using semi-composted manure can be similar to compost. Compared to fresh manure, the risks of soil and water contamination will be reduced and some of the weed seeds may be eliminated. However, semi-composted manure is not true compost by NOP regulations, so rules of raw manure application will apply (refer to Table 4-7). Also, producers should be aware that immature compost may tie up available nitrogen when it is applied to a field.

PRODUCER PROFILE

Here is the fertility management plan of an organic producer from Waseca County. He tests his soil for nutrients and pH on a yearly basis. He uses alfalfa in a rotation of Oats-Alfalfa-Alfalfa-Corn-Soybean-Corn to supply forage and nitrogen for a corn crop. In addition, he adds turkey manure after soybean in the fall before the second corn in the rotation. He tests manure before application—it usually has about 45 pounds N per ton and he applies four tons per acre. He feels that the non-nitrogen nutrients in the turkey manure are beneficial to alfalfa and the other crops.

Table 4-14. C:N ratios of compost materials.

MATERIAL	C:N
dairy manure	20:1
sheep manure	14:1
poultry manure	10:1
straw	80:1
corn stalks	60:1
leaves	45:1
alfalfa	13:1
legume/grass hay	25:1
grass hay	80:1
rotted sawdust	200:1
fresh sawdust	500:1

Table 4-15. NOP rules for producing compost.

FIRST
Establish an initial C:N ratio between 25:1 and 40:1
THEN
Maintain a temperature of between 131° F and 170° F for 3 days using an in-vessel or static aerated pile system
OR
Maintain a temperature of between 131° F and 170° F for 15 days using a windrow composting system, during which period, the materials must be turned a minimum of five times.

Reducing risk: compost. **Have compost tested for nutrient content prior to application. If producing your own compost, keep records to note that the composting was done by NOP rules.**

Other amendments

Organic producers are allowed to use natural, non-synthetic amendments. As opposed to green manures, compost and animal manures, which have a longer history and research that demonstrates effects, other amendments marketed to organic producers do not have a proven track record. It is important to choose and use amendments pru-

Should you compost?

Below is a checklist of questions to think about.

- ✔ Do you have the necessary equipment? Windrow composting will require a loader or other specialty equipment to turn compost. Aerated pile composting will require piping and a mechanical source to blow air. In vessel composting requires units such as bins.
- ✔ Do you have the necessary time? Producing compost can be labor-intensive.
- ✔ If planning to sell compost, do you have a local market? Hauling costs can be prohibitive if buyers are not located nearby.
- ✔ Do you have spare land and equipment space? Compost production occurs over the long-term.
- ✔ Do you have the financial resources? Equipment and facilities can be an added cost.
- ✔ If you are not a livestock producer, do you have local access to raw materials? Hauling costs of raw manure to your farm for composting need to be considered.

Producers who have the raw materials and necessary equipment to turn windrows can experiment with on-farming composting by starting with windrow methods on a small scale.

Adapted from LaCross and Graves, 1992.

JEFF VANUGA, NRCS.

Figure 4-12. ***Composted turkey manure.***

> **Organic producers say that many amendments to adjust fertility are secondary to long-term management like diverse rotations including green manures and cover crops. Over time, the need for temporary supplementation will lessen.**

dently. Producers need to ensure they are using products that are:

Effective. Study research results supporting the use of the amendment. If a nutrient is purported to be present in the product, how available to crops will that nutrient be? Avoid products with vague, generalized claims.

Necessary. Has a need for the amendment been demonstrated via soil testing or plant analysis?

Not cost prohibitive. While an amendment can be effective and its nutrients deemed necessary, it may not provide cost-effective benefits. Explore options to see if acceptable, less expensive alternatives exist. Producers should analyze cost relative to increased yields and/or other parameters like an increase in soil organic matter.

"Buyer beware" is a good motto to follow as alternative products may not be regulated and can be marketed without research evaluation. Some amendments may produce little to no effect on crops and soil, and in addition can be quite expensive. Producers need to carefully evaluate claims and the sources for the claims. It is always a good idea to conduct small-scale trials before committing a large-scale financial obligation to a product.

Producers should verify a new product with their certifiers prior to using amendments. As with manure and compost, apply organic amendments several weeks before the crop needs it.

PRODUCER PROFILE

A producer from Faribault County uses turkey manure compost (Figure 4-12) which he purchases. The nutrient composition is usually either 5-3-3 or 5-4-3. He applies two tons compost per acre prior to corn and one ton per acre prior to other crops in his rotation. The compost is disked in the fall because his heavy soils get compacted by spring work. He tests the soil for macro and micronutrients every three years.

TYPES OF AMENDMENTS

A general way to classify allowed amendments is by their source. They are either biologically-based like plant- or animal-derived amendments that include fish meal, kelp meal, and others (Table 4-16). Or, they can be mineral-based like rock phosphates or greensand (Table 4-17). When compared to minerals, the nutrients in biologically-based amendments will be available more quickly and contain a greater complement of both macro- and micronutrients. For example, granite dust mainly provides potassium, which is released very slowly, while soybean meal includes a greater complement of nutrients that is more readily available.

Another important difference between amendment types will be price, as some of the biologically-derived amendments can be expensive. Some of the most expensive amendments are used

Table 4-16. Composition and use of biologically-based amendments.
Adapted from Rosen and Bierman, 2005 and others.

MATERIAL	N	P	K	USE	NOTES
Blood meal	12 - 15	1 - 2	1	Primarily N source with P, K	Derived from livestock processing; can burn plants; risk of N loss through volatilization; use is prohibited for markets in Europe and Japan
Bat guano	10	3	1	Primarily N source with P, K	Derived from bat manure; can burn plants
Fish meal	10	4 - 6	0	N, P source	Make sure that source does not contain prohibited substances like preservatives; can contain high levels of PCBs
Fish emulsion	3 - 5	1	1	N, P, K source; micronutrients	Make sure that source does not contain prohibited substances like preservatives; can contain high levels of PCBs
Kelp meal	1 - 1.5	0.1 - 1	2 - 5	N, P, K source; micronutrients	Good for starter fertilizer; high in micronutrients; can be high in salts and heavy metals
Alfalfa hay meal	2.5 - 3.0	0.5	2.5	N, P, K source; micronutrients	Good for starter fertilizer
Soybean meal	7	1.2	2	N, P, K source; micronutrients	Some certifiers and European markets may not allow GMO soybean meal, moderate release rate
Bone meal raw	3	22	0	Primarily P source with N	Use is prohibited for markets in Europe and Japan; slow nutrient release rate
Bone meal steamed	1	15	0	Primarily P source with N	Use is prohibited for markets in Europe and Japan; slow nutrient release rate

Table 4-17. Composition and use of mineral-based amendments.
Adapted from Rosen and Bierman, 2005 and others.

MATERIAL	N	P	K	USE	NOTES
Rock phosphate	0	20 - 32	0	P source, some Ca	2-3% available, will need to apply far in advance of crop needs, may have heavy metal contamination, less availability at pH greater than 5.5
Greensand	0	0 - 1.3	3 - 9.5	P, K source	Very slow availability, best to incorporate 6-8” into soil, contains other trace elements
Colloidal phosphate	0	25	0	P source	P is more available compared to rock phosphates
Granite dust	0	0	3 - 5	K source	Very slow availability
Langbeinite (Sul-Po-Mag or K-Mag)	0	0	22	K, Mg source	Make sure source is not chemically treated, best to incorporate 6-8" into soil
Potassium sulfate	0	0	50	K source	Make sure source is natural and not chemically treated; fairly reactive, best to incorporate 6-8” into soil, better for high magnesium soils than langbeinite

primarily for high-value crops, rather than row crops. Another aspect that factors into price is local availability. Regardless of the type of amendment, it is necessary to verify that it is NOP-approved and not from a synthetic or contaminated source.

USING AMENDMENTS

Natural materials can vary in composition. Producers should obtain a nutrient analysis for all materials from the supplier. If in doubt about composition, samples can be sent to independent laboratories. Before purchasing new materials, producers need to consider how to transport, store, and apply the amendment. Some materials may need special equipment to apply or may be more difficult to spread out evenly than other amendments.

Reducing risk: amendments.

Understand the nutrient composition of the amendment. Be sure that amendments are effective, worth the expense, and necessary for your operation. Verify needs with soil or plant analysis and apply amendments at recommended levels. Never apply amendments above the recommended levels; particularly as some can contaminate soils with salt or heavy metal accumulation. As always, check with your certifier before trying a new product.

Conclusion

The topics of soil and fertility can be complex. Take the fertility quiz to assess your risk in this area.

Quiz: Fertility Management

	Points	Score
1. What is your soil pH?		
Less than 6.0	1	
Greater than 7.0	1	
Between 6.0 and 7.0	5	
I don't know	0	
2. If your soil is acidic, do you add lime?		
Yes	5	
No	0	
3. Are you familiar with the pH requirements of each crop you grow?		
Yes	5	
No	0	
Not sure	0	
4. Do you check with your certifier before using new amendments or new sources for your amendments?		
Always	5	
Sometimes	1	
I don't check with my certifier	0	
5. When using manure or compost, do you monitor phosphorus levels in the soil closely?		
Yes	5	
No	0	
I do not use manure or compost	1	
6. Are you familiar with symptoms that indicate nutrient deficiencies in your crops?		
Yes, for all my crops	5	
Yes, for most crops	3	
No, not really	0	
7. Do you know if you are in a region where micronutrient deficiences tend to occur?		
Yes	5	
No	0	
Not sure	0	
8. What is your soil testing regimen?		
I test yearly	5	
I test on a regular basis, but not yearly	5	
I test when I suspect a problem	3	
I never test my soil (skip next 4 questions)	***0***	
9. What time of year do you conduct soil testing?		
Early spring	3	
Late spring	1	
Summer	1	
Late fall	5	

	Points	Score
10. Do you test your soil at the same time of year each time?		
Yes, always	5	
Yes, usually	3	
No	1	
11. Do you precisely follow the guidelines of your soil testing laboratory when taking samples?		
Yes, always	5	
Yes, usually	3	
Not sure	0	
12. Do you submit your soil samples to the same laboratory every time?		
Yes, always	5	
Yes, usually	3	
No	0	
13. Which of the following sources do you primarily use to supply fertility?		
Green manure ***Answer Questions 14-20***		
Manure ***Answer Questions 21-30***		
Compost ***Answer Questions 31-40***		
Other amendments ***Answer Questions 41-50***		
14. Are you aware of how nutrient availability of green manures are affected by environmental conditions?		
Yes	5	
No	0	
Not sure	0	
15. Do you have an approximate idea of how much nitrogen your green manure is providing initially?		
Yes	5	
No	0	
Not sure	0	
16. Do you have an approximate idea of how much nitrogen your green manure is providing over time?		
Yes	5	
No	0	
Not sure	0	

continued next page

Quiz: Fertility Management

		Points	Score
17. Do you choose green manures that are adapted to your area?	Yes	5	
	No	0	
	Not sure	0	
18. Do you plant the heaviest feeding crop in your rotation after using a green manure crop?	Yes	7	
	No	0	
	Not sure	0	
19. Do you use moldboard plowing to terminate your green manure crop?	Yes, there's no other way for my conditions	2	
	Yes, but I haven't tried another method	1	
	No, I use a chisel plow	3	
	I use green manure crops that winter kill	3	
20. Is the method you use to terminate your green manure crop reliable?	Yes	5	
	No, sometimes the green manure comes back	0	
21. Do you verify if the source of your manure is approved with your certifier?	Yes	3	
	No	0	
22. Is your manure tested prior to application?	Yes, I always get it tested	5	
	Yes, the supplier gives an analysis	5	
	Yes, usually	2	
	No	0	
23. Do you have an approximate idea of how much nitrogen your manure is providing initially?	Yes	5	
	No	0	
	Not sure	0	
24. Do you have an approximate idea of how much nitrogen your manure is providing over time?	Yes	3	
	No	0	
	Not sure	0	
25. If you sell to an international market, do you know their regulations for manure application?	Yes	5	
	No	0	
	Not sure	0	
	I do not sell internationally	5	

		Points	Score
26. Do you carefully follow sampling guidelines for manure testing?	Yes	5	
	Not really	0	
	Not sure	0	
	Not applicable - supplier provides analysis	5	
27. Do you use manure as the sole source to provide nutrients?	Yes	0	
	No, I include other sources like green manures	5	
28. Do you apply manure two weeks to one month prior to planting to synchronize nutrient availability?	Yes	4	
	No, doesn't work with my crop due to NOP restrictions	3	
	No, I need to apply at other times of the year	1	
29. Do you use manure to supply all your crops' nutrient needs?	Yes	1	
	No, I also utilize green manures and/or other sources	5	
	Not sure	0	
30. Do you incorporate manure to retain nutrients and to protect environment from runoff and leaching?	Yes, I incorporate immediately	5	
	Yes, I incorporate within 24 hours	4	
	Yes, I incorporate within a few days	2	
	No	0	
31. Do you verify if the source of your compost is approved with your certifier?	Yes	5	
	No	0	
32. Do you use compost to supply all your crops' nutrient needs?	Yes	1	
	No, I also utilize green manures and/or other sources	5	
	Not sure	0	
33. Is your compost tested prior to application?	Yes, I always get it tested	5	
	Yes, the supplier gives an analysis	5	
	Yes, usually	2	
	No	0	

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Quiz: Fertility Management

		Points	Score
34. Do you carefully follow sampling guidelines for compost testing?	Yes	5	
	Not really	0	
	Not sure	0	
	Not applicable - supplier provides analysis	5	
35. Do you have an approximate idea of how much nitrogen your compost is providing initially?	Yes	5	
	No	0	
	Not sure	0	
36. Do you have an approximate idea of how much nitrogen your compost is providing over time?	Yes	3	
	No	0	
	Not sure	0	
37. If you make your own compost, does it reach the required temperatures for the required length of time?	Yes	5	
	No	0	
	Not sure	0	
	I don't make compost	5	
38. If you make your own compost, do you keep records on the entire process?	Yes	5	
	No	0	
	I don't make compost	5	
39. Do you apply compost two weeks to one month prior to planting to synchronize nutrient availability?	Yes	4	
	No, I need to apply at other times of the year	1	
40. Do you incorporate compost?	Yes	3	
	No	0	
41. Do you verify if the source of your amendment is approved with your certifier?	Yes	3	
	No	0	
42. Can you verify that your other amendments are effective, worth the expense, and necessary for your operation?	Yes	10	
	No	0	
	Not sure	0	

		Points	Score
43. Do you conduct small-scale trials before you commit to purchasing a new amendment?	Yes	5	
	No	0	
44. Do you have an approximate idea of the levels of nutrients your amendments are providing initially?	Yes	5	
	No	0	
	Not sure	0	
45. Do you have an approximate idea of the levels of nutrients your amendments are providing over time?	Yes	3	
	No	0	
	Not sure	0	
46. Do you apply other amendments in a timely manner when they are needed by the crop?	Yes	5	
	No	0	
	Not sure	0	
47. Do you document a nutrient deficiency prior to using other amendments?	Always	5	
	Sometimes	3	
	Never	0	
48. Do you verify that amendments are necessary with soil testing or plant/tissue analysis?	Yes	5	
	No	0	
49. Do you incorporate amendments into the soil?	Yes	3	
	No	0	
50. If you sell to an international market, do you know their regulations for which amendments are allowed?	Yes	5	
	No	0	
	Not sure	0	
	I do not sell internationally	5	
		TOTAL	

If your score is:	Your risk is:
39 or less	High
40 to 59	Moderate
60 or more	Low

FOR MORE INFORMATION

Manure Nutrient Availability Calculator—this website can calculate the nutrients available in manure. http://www.agry.purdue.edu/mmp/webcalc/nutAvail.asp

Using Manure as Fertilizer for Vegetable Crops http://www.soils.umn.edu/academics/classes/soil3416/veg_manure.htm

Manure Management Plan: A step-by-step guide for Minnesota Feedlot Operators http://www.pca.state.mn.us/publications/wq-f8-09.pdf

Making and using compost at the Rodale Institute Farm. http://www.newfarm.org/features/0804/compost/index.shtml

Basic On-Farm Composting Manual. http://www.cwc.org/wood/wd973rpt.pdf

The Art and Science of Composting: A resource for farmers and compost producers. University of Wisconsin-Madison. http://www.cias.wisc.edu/wp-content/uploads/2008/07/artofcompost.pdf

Composting on Organic Farms. http://www.cefs.ncsu.edu/resources/organicproductionguide/compostingfinaljan2009.pdf

ATTRA Arsenic in poultry litter: organic regulations. http://attra.ncat.org/new_pubs/attra-pub/PDF/arsenic_poultry_litter.pdf?id=Minnesota

REFERENCES

Bary, A., C. Cogger, and D.M. Sullivan. 2000. Fertilizing with Manure. PNW0533. Washington State University Cooperative Extension.

Blanchet, K. and M.A. Schmitt. 2007. Manure Management in Minnesota. WW-03553 Revised 2007. University of Minnesota Extension Service. http://www.extension.umn.edu/distribution/cropsystems/components/WW03553.pdf

Busch, D.L., P. Nesse, and L. Busman, 1998. Estimating Manures' Fertilizer Replacement Value. Publication FO-07197. University of Minnesota Extension.

Canadian Organic Growers. 2001. *Organic Field Crop Handbook*, 2nd edition.

Cherr, C.M., J.M.S. Scholberg, and R. McSorley. 2006. Green manure approaches to crop production: a synthesis. *Agronomy Journal* 98:302-319.

Cogger, C. 2000. Soil Management for Small Farms. EB1895. Washington State University Cooperative Extension.

Diver, S. 2002. Alternative soil testing laboratories. Appropriate Transfer of Technology to Rural Areas, National Sustainable Agriculture Information Service. http://attra.ncat.org/attra-pub/soil-lab.html

Gaskell, M., R. Smith, J. Mitchell, S.T. Koike, C. Fouche, T. Hartz, W. Horwath, and L. Jackson. 2006. Soil Fertility Management for Organic Crops. Publication 7249. University of California. http://ucanr.org/freepubs/docs/7249.pdf

Hall, B. and P. Sullivan. 2001. Alternative soil amendments. Appropriate Transfer of Technology to Rural Areas, National Sustainable Agriculture Information Service. http://attra.ncat.org/attra-pub/altsoilamend.html

LaCross, C. and R.E. Graves. 1992. On-farm composting. Agricultural and Biological Engineering. Pennsylvania State University Extension. http://www.abe.psu.edu/extension/factsheets/c/C3.pdf

Martens, K. and M. H. Martens. 2004. What can I use to boost my soil fertility? Rodale Institute.

McGuire, A. 2009. How to evaluate alternative soil amendments. Washington State University Extension. http://grant-adams.wsu.edu/agriculture/Soils/How%20to%20Evaluate%20Alternative%20Soil%20Amendments.pdf

Northeast Regional Agricultural Engineering Service. 1992. On-Farm Composting Handbook. NRAES-54.Cornell University Cooperative Extension, Ithaca, New York.

Rehm, G. 1994. Soil cation ratios for crop production. North Central Regional Extension Publication 533.

Rehm, G. 2002. The value of gypsum. Minnesota Crop News, University of Minnesota Extension.

Rehm, G. and M. Schmitt. 1997. Copper for crop production. FS-06790-GO. University of Minnesota Extension Service.

Rehm, G. and M. Schmitt. 1997. Zinc for Crop Production. Minnesota Extension Service Publication FO-0720-B.

Rehm, G. and M. Schmitt. 1989. Sulfur for Minnesota Soils. Publication AG-FO-0794. University of Minnesota Extension Service.

Rehm, G.W., W.E. Fenster, and C.J. Overdahl. 2002. Boron for Minnesota soils. University of Minnesota Extension Service.

Rehm, G., R. Munter, C. Rosen, and M. Schmitt. 1992. Liming materials for Minnesota Soils. Publication AG-FS-5957A. University of Minnesota Extension Service.

Rehm, G., R. Munter, C. Rosen, and M. Schmitt. 2002. Lime Needs in Minnesota. Publication FO-05956-GO. University of Minnesota Extension Service.

Rehm, G., C. Rosen, and M. Schmitt. 1994. Magnesium for Crop Production in Minnesota. FO-0725-D. University of Minnesota Extension Service.

Rodale Institute. 2009. Organic Transition Course. http://www.tritrainingcenter.org/course/

Rosen, C. 2000. Calcium and Magnesium Management, MN-Vegetable IPM Newsletter. Vol. 2 No. 4, May 2000. http://www.vegedge.umn.edu/mnveg-new/vol2/0505car.htm

Rosen, C.J. and B.M. Bierman. 2005. Using Manure and Compost as Nutrient Sources for Fruit and Vegetable Crops. University of Minnesota Extension M1192. http://www.extension.umn.edu/distribution/horticulture/M1192.html

Rosen, C.J. and B.M. Bierman. 2005. Maintaining soil fertility in an organic system. University of Minnesota Extension. http://www.extension.umn.edu/distribution/horticulture/M1191.html

Schmitt, M.A. 1999. Manure Management in Minnesota. FO-3553-C. University of Minnesota Extension Service. http://www.extension.umn.edu/distribution/cropsystems/DC3553.html

Sheaffer, C.C., N.J. Ehlke, K.A. Albrecht, and P.R. Peterson. 2003. Forage Legumes: Clovers, Birdsfoot Trefoil, Cicer Milkvetch, Crownvetch and Alfalfa. 2nd edition. Minnesota Agricultural Experiment Station, University of Minnesota. Station Bulletin 608-2003.

Undersander, D. 2005. Alfalfa. University of Wisconsin Extension. http://www.uwex.edu/ces/crops/uwforage/alfalfa.htm

USDA-NRCS, Soil Quality Institute. March 1998. Legumes and Soil Quality. Soil Quality—Agronomy Technical Note, No. 6.

Wander, M. 2008. Soil fertility in organic systems: much more than plant nutrition. eOrganic. http://www.extension.org/article/18636

Wander, M. 2009. Managing manure fertilizers in organic systems. eOrganic. http://www.extension.org/article/18628

Wander, M., N. Andrews, and J. McQueen. 2009. Organic Soil Fertility. eOrganic. http://www.extension.org/article/18565