Fertilizing Gardens in South Dakota

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Most people would agree that eating vegetables is good for your health, but sometimes we forget what is good for a vegetable's health. Home-grown vegetables and fruits, are nutritious, but they also need optimal nutrients to produce a peak yield of high quality produce. This fertilizer guide will help you to give your garden vegetables, fruits and flowers the correct nutrition so that they can produce to their best potential. Compare the photos of a malnourished tomato leaf with the healthy, dark-green tomato leaf. The malnourished tomato is lacking in nitrogen, the nutrient required in the most abundance. Not only does the nitrogen-deficient tomato look "sick," but it will also not be able to produce as much high-quality fruit (Fig. 1).

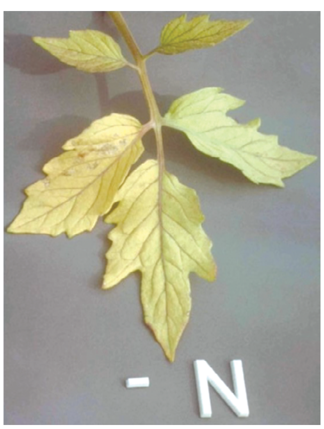

Figure 1. Left: Nitrogen-deficient tomato (Photo credit: Epstein and Bloom, 2004, Bugwood.org) and Right: Healthy tomato leaf (Photo credit: David Graper)

Soil Testing

The natural fertility level of soils in South Dakota varies from location to location. The natural fertility of a soil is a result of its history and composition. Undisturbed soils of eastern South Dakota in general are very productive because, over thousands of years, the native prairies there accumulated rich soil organic matter. Other soils may have very little natural fertility. Even on naturally fertile soils, some of the nutrients in the soil may have been used by crop plants or may have been lost through erosion.

To determine the fertility status of the soil in your garden, it needs to be tested.

Taking a sample

The depth of the soil sample should be approximately the depth of tillage, usually around 6 inches. This represents the soil in the 0-6-inch depth of your garden, where the majority of the plant roots will be active.

First, scrape away or discard any surface litter. Use a garden trowel, spade, or sampling tube to take your sample (Fig. 2). Put the sample (a slice or core about 1 inch thick) in a clean container. Repeat this sampling procedure in 10 spots within the garden, adding the samples to the original container. Thoroughly mix the soil from all samples to make a composite (mixed) sample. Take out about two cups and label with your name, contact information, and the location sampled.

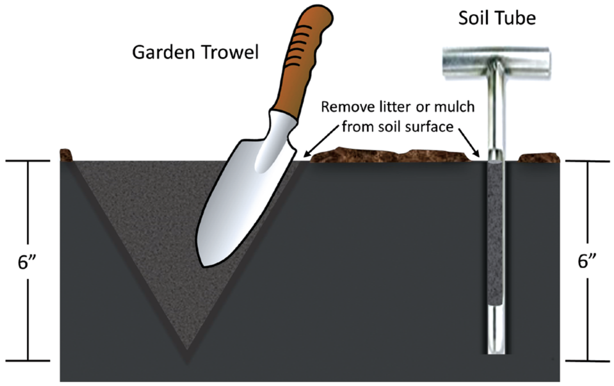

Figure 2.

One composite sample should be taken for each garden or flower bed. The soil from multiple raised beds can be combined into one sample if it came from the same source, and has been managed similarly (fertilized the same, mulched with the same materials, etc.). If an area exists in your garden that produces poor plant growth, sample it separately, as soil fertility, pH, or salts may be the problem there. Avoid (or sample separately) unusual areas such as borders, low spots, pet runs, along foundations, etc. Lawn areas should be sampled separately from gardens.

If samples are wet, dry by spreading them on clean paper and air dry the soil (do not heat) before placing in mailing containers.

When to sample

Soil samples may be taken any time of the year. However, if the soil is frozen or too wet, obtaining a good sample will be very difficult. Many samples are taken in the fall or early spring to determine nutrient needs for the upcoming season. If a problem surfaces, a sample can be taken during the growing season as well.

Submitting samples

South Dakota State University no longer offers commercial testing. For a list of neighboring universities and private labs that do soil analysis visit: extension.sdstate.edu/soil-testing-labs.

For the vast majority of South Dakota soils, the "regular series" or "garden" tests will be sufficient. This series includes organic matter, nitrogen, phosphorus, potassium, pH, soluble salts, and texture. Other nutrient tests are also available. Discuss your specific needs with the soil testing lab that you select. Test results may take several days so plan ahead for time to submit your sample and receive your results.

Fertilizers

Plants require 17 essential nutrients with 14 of these coming from the soil: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), Magnesium (Mg), Sulfur (S), iron (Fe), manganese (Mn), copper (Cu), boron (B), zinc (Z), molybdenum (Mo), chlorine (Cl), and nickel (Ni). Fortunately, most of our South Dakota soils have most of these in abundance.

Once the soil test is complete, the returned recommendation often will tell you what nutrients are needed for your garden and how much to apply. The choice of the nutrient source (fertilizer) is yours.

In general, N and sometimes P are needed on many soils of South Dakota. Less often K is needed, generally on some soils in eastern South Dakota or on very sandy soils. For soils that have had repeated applications of compost or manure, P and K tend to be adequate for plant needs, and only nitrogen is needed.

Inorganic fertilizers

The advantages of commercial inorganic materials are that they are readily available, easy to apply, and can be applied to exactly meet your garden's particular nutrient needs.

Be aware, however, that many fertilizers contain more than one nutrient (mixed forms). If a fertilizer can't be found with only the nutrients that are recommended for your garden, the risk of over-fertilization becomes a disadvantage similar to that of organic fertilizers.

The content of N, P, and K is stated on the fertilizer bag as percent of that nutrient by weight. Note that the numbers for P and K are listed as P_2O_5 (phosphate) and K_20 (potash) rather than pure P and K. P and K fertilizer recommendations are also usually given in terms of P_2O_5 (phosphate) and K_20 (potash). Therefore, a 15-10-5 fertilizer contains 15% nitrogen, 10% phosphate (P_20_5) and 5% potash (K_2O) by weight. These numbers are called the fertilizer analysis and are always listed in the order of N, P, and K. (Any other nutrient present will also be listed on the fertilizer bag.) The fertilizer pictured here is a 10-10-10 which means it contains 10% nitrogen, 10% phosphate (P_20_5) and 10% potash (K_2O) (Fig. 3).

Figure 3. Example of garden fertilizer (Photo credit: Lance Stott)

To calculate the amount of fertilizer needed for a given area, the amount of nutrient recommended is needed (from soil test report) as well as the fertilizer analysis. Divide the recommended amount by the percent (in decimal form) of the nutrient you wish to apply.

For example, if the soil test recommends an application of 2.0 lbs of N per 1000 square feet of garden and the fertilizer analysis is 10-10-10, an application of 20 lbs per 1000 square feet of such a fertilizer is needed to supply the plant with its nitrogen needs (2.0 / 0.10 = 20). In this example, P and K are also applied with this mixed fertilizer (10-10-10). The method of determining how much to apply is the same as that for N. If the soil test does not recommend additional P or K, look for materials higher in N than in P or K.

For a straight nitrogen material such as urea (46-0-0), the amount to apply would be 2 / 0.46 = 4.3 pounds per 1000 square feet.

If fertilizer recommendations are given in lbs/acre, a handy conversion is 100 lbs/acre = 3.5 oz per 100 square feet = 2.4 tbsp per 10 ft. of row.

Heavy over-fertilizing with nitrogen can lead to poor fruit set. Over-fertilizing with nitrogen or phosphorous can lead to contamination of surface waters if rain or irrigation washes soil or unincorporated fertilizer into them. Although unlikely with smaller gardens, water quality issues could be of concern if many yards or gardens in a given area are over-fertilized.

Some gardeners believe that using a commercial fertilizer harms the soil over time. Over-fertilization can lead to water pollution and plant toxicity—such as when fertilizer spills on the ground while loading it into the spreader and the grass dies in that spot. Applying too much of any one nutrient over time can hinder uptake of other nutrients. However, judicious application of commercial fertilizers does not cause harm to the soil or the soil microbial community. (That being said, legumes such as peas and beans are less likely to enter into a symbiosis with soil bacteria to fix nitrogen when there is ample nitrogen available.) Soil testing and careful application will help to avoid problems with over-fertilization.

Organic fertilizers

This type of fertilizer may include manures, composts, green cover crops, mulches, leaves, fish emulsions, blood meal, and many other organic materials. Organic matter is beneficial to the soil and, when incorporated, the decaying organic residue provides multiple benefits including:

1. **Good soil structure** is created as organic residues and the resulting microbial growth bind individual soil particles together. This aggregation can help aeration and drainage, particularly in clay soils. It also makes the soils easier to work with.
2. Increase in **soil water-holding capacity**, lessening the need to water soils often. This is especially helpful for coarse sandy soils.
3. An array of **plant nutrients**, including micronutrients, supplied through breakdown of the organic material by soil microorganisms.

Organic fertilizers such as compost and manures are usually plentiful and may be available to many gardeners for little cost. However, fertilizers such as fish emulsion or blood meal may be more expensive. A disadvantage of most organic fertilizers is that they usually need soil microbes to release the nutrients for plant use, and this can take some time. Applying the organic fertilizers in fall or early spring would be advisable for those materials. Fish emulsions and blood meal are two exceptions, as these materials tend to be quickly available to the plant after application.

Determining an application rate that supplies the needed amounts of plant nutrients can be difficult for materials such as compost or manure, because of the variability of nutrients in these materials. An approximate rate of various materials to apply per 1000 square feet is given in Tables 1 and 2. Most of these materials contain an array of nutrients. This can be a disadvantage. For example, if your soil test recommends only nitrogen be added and you apply an organic fertilizer, you will also be applying other nutrients that are not needed for optimal plant growth.

The variability of nutrients and the multiple nutrients contained in organic fertilizers can lead to applied nutrient levels that exceed your plant needs. As mentioned above under "Inorganic Fertilizers," this can lead to contamination of surface or ground water, and can also lead to buildup of harmful salt levels. For example, repeated application of manure can build up soil salts, as well as lead to phosphorus levels high enough to restrict the uptake of other nutrients.

For food safety reasons, all manures should be at least 6 months old prior to application to vegetable production areas. Composting can reduce harmful microorganisms as well as weed seeds, and is a recommended practice for many organic materials.

There are many different ways to design a compost bin (Fig. 4), but is important to remember a few composting basics:

- The bacteria responsible for composting are aerobic. This means that adequate aeration in the compost must be maintained at all times. Using a container with a lot of ventilation and turning the compost every few weeks will help maintain aerobic conditions.
- Compost must remain continuously moist, but not soggy.
- To work most effectively, compost must be balanced. Try to keep the ratio of carbon to nitrogen (C:N ratio) around 30:1. Green materials such as lawn clippings and kitchen wastes have a C:N ratio of about 25:1. Brown materials like leaves and straw have a C:N ratio of about 70:1, while sawdust and cardboard have a C:N ratio of about 300:1. If your compost is all brown materials it will take a long time to be ready. If it is all green materials, the compost will turn anaerobic quickly and get smelly.
- Avoid adding materials such as meats, dairy, and fats in your compost, as these may not only attract insects and rodents, but turn the compost anaerobic (and smelly!)

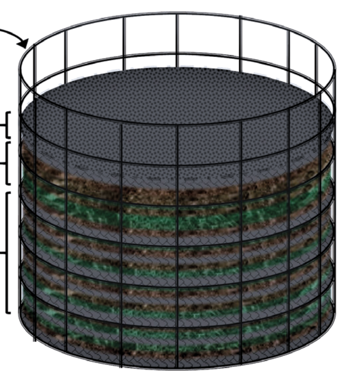

Figure 4. Compost bin

Table 1. Average N, P, and K contents of manures and amounts needed to provide 2.0 pounds of N per 1000 square feet.

Manure[1] (assuming about 50% moisture)	N	P (as P_2O_5)	K (as K_2O)	Amount to supply 2.0 lbs N per 1000 ft^2 (30' x 35' area)	Amount to supply 2.0 lbs N per 100 ft^2 (10' x 10' area)
	%			Pounds[2]	Pounds[2]
Chicken	1.7	1.8	1.3	118	12
Sheep	1.3	0.9	1.9	154	15
Dairy	0.8	0.4	1.7	250	25
Cattle	0.8	0.6	1.1	250	25
Pig	0.6	0.5	0.6	333	33
Horse	0.4	0.3	0.7	500	50

[1] Avoid applying fresh manure to growing plants. Instead, apply composted manure or apply and incorporate fresh manure the previous fall Any manure applied to vegetable production areas should be at least 6 months old.
[2] If significant bedding is in the manure, these amounts should be doubled.

Quickly available vs. slowly available fertilizers

Most commercial fertilizers are very soluble (release nutrients quickly), and nutrients are immediately available for plant use. Some fertilizers release nutrients over a period of time (3-10 weeks) and are considered slowly available fertilizers. These less soluble fertilizers are more suitable for turf where a slow release keeps grass green for longer periods.

For most garden areas, an application of a quickly available fertilizer will work fine. For some very sandy soils, a slowly available fertilizer may reduce nitrogen leaching losses. Some of these slowly available materials include sulfur-coated urea or polymer-coated urea.

Many of the organic fertilizers (Table 2) can be considered slowly available as well. The exceptions are fish emulsions and blood meal.

Nitrogen Tie Up

Adding organic materials to soil is usually of benefit. However, sawdust and other slowly decomposing organic materials that can be used as soil amendments are rich in carbon. When they are incorporated into garden soil, the large amount of added carbon stimulates the soil microbial community. Because of the ample carbon supply, these microbes rapidly multiply and begin to break down the organic materials. However, these microbes require nitrogen, and are better-equipped to scavenge nitrogen from the soil than are plants. Because of this, adding slowly decomposing organic materials to a garden may cause a temporary lack of plant available nitrogen in the soil. This is often referred to as nitrogen tie-up.

Composting sawdust and other slowly decomposing materials with grass clippings and other rapidly decomposing materials before applying them to the garden can help to avoid this issue. Alternatively, adding extra nitrogen fertilizer to the soil when adding sawdust and other slowly decomposing materials helps ensure that there is enough nitrogen for the plants while the microbes are at work breaking down the organic materials and eventually releasing nutrients.

Methods of Application

Broadcast. Most fertilizers are spread over the soil surface and incorporated into the soil by tillage (plow, spade, rototiller, etc.). Incorporation helps protect the nutrients from loss, and puts the nutrients close to the plant root for quick uptake.

The application should be uniform and can be done by hand or a small fertilizer spreader.

Table 2. Average N, P, and K contents of other organic fertilizer materials and amounts to provide 5.0 pounds of N per 1000 square feet

Material	N	P (as P_2O_5)	K (as K_20)	Amount to supply 2.0 lbs N per 1000 ft^2 (30' x 35' area)	Amount to supply 2.0 lbs N per 100 ft^2 (10' x 10' area)
	%			Pounds[2]	Pounds[2]
Blood meal	13.0	0.9	0.5	15	1.5
Fish meal	10.0	6.0	0.0	20	2
Fish emulsion	4.0	1.5	1.5	50	5
Bone meal	3.0	22.0	0.2	67	7
Peat	2.0	0.3	0.6	100	10
Municipal compost (moist)[1]	1.0	0.4	0.6	200	20
Cornstalks[2]	0.8	0.4	2.0	250	25
Dried Leaves	0.7	0.3	0.6	286	29
Grass clippings (fresh)	0.6	0.3	0.8	333	33
Sawdust[2]	0.2	0.1	0.2	1000	100
Wood ashes[3]	0.0	1.5	3.5	---	---

[1] Municipal compost may have been tested. Consult your municipality to find out more. Compost that is sold will have been tested and should be labeled with a nutrient analysis. Be cautious, as some municipal compost contains harmful herbicides.
[2] Cornstalks, sawdust, straw, and leaves should be composted before applying to garden (unless they are used as mulch).
[3] Wood ashes should not be applied if treated wood is burned. Wood ash tends to act as a liming material and should only be used on soils with pH below pH of 6.0, at a rate of 300 to 400 lbs/1000 ft^2

Band. The fertilizer is applied in a uniform band in the soil usually below and to the side of the plant seed or row. In general, this method has no particular benefit over broadcasting for most garden crops and can cause seed injury if applied too close to the seed.

Starter or transplant solution. Young plants may respond to a weak solution of phosphorus applied at transplanting, especially in cooler springtime soils. These starter solutions can be purchased or made at home by mixing 2 tablespoons of a high phosphorus fertilizer with 1 gallon of water. Dissolve as much as possible and apply about 1 cup of this solution around each plant.

Side dressing. Fertilizer is applied to the side of the crop row sometime during the growing season. It can be beneficial to side dress nitrogen for vine crops and tomatoes, as applying too much nitrogen at planting can produce heavy foliage and sometimes delay or retard fruit set. Split the recommended nitrogen into ⅓ to ½ broadcast before planting and the remainder as a side dress after the first fruit have set. For very sandy soils, splitting the nitrogen application is done to limit the nitrogen washed out of the soil by rain or watering.

Soil pH

A pH analysis measures the soil's acidity or alkalinity. The standard pH scale is from 0 to 14 with a neutral value at 7.0. Values below 7.0 are acidic and above 7.0 are basic or alkaline. The range of pH for most soils in South Dakota is 6.0 to 8.0.

Most plants grow very well within this pH range. However, some plants such as blueberries, azaleas, and rhododendrons prefer more acid conditions (4.0-5.5). Some berry crops, fruit trees, and beans may develop chlorotic symptoms (leaf yellowing with green veins) if the pH is above 7.3.

Lowering pH is not always easy. You can use elemental sulfur, but since this is a reaction that involves soil microbes, it can take up to 6 months for the soil pH to change. Iron sulfate can also be used, and takes only 3 to 4 weeks to take effect, but needs to be applied at a rate of six times that of elemental sulfur (but no more than 9 lbs/100 sq ft at a time).

Lowering the pH of clay soils is usually unsuccessful because of their high buffering capacity. High levels of free lime (calcium carbonate) present in many soils in South Dakota also buffer the soil, so that lowering pH is usually not practical unless only a very small area (for a few plants) is treated. **Free lime** is determined with a soil test.

If free lime is not present, the amount of sulfur to use will depend on your current pH, your desired pH, and your soil texture. Ask your soil testing laboratory what amount of sulfur should be used to lower soil pH for your stated purpose, or use Table 3 as a guide. In general, 2 to 3 pounds of finely ground sulfur is needed per 100 square feet of silt loam soil to lower the pH by one (1.0) unit. Incorporate the sulfur into the top 6 inches of soil. Keep in mind that too much sulfur can lead to high salt levels in the soil, so follow recommendations carefully.

Raising pH: Many gardening references, catalogs, and garden retailers routinely recommend lime applications. Lime should not be applied unless its need is confirmed by a soil test. South Dakota soils are rarely in need of raising the soil pH, and lime or wood ashes should never be applied unless a soil test indicates a need. There is a specific soil test used for making the recommendation, called the lime need test.

Table 3. The amount of finely ground elemental sulfur to lower soil pH by one unit (1.0).

Texture	Sulfur to apply[1] lbs/1000 ft²	Sulfur to apply[1] lbs/100 ft²
Coarse (sand, sandy loam, loamy sand)	10-20	1-2
Medium (loam, silt loam)	20-30	2-3
Fine (clay, silty clay loam, clay loam, peat)	30-40	3-4
[1] Assuming free lime is not present in the soil		

Liming is really not necessary if your pH is 6.0 or above. For many soils, a recommendation of 8 lbs of finely ground limestone per 100 square feet, worked into the top 6 inches of soil, would raise soil pH from 0.5 to 1.0 unit. However, a lime need test should be used to make a specific lime recommendation (Table 4), as too much lime can cause certain micronutrients to become unavailable for plant uptake.

Table 4. Raising soil pH with lime.

Lime test (buffer test)	Lime[1] required for 6-inch soil depth lbs/1000 ft^2	Lime[1] required for 6-inch soil depth lbs/100 ft^2
6.5 and greater	0	0
6.1-6.4	65	6.5
5.9-6.0	80	8.0
5.8 and lower	95	9.5

[1] Based on 100% calcium carbonate, very finely ground.

Soil Salts

Soil salts are naturally present in all soils. These soluble salts are minerals and nutrients that have dissolved from the soil and rock into soil water. If soluble salts become too high they can be detrimental to plant growth. This usually occurs in soils where water tends to pond or concentrate, such as lower areas on the landscape or near saline seeps.

Salts can also accumulate in the garden if irrigated with water that is high in salts. Most municipal water sources have low salt concentrations, but some private wells may have higher than desirable salt levels. Water can be checked for irrigation suitability by obtaining an irrigation water test. (There are several types of water tests, so be sure to indicate that you want an irrigation suitability test.)

A soil test will show the soil salt level and the interpretation. Typically, soils will have salt values less than 1.0 deciSiemen per meter (dS/m). For most gardens, salt levels of less than 2.0 dS/m (or 2 mmhos/cm) should not be a problem for plant growth, especially if the soil is kept moist. If your water supply has low salts and if the soil drains relatively well, you can lower the soil salt content by applying 6 to 8 inches of water as quickly as the soil can absorb it. That should move the salts below the root zones of many garden plants.

If the soil test indicates that the sodium portion of the soluble salts is high, soil structure and plant growth may be poor. The most common sources of added sodium are private wells (especially artesian water) and softened household water. Correction of this problem is very difficult. Adding gypsum may help by replacing Na with Ca, but will take time. If growing plants is difficult and if the soil test indicates a sodium problem, it's best to move your garden to a different (low sodium) area, or use raised beds with soil from a different source

South Dakota State University Extension

SOUTH DAKOTA STATE UNIVERSITY®
AGRONOMY, HORTICULTURE AND PLANT SCIENCE DEPARTMENT

P-00082

Soil Test Report

Soil Testing Laboratory - Box 5555 - Selected Town, State 00000

Submitted by:	Ima Gardener	Date Sampled:	6/1/2024
	12345 200th St	Date Received:	6/5/2024
	Anywhere, SD 57000	Date Reported:	6/9/2024

Interpretation of Soil Test Levels

	Alkaline		Satisfactory	SS				K	**High**
				SS				K	
				SS				K	
				SS			P	K	
	Satisfactory		Possible Problem	SS			P	K	**Medium**
				SS			P	K	
				SS	OM		P	K	
		pH		SS	OM	NO_3	P	K	
	Acid	pH	Poor	SS	OM	NO_3	P	K	**Low**
		pH		SS	OM	NO_3	P	K	
		pH		SS	OM	NO_3	P	K	
		pH		SS	OM	NO_3	P	K	

Soil Test Results

Sample or Field ID	Texture Class	pH	Buffer pH	Soluble Salts	Sodium	O.M.	Nitrogen NO_3-N	P		K	Sulfur SO_4-S	Zn	Fe	Mn	Cu	Ca	Mg	Chloride	B
								Olsen	Bray										
				mmho/cm	me/l	%	lbs/A	ppm	ppm	ppm	lbs/A	ppm	ppm	ppm	ppm	ppm	ppm	lbs/A	ppm
Garden	Medium	6.5	–	0.5	–	3.2	60	12	–	250	–	–	–	–	–	–	–	–	–

Recommendations (lbs/1000 sq. ft.)

Choice	Sample or Field ID	N	P_2O_5	K_2O	S	Zn	Fe	Mn	Cu	Ca	Mg	Cl	B
1st	Garden	1.7	0.8	–	0	–	–	–	–	–	–	–	–
2nd													

Some useful measures and conversions:

- 1 dS/m = 1 mmho/cm = 1000 micromhos/cm
- 1 acre = 43,560 ft^2
- 1000 ft^2 = 32 ft x 32 ft
- 100 lbs/acre = 3.5 ounces per 100 ft^2
- 2 tablespoons (level) = 1 ounce (liquids)
- 8 ounce = 1 cup (liquids)
- 2 cups = 1 pint (liquids)
- 1 pint (2 cups) = 1 pound of most dried fertilizers