Managing Phosphorus and Other Nutrients in Gardens

Hans Klopp, SDSU Extension Soil Health Field Specialist

September 2025

For plants to grow, they require a variety of essential nutrients, including nitrogen, phosphorus, potassium, sulfur, calcium, magnesium, zinc, iron, manganese, copper, boron, chloride, molybdenum, nickel, cobalt, as well as carbon, hydrogen, and oxygen. Plants obtain carbon, hydrogen, and oxygen from the atmosphere and water, but they acquire the rest of their nutrients from the soil.

The exception to this is leguminous plants, which can take nitrogen gas from the atmosphere and convert it into organic nitrogen by nitrogen-fixing bacteria.

The levels of these nutrients vary in the soil, with some being in an available form and others being in an unavailable form. The level of many of these nutrients in non-available form is much greater than in a plant-available form. The available forms of these nutrients are shown in Table 1. Although plants need all these nutrients, their level in the soil is frequently adequate.

The nutrients that are often deficient in the soil are nitrogen, phosphorus, and potassium. That is why many of the garden fertilizers contain these three nutrients. Too much of specific plant nutrients in the soil can create environmental quality issues, particularly nitrate leaching into groundwater and phosphorus runoff into surface waters. Excessive nitrate in groundwater can be hazardous to humans, and excessive phosphorus in surface waters can lead to excessive algae blooms. That is why soil testing and having a nutrient management plan are essential to improve nutrient use efficiency, reducing nutrient losses and input costs.

Table 1. Essential Plant Nutrients and Their Available Forms.

Nutrient	Available Form
Nitrogen	NO_3^-, NH_4^+
Phosphorus	$H_2PO_4^-$
Potassium	K+
Carbon	CO_2, HCO_3^-
Hydrogen	H_2O
Oxygen	H_2O, O_2
Sulfur	SO_4^{-2}
Calcium	Ca^{+2}
Magnesium	Mg^{+2}
Iron	Fe^{+2} and Fe^{+3}
Copper	Cu^{+2}
Manganese	Mn^{+2}
Boron	H_3BO_3, BO_3^{-3}, B_40_7
Zinc	Zn^{+2}
Molybdenum	MoO_4^{+2}, $HMoO^{-4}$
Chlorine	Cl^-
Nickel	Ni^{+2}
Cobalt	Co^{+2}

Know What is Present in the Soil

Many gardeners and agricultural producers add fertilizer on an annual basis. Gardeners frequently apply fertilizer by adding the amount they think the plant needs, or based on the amount of compost or manure available for use. However, many gardeners do not test their soil before applying fertilizer. Knowing what is present in the soil is vital to prevent soil nutrient levels from becoming excessive. Having excessive amounts of certain nutrients can lead to nutrient imbalances in plants, alter soil microbial composition, and compromise environmental quality. Sending the samples to the laboratory prior to adding fertilizer is essential to optimizing fertilizer use and preventing excessive nutrient levels in the soil.

How to Sample a Garden

When taking a soil sample from a garden, taking a sample from one spot is not adequate. The concentration of nutrients in the garden may vary throughout the garden. The best way to sample is to take samples from multiple locations in the garden and then homogenize them together. This will give the average value contained in the garden. An extension article on how to sample lawns and gardens is in Clark 2020 listed in the references.

Sampling from the 0-6 in depth is adequate because crops get most of their nutrients from near the surface. The exception is nitrogen, sulfur, and chlorine, which are more mobile nutrients, and plants uptake some of these nutrients from deeper in the soil. That is why some soils are sampled at depths of 0-6 and 6-24 inches to determine the level of these nutrients. If using a shovel, the same volume of sample should be taken from each location. For example, a 6-inch-deep x 3-inch-wide x 3-inch-thick sample should be taken from multiple spots in the garden.

If using a soil probe, take a sample from many spots in the garden, then trim a sample from the 0-6 in depth and place it into the container used to homogenize the sample. An adequate number of samples to take from a garden would be 6 to 10 samples. The sample from each spot should be placed into a bucket, then thoroughly mixed by hand. Then, a subsample of the collected soil should be taken, put into a bag, and sent to a laboratory. Approximately 2 cups of the sample are needed to conduct a complete soil fertility analysis.

A list of available soil testing labs is available from SDSU Extension. [extension.sdstate.edu/soil-testing-labs]

If gardeners are only interested in nitrogen, phosphorus, and potassium, having them tested is sufficient. As many soils in South Dakota have pH values in the 7-8.5 range, the Olsen or Bray P-1 test should be used to measure soil phosphorus levels. Those methods are more effective in high-pH soil than some of the other methods used to measure soil phosphorus levels. The methods used in the SDSU recommendations to measure the level of each nutrient are shown in Table 2.

If gardeners are interested in a more comprehensive soil analysis, they can have an analysis conducted that includes both macro- and micronutrients. However, micronutrients are not as frequently deficient as some of the macronutrients are. Soil testing is probably only necessary every couple of years to monitor how the levels are trending in the garden.

Interpreting Soil Test Levels

Maintaining adequate levels of each nutrient is crucial for optimizing crop yield and quality. If the level of just one of the essential nutrients is low, it may reduce crop production.

Soil tests provide a level measured in parts per million or pounds per acre. Some soil testing labs will interpret the levels and categorize them as low, medium, and high. An example of this process is illustrated in Table 2. If the soil nutrient level is low, adding the nutrient is likely to increase yield; however, if it is already high, adding more of that nutrient is unlikely to yield further increases. If the level is high or very high, adding more of that nutrient is not needed.

Examples of soil test levels and their interpretations are presented in Table 3. On the Opal Clay soil, the only nutrient that is required is nitrogen. On soil collected from a garden (Loam from Garden), the recommended levels of nitrogen, phosphorus, potassium, and sulfur are present, and there may be some benefit from adding iron. On sandy soil, nitrogen, potassium, and sulfur fertilization are needed, and there may be some benefit to adding calcium, zinc, and copper fertilizers. The high-nutrient garden sample does not require any fertilization.

Table 2. Soil test calibration levels used in South Dakota from the Fertilizer Recommendations Guide (Clark, 2023)

Nutrient	Soil Test	Very Low (VL)	Low (L)	Medium (M)	High (H)	Very High (VH)
Probability of yield response		**80%**	**60-80%**	**40-60%**	**20-40%**	**<20%**
				ppm extractable (0-6 inch samples)		
Phosphorus	Bray P-1	0-5	6-10	11-15	16-20	21+
Phosphorus	Olsen	0-3	4-7	8-11	12-15	16+
Potassium	NH_4Ac	0-40	41-80	81-120	121-160	161+
Zinc [1]	DTPA	0-0.25	0.26-0.50	0.51-0.75	0.76-1.00	1.01+
Iron [2]	DTPA	—	0-2.5	2.6-4.5	4.5+	—
Manganese [3]	DTPA	—	0-0.50	0.51-1.00	1.00+	—
Copper [3]	DTPA	—	0-0.10	0.11-0.20	0.20+	—
Boron [3]	Hot H_2O	—	0-0.25	0.26-0.50	0.50+	—
Magnesium [3]	NH_4Ac	0-10	11-20	21-30	31-40	41+
Calcium [3]	NH_4Ac	0-100	101-200	201-300	301-400	401+
				lbs/ac 2 ft		
Sulfur	500 ppm P	0-9	10-19	20-29	30-39	40+
Chloride [4]	0.01M $Ca(NO_3)$	0-15	16-30	31-45	46-60	61+

[1] Calibration only for corn, sorghum, flax, potatoes, and edible beans
[2] pH is a better indicator to predict iron deficiency
[3] Deficiencies have not been confirmed in South Dakota
[4] Calibration only for wheat, barley, and rye

Table 3. Soil laboratory analysis was conducted on various soils and their corresponding interpretations. VL is very low, L is low, M is medium, H is high, and VH is Very High.

Nutrient	Opal Clay		Loam from Garden		Sand		High Nutrient Garden	
Organic Matter (%)	4		5.2		1		9.0	
pH	8		8		5.8		7.4	
EC (dS/m)	0.57		0.32		0.04		1.3	
CEC cmol+/ kg soil	38.1		18.7		4.4		26.4	
Nitrogen (NO_3) (ppm)	4		12.4		2.43		123	
Phosphorus (ppm)	25.8	VH	5.1	L	82*	H	437	VH
Potassium (ppm)	703	VH	75	L	30	VL	2120	VH
Sulfur (ppm)	37.1	H	8.1	VL	10.6	L	75	VH
Calcium (ppm)	6081	VH	2959	VH	254	M	2696	VH
Magnesium (ppm)	685	VH	530	VH	63	VH	883	VH
Zinc (ppm)	0.8	H	0.76	H	0.62	M	11.4	VH
Iron (ppm)	10.1	H	4.2	M	19.2	H	52	H
Manganese (ppm)	3.2	H	1.6	H	1.7	H	9	H
Copper (ppm)	1.68	H	0.27	H	0.12	M	2.4	H

Add Fertilizer Amount and Source Based on Soil Test Values

As shown in the soil tests in Table 3, different soil samples contain varying levels of nutrients. If the soil only requires nitrogen fertilization, adding a source of fertilizer that contains only nitrogen would be best if the levels of other nutrients are adequate. The same would be the case for different nutrients.

Often, gardens utilize composts and manures as fertilizers. These fertilizers contain all the necessary nutrients because they are derived from decomposed or digested plant materials. Manure fertilizer sources can vary widely in nutrient levels, depending on the animal from which they are derived, the amount of bedding used, and whether they are in liquid or solid form. Additionally, composts can vary in nutrient levels depending on what is used to make the compost and how thoroughly it is finished. Many gardeners make their own compost and do not test it for quality.

Sending a sample of compost or manure to the laboratory before use would help determine the amount needed to meet crop nutrient requirements based on the soil test results. Continuously adding composts or manures without monitoring soil test levels can lead to a buildup of specific plant nutrients. Also, plants generally remove more nitrogen and potassium than phosphorus (Michigan State University Extension 2004). However, manures and composts have a lower nitrogen/phosphorus and potassium/phosphorus ratio than what is removed by the harvested portion of the plant (Stock et al., 2019). This can lead to the soil phosphorus level becoming high due to the long-term application of these fertilizer sources without monitoring the soil level.

Additionally, adding manure to the crop's nitrogen requirement can lead to soil phosphorus buildup. Not all the nitrogen contained in manures is available in the first year, but most of the potassium and phosphorus are considered available in the first year. Plants besides legumes generally have a higher nitrogen requirement than phosphorus. Having a fertility management plan that includes soil and compost, or manure testing, can help prevent nutrient levels from becoming too high.

Take Home Messages

Without monitoring the nutrient levels present in the soil, the levels of specific nutrients can become excessive. Conducting occasional soil testing in the garden is a valuable tool for assessing the current soil nutrients and evaluating the impact of applied fertilizers on soil quality. If the level of nutrients is high, money can be saved by skipping the application of fertilizer.

Fertilizer sources should be selected based on the specific needs of the soil, as determined by a soil test, rather than simply adding fertilizer because you think the garden needs it. Testing the nutrient composition of compost and manure can also help to see how much of these nutrients are being added to the soil. If there are excess levels of nutrients present, it can cause adverse effects on the environment and produce quality issues.

Monitoring nutrient levels and fertilizing based on the ones needed can help improve nutrient use efficiency and prevent them from reaching excessive levels.

References

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P-00355