THE TENNESSEE VEGETABLE GARDEN

MANAGING PLANT NUTRITION

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Vegetable production is increasingly popular for Tennessee residents. Growing vegetables at home provides financial and nutritional benefits through the bounty of a fresh harvest, and the activity enhances personal health and well-being. However, a basic understanding of soils, site selection and crop maintenance is required before backyard growers can take full advantage of these benefits of home food production. To meet these needs, this series of fact sheets has been prepared by UT Extension to inform home gardeners and propel them to success in residential vegetable production.

WHAT PLANTS NEED

There are 17 essential elements that plants need to grow and reproduce. These required nutrients are often placed in four categories. The first group is the carbon (C), hydrogen (H) and oxygen (O) that plants obtain primarily from water and air. The remaining three categories — primary macronutrients, secondary macronutrients and micronutrients — contain the 14 essential nutrients generally taken up by plant roots from soil (Table 1). The primary macronutrients are nitrogen (N), phosphorus (P) and potassium (K). These three elements are required in large amounts by the plant and are the most commonly applied nutrients in most fertilizers. The secondary macronutrients, calcium (Ca), magnesium (Mg) and sulfur (S) are usually required in slightly lower amounts than primary macronutrients. Applications of these nutrients may be needed but are generally less frequently required than the primary macronutrients.

Figure 1. *Plant roots are responsible for taking up key nutrients to support plant growth and productivity.*

Classification	Name	Chemical forms commonly taken up by plants
Primary Macronutrients	Nitrogen (N)	NO^{3-}, NH^{4+}
	Phosphorus (P)	$H_2PO_4^-$, HPO_4^{2-}
	Potassium (K)	K^+
Secondary Macronutrients	Calcium (Ca)	Ca^{2+}
	Magnesium (Mg)	Mg^{2+}
	Sulfur (S)	SO_4^{2-}
Micronutrients	Boron (B)	BO_3^{3-}
	Chloride (Cl)	Cl^-
	Copper (Cu)	Cu^{2+}
	Iron (Fe)	Fe^{2+}
	Manganese (Mn)	Mn^{2+}
	Molybdenum (Mo)	MoO_4^{2-}
	Zinc (Zn)	Zn^{2+}
	Nickel (Ni)	Ni^{2+}

Table 1. *Description of essential nutrients for plant growth.*

The fourth and final category of plant nutrients is the micronutrients. Although just as essential for proper plant growth and reproduction, micronutrients are needed in much smaller quantities. In many soils, micronutrients are present in sufficient amounts for plant growth. Micronutrient excess, called toxicity, can also be problematic. Care must be taken to not oversupply micronutrients through fertilization or pH management. Soil tests are the best way to be certain that micronutrient levels are adequate but not too high.

HOW PLANTS FILL NUTRIENT NEEDS

Plant roots serve many functions, but one of their most critical roles is the ability to take up water and nutrients from the soil. Water is important for many plant processes, and soil water contains the vast majority of nutrients that plants take up. Maintaining proper plant nutrition for garden vegetables means soils need to contain the right nutrients and water to enable plant roots to take up those nutrients.

SOIL AND NUTRIENTS

Nutrients are taken up by roots as charged ions (Table 1). Many plant nutrients (mostly those with a positive charge) can be attracted to and held by soil particles. Ions can also be dissolved in the water that fills the spaces between soil particles, called the "soil solution." When plants take up nutrients from the soil solution, nutrients held by the soil often move into the soil solution to replace them. This exchange of nutrients between soil and soil water maintains nutrients for current and future plant use.

THE ROLE OF PH

A measure of soil pH refers to the acidity or alkalinity of the water in the soil and describes the balance between H^+ and OH^-. Values below 7.0 refer to higher H^+ in solution while pH values higher than 7.0 mean more OH^- is in solution. There are multiple ways soil solution pH can impact nutrient availability for plants. Due to reactions with soil particles and with other nutrients, many plant nutrients can be available for plant uptake at certain pH levels, but less available at other pH levels (Figure 2).

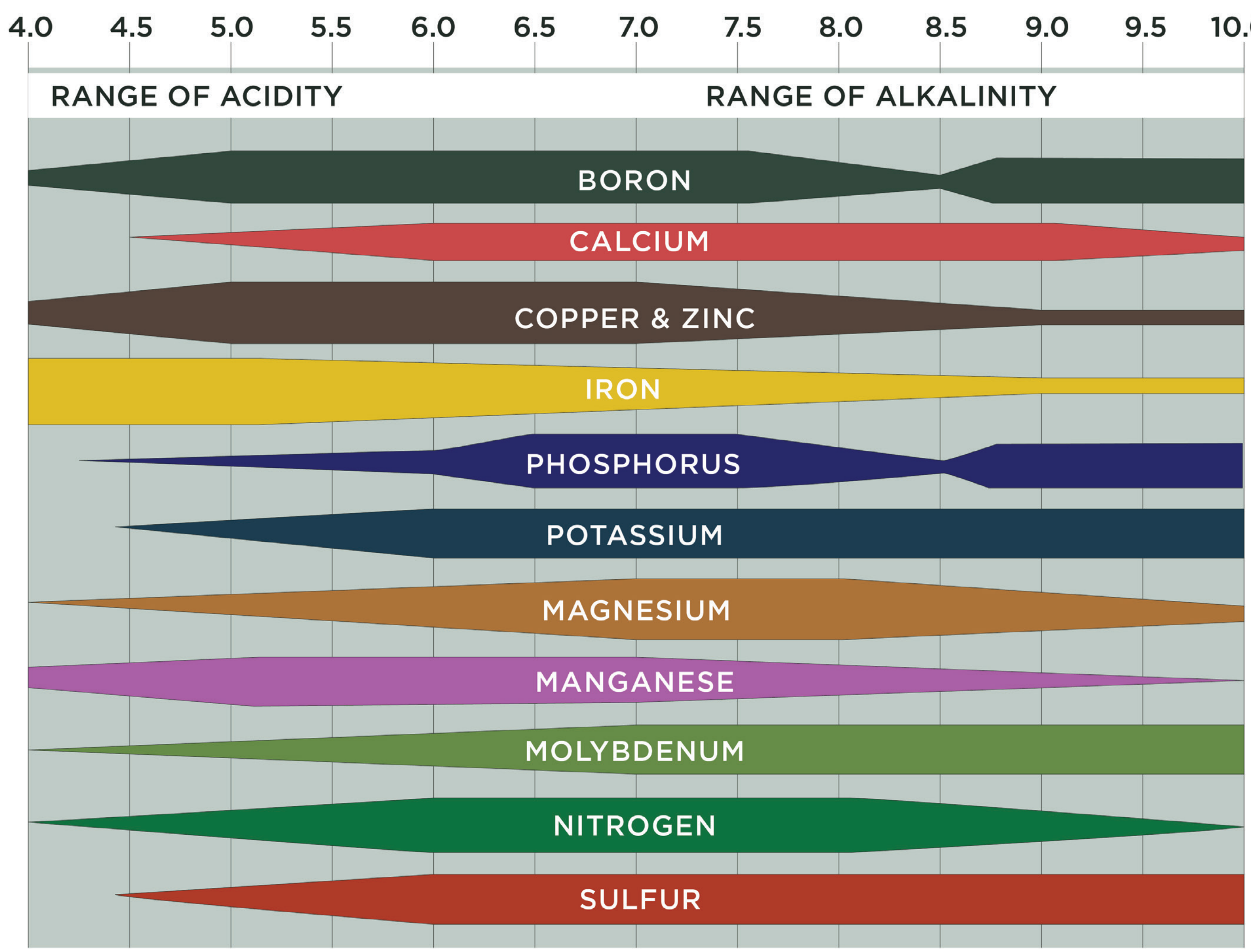

Figure 2. *The influence of pH on nutrient availability in soil.*

SUPPLYING NUTRIENTS TO PLANTS THROUGH SOILS

There are several ways plant nutrients are provided to plants through soil. The weathering of soil minerals and breakdown of organic matter serve to release nutrients. While these methods are critical, gardeners often require more rapid and specific management tools for plant nutrition. Fertilizers, both chemical (inorganic or conventional) and organic, are important nutrient management tools.

CHEMICAL (INORGANIC) FERTILIZERS

Inorganic fertilizers are essentially salts that are added to the soil to provide nutrients when the salt dissolves. These fertilizers react quickly and are available for plant uptake soon after application. Once the ions in the fertilizer dissolve in the soil solution, the nutrients can be immediately taken up by plants. For instance, potassium nitrate (KNO_3) fertilizer will provide K^+ and NO_3^- ions that plants can use (Table 1). Once dissolved, nutrients can also be held by soil particles or form other salts, which can limit their availability to plants. This formation of other salts is one reason pH management is important.


Figure 3. An inorganic fertilizer.

ORGANIC FERTILIZERS

As used here, the word organic means the fertilizer material came from previously living things, such as compost from plants, animal manures, or bone or blood meal. The term organic fertilizer can more specifically describe fertilizers that are suitable for certified organic production as described by the U.S. Department of Agriculture National Organics Program.

Organic fertilizers provide the same nutrients (Table 1) to plants as chemical fertilizers. However, they may be more slowly available because microbes are needed to transform nutrients in organic materials to a form that can be readily taken up by the plants. While the slower release of nutrients from organic fertilizers can be a drawback, it also can reduce nutrient leaching (when water moves through the soil and takes nutrients along with it). Commercial organic fertilizers provide guaranteed nutrient analysis (discussed below) just like chemical fertilizers, so the calculations discussed below are appropriate. Organic fertilizers often contain lower nutrient percentages by weight so more may be needed to supply the same amount of nutrients compared to chemical fertilizers. However, addition of organic matter to soil is an added benefit.

FERTILIZATION AND PH MANAGEMENT IN THE GARDEN

USING A SOIL TEST TO UNDERSTAND AND ADDRESS PH

Soil test results are one of the most useful methods for tailoring pH and nutrient applications to your garden. See W 346-A for information on taking a soil sample and sending in a soil test. Because soil pH and nutrient availability are linked, it is important to address both of these facets of soil management. Recommendations for management are based on bringing the soil to the ideal pH range for the specific crops. If your soil pH is lower than ideal, then a lime recommendation will be given. If the soil pH is higher than ideal, specific rates of a sulfur material may be recommended to lower pH.

AN INTRODUCTION TO FERTILIZERS: LABELS AND FORMS

Fertilizer labels are required by law to display quantities of nutrients provided. Percentages by weight of macronutrients nitrogen (N), phosphorus (P) and potassium (K) are always listed in the order N-P-K. Therefore 10-10-10 on the label means 10 percent N, 10 percent P_2O_5, and 10 percent K_2O. The percentages of P and K on fertilizer labels are reported in terms of P_2O_5 and K_2O because of tradition in soil science and fertilizer management. Most fertilizer recommendations from soil tests are given in pounds of P_2O_5 and K_2O per unit area to match the product labeling and eliminate the need for conversions to actual P or K.

There are several ways to describe fertilizers in addition to the terms inorganic and organic. Some important categories include complete or incomplete and dry or liquid. Complete fertilizers refer to those containing all three of the primary macronutrients (N, P and K). They are commonly used in home gardens due to ease of use and simplicity. In fact, many soil tests recommend certain quantities of specific complete fertilizers based on soil needs. Incomplete fertilizers contain just one or two of N, P and K elements. They are more commonly used to address specific needs of soils or to directly apply a nutrient that is used in higher quantities by certain crops or at certain times of the year.

Figure 4. Fertilizer bag showing the guaranteed analysis of N, P, and K.

Fertilizers can be purchased in dry, or granular, forms as well as liquid. Dry fertilizers are quite common because they are the most cost-efficient means of delivering nutrients to plants. Liquid fertilizers can be simple to use, but may be more expensive due to the need to purchase and ship water.

USING A GARDEN SOIL TEST TO ADDRESS FERTILIZATION

Initial fertilizer application

In addition to providing instructions for adjusting soil pH, soil tests provide recommendations for nutrient additions. Vegetable crops may require slightly different amounts of specific nutrients, but the close proximity of crops and size of home gardens makes it difficult to manage crops separately. As a result, it is common for the initial fertilization of the garden to be uniform across the whole garden area. The soil test report will list recommended amounts of N, P and K needed. A couple of simple calculations will be needed to determine the correct amount of fertilizer.

1. (Area of the garden/area used in the recommendation) x recommended nutrient from the soil report = nutrient weight needed for garden area

2. Nutrient weight for garden area/ percentage of that nutrient in the fertilizer material = fertilizer needed for the garden area

A specific example is provided on the right.

The soil test report recommends applying 2 pounds of N per 1,000 square feet, and the garden is 500 square feet (20 x 25 feet). The gardener has purchased a 10-10-10 fertilizer.

First, divide the garden size by 1,000 square feet (as used in the recommendation), and then multiply by 2 (the recommended lb N from the soil test) to determine the pounds of N needed in the entire garden.

(500 sq. ft./1000 sq. ft.) x 2 lb N = 1 lb N for the 500 sq. ft. garden

Since it is a 10-10-10 fertilizer, 10 percent (or 0.1) of the weight of the fertilizer is N. So, divide the amount of N needed for the area by the amount of N in the fertilizer.

1 lb N/ 0.1 (10% N in fertilizer) = 10 pounds of 10-10-10 fertilizer is needed in a 500 sq. ft. garden to provide the recommended N*

**Keep in mind that this application of 10-10-10 fertilizer will also supply 1 pound of P_2O_5 and 1 pound of K_2O. If these values greatly exceed the recommended applications of P and K, then another fertilizer material will need to be selected that has lower amounts of P or K.*

Typically, this calculated amount of fertilizer is evenly applied to the top of the soil before planting (called broadcasting) and incorporated through tilling or by hand to thoroughly mix with the soil. It is also possible to apply the fertilizer at planting using a method called banding where a narrow band of fertilizer is applied approximately 2 inches to the side and 2 inches below the seed or seedling.

This method of fertilization ensures soil serves as a buffer to prevent the fertilizer salts from burning the seed or young plant while also keeping nutrients near young plant roots. Table 3 provides information on converting recommended pounds of fertilizer per 1000 square feet to 100-foot rows if you prefer to band fertilizer instead of broadcasting.

Recommended rate per acre	Recommended rate per 1000 sq. ft.	Fertilizer rates in pounds per 100-ft rows for various row widths				
		18 inches	24 inches	30 inches	36 inches	48 inches
435 lbs.	10 lbs.	1.5	2.0	2.5	3.0	4.0
650 lbs.	15 lbs.	2.3	3.0	3.8	4.5	60
870 lbs.	20 lbs.	3.0	4.0	5.0	6.0	8.0
1,090 lbs.	25 lbs.	3.8	5.0	6.3	7.5	10.0
1,305 lbs.	30 lbs.	4.5	6.0	7.5	9.0	12.0

Table 3. *Approximate pounds of fertilizer to apply in a band to 100-foot rows to equal recommended broadcast rates.*
(Revised from similar table in UT Extension Publication PB-901)

Crop	Ammonium nitrate per 100-ft row	Ammonium nitrate per plant	Timing of application
Cucumbers, muskmelon, pumpkin, squash, watermelon	1 to 1 ½ pounds	1 tablespoon	When vines are 1 foot long
Tomato, eggplant, pepper	1 to 1 ½ pounds	1 tablespoon	When first fruits are 1 inch or more in diameter
Sweet corn	1 to 1 ½ pounds	--------	When 12 to 18 inches tall
Okra	1 to 1 ½ pounds	--------	After the first picking
Lettuce	1 to 1 ½ pounds	--------	3-4 weeks after seeding
Turnips, spinach, collards, kale, mustard	2 to 3 pounds	--------	6 weeks after seeding
Broccoli, cabbage, cauliflower, Brussels sprouts	1 to 1 ½ pounds	1/2 tablespoon	3-4 weeks after transplanting

Table 4. *Recommendations for applying nitrogen as a side-dressing to garden vegetable crops*
(Revised from similar table in UT Extension Publication PB-901)

Fertilization throughout the growing season

Garden vegetables can benefit from nutrient additions during the growing season. Nitrogen is the most commonly applied nutrient during the growing season, but P and K can also be applied as needed. The term most often used for this fertilization method is side-dressing, which means fertilizer is added to the side of the row and gently incorporated. Fertilizer should always be applied 6 to 8 inches from the plants to prevent salt burn. Applying water after side-dressing is also important to dissolve the fertilizer and move it into the rooting zone where it can be utilized.

Soil tests will often include recommendations for side-dressing, which can be carried out with complete or incomplete fertilizers. Ammonium nitrate is a common side-dressing fertilizer that adds only N. Carefully follow suggestions for timing and rate because over or undersupply of nutrients can alter pH and interfere with crop productivity. Table 4 provides general instructions for rate and timing of nitrogen fertilizer additions during the growing season for specific crops if not provided on the soil test report. Keep in mind that without soil testing, this nitrogen fertilizer application may not be effective because pH, P or K may be limiting. It is always best to manage fertility and pH through the use of yearly soil tests.

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