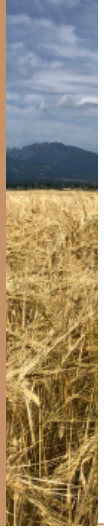
MONTANA STATE UNIVERSITY EXTENSION

MontGuide



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AGRICULTURE AND NATURAL RESOURCES

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Soil Fertility Considerations for Market Gardens

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This MontGuide summarizes three MSU Extension bulletins focused on soil fertility for market gardens: Soil Characteristics & Testing (EB0239), Nitrogen & Sulfur (EB0240), and Phosphorus, Potassium & Micronutrients (EB0241).

Soil Testing

It is ideal to test soil in early spring or possibly in late fall if spring soil is expected to be too wet. Collecting samples annually at the same time of year helps producers track soil test levels over time and reduces variability in test results due to climatic conditions, microbial activity, and the amount of time plant residue has had to decompose and release nutrients. It is also important to minimize the amount of time between collecting a sample and testing the sample. **Table 1** shows desirable levels of several soil characteristics for market vegetable farms. For more detailed information on soil testing, consult *Market Gardens: Soil Characteristics & Testing* and *Home Garden Soil Testing & Fertilizer Guidelines*.

Nutrients

It is important for market garden farmers to know how much of each nutrient is in their soils. Too little of a nutrient can cause a deficiency, while too much can cause toxicity or interference with other nutrients. Both can negatively impact plant production. Based on soil samples from market vegetable farms across Montana (Neff 2014), nitrogen (N) was the nutrient most often in low supply. Soils with adequate soil organic matter (SOM) levels generally provide sufficient micronutrients.

Some nutrients are mobile in the soil [e.g., N, chloride (Cl), sulfur (S)]; they can move through the soil easily. Therefore, mobile nutrients can leach out of the root zone. Losses of immobile nutrients, like phosphorus (P), are more often the result of soil erosion, which can lead to surface water contamination. Potassium (K) has intermediate mobility. Note that nutrients mobile in soil are not necessarily mobile in plants. Mobility of nutrients in plants is used in diagnosing nutrient deficiencies based on visible plant characteristics. Visit the Nutrient Deficiency and Toxicity page on the MSU Soil Fertility website for more information (landresources.montana.edu/soilfertility/nutrientdeficient).

Table 1. Desirable soil nutrient levels for market vegetable farms (from *Home Garden Soil Testing & Fertilizer Guidelines* unless otherwise noted).

	Desirable (ppm) in top 6-inches
Nitrogen (nitrate-N)[1.]	30 ppm 1.2 lb N/1000 ft² in 6-inch, 2.4 lb N/1000 ft² in 12-inch deep samples
Phosphorus (P_2O_5)[2.]	16; > 30 risks water contamination
Potassium (K_2O)	250; 800 = excess
Boron	1.0; 3 = toxic[3.]
Copper	0.5
Iron	5.0
Manganese	1.0
Zinc	0.5; 60 = toxic
Soil organic matter (SOM)	5 – 8%
pH	6.5 – 8.0
Salts (EC)	< 4 dS/m (=mmhos/cm)

1. *Soil Nitrate Testing for Willamette Valley Vegetable Production.* lb N/1000 ft² x 43.6 = lb N/acre
2. Using Olsen-P extraction process
3. From Abreu et al. (2005)

Plant nutrients have many forms in soil, and only some can be taken up by plant roots. For example, soils often have large total amounts of P and K, but only a fraction of the total pool is available to plants. Nutrients undergo transformations in the soil and can become available or unavailable to plants over time. These transformations are influenced by biological activity, temperature, and moisture. It is important to understand how nutrient levels change over a growing season, as producers will want to make sure levels match crop demands.

Soil nutrient tests estimate the amount of a nutrient available to plants at the time of sample collection. Montana vegetable farmers should have soils tested for nitrate-N, Olsen-P, and exchangeable K, and may want to opt for additional analyses of other nutrients if a deficiency is suspected. Basing application rates on soil tests, supported by visual plant deficiency symptoms, ensures the correct nutrients are applied in the right amounts. Soil tests can also help producers select the correct amendment. For example, applying poultry manure to soil already high in P and K would not be beneficial. A high-N amendment, like blood or feather meal, would be more appropriate.

Nitrogen is the nutrient needed in the greatest amount by plants, and it is also most commonly low on vegetable farms. Its many forms and transformations in soil make it a difficult nutrient to manage. Plants take up N from soil as nitrate (NO_3^-) or ammonium (NH_4^+). Organic materials can supply N to the soil, but N must first be transformed into plant-available forms by microbes via decomposition. Soil conditions affect N release from organic material. Soil temperatures between 70 and 95°F are ideal for release. Decomposition slows below 70°F, and there is little to none below 50°F. The optimal soil moisture for decomposition is around 35% water content (50-60% water-filled pore space; Lei and McDonald, 2019). Because fall and early spring conditions are not ideal for N release from organic matter, crops planted at those times could require N fertilization at planting. Conversely, late-spring planted crops may access sufficient N released from organic material.

Fresh materials (manure or plant residues) release N more rapidly than dried or composted materials. The degree to which organic materials contribute to plant-available nitrogen (PAN) depends on their N concentration. Materials with low N concentrations add very little PAN and can even cause soil microbes to deplete PAN. Materials with high N concentrations will result in greater PAN. Fresh legume residue (3% N) can provide a large, rapid flush of N to soil, while beef manure compost (0.8% N) will add less PAN (**Figure 1**). A material like feather meal (12% N) would add even more PAN than

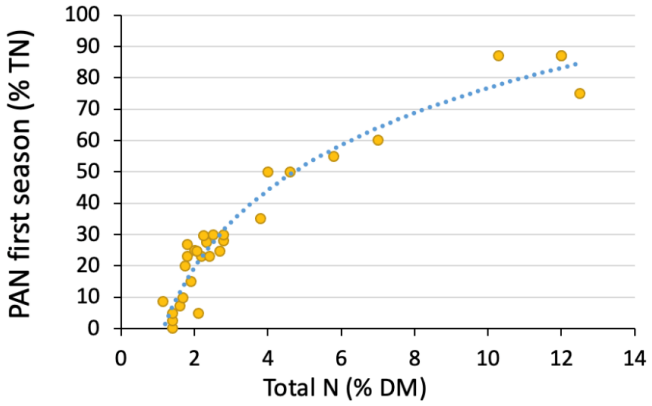

Figure 1. Plant available N in the first season increases with total N concentration in the amendment added. Total N is on a % dry matter basis (% DM) and PAN is a % of total N (TN; Collins et al. 2013, Bary et al. 2016, Sullivan et al. 2020

fresh legume residue. Ideally, N is supplied by multiple sources that provide N at needed amounts over the growing season. For example, SOM provides a baseline amount of N, a legume green manure adds to that baseline as it decomposes, and an application of feather meal at planting will provide a rapid N boost. Note that applying products like feather and blood meals should be done in a calculated manner, as these products are expensive and easy to overapply.

Soil Amendments

The choice of soil amendments used in market vegetable farms depends upon several factors, such as budget, space, time, machinery, local availability, weather, and labor. Amendments vary in relative amounts of each nutrient they supply and the rate at which nutrients will be released for plant uptake. Whichever amendment option a producer chooses, there are four main management options, plus crop rotations, that will help ensure nutrients are supplied efficiently (**Table 2**).

Source

Most manures (besides poultry) are low in N yet are excellent sources of several other nutrients and organic matter. Barriers to using manure are transportation, odor, runoff or leaching risk to water quality, nutrient content variability, time, labor, and plant burn if manure is high in ammonia. Soils amended with fresh or composted manure to meet crop N needs or improve soil condition can quickly accumulate excess P and K (**Figure 2**). Manure can also be high in salt and contain viable weed seed and herbicide residues, which are reduced, but not eliminated by composting. Check your state and federal guidelines regarding manure application to ensure compliance and prevent food contamination.

Table 2. Four key fertilization management options, along with using crop rotations, ensure the maximum amount of nutrients applied is taken up by the crop.

Source	Select among sources that supply nutrients quickly (e.g., urea, compost tea, potash) for in-season fertilization, and slowly over time (compost, elemental S, bone meal) for baseline nutrients.
Rate	Determine rates based on soil tests and estimated crop demand.
Timing	Apply readily available sources shortly before crop growth spurt, or in small doses over the growing season, especially in coarse or shallow soils. Slow-release sources require months or years to provide substantial available nutrients.
Placement	Place mulch and elemental S on the soil surface; incorporate fresh plant residue/ manure/urea/meals; band to reduce weeds; use foliar spray as rescue.
Rotation	Have a crop or cover crop in place to catch available N and reduce erosion; alternate crops that require high vs. low amounts of nutrients; plant leafy crops rather than root crops after high N input; rotate low residue with high residue crops and amendments.

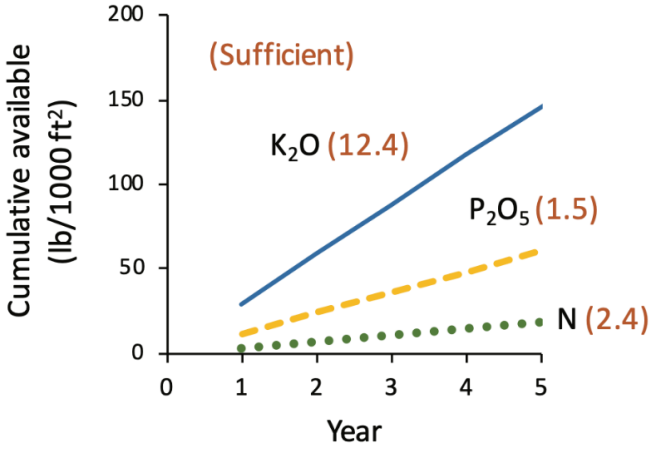

Figure 2. The availability of different nutrients grows at different rates as 1-inch of compost manure is added each year. Adding 1-inch of manure compost annually builds up much more P and K in the soil than needed by plants. Sufficient levels are in parentheses. Adapted from Hartz (2009).

Compost is material created by the decomposition of organic material. Finished compost is crumbly and dark. Compost is better suited as a soil conditioner and source of P, K, and micronutrients than of N. Fresh manure and compost have low and variable concentrations of nutrients, so it is difficult to know at what rate nutrients are applied. They are bulky and require a lot of labor for low nutrient input.

Cover crops, also called green manure, are plants grown in time and/or space between cash crops. Cover crops add plant residue, extend the portion of the year that active roots are in the soil, protect the soil from erosion, suppress weeds (or add weeds if left to go to seed), and increase soil microbial activity, which can increase nutrient availability. Cover crops require a long-term perspective on soil fertility because they improve soils slowly.

Mulch is material left on the ground to protect soil from erosion, reduce weeds, and hold in soil moisture. Mulch can come from various sources, including mowed cover crops, compost, woody chips and debris, or straw. In contrast to incorporated organic material, mulch decomposes slower, adds nutrients more slowly and does more to protect the soil surface.

There are several specialty products available that generally come in a bag from off the farm. Those intended to supply a specific nutrient usually have a guaranteed nutrient content level, called grade. Grade labels specify percent by weight of total N, available P_2O_5, soluble K_2O and sometimes S. Common specialty items include elemental S, blood meal or feather meal. Materials that are more complex (e.g., feather meal is more complex than elemental S) are more variable in nutrient content and less likely to have an exact grade. Farmers can submit these products to a laboratory for an exact nutrient analysis. Visit the Soil and Tissue Testing Laboratories page on the MSU Soil Fertility website for a list of regional testing laboratories (landresources.montana.edu/soilfertility/html/SoilTestLabs.html).

RATE

Nitrogen application rates are based on soil test values and PAN coming from plant residue and SOM during the growing season. Vegetables generally require around 2.4 lb PAN/1000 ft^2 in the top foot of soil (105 lb N/acre) for maximum yields, though the amount varies between crops. Application rates of other nutrients should be based on soil tests (**Table 1**). Adding more nutrients than the plant needs will not increase yields and has costs, as does under-fertilization in lost yields. Consult *Market Vegetable Farms: Soil Nitrogen & Sulfur* and *Market Vegetable Farms: Soil Phosphorus, Potassium & Micronutrients* to learn how to determine fertilizer rates.

TIMING

Different amendment sources release nutrients at different rates, and this is important to consider when producers are planning an amendment application. Amendments that rapidly release nutrients should be applied a few weeks before rapid crop growth or in small doses over the growing season. Materials that release nutrients slowly need to be applied months before plants need them. Amendment characteristics (e.g., N concentration and freshness) and soil microbial activity dictate the rate of nutrient release. Therefore, it can be tricky to determine the right time to apply an amendment. Producers can apply multiple nutrient sources that will release nutrients at different times can help manage this variability.

PLACEMENT

Placement depends on amendment type and how nutrients behave in the soil. For example, P is immobile in soil. Therefore, P fertilizers are best placed in a band near the seed or in the planting row, known as subsurface banding. If banding equipment is unavailable, broadcasting P fertilizer and tilling to incorporate it is also effective. Manure and readily decomposable materials high in N should be incorporated with tillage or followed by irrigation to minimize N volatilization, a process in which N is lost to the atmosphere. In environments susceptible to overwinter leaching (coarse or shallow soils, high chance of amendment/cover crop decomposition in the fall), waiting to till materials into the soil until just before fall freeze can help decrease N leaching.

ROTATIONS

Vegetable families (e.g., brassica, squash, legume) extract different types and amounts of nutrients from the soil and are susceptible to different pests and diseases. Crop rotations help balance soil nutrients and break pest and disease cycles. An early spring crop, a crop that requires high N, or a deep-rooted crop should follow legumes or other high N residues (e.g., brassicas) to use soil N and minimize leaching loss. Leafy crops tend to have greater yield increases than root, bulb, or fruiting crops after adding organic materials, especially those high in N (Wortman et al. 2017).

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Montana State University Extension bulletins are available at store.msuextension.org or by contacting the Distribution Center at 406-994-3273, orderpubs@montana.edu.

Home Garden Soil Testing & Fertilizer Guidelines

Market Vegetable Farms: Soil Characteristics & Testing

Market Vegetable Farms: Soil Nitrogen & Sulfur

Market Vegetable Farms: Soil Phosphorus, Potassium & Micronutrients

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