MANAGING VEGETABLE GARDEN SOIL FERTILITY IN VERMONT

Vern Grubinger, Extension Professor, University of Vermont

Soil fertility is determined by the chemical, physical and biological characteristics of soil. Chemical characteristics include nutrient availability which is determined by soil pH (acidity level) and the levels of plant nutrients. Physical characteristics include soil structure (tilth), compaction and drainage. Biological characteristics include the amount and type of organic matter in the soil and its availability to soil microbes for decomposition.

Soil pH affects the availability of plant nutrients. Maintaining soil pH between 6.0 and 7.0 optimizes the availability of nutrients already in the soil. A pH of 6.5 to 6.8 is ideal for most vegetable crops. To raise the pH, lime is added; to reduce it, elemental sulfur can be added. It requires more lime, or sulfur, to change the pH of 'heavier' textured soils (with a lot of clay and silt) compared to those that are 'lighter' textured (contain more sand). A soil test is needed to determine whether or not lime or sulfur is needed to adjust a soil's pH, and in what quantity.

Nutrients. Plants require many nutrient in order to grow, but only a few are required in large amounts, and these are the focus of fertility management: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg). The minor elements needed for plant growth are usually adequate in Vermont soils, and their supply can be easily and safely maintained by applying amendments such as compost or manure to soil. In general, Ca and Mg are provided by liming to maintain proper pH while N, P and K can be provided from fertilizers, but only after the contribution of compost, manure, cover crops and soil organic matter are considered and it is clear that fertilizers are actually necessary. A UVM soil test can help you determine which nutrients, and in what quantities, should be added to the soil for your plants.

Soil organic matter is formed by the decomposition of carbon-containing residues such as crop residues, manures, compost and cover crops. Soil organic matter is beneficial in many ways. It is a reservoir of plant nutrients since it is slowly but continuously decomposed by soil microbes over time. This enhances soil tilth by promoting soil aggregation, which is the clumping together of small particles. Good soil tilth allows air and water move through the soil and it promotes good root growth.

To maintain soil organic matter, carbon-containing residues should be added to the soil on a regular basis. However, if soil nutrient levels are high, then compost and manure should be avoided and the focus should be on cover crops and, if necessary, high carbon materials with low N-P-K content such as leaf mold and peat moss.

Compost and manures contain N, P, K and small amounts of micronutrients. On low fertility soils, as in many new gardens, a relatively high rate of compost or manure can be used for several years to build up nutrient and organic matter levels, because N, P, K and carbon are all needed. In well-established gardens with high levels of nutrients and organic matter, compost and manure should be used very little, if at all, to avoid excess application of N, P and K.

Cover crops can and should be used on soils of all fertility levels, as they will not add excess nutrients. Cover crops take up existing nutrients from the soil and 'recycle' them after the crops die and decompose. Legumes such as alfalfa, clovers, field pea, and hairy vetch can also add N to the soil because the nodules on their roots work with bacteria to capture it from the air. This is very useful in low fertility soils, but in soils with a lot of available N legumes won't form many nodules. To get a significant amount of N from legumes one must allow them to produce a lot of growth, which means that some space must allocated to the cover crop instead of vegetables during the growing season. Before planting cover crops, one should be sure the necessary equipment will be available to manage the biomass they produce by mowing, cutting and/or incorporation into the soil.

Winter cover crops can be grown without taking space away from vegetables because they are sown at the end of the traditional growing season, in early fall. Winter covers help maintain soil organic matter and they protect against soil erosion by wind and water. They also 'mop up' available nutrients from the soil in the fall and release them later when they decompose. Winter rye is a hardy cover crop that can be sown until the end of September in most Vermont locations. It will grow again in the spring and must be completely turned under before planting vegetables. Oats can be used instead of rye, and these will winter-kill, leaving only dead residues to incorporate the following spring. Sow 4 to 5 pounds of either crop per 1,000 sq ft.

Fertilizers come from different sources and thus contain different amounts of nutrients. They can be organic (containing carbon), mineral (from certain rocks) or synthetic ('chemical'). The nutrient content of fertilizers is described by their N, P, and K content by weight. For example, a 10-10-10 fertilizer contains 10% by weight of all 3 of those nutrients. The P and K in fertilizers are referred to as phosphate and potash, respectively.

Fertilizer value of compost and manure. Compost, though variable, is a 1-1-1 fertilizer on average, so it adds N, P and K to the soil. Fresh manure also varies in nutrient content. It should be avoided in the garden due to potential weed seed contamination and food safety risks from pathogens like *E.coli.* Rotted, aged manure that is not completely composted but no longer has a strong odor is safer to use than fresh manure; it has a nutrient content similar to finished compost. If using fresh manure in the garden it is best to incorporate it thoroughly and wait several months before harvesting any food crops.

The goal of fertilization is to apply only the nutrients that plants need to grow well. This is true whether one is using organic or conventional fertilizers, bulk amendments like compost or bagged materials like 10-10-10. For example, if a soil test indicates that there is adequate or excessive P in the soil, then any fertilizer applied should contain little or no P while providing the necessary N and K. If only K is needed, then a fertilizer low in N and P is best. Continuous use of P-containing fertilizer or high rates of manure or compost is of special concern because it results in P buildup in the soil. When rain causes soil runoff, this contributes to phosphorus pollution in lakes and other bodies of water.

Synthetic fertilizers. These chemical, or conventional, materials are generally water soluble and rapidly available to plants. Common materials and their nutrient content are listed below.

fertilizer	analysis	amount of fertilizer needed to add 1 lb of nutrient		
		N	phosphate (P)	potash (K)
garden blend	10-10-10	10 lb	10 lb	10 lb
garden blend	5-20-20	20 lb	5 lb	5 lb
ammonium nitrate	34-0-0	3 lb	--	--
urea	45-0-0	2.2 lb	--	--
superphosphate	0-20-0	--	5 lb	--
potassium chloride	0-0-60	--	--	1.7

Organic fertilizers. Unlike soluble chemical fertilizers, the nutrient release from organic residues is delayed, since microbes must break them down before the nutrients become available to plants. Materials such as plant meals (alfalfa, soybean, etc.) and blood meal release nutrients within a few weeks and continue to do so during the main growing season. Use a dust mask when working with animal byproducts or other materials that can be harmful if inhaled.

fertilizer	analysis	amount of fertilizer needed to add 1 lb of nutrient		
		N	phosphate (P)	potash (K)
compost*	1-1-1	100 lb	100 lb	100 lb
heat treated poultry manure*	4-3-4	25 lb	33 lb	25 lb
'Pro-Gro'	5-3-4	20 lb	33 lb	25 lb
'Pro-Booster'	10-0-0	10 lb	--	--
soybean meal	7-2-1	14 lb	50 lb	100 lb
alfalfa meal	3-0.5-2.5	33 lb	200 lb	40 lb
dried blood	12-0-0	8.3 lb	--	--
bone meal*	3-15-0	33 lb	6.7 lb	--
wood ash*	0-1-7	--	100 lb	14 lb

* nutrient content will vary based on source and handling

Some mineral fertilizers are allowed for use by organic growers since they occur naturally. (Check with your certifier before using amendments if you plan to become commercial organic grower.) Although rock powders like rock phosphate are added to the soil based on their available nutrient content, over time the remaining nutrients will become available so plan to test the soil every few years in order to track this release of 'reserve' nutrients.

fertilizer	analysis	amount of fertilizer needed to add 1 lb of nutrient		
		N	phosphate (P)	potash (K)
Chilean nitrate*	16-0-0	6 lb	--	--
rock phosphate**	0-30-0	--	3.3 lb	--
potassium sulfate	0-0-52	--	--	2 lb
sul-po-mag***	0-0-22	--	--	4.5 lb
greensand	0-0-7	--	--	14 lb

* organic farms are restricted in their use of Chilean nitrate.

** only ~10% of the total phosphate in rock phosphate is available in the year of application.

*** also contains 11% Mg

Fertilizer application. The timing and placement of fertilizers affects how well plants will be able to use the nutrients that are applied.

Compost and manure release nutrients relatively slowly, so they should be applied early in the season, and their nutrient contribution should be considered over several seasons. Typical N release rates from fresh manure is only 30% to 50% the first year, 15% to 25% the second year, 7% to 12% the third year, 3% to 6% the fourth year, and so on. With compost and composted manure, the release rate is even slower, 5% to 25% the first year, 3% to 12% the second year and 1% to 6% the third year, and so on. The more 'finished' or completely decomposed compost is, the more slowly it will break down further and release nutrients.

Organic materials that come from plants and animals, such as seed meals, bone meal, blood meal, etc. also require microbial activity to break down and release nutrients. However, they are typically decomposed over the course of a single growing season. Once soils are warm and moist they begin to release nutrients, with peak release coming in a month or so after application. These materials should be applied early in the season; placing them in the beds or rows where crops will be grown rather than over the entire garden will save money and can help reduce weed pressure between the rows by concentrating nutrients near crops. Mineral fertilizers with low solubility such as rock phosphate (for P) greensand (for K) can be applied in spring or fall; they will release nutrients over several years.

Fertilizers that are highly soluble, like Chilean nitrate, potassium sulfate, and most synthetic fertilizers, can be divided into several applications over the growing season in order to 'spoon feed' crops with nutrients rather than loose them to leaching with rainfall. Spread a portion of these fertilizers evenly over the width of the crop bed prior to planting, then sidedress the remainder (dribble by the row) 3 to 4 inches to the side of the plants early in the summer. Do not concentrate soluble fertilizers in the seed row or next to plants or injury may result.

Nitrogen is the nutrient needed in largest quantities by plants and is usually applied on an annual basis. However, soil tests don't measure N because its availability changes rapidly depending on temperature, moisture and microbial activity. Instead, we estimate how much N will be available from the soil over the season to determine how much fertilizer N is needed. A reasonable application for home vegetable gardens with soil organic matter content of less than 2% is 3 lbs. of total N per 1,000 sq.ft., or about 5 oz. of N per 100 sq. ft. In soils with 3-5% soil organic matter, apply 2 pounds of total N per 1,000 sq. ft. or 3 oz. per 100 sq. ft. and in soils with 5% or more soil organic matter apply 1 lb. of N per 1,000 sq. ft. or 1.5 oz. per 100 sq. ft. Except for short season crops, it's a good idea to split the application; apply 2/3 of the N at planting and sidedress the rest by dribbling along the row about a month later. If manure or a legume cover crop is added to the soil then sidedressing of N is not usually needed.

Phosphorus is adequate in the majority of established gardens due to prior applications of P fertilizers, manure, etc. Deficiencies are most likely in new gardens where the organic matter content is low, or in soils with low pH. In the latter case, add lime if needed before adding P fertilizer. Where P levels are low, a reasonable application rate is 2 lbs. of total phosphate per 1,000 sq. ft. or about 3 oz. per 100 sq. ft.

Potassium levels are naturally adequate in soils that contain certain types of clays. Deficiencies are most likely in new gardens low in organic matter and in sandy soils low in organic matter. Where K levels are low, a reasonable application rate is 3 lbs. of potash per 1,000 sq. ft. or about 5 oz. per 100 sq. ft.

Avoid soil compaction, which can harm crop growth. In compacted soils, roots have difficulty growing and this can limit nutrient uptake, even if nutrient levels are high. Soils can become compacted by construction activity, walking on wet soils, cultivating wet soils, and the impact of rain on soils without cover crops in late fall and early spring. Avoid cultivating or working soil when wet. To test the soil for wetness, squeeze a handful of soil then try to crumble it. If it will crumble, it can be worked. If it will not crumble but stays in a ball, it is too wet to be worked. Minimize mechanical cultivation such as rototilling; till the soil only as much as needed to prepare a seed bed or incorporate organic matter and fertilizers. For weed control, use mulch, hand hoeing or very shallow cultivation only.

Fertilization examples. Keep in mind that it is not always practical to apply *exactly* the quantities of nutrients recommended; the goal is to come as close as reasonably possible.

Example #1 - A soil with 2.5% organic matter; nutrients recommended: 3 lb of nitrogen N, 2 lb of phosphate (P) and 3 lb of potash (K) per 1,000 sq. ft. Possible fertilizers to meet these needs:

- 30 lb of 10-5-10 will add 3 lb N, 1.5 lb P, 3 lb K; add 3 lb of bone meal (15% phosphate content) in the planting holes or rows to provide the additional ½ lb of P needed; or
- 75 lb of pelletized poultry manure fertilizer (4-3-4) will provide 3 lb N, 2.2 lb P and 3 lb K; or
- 200 lb (about ¼ cu yd) of 1-1-1 compost will add ~2 lb each of N, P, and K. Since this is very slowly available, also add 25 lb soymeal (7-1-2) to provide ~2 lb N, ¼ lb P and ½ lb K

Example #2 - A soil with 5% organic matter; nutrients recommended: 1 lb N, 0 lb P, 2 lb K per 1,000 sq. ft. Possible fertilizers to meet these needs:

- 3 lb ammonium nitrate (33-0-0) for 1 lb N, 3.5 lb potassium chloride (0-0-60) for 2 lb K; or
- 15 lb soybean meal (7-1-2) for 1 lb N, 9 lb sul-po-mag (0-0-22) for 2 lb K; or
- 9 lb dried blood (12-0-0) for 1 lb N, 4 lb potassium sulfate (0-0-52) for 2 lb K

Example #3 - A soil with 7% organic matter and very high P and K levels, 1 lb N per 1,000 sq. ft. is recommended. Possible fertilizers to meet this need:

- 10 lb of Pro-Booster (10-0-0); or
- 9 lb of dried blood (12-0-0); or
- 2 lb of urea (46-0-0)

Converting fertilizer weight to volume for small scale gardens:

type of fertilizer	weight of fertilizer per cup
compost	1/6 lb
organic seed meals, blends, wood ash	1/3 lb
rock powders (lime, rock phosphate, greensand)	3/4 lb
coarse synthetic blends (5-10-10 garden fertilizer)	1/2 lb
synthetic N fertilizers (ammonium nitrate, urea)	1/3 lb

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