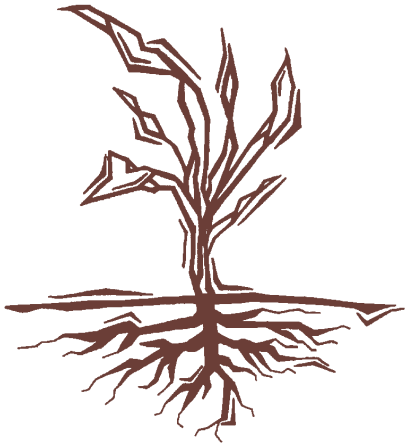

SOIL

Phosphorus Fertilizers for Organic Farming Systems

no. 0.569

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Quick Facts...

Adequate soil phosphorus (P) is essential for optimal crop yields.

Phosphorus tends to move downhill across the field and is less likely to leach vertically into the ground water.

On alkaline soils research shows that it is best to use composted or vermicomposted manure to minimize environmental impacts.

Before purchasing any P amendments it is important to assess what implements are needed to spread the material on the field and at what time it is most beneficial to apply the P.

Adequate soil phosphorus (P) is essential for optimal crop yields. Phosphorus (P) enables a plant to store and transfer energy, promotes root, flower and fruit development, and allows early maturity. Agricultural soils in Colorado generally contain from 800 to 2,000 pounds of total P per acre in the tilled layer. However, most of it is in insoluble compounds that are unavailable to plants. Second to nitrogen, P is the most limiting macronutrient in Colorado soils.

The soil pH range at which maximum P availability occurs is between 6.0 and 7.0. In Colorado, the majority of our soils are alkaline and have a pH of 7.0 to 7.8 and greater. Soils with a pH of 7.5 and higher typically have a high calcium concentration that binds P as calcium-phosphate creating an insoluble compound that is not available to plants. Therefore, it is necessary to amend agricultural soils with available forms of P at the correct agronomic rate.

Although P inputs are vital to crop production, P export in runoff from over-manured and over-composted soil can hasten the eutrophication of receiving waters. Eutrophication occurs when undesirable algae and underwater weeds grow as the result of an increased nutrient supply. As the biota die and decompose, bacteria consume dissolved oxygen, resulting in oxygen shortages in the water bodies. Therefore, it is important both economically and environmentally to apply agronomic rates of nutrients.

Phosphorus Fertilizer Options

Annual sampling of each field is important to assure accurate nutrient management recommendations. Refer to fact sheets 0.501, *Soil Testing; 0.500*, *Soil Sampling*; and 0.520, *Selecting an Analytical Laboratory* for additional information. Take soil samples from 0 to 6 inches in no-till fields and 0 to 12 inches in tilled fields to determine the concentration of available P in an agricultural field. Unlike nitrogen, phosphorus tends to move downhill across the field and is less likely to leach vertically into the ground water. Manure is often an inexpensive source of P, although its transportation to the field can add significantly to the final cost.

Many feedlots and dairies in Colorado offer manure at no cost if the buyer provides transportation. On average, the P content is 24 lbs P_2O_5 per ton in beef feedlot manure and 18 lbs P_2O_5 per ton in dairy manure. However, it is necessary to test the manure to know exactly how much P is present. Composted feedlot and dairy manure are also a good source of available P. As compost undergoes microbial digestion its volume decreases by one-third to one-half, therefore increasing the P concentration. In return, this lowers transportation costs per unit of P. Compost nutrient levels vary based on the source material used to produce the amendment. According to Davis et al. (2002)[2], an average P content for dairy manure compost in Colorado, New Mexico and Utah is 22 lbs P_2O_5 per ton of compost (see Table 1). It is important to note that well-finished,

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Table 1. Compost nutrient levels based on the source material.

Amendment	%Total N	% P_2O_5	% K_2O_5	Other	$/lb P_2O_5	P Available in
Beef Manure Dairy Manure	1 1	1 1	2 2	micronutrients micronutrients	N/A *	3-6 months (apply in fall)
Dairy Compost	1	1	2	micronutrients	$6.60	3-6 months (apply in fall)
Vermicompost	2	2	1	micronutrients	$12.00	3-6 months (apply in fall)
Rock Phosphate	0	8-20	0	Calcium	$4.50	Not available in alkaline soils
Bone Meal	2	11-22	0	Calcium	$4.00	Not available in alkaline soils

*There is no average cost of manure in Colorado since many producers offer it free for pick-up.
The above manure-based nutrient values are based on Colorado averages.
Other P sources exist but the ones listed have the greatest P concentration by percentage.
For reference, 1% nutrient on a weight basis = 20 lb of nutrient /ton of material

cured compost should smell "earthy" and should not have a strong ammonia odor. Cured compost nutrients are stabilized and provide a slow release of plant available nutrients. Manure based compost currently costs about $30 per ton (about $6.60 per lb P_2O_5) with some dealers offering delivery at no cost. A good rule of thumb to follow is that 2 cubic yards of compost at 30 percent moisture (feels like a wrung out sponge) weighs approximately 1 ton. Keep in mind that the moisture content of the compost will change the weight.

Organic farming standards require a natural source of fertilizer for all amendment needs. In alkaline soils, this makes P fertilizing more challenging. Commercial fertilizers are manufactured with a dissolving agent that, given adequate moisture, produces a plant available P molecule in the soil solution. However, in alkaline soils, dissolving organic amendment P particles to provide plant available P is the challenge. Several organic options are available.

Manure that has been digested by worms is called vermicompost. This process reduces volume and adds additional microbial diversity to the compost. Of the three above-mentioned manure-based amendments, vermicompost is the most expensive. The finely screened moist material sells for about $600 per ton ($300 per cubic yard) at $12 per pound P_2O_5. Concentrations of P vary based on the material used for vermicomposting but average 2 percent P_2O_5 per unit of volume (i.e., 40 lb P/ton of material).

Rock phosphate is mined from areas within the United States and has a slightly different chemical composition depending on its origin. Hard and soft (colloidal) rock phosphates are sold as different products although they are the same chemically, with soft rock only having a smaller particle size. Rock phosphate contains, on average, 280 lbs P_2O_5 per ton of material and sells for about $4.50 per lb P_2O_5. Although rock phosphate is useful in many farming applications, it is not readily available for plant use in soils with pH above neutral (pH 7). In order for rock phosphate to become plant available, the acidity of the soil solution must dissolve the P into a plant-available inorganic P. Therefore, check the pH of your soil prior to applying rock phosphate as your P source.

Bone meal is comprised primarily of bones and has a concentration of 330 lbs P_2O_5 per ton of material. Bone meal also should be applied to soils that have a pH below 7 to provide the necessary acidic soil solution for the P to convert to plant-available P. On average, bone meal P cost $4 per lb P_2O_5. Both rock phosphate and bone meal are sold as a finely ground powder with a consistency similar to baking flour.

Before purchasing any P amendments, it is important to assess what implements are needed to spread the material on the field and at what time it is most beneficial to apply the P. It is also important to take into consideration the costs for shipping or transporting the materials.

Research Results

For two years, Colorado State University research compared the plant availability of P in dairy manure, dairy compost, dairy vermicompost and rock phosphate (Table 2) on a certified organic field (pH 7.8) of cucumbers. All plant material from the first year's crop was incorporated into the field in order to retain nutrients while the second years cucumbers were harvested. The highest P application rates were for research purposes only and are not recommended as agronomic rates for crop production.

Table 2. Mean effect of P amendments on soil P concentration (Olsen P), runoff P, plant tissue petiole P concentration, and cucumber yield two years after treatments were applied. The control treatment had no P applied.

	ppm	ppm	ppm	lb/A
Control	6.4 c†	3.22 b	1,767 b	17,860 c
Raw Manure				
80 lb P_2O_5/A	7.7 c	3.24 b	1,779 b	20,038 bc
160 lb P_2O_5/A	15.9 a	4.72 a	2,149 a	27,443 ab
Composted Manure				
80 lb P_2O_5/A	8.0 c	2.88 b	1,672 b	31,799 a
160 lb P_2O_5/A	11.6 b	2.71 b	1,821 b	30,056 a
Vermicompost				
80 lb P_2O_5/A	11.1 b	2.60 b	1,798 b	23,522 bc
160 lb P_2O_5/A	9.7 bc	2.57 b	2,102 a	31,799 a
Rock Phosphate				
80 lb P_2O_5/A	7.1 c	2.71 b	1,818 b	16,553 c
160 lb P_2O_5/A	8.9 bc	2.37 b	1,797 b	15,682 c

† Means with a common letter within a column are not significantly different ($p < 0.10$) by least significant difference.
*To convert to smaller area, lb/A * 0.023=lb/1,000 ft²

The soil in plots amended with raw dairy manure, composted manure and vermicompost each had greater plant available soil P (Olsen P testing method is suggested for CO soils) concentrations than the rock P or control (no P) plots. The concentration of P that left the field as runoff was highest for the raw manure amendment. Accumulation of P in the plant tissue was highest in the raw manure and vermicompost treatments. The yield weights were the greatest for plots amended with raw manure, composted manure and vermicomposted manure. No yield difference occurred between the rock P and control plots.

Conclusion

Of the treatments studied for P availability in alkaline soils, rock phosphate provided no soil P concentration differences or yield improvements over the control after two growing seasons. Therefore, rock P was not effective in providing plant available P in high pH soils. Most cultivated soils in Colorado have a pH above 7.0.

On alkaline soils, research shows that it is best to use composted or vermicomposted manure to minimize environmental impacts. However, raw manure also proves to be a beneficial and provides plant available P. The runoff data in Table 2 illustrates that raw manure P was more likely to move from the plot via runoff than the composted and vermicomposted P. Therefore, a larger fraction of P added to the crop from manure may leave the field during a rainfall or irrigation event, which not only wastes farm resources but increases water pollution. Although P is necessary for optimal plant yield, excess application may lead to environmental P pollution in surface water bodies. Phosphorus is the limiting nutrient for aquatic plant growth and as these plants decompose dissolved oxygen is consumed, producing unhealthy water for plant, animal and human consumption.

If a manure or compost source is not available in your area, cover crops offer another way to increase soil fertility. Cover crops can help recycle other nutrients on the farm, and legume cover crops fix atmospheric nitrogen. Nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S) and other nutrients are accumulated by cover crops during a growing season. When the green manure is incorporated, or laid down as no-till mulch, these plant-essential nutrients slowly become available during decomposition.

More information about cover crops is available through the Sustainable Agriculture Network (www.sare.org).

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[2] Davis, J.G., K.V. Iverson, and M.F. Vigil. (2002). Nutrient variability in manure: Implications for sampling and regional database creation. Journal of Soil and Water Conservaion. 57(6): 473-478.