Phosphorus Management for Christmas Tree Production

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In a previous *Great Lakes Christmas Tree Journal* article, we discussed nitrogen fertilizer management, which has gained renewed interest due to the exceptional price increases of fertilizer inputs. The same challenge will be true for other fertilizer nutrients and in this article, we will analyze phosphorus (P) management.

Understanding the basics of P dynamics in the soil is essential to optimizing P management, which can help reduce costs and improve profitability. Ultimately, growers should strive to promote tree growth and quality, while also minimizing loss of P inputs to the environment and promoting environmental stewardship.

Phosphorus in plants

Phosphorus (P) is a macronutrient and is needed for a unique array of essential cellular functions. One of the most important functions of P is as part of the energy currency in plants. Phosphorus is involved in the storing of energy as sugars during photosynthesis and in the utilization of sugars for growth and maintenance of plant tissues during respiration. Phosphorus is a component of nucleotides, which are the building blocks of DNA and RNA and are required for protein synthesis. Finally, P is also used for the structure of membranes in cells and cellular organelles.

Due to the critical role of P in these fundamental plant functions, insufficient P levels can severely limit growth (Photo 1). However, P deficiencies in trees can be difficult to diagnose based on visual symptoms alone and can be easily mis-diagnosed as other nutritional deficiencies or other plant stresses. In many plants, severe P deficiency can be characterized by a purplish color to foliage. Matching P needs for Christmas trees is important to prevent reductions in tree productivity, while also eliminating unneeded fertilizer applications that increase grower's expenses and cause potential environmental damage.

Photo1: *Phosphorous deficient Christmas trees.*
Photo Credit, Dr Jim Shelton, North Carolina State University

Assessing need for P

There are several options to determine whether, or how much, additional P amendments are needed prior to the onset of deficiency symptoms and reduced growth. Soil testing (Photo 2) can be done to determine P levels in the soil. Soil P test results (Photo 3) near 20 ppm (Bray P1), are generally sufficient for tree needs. In 2021, 75% of all soil sample results from the Great Lakes region submitted through A & L Great Lakes Laboratory, were above this threshold (Table 1). Foliar tissue testing can also be used to determine P levels in plants. Nutrient levels fluctuate naturally based on the age of tissue and the time of year sampled. To improve the accuracy of test results, samples should be collected from the current year's growth, in the top one third of the tree, and avoiding the leader. Samples should be taken from early fall (Oct.) through late winter

Photo 2: *Soil sampling probe.*
Credit: Bill Lindberg, MSU Extension

(Feb.). Foliar P levels of between 0.2 to 0.4% of P are sufficient for Fraser fir.

Unfortunately, P soil and foliar levels do not always correlate, as soils that test low in P may also test adequate for foliar P (and vice versa). There are several reasons for this inconsistency. First, tree roots can partner with ectomycorrhizal fungi; the thin strands of the mycorrhizae (mycleia) can aid in acquiring P from soil and making it available to the tree. In this situation, sufficient P may be present in trees, even in soils that test low for P due to the greater volume of soil being mined. Another possibility could be the impact of soil pH and nutrient availability. As soil pH decreases, soil P becomes less and less available for plant uptake. If soil pH becomes extremely acidic (pH <5), soil test P levels could be adequate, but foliar tissue testing may be deficient. As a result of these confounding factors, using both soil and foliar tissue testing can best determine P needs.

Fertilizing with phosphorus

When testing does indicate a need, P can be applied from several sources (Table 2). However the most common method is through use of dry fertilizer products, such as monoammonium phosphate (MAP) (11-52-0), and diammonium phosphate (DAP) (18-46-0). Both MAP and DAP products also contain nitrogen, so make sure to account for those values in your total nitrogen application rates. Other possible soil amendments include organic materials, such as manure or compost. These can have a wide range of nutritional values, so a laboratory test determining P content of these products can be helpful. Standard book nutritional values (Table 3) are also available and can help determine desired application rates. The nutrient

Table 1: *2021 average soil test results and percent of total samples by soil test rating from the Great Lakes Region. Numbers in parentheses indicate range for soil test rating for each variable. Adapted from the A&L Great Lakes Laboratories, Inc. 2021 Great Lakes soil test summary.*

		Percent samples by soil test rating				
Soil Test	**Average Value**	**Very Low**	**Low**	**Medium**	**High**	**Very High**
Organic Matter, %	3.3	(<1.0) 1.2	(1.0-2.5) 40.3	(2.5-5.0) 51.2	(5.0-7.0) 5.0	(>7.0) 2.3
Phosphorus (Bray P1), ppm	43.0	(<10) 5.8	(10-20) 18.5	(20-30) 21.3	(30-50) 27.2	(>50) 26.5
pH	6.6	(<5.1) 0.9	(5.1-5.8) 11.3	(5.9-6.9) 62.0	(7.0-7.5) 19.2	(>7.5) 6.5
CEC, meq/100g	11.0	(<3.1) 0.9	(3.1-8.0) 28.8	(8.1-15.0) 52.8	(15.1-25.0) 16.2	(>25.0) 1.3

Photo 3: *Example soil test report. Credit: A & L Great Lakes Laboratories*

To: COMPANY NAME
1234 STREET NAME
CITY NAME, US 46804

For: GROWER NAME

Farm: FARM NAME
Field: FIELD NAME

Date Sampled: 9/22/2015
Date Received: 9/24/2015
Date Reported: 9/25/2015

Attn: CONTACT NAME

SOIL TEST REPORT

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Sample ID	Lab Number	Organic Matter %	Phosphorus		Potassium K ppm	Magnesium Mg ppm	Calcium Ca ppm	Sodium Na ppm	Soil pH	Buffer pH	CEC Meq/100g	Percentage Cation Saturation				
			Bray-1 Equiv ppm-P	Bray P2 ppm-P								% K	% Mg	% Ca	% H	% Na
1	1001	2.8	90 *VH*	126 *VH*	198 *H*	245 *H*	1550 *M*	15 *VL*	7.0		10.4	4.9	19.7	74.8		0.6
2	1002	1.4	123 *VH*	165 *VH*	147 *H*	90 *H*	500 *L*	15 *VL*	6.1	6.9	4.9	7.7	15.3	51.1	24.5	1.3
3	1003	1.5	103 *VH*	155 *VH*	155 *H*	115 *H*	700 *M*	15 *VL*	6.1	6.9	6.1	6.5	15.7	57.2	19.6	1.1
4	1004	2.3	58 *VH*	86 *VH*	209 *H*	260 *H*	1250 *M*	15 *VL*	6.7	6.9	10.2	5.2	21.2	61.2	11.7	0.6
5	1005	1.1	89 *VH*	103 *VH*	133 *H*	90 *H*	750 *H*	15 *VL*	6.9		5.0	6.8	15.1	75.3	1.5	1.3
6	1006	2.1	46 *H*	69 *H*	174 *H*	185 *H*	1150 *M*	15 *VL*	6.6	6.9	9.0	5.0	17.1	63.9	13.5	0.7
7	1007	2.1	67 *VH*	93 *VH*	240 *VH*	200 *H*	1150 *M*	15 *VL*	6.9		8.2	7.5	20.3	69.9	1.5	0.8
8	1008	2.3	76 *VH*	97 *VH*	186 *H*	145 *M*	1050 *M*	15 *VL*	6.2	6.9	8.2	5.8	14.7	64.0	14.6	0.8
9	1009	1.8	39 *H*	42 *M*	102 *M*	140 *M*	1050 *M*	15 *VL*	6.7	6.9	7.9	3.3	14.7	66.1	15.6	0.8
10	1010	2.3	49 *H*	61 *H*	181 *H*	310 *H*	1800 *M*	15 *VL*	7.6		12.1	3.8	21.3	74.3		0.5

VL **= Very Low** ***L*** **= Low** ***M*** **= Medium** ***H*** **= High** ***VH*** **= Very High**

Sample ID	Sulfur S ppm	Zinc Zn ppm	Manganese Mn ppm	Iron Fe ppm	Copper Cu ppm	Boron B ppm	Soluble Salts mmhos/cm	Nitrate NO_3-N ppm	Ammonium NH_4-N ppm	Bicarb-P P ppm		Chloride Cl ppm		Comments
1	8 *M*	5.9 *H*	50 *VH*	70 *VH*	1.6 *H*	0.6 *M*	0.3 *VL*	16 *M*	8 *L*	45 *H*		50 *L*		
2	9 *M*	5.3 *H*	41 *H*	60 *VH*	1.0 *M*	0.2 *VL*	0.1 *VL*	18 *M*	9 *L*	62 *VH*		41 *L*		
3	8 *M*	8.8 *H*	41 *H*	36 *H*	1.1 *M*	0.3 *VL*	0.2 *VL*	16 *M*	8 *L*	52 *VH*		41 *L*		
4	6 *L*	4.3 *M*	49 *H*	37 *H*	1.4 *H*	0.4 *L*	0.2 *VL*	12 *M*	6 *L*	29 *H*		49 *L*		
5	7 *L*	3.4 *M*	37 *H*	30 *H*	0.8 *M*	0.2 *VL*	0.1 *VL*	14 *M*	7 *L*	45 *H*		37 *L*		
6	5 *L*	3.9 *M*	44 *H*	34 *H*	1.1 *M*	0.3 *VL*	0.2 *VL*	10 *M*	5 *L*	23 *M*		44 *L*		
7	5 *L*	4.7 *M*	46 *H*	37 *H*	1.0 *M*	0.3 *VL*	0.2 *VL*	10 *M*	5 *L*	34 *H*		46 *L*		
8	6 *L*	3.8 *M*	48 *H*	41 *H*	1.0 *M*	0.2 *VL*	0.1 *VL*	12 *M*	6 *L*	38 *H*		48 *L*		
9	5 *L*	2.7 *L*	43 *H*	24 *H*	0.9 *M*	0.2 *VL*	0.1 *VL*	10 *M*	5 *L*	20 *M*		43 *L*		
10	4 *L*	3.6 *M*	52 *VH*	22 *H*	1.2 *H*	0.4 *L*	0.2 *VL*	8 *L*	4 *VL*	25 *M*		52 *L*		

Table 2: Characteristics of common phosphorus fertilizer products.

Product	Analysis (N-P-K)	Relative Soil Acidifying Potential	Availability in Marketplace	Form
Monoammonium phosphate	11-52-0	High	High	Dry
Diammonium phosphate	18-46-0	Medium	High	Dry
Triple Superphosphate	0-46-0	None	Low	Dry
Ammonium Polyphosphate (APP)	10-34-0	Low	High	Liquid

Table 3: Range in nitrogen (N), phosphate (P_2O_5), and potash (K_2O) content of various animal manures. Adapted from Nutrient Recommendations for Field Crops in Michigan, Extension Bulletin E2904.

	N (lb/ton)	P_2O_5 (lb/ton)	K_2O (lb/ton)
Dairy	5-16	2-16	2-31
Beef	4-20	1-13	3-29
Swine	3-27	1-62	2-18
Poultry	1-111	1-96	2-55

content of organic amendments is often low, which may lead to high application rates (tons/acre). From a material-handling and application standpoint, the use of these products may be easier to implement between tree rotations.

It is important to note that, unlike nitrogen, P does not move readily within the soil. Phosphorus forms strong chemical bonds with mineral particles and as a result moves extremely slowly. A common rule of thumb is that surface-applied P will move downward in the soil profile approximately 1" per year, though actual movement can be as little as ¼" per year. Therefore, P levels often become stratified, with higher concentrations near the surface and lower amounts at the bottom of the soil profile. To offset nutrient stratification, an ideal time to apply P products is between tree rotations. Once fields are cleared of trees, apply and incorporate P through the soil profile with tillage equipment. This will aid in distributing P throughout the soil profile, leading to greater root absorption during the next tree rotation. Surface fertilizer applications will often not move quickly enough into the root zone to be intercepted by the majority of Christmas tree roots.

Phosphorus concerns

Unfortunately, agricultural production can be a major contributor to P pollution. The most common pollution problems involve altering aquatic ecosystems. Phosphorus is often the most limiting nutrient in these systems, so even adding very small quantities of P can cause extreme problems. A common result of P pollution is the rapid growth of algal populations, called agal blooms. Agal blooms cause unsightly waterways, reducing the enjoyment of those on the water. Depending on the algal species, it can also create unsafe water for human consumption, which occurred during the 2014 Toledo water crisis. Finally, once these agal populations die off, the resulting decomposition process starves oxygen from the body of water; this creates large zones of deoxygenated water that kill fish and other aquatic species.

Understanding how P can become a pollutant is important to minimizing those effects. Unlike nitrogen which can be lost through a myriad of processes, the main mechanisms of P pollution are soil erosion and water runoff. As mentioned earlier, P in soils is bound tightly to mineral particles. Once those particles are moved off the field due to erosion, the bound P is also moved. Eventually these particles are deposited into streams or bodies of water where they release P. Many conservation practices, such as reducing tillage, addition of cover crops, leaving plant residues on fields, and the use of vegetated buffers between fields and waterways have been documented to reduce erosion and thereby prevent P pollution. The United States Department of Agriculture (USDA) has many funding opportunities available to farmers to implement these conservation practices. Growers can contact their local National Resource Conservation Service (NRCS) office to learn what funding opportunities are available in their region/watershed to implement conservation practices.

Another source of P pollution comes when excessive water leaves farmland. A portion of soil P that is available for plant uptake is dissociated from mineral particles as an ion, either as dihydrogen phosphate ($H_2PO_4^-$) or hydrogen phosphate (HPO_4^{2-}). During heavy rains or irrigation events, those ions can leach through tile drains or off the field through ditches. This is especially problematic on light textured soils and fields located near waterways. For growers that irrigate, avoid over-irrigation as this leads to greater risks of P runoff. Finally, soils that have high concentrations of P are at greater risk to P pollution. To minimize this, growers should manage high testing P fields carefully. In Michigan, generally accepted agricultural management practices (GAAMPS) provide thresholds on soil test P levels and P applications. Soil tests that are at or greater than 150 ppm (Bray P1) should not receive any P containing products. Those fields that test at 75 to 150 ppm (Bray P1) can only receive up to crop removal rates.