UNIVERSITY OF DELAWARE
COOPERATIVE EXTENSION

Phosphorus Removal by Delaware Crops

Amy L. Shober, J. Thomas Sims, and Jennifer L. Walls

March 2025

Introduction

The Delaware Nutrient Management Commission defines high phosphorus (P) soil as any soil with a Mehlich-3 soil test P concentration >150 FIV (equivalent to 150 ppm or 300 lb/ac). Fields with Mehlich-3 soil test P concentrations between 150 and 499 FIV can receive P applications at rotational P removal rates without a Delaware P Site Index (PSI) assessment. The PSI is strongly encouraged for all fields with Mehlich-3 soil test P concentrations between 150 and 499 FIV and required if planned application rates exceed rotational P removal. A PSI is required for all fields with Mehlich-3 soil test P concentrations that exceed 499 FIV (499 ppm or 998 lb/ac) prior to P application.

The results of the PSI should drive P management for all fields that were assessed as outlined in ***Soil Management Options Based on the Phosphorus Site Index*** (available at http://www.udel.edu/0013355). Phosphorus application is allowed if the PSI rating is low (rotational N-based applications permitted), medium (rotational N-based application permitted in one year of the rotation), or high (rotational P-based application permitted). If the PSI rating is "very high", no additional P application is permitted. Landowners may always opt for a more conservative P management approach than allowed by the PSI (e.g., following rotational P removal rate when an N-based rate is permitted).

Restrictions on P applications to "high P" soils are intended to protect water quality by preventing the buildup of P in soils to values above those needed for economically optimum crop yields. To meet the requirements of the Delaware Nutrient Management Act of 1999 (3 Del. C. § 2202) and prevent build of soil test P, producers need to know how much P is removed in a harvested crop so that the total amount of P removed during a crop rotation can be calculated. The purpose of this publication is to provide P removal values for common Delaware grain, forage, and vegetable crops and compare nutrient removal to the amount of P added in fertilizers, manures, biosolids, and other materials.

What is "Crop Nutrient Removal"?

Crop nutrient removal is defined as the total amount of plant nutrient removed from the field in the harvested portion of the crop (e.g., grain, silage, hay). The term crop nutrient removal should not be confused with crop nutrient uptake, which is defined as the total amount of nutrient contained in the entire crop at maturity (e.g., in the grain, stover, and roots of a corn crop). Crop nutrient removal is lower than crop nutrient uptake because a significant percentage of the nutrients taken up by a crop are returned to the soil in the form of crop residues. Nutrients remaining in crop residues may be available for uptake by crops planted in the next season.

Determining Crop Phosphorus Removal for Delaware Crops

Crop P removal can be readily estimated from standard values for the P content in the harvested portion of the crop and crop yield. The USDA Natural Resources Conservation Service (NRCS) Crop Nutrient Uptake Tool (part of the PLANTS Database at https://plants.usda.gov/) provides

standard values for estimating P removal for Delaware crops. However, the most accurate way to determine crop P removal from your own fields is to test a representative subsample from the harvested portion of the crop for nutrient content. It is important to note that testing for crop nutrient removal is different from routine plant tissue analysis, which is used to monitor the nutrient content of a crop or to identify nutrient deficiency or toxicity. For example, a subsample of the harvested corn grain would be collected from the weigh wagon or combine and analyzed to determine crop P nutrient removal, while ear leaf samples would be collected at initial silking to monitor corn nutrient content during the growing season. For vegetable crops, the use of standard values may be preferred because it is difficult to dry vegetables due to their high water content. Usually, a freeze drier is needed to prevent the vegetable samples from rotting prior to analysis.

Nutrient analysis reports from laboratories typically provide the nutrient content of tissue samples on a dry weight basis. In other words, nutrient content is expressed as units of nutrient per unit of dry plant tissue (i.e., dry matter). To determine crop P removal, these dry weight values must be adjusted to account for the moisture content of the crop. In addition, for crops where yield is reported in units other than pounds per acre, the P content of the harvested tissue must be adjusted based on the weight per unit (such as pounds per bushel).

The following example illustrates how to determine crop P_2O_5 removal for barley grain containing 0.37% P based on results of lab analysis:

Convert % P in the grain sample to % P_2O_5:

$$\%\, P \times 2.29 \;=\; \%\, P_2O_5$$

$$0.37\%\, P \times 02.29 \;=\; 0.847\%\, P_2O_5$$

This corresponds to 0.847 lb P_2O_5 per 100 dry pounds of barley. Because this value is listed on a dry weight basis, it must be adjusted to account for the moisture content of the crop. For barley, if we assume a moisture content of 14%, which is equivalent to 86% dry matter or 0.86 lb dry barley per lb barley:

$$\frac{0.847\ lb\ P_2O_5}{100\ lb\ dry\ barley} \times \frac{0.86\ lb\ dry\ barley}{1\ lb\ barley} = 0.0073 \text{ lb } P_2O_5/lb \text{ barley}$$

Crop P removal must then be adjusted (when applicable) based on the standard test weight. The standard test weight for barley is 48 lb/bu:

$$\frac{0.0073\ lb\ P_2O_5}{1\ lb\ barley} \times \frac{48\ lb\ barley}{1\ bu} \;=\; 0.35\ lb\ P_2O_5/bu$$

Therefore, the actual nutrient removal for barley in this example would be 0.35 lb P_2O_5 per bushel. This value is useful since P fertilizer rates are based on the lb of P_2O_5 per 100 lb of fertilizer (fertilizer grade or analysis).

Phosphorus Removal by Typical Delaware Crops

Phosphorus removal rates for typical Delaware grain crops presented in this publication were determined from measured nutrient content of the harvested portion of selected crops (Binford, 2008). Grain samples collected at harvest between 2003 and 2007 from locations across the state of Delaware (a small number of samples were collected on the eastern shore of Maryland under climate, soil, and cropping conditions similar to those encountered in Delaware) were analyzed for P content. A total of 668 corn grain samples, 175 soybean samples, 322 winter wheat samples, and 117 winter barley samples were analyzed (Binford, 2008). Nutrient removal rates reported by Binford (2008) for grain crops were in good agreement with standard values obtained from the USDA-NRCS Crop Nutrient Tool.

Crop P removal for selected vegetable and forage crops was determined based on standard values for P content from the USDA-NRCS Crop Nutrient Uptake Tool. While vegetable and forage harvest samples were also collected from Delaware fields between 2003 and 2007, only a small number of harvest vegetable and forage samples collected in

2004 were analyzed for P content due to issues related to drying samples for analysis. However, values obtained from the USDA database were in good agreement with the vegetable and forage crops data presented by Binford (2008). The amount of P removed per acre by grain and forage crops (Table 1) and vegetable crops (Table 2) can then be used to determine estimated P removal based on a realistic yield goal for the crop as outlined in *Estimating Yield Goal for Crops* (available at http://www.udel.edu/0013363), where removal is the product of P content and crop yield goal.

Table 1. Estimated Phosphorus Removal in the Harvested Portion of Selected Delaware Grain and Forage Crops.

Crop	Yield Unit	Crop P_2O_5 Content (lbs P_2O_5/yield unit)	Yield (yield unit/ac)	Crop P_2O_5 Removal (lbs/ac)
Barley	bu (48 lbs/bu @ 14% moisture)	0.35	40	14
			60	21
			80	28
			100	35
Corn	bu (56 lbs/bu @ 15.5% moisture)	0.33	150	50
			200	66
			250	83
			300	100
Soybean	bu (60 lbs/bu @ 13% moisture)	0.72	40	29
			50	36
			60	43
			70	50
Wheat	bu (60 lbs/bu @ 13% moisture)	0.42	40	17
			60	25
			80	34
			100	42
Corn silage	ton (@ 70% moisture)	5.2	15	78
			20	104
			25	130
			30	156
Grass-legume hay	ton (@12% moisture)	10.8	2	22
			3	32
			4	44
			5	54

Table 2. Estimated Phosphorus Removal in the Harvested Portion of Selected Delaware Vegetable Crops.

Crop	Yield Unit	Crop P_2O_5 Content (lbs P_2O_5/yield unit)	Yield (yield unit/ac)	Crop P_2O_5 Removal (lbs/ac)
Bell pepper, fresh market	boxes (25 lbs/box @ 92.5% moisture)	0.018	750	14
			1000	18
			1250	23
			1500	27
Bell pepper processing	lbs (@ 92.5% moisture)	0.002	18000	36
			21000	42
			23000	46
			26000	52
Cantaloupe	melons (6 lbs/melon @ 96% moisture)	0.004	3500	14
			5000	20
			6500	26
			8000	32
Cucumber, pickler processing	bu (50 lbs/bu @ 95.5% moisture)	0.025	150	4
			200	5
			250	6
			300	8
Cucumber, slicer	boxes (55 lbs/box @ 95.5% moisture)	0.026	250	7
			300	8
			350	9
			400	10
Eggplant	boxes (32 lbs/box @ 93% moisture)	0.022	700	15
			800	18
			900	20
			1000	22
Jalapeno pepper	lbs (@ 92% moisture)	0.0006	25000	15
			30000	18
			35000	21
			40000	24
Lima bean	lbs (@ 69% moisture)	0.004	1000	4
			2000	6
			3000	9
			4000	11
Peas	cwt (@ 79% moisture)	0.25	15	4
			25	6
			35	9
			45	11
Potatoes	cwt (@ 77.2% moisture)	0.14	150	21
			200	28
			250	35
			300	42

Table 2 (Continued). Estimated Phosphorus Removal in the Harvested Portion of Selected Delaware Vegetable Crops.

Crop	Yield Unit	Crop P_2O_5 Content (lbs P_2O_5/yield unit)	Yield (yield unit/ac)	Crop P_2O_5 Removal (lbs/ac)
Sweet corn, processing	tons (@ 75% moisture)	3.6	4	14
			6	22
			8	29
			10	36
Squash, fresh market	boxes (20 lbs/box @ 95% moisture)	0.014	550	8
			600	8
			650	9
			700	10
Squash, processing	lbs (@ 95% moisture)	0.0007	12500	9
			15000	11
			17500	12
			20000	14
Tomato	boxes (25 lbs/box @ 94% moisture)	0.018	750	14
			900	16
			1050	19
			1200	22
Watermelon	lbs (@ 96% moisture)	0.0004	45000	18
			60000	24
			75000	30
			9000	36

Based on calculated P removal rates for Delaware crops, growers can estimate the amount of P removed in a planned crop rotation. The following are examples of estimated P removal for some common Delaware cropping systems.

System #1: Corn-Wheat/Soybean-Corn, Dryland

Year	Crop	Yield	Crop P_2O_5 Removal (lb/ac)
1	Corn	150 bu/ac	50
2	Wheat Soybean	70 bu/ac 35 bu/ac	30 25
Rotational Crop Removal			**105**

System #2: Corn-Wheat/Soybean-Corn, Irrigated

Year	Crop	Yield	Crop P_2O_5 Removal (lb/ac)
1	Corn	275 bu/ac	91
2	Wheat Soybean	90 bu/ac 55 bu/ac	38 43
Rotational Crop Removal			**172**

System #3: Corn-Full Season Soybean

Year	Crop	Yield	Crop P_2O_5 Removal (lb/ac)
1	Corn	225 bu/ac	74
2	Soybean	60 bu/ac	43
Rotational Crop Removal			**117**

System #4: Grain Crops and Vegetables

Year	Crop	Yield	Crop P_2O_5 Removal (lb/ac)
1	Corn	150 bu/ac	50
2	Wheat Soybean	70 bu/ac 35 bu/ac	30 25
3	Peas Lima Beans	30 cwt/ac 2,500 lbs/ac	8 10
Rotational Crop Removal			**123**

Summary

Applications of P to "high P" soils are often limited to a rotational crop P removal rate to prevent the buildup of P in soils to values above those needed for economically optimum crop yields. The amount of P

removed in the harvested portion of the crop can be determined using standard crop removal values or by analyzing the P content of harvested crops. Once crop P removal is calculated, the rotational removal rates for specific rotations can be determined. Rotational crop P removal rates are then used in nutrient management planning to balance P inputs. This allows one to determine the amount of P that can be applied in fertilizers, manures, biosolids, and other materials to allow growers to use available sources of plant nutrients while complying with the requirements of the Delaware Nutrient Management of 1999.

References

Binford, G. 2008. Nutrient removal rates for common crops in Delaware: Final report. Submitted to the Delaware Center for the Inland Bays. University of Delaware. Newark.

Nutrient Management, Delaware Administrative Code Title 3 Section 22. (3 Del. C. §§ 2201-2290). https://delcode.delaware.gov/title3/c022/index.html

USDA, NRCS. 2025. The PLANTS Database (http://plants.usda.gov, 3 March 2025). National Plant Data Team, Greensboro, NC 27401-4901 USA.

About the Authors

Amy L. Shober (corresponding author), Professor and Extension Specialist, University of Delaware, Newark, DE (ashober@udel.edu)

J. Thomas Sims, Professor and Extension Specialist, University of Delaware, Newark, DE (retired)

Jennifer L. Walls, Manager of Planning, Delaware Emergency Management Agency, Dover, DE

About this Publication

Original Publication Date: 2002
Revision date(s): 2012, 2025
Adapted from an original publication developed by J.L. Campagnini and J.T. Sims (2002)

Peer Reviewers

Jarrod Miller, Associate Professor and Extension Specialist, University of Delaware, Georgetown, DE

Sydney Riggi, Extension Agent, University of Delaware Cooperative Extension, Dover, DE