

## Phosphorus Removal by Delaware Crops

In Delaware, applications of phosphorus to “high P” soils (soil test P  $\geq$  150 FIV, as defined by the Delaware Nutrient Management Commission) cannot exceed a three-year crop removal rate unless alternative P management strategies (i.e. N-based management during one or more years of a crop rotation) are permitted based on results of a P Site Index. These 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 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 are subsequently 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) “Plant Nutrient Content Database” contains reliable information on the P content of most crops grown in Delaware. Standard values for P removal for Delaware crops can be estimated using the [Plant Nutrient Content Database](#). 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 than 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 after yield determination 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<sub>2</sub>O<sub>5</sub> removal for barley grain containing 0.37% P based on results of lab analysis:

Convert % P in the grain sample to % P<sub>2</sub>O<sub>5</sub>:

$$\begin{aligned} \% P \times 2.29 &= \% P_2O_5 \\ 0.37\% P \times 2.29 &= 0.847\% P_2O_5 \end{aligned}$$

This corresponds to 0.847 lb P<sub>2</sub>O<sub>5</sub> 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:

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

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:

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

Therefore, the actual nutrient removal for barley in this example would be 0.35 lb P<sub>2</sub>O<sub>5</sub> per bushel. This value is useful since P fertilizer rates are based on the lbs of P<sub>2</sub>O<sub>5</sub> per 100 lbs 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 Removal database.

Crop P removal for selected vegetable and forage crops was determined based on standard values for P content from the USDA Plant Nutrient Content Database. 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) at a range of realistic yield goals for individual crops was calculated for major Delaware crops, where removal is the product of P content and crop yield.

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

| <b>Crop</b> | <b>Yield Unit</b>               | <b>Crop P<sub>2</sub>O<sub>5</sub> Content<br/>(lbs P<sub>2</sub>O<sub>5</sub>/yield unit)</b> | <b>Yield<br/>(yield unit/ac)</b> | <b>Crop P<sub>2</sub>O<sub>5</sub> Removal<br/>(lbs/ac)</b> |
|-------------|---------------------------------|--|----------------------------------|---|
| 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   | 50                               | 17  |
|             |                                 |  | 100                              | 33  |
|             |                                 |  | 150                              | 50  |
|             |                                 |  | 200                              | 66  |
| Soybean     | bu (60 lbs/bu @ 13% moisture)   | 0.72   | 30                               | 22  |
|             |                                 |  | 40                               | 29  |
|             |                                 |  | 50                               | 36  |
|             |                                 |  | 60                               | 43  |
| 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 <sub>2</sub> O <sub>5</sub> Content<br>(lbs P <sub>2</sub> O <sub>5</sub> /yield unit) | Yield<br>(yield unit/ac) | Crop P <sub>2</sub> O <sub>5</sub> Removal<br>(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 |
| 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 |
|                        |                                   |        | 90000 | 36 |

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

*System #1: Corn-Wheat/Soybean-Corn*

| Year                       | Crop    | Yield     | Crop P <sub>2</sub> O <sub>5</sub> Removal (lbs/ac) |
|----------------------------|---------|-----------|---|
| 1                          | Corn    | 150 bu/ac | 50  |
| 2                          | Wheat   | 70 bu/ac  | 30  |
|                            | Soybean | 35 bu/ac  | 25  |
| 3                          | Corn    | 150 bu/ac | 50  |
| <b>3-Year Crop Removal</b> |         |           | <b>155</b>  |

*System #2: Corn-Wheat/Soybean-Corn (high-yield, irrigated)*

| Year                       | Crop    | Yield     | Crop P <sub>2</sub> O <sub>5</sub> Removal (lbs/ac) |
|----------------------------|---------|-----------|---|
| 1                          | Corn    | 250 bu/ac | 75  |
| 2                          | Wheat   | 90 bu/ac  | 38  |
|                            | Soybean | 55 bu/ac  | 43  |
| 3                          | Corn    | 250 bu/ac | 75  |
| <b>3-Year Crop Removal</b> |         |           | <b>231</b>  |

*System #3: Corn-Soybean-Corn*

| Year                       | Crop    | Yield     | Crop P <sub>2</sub> O <sub>5</sub> Removal (lbs/ac) |
|----------------------------|---------|-----------|---|
| 1                          | Corn    | 150 bu/ac | 50  |
| 2                          | Soybean | 50 bu/ac  | 36  |
| 3                          | Corn    | 150 bu/ac | 50  |
| <b>3-Year Crop Removal</b> |         |           | <b>136</b>  |

#### System #4: Grain Crops and Vegetables

| Year                       | Crop       | Yield        | Crop P <sub>2</sub> O <sub>5</sub> Removal (lbs/ac) |
|----------------------------|------------|--------------|---|
| 1                          | Corn       | 150 bu/ac    | 50  |
| 2                          | Wheat      | 70 bu/ac     | 30  |
|                            | Soybean    | 35 bu/ac     | 25  |
| 3                          | Peas       | 30 cwt/ac    | 8   |
|                            | Lima Beans | 2,500 lbs/ac | 10  |
| <b>3-Year Crop Removal</b> |            |              | <b>123</b>  |

#### Summary

Applications of P to “high P” soils are often limited to a three-year crop 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 three-year removal rates for specific rotations can be determined. Three-year crop 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 Act 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.
- USDA, NRCS. 2012. The PLANTS Database (<http://plants.usda.gov>, 10 September 2012). National Plant Data Team, Greensboro, NC 27401-4901 USA.

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