PHOSPHORUS GUIDELINES FOR FIELD CROPS IN NEW YORK

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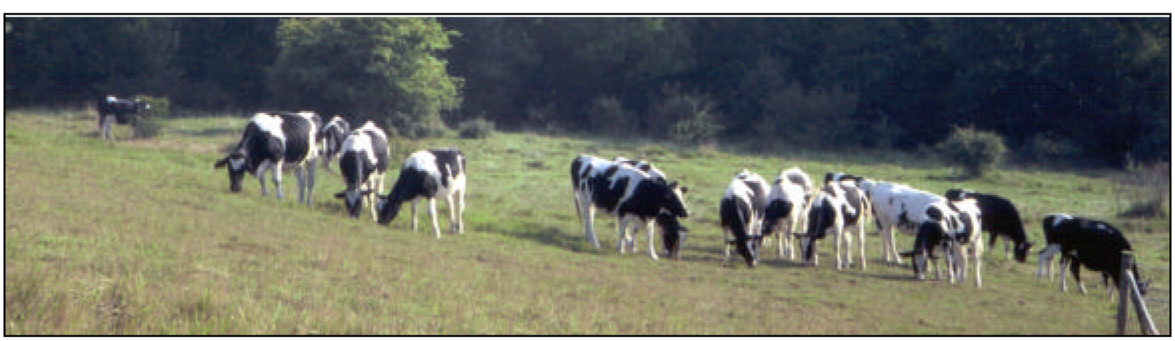


1. INTRODUCTION

Phosphorus (P) is a macronutrient belonging to the group of 17 nutrients that are essential for plant growth and crop production. It is a key component of cell membranes and cellular compounds such as adenosine triphosphate (ATP, energy-rich compounds used as “fuel” for cell activity), deoxyribonucleic acid (DNA, the genetic code), and ribonucleic acid (RNA, essential in the production of proteins). Phosphorus is important for animals and humans as well. It is used to make bones, teeth, and shells and to strengthen muscles in addition to being essential for production of ATP, DNA, RNA, and cell membranes. In plants, phosphorus plays an essential role in photosynthesis, respiration, N fixation, root development, maturation, flowering, fruiting, and seed production. An adequate supply of P in the early life of a plant is essential for development of reproductive parts (seeds and fruits contain large quantities of P). A deficiency in P results in reduced plant growth, delay of maturity, and harvest declines or even failures. Because P is mobile in the plant, deficiency symptoms are expressed in the older leaves. In corn and some other grass species, P deficiency symptoms can be recognized by a purple discoloration of the leaves or leave edges. For other crops, deficiency symptoms are less distinctive.

Phosphorus accumulation in soil on dairy farms is common. Klausner found that on typical New York State dairy farms 70 to 80% of the annual input of P remained on the farm (Klausner, 1997). Phosphorus can also accumulate in soils on cash crop, vegetable, and fruit farms when there is a history of high fertilization rates. Soil tests confirm the medium to very high P levels on many dairy farms. Soil test levels can vary widely from field to field depending on the distribution of manure and past fertilizer practices. Manure application rates calculated to meet N requirements will usually result in an over application of P because the P to N ratio in manure is higher than the requirements of most agronomic crops.

Phosphorus, like nitrogen, needs careful management to maximize economic returns and prevent losses to the environment. Phosphorus is the most limiting nutrient for the growth of aquatic plants in temperate lakes and, as a result, an overabundance of dissolved P in water can cause eutrofication resulting in oxygen deficiency and fish kills. The concentration of Morgan extractable P above which the loss of P is unacceptable, even when excellent management practices are followed, is unknown, but a reduction in the amount of surplus P in the soil will minimize the potential for loss. Phosphorus inputs could be reduced if:

- P content in the feed can be reduced and uptake efficiency can be increased without harming production or animal health.
- Manure application rates are reduced to match P removal of the crop.
- Manure is removed from farms having a surplus and transported to those having a deficit.

Although there is a limited amount of data, much of the annual P loss from fields appears to be associated with one or two severe runoff events that usually occur during the winter or very early spring. Soil management, timing of manure applications, fertilizer management, and the use of soil erosion and surface runoff control measures are crucial to ensure P loss is minimized.

2. PHOSPHORUS FORMS AND PLANT AVAILABILITY

Phosphorus is the least mobile of the major plant nutrients and exists in soils in many different forms:

- Dissolved P
  - Inorganic P (PO_4^{3-}, HPO_4^{2-}, $H_2PO_4^-$, H_3PO_4 and some soluble organic compounds).
- Particulate P
  - Calcium phosphorus minerals.
  - Phosphorus attached to clay minerals and to iron and aluminum oxides.
  - Phosphorus incorporated into iron and aluminum oxides.
  - Phosphorus in soil organisms and in active and stable organic matter.

Plants take up dissolved HPO_4^{2-}, $H_2PO_4^-$, and some soluble organic P compounds from the soil. The plant converts these forms of P into organic P forms. When plants die, this plant-P is returned to the soil through decomposition by microorganisms. Other pathways through which P can be made available are:

- Weathering of soil minerals.
- Desorption from clay minerals.
- Mineralization of and desorption from manure and plant residues.
- Inorganic fertilizer.

The various forms of P are continually undergoing change with the general tendency towards less soluble or less available forms. When relatively soluble P is added to the soil in fertilizer or manure, the soluble fractions increase, but with time these slowly transform to less soluble and therefore less plant available forms. Phosphorus is in its most available form in near neutral soils. At pH 7.2, the amount of $H_2PO_4^-$ and HPO_4^{2-} are approximately equal. At low pH, soluble forms of iron, aluminum, manganese, and their hydrous oxides fix inorganic P. At high pH, P is mostly fixed as calcium phosphates.

Soils can hold large amounts of P. However, they are not bottomless pits and can reach a point where it is difficult to hold more P. Phosphorus can be lost from a field with crop harvest and through leaching, runoff, and erosion. Research is being conducted to determine the soil test level beyond which runoff and leaching risks become unacceptable.

3. CALCULATING PHOSPHORUS RECOMMENDATIONS FOR SPECIFIC FIELD CROPS

Phosphorus fertilizer recommendations are based on agronomic soil tests. These soil test results do not reflect the total amount of plant available P but are relative indices of plant available nutrients. At Cornell University, soil test P levels are classified as "Very Low", "Low", "Medium", "High" and "Very High". These classifications may differ depending on the crop. For example, for corn, Cornell University classifies soil test P (STP) levels of 9-39 and ≥40 lbs P/acre (Morgan extractable P) as “High” and “Very High”, respectively (See Table 1). Soil test levels <1 lb P/acre are considered “Very Low”, 1-3 lbs P/acre is classified as “Low”, and 4-8 lbs P/acre constitutes “Medium”. Yield benefits from applied P are greatest for soils with a very low or low agronomic soil test. Once a high STP reading is reached, minimal P fertilization, from any source, is required to support optimum yields. For most field crops, Cornell recommends little or no P fertilizer additions to fields with STP levels of 40 lbs P/acre or higher for two reasons: (1) P addition to these soils is not likely to result in yield gains; and (2) over-application may lead to P losses to surface and ground waters and thus contribute to environmental degradation.

Table 1: Classification of phosphorus status using the Cornell Morgan P soil test.

Cornell Morgan Test P	Classification*	Likeliness of an economic yield response to fertilizer P addition
<1	Very Low	Very High
1-3	Low	High
4-8	Medium	Medium
9-39	High	Low
=40	Very High	Very Low

*Cornell P test classifications differ for winter grains (high is 9-20 and very high is =20 lbs P/acre).

Cornell’s P recommendations for NY are based on soil P level extracted with the Morgan solution (Morgan, 1941). If soil tests are conducted at a laboratory other than Cornell University’s Nutrient Analysis Laboratory (CNAL), a Cornell Morgan equivalent needs to be determined. See section 4 for details on the use of conversion equations.

In the following sections, Cornell University recommendations are listed for agronomic field crops grown in New York. For each of these crops, the crop codes that are used in Cornell University’s nutrient management software (Cropware) and the nutrient analyses laboratory (CNAL) are listed as well. For a complete overview of crops and crop codes, see Table A in the Appendix. Recommendations are expressed in lbs of P_2O_5 per acre. This is a legacy from old chemistry when fertilizers were thought to exist as oxides. In reality P_2O_5 does not exist but the oxide notation continues to be used to express fertilizer value. A fertilizer blend characterized as “10-20-20” contains 10%N, 20% P_2O_5 and 20% K_2O on a weight basis. Thus, when 200 lbs/acre of this fertilizer is applied, the actual application rate is 20 lbs of N (200*10%), 40 lbs of P_2O_5 (200*20%), and 40 lbs of K_2O (200*20%). One lb of P equals 2.3 lbs of P_2O_5. One lb of P_2O_5 equals 0.44 lb of P. A Cornell soil test result of 40 lbs P/acre does not mean that, for example, a corn crop will take up 40 lbs/acre only. Nor does it mean that there is only 40 lbs of P/acre. It simply implies that phosphorus is not limiting yields and that further addition is not needed (See also section 3.1). For all field crops, if the recommendation exceeds 25 lbs of P_2O_5, 25 lbs P_2O_5 may be applied as banded starter fertilizer and the remainder as manure or additional fertilizer. For topdressing, manure or inorganic fertilizer may be broadcast to meet the requirements. Careful timing is advised to prevent manure from being transported to surface waters (see section 6 on the New York P Runoff Index).

3.1 Grain corn and corn silage

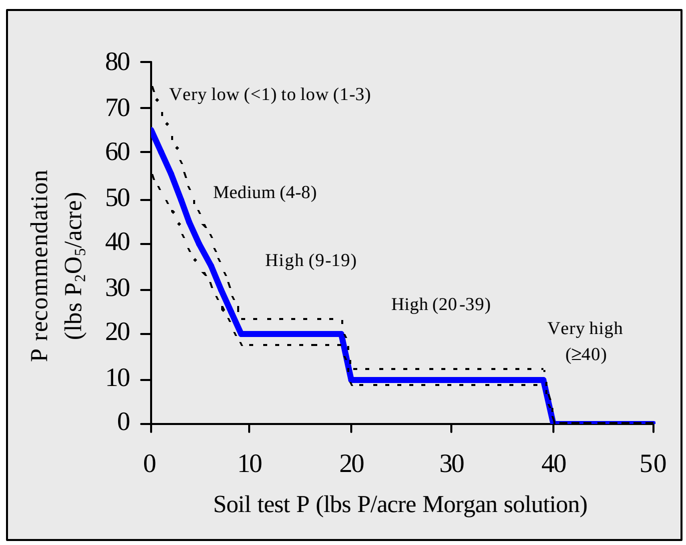
Phosphorus recommendations for grain corn (COG) and corn silage (COS) on soils with STPs <50 lbs P/acre are presented in Figure 1. The solid line is the "average" recommended fertilizer P application derived from the following equation:

$$\text{P recommendation (lbs } P_2O_5\text{/acre)} = 65 - (5 * \text{STP}) \qquad [1]$$

In this equation, STP stands for the Cornell Morgan soil phosphorus test results expressed in lbs P/acre. The dashed lines on the chart imply that recommendations are ranges rather than absolute values. Thus, optimum economic recommendations fall with the dashed lines for each soil test P level.

Soil test P (lbs P/acre*)	Recommendation (lbs P_2O_5/acre)
<1	65
1	60
2	55
3	50
4	45
5	40
6	35
7	30
8	25
9-19	20
20-39	10
>40	0

* CNAL Morgan solution.



The solid line is the recommendation derived from fertilizer-response curves. Recommendations are optimal when between the dashed lines.

Figure 1: Phosphorus recommendations for grain corn (COG) and silage (COS) in NY.

3.2 Alfalfa, alfalfa birdsfoot-trefoil, and alfalfa grass

Recommendations for alfalfa (ALE, ALT), alfalfa/birdsfoot-trefoil (ABE, ABT), and alfalfa/grass (AGE, AGT) are given in Table 2. Note that once an alfalfa stand is established, the P requirements can be reduced by about 30 lbs of P_2O_5 per acre for a given STP level. These recommendations can also be derived using the following set of equations:

For ALE, ABE and AGE:

If STP = 80, P recommendation = 0 lbs P_2O_5/acre
If STP = 40 but <80, P recommendation = 10 lbs P_2O_5/acre
If STP = 20 but <40, P recommendation = 20 lbs P_2O_5/acre
If STP = 10 but <20, P recommendation = 40 lbs P_2O_5/acre
If STP <10, P recommendation (lbs P_2O_5/acre) = 85 - (5 * STP) [2]

For ALT, ABT and AGT:

If STP =20, P recommendation = 0 lbs P_2O_5/acre
If STP =9 but <20, P recommendation = 10 lbs P_2O_5/acre
If STP <9, P recommendation (lbs P_2O_5/acre) = 55 – (5 * STP) [3]

For topdressing, the P in broadcasted manure is considered to be as efficient as P in fertilizer. For establishment, optimum results can be achieved by applying the first 25 lbs of the recommendations in a band-placed fertilizer. Manure can be used to supply the rest.

Table 2: P recommendation for alfalfa (ALE, ALT), alfalfa/birdsfoot-trefoil (ABE, ABT), and alfalfa/grass mixtures (AGE, AGT).

Soil test P (lbs P/acre*)	Recommendation (lbs P_2O_5/acre)	
	Establishment (ALE, ABE, AGE)	Established (ALT ABT, AGT)
<1	85	55
1	80	50
2	75	45
3	70	40
4	65	35
5	60	30
6	55	25
7	50	20
8	45	15
9	40	10
10-19	40	10
20	20	10
21-39	20	0
40-79	10	0
80 or more	0	0

* CNAL Morgan solution.

3.3 Birdsfoot-trefoil, birdsfoot-trefoil/grass, birdsfoot-trefoil/clover, birdsfoot-trefoil seed, and crownvetch

Phosphorus recommendations for birdsfoot trefoil, birdsfoot trefoil grass, birdsfoot trefoil clover, birdsfoot trefoil seed, and crownvetch are listed in Table 3. As with alfalfa stands, recommendations are lowered by about 30 lbs P_2O_5/acre once the stands have been established.

Table 3: P recommendation for birdsfoot-trefoil (BTE, BTT), birdsfoot-trefoil/grass (BGE, BGT), birdsfoot-trefoil/clover (BCE, BCT), birdsfoot-trefoil seed (BSE, BST), and crownvetch (CVE, CVT).

Soil test P (lbs P/acre*)	Recommendation (lbs P_2O_5/acre)	
	Establishment (BTE, BGE, BCE, BSE, CVE)	Established (BTT, BGT, BCT, BST, CVT)
<1	85	50
1	80	45
2	75	40
3	70	35
4	65	30
5	60	25
6	55	20
7	50	15
8	45	10
9	40	5
10-20	40	0
21-29	30	0
30-39	20	0
40-49	10	0
50 or more	0	0

* CNAL Morgan solution.

These recommendations can also be derived using the following set of equations:

For BTE, BGE, BCE, BSE, and CVE:

If STP = 50, P recommendation = 0 lbs P_2O_5/acre
If STP = 40 but <50, P recommendation = 10 lbs P_2O_5/acre
If STP = 30 but <40, P recommendation = 20 lbs P_2O_5/acre
If STP = 20 but <30, P recommendation = 30 lbs P_2O_5/acre
If STP = 10 but <20, P recommendation = 40 lbs P_2O_5/acre
If STP <10, P recommendation (lbs P_2O_5/acre) = 85 - (5 * STP) [4]

For BTT, BGT, BCT, BST, and CVT:

If STP = 10, P recommendation = 0 lbs P_2O_5/acre

If STP <10, P recommendation (lbs P_2O_5/acre) = 50 - (5 * STP) [5]

The P in broadcasted manure is about as efficiently used as P in broadcasted fertilizer so for topdressing (established fields), the requirement can be met with either manure or fertilizer P. For establishment of these field crops, banded applications are far more efficient than broadcast P applications and are thus more likely to result in a yield response.

3.4. Spring or winter barley with legumes, oats with legumes, and wheat with legumes

Phosphorus recommendations for spring barley with legumes (BSS), winter barley with legumes (BWS), oats with legumes (OAS), wheat with legumes (WHS), and triticale/peas (TRP) are listed in Table 4.

Table 4: P recommendation for spring barley with legumes (BSS), winter barley with legumes (BWS), oats with legumes (OAS), wheat with legumes (WHS), and triticale/peas (TRP).

Soil test P (lbs P/acre*)	Recommendation (lbs P_2O_5/acre)
<1	85
1	80
2	75
3	70
4	65
5	60
6	55
7	50
8	45
9	40
10-20	40
21-29	30
30-39	20
40-49	10
50 or more	0

* CNAL Morgan solution.

These recommendations can also be derived using the following set of equations:

If STP = 50, P recommendation = 0 lbs P_2O_5/acre

If STP = 40 but <50, P recommendation = 10 lbs P_2O_5/acre

If STP = 30 but <40, P recommendation = 20 lbs P_2O_5/acre

If STP = 20 but <30, P recommendation = 30 lbs P_2O_5/acre
If STP = 10 but <20, P recommendation = 40 lbs P_2O_5/acre
If STP <10, P recommendation (lbs P_2O_5/acre) = 85 - (5 * STP) [6]

3.5 Buckwheat, oats, sorghum forage, soybeans, sorghum sudan hybrid, and sudangrass.

Phosphorus recommendations for buckwheat (BUK), oats (OAT), sorghum forage (SOF), soybeans (SOY), sorghum/sudan hybrids (SSH), and sudangrass (SUD) as a function of soil test P level are listed in Table 5.

These recommendations can also be derived using the following set of equations:

If STP = 40, P recommendation = 0 lbs P_2O_5/acre
If STP = 6 but <40, P recommendation = 20 lbs P_2O_5/acre
If STP <6, P recommendation (lbs P_2O_5/acre) = 50 - (5 * STP) [7]

Table 5: P recommendation for buckwheat (BUK), oats (OAT), sorghum forage (SOF), soybeans (SOY), sorghum/sudan hybrid (SSH), and sudangrass (SUD).

Soil test P (lbs P/acre*)	Recommendation (lbs P_2O_5/acre)
<1	50
1	45
2	40
3	35
4	30
5	25
6-39	20
40 or more	0

* CNAL Morgan solution.

3.6 Spring barley, winter barley, millet, sorghum grain, wheat, and sunflowers.

Phosphorus recommendation for spring barley (BSP), winter barley (BWI), millet (MIL), sorghum grain (SOG), wheat (WHT), and sunflowers (SUN) are given in Table 6. These recommendations can also be derived using the following set of equations:

If STP = 40, P recommendation = 0 lbs P_2O_5/acre
If STP = 9 but <40, P recommendation = 20 lbs P_2O_5/acre
If STP <9, P recommendation (lbs P_2O_5/acre) = 65 - (5 * STP) [8]

Table 6: P recommendation for spring barley (BSP), winter barley (BWI), millet (MIL), sorghum grain (SOG), wheat (WHT), and sunflowers (SUN).

Soil test P (lbs P/acre*)	Recommendation (lbs P_2O_5/acre)
<1	65
1	60
2	55
3	50
4	45
5	40
6	35
7	30
8	25
9-39	20
40 or more	0

* CNAL Morgan solution.

3.7 Clover, clover grass, and clover seed production

Recommendations for clover (CLE and CLT), clover grass (CGE and CGT), and clover seed production (CSE, CST) can be found in Table 7.

Table 7: P recommendation for clover (CLE, CLT), clover grass (CGE, CGT), and clover seed production (CSE, CST).

Soil test P	Recommendation (lbs P_2O_5/acre)	
(lbs P/acre*)	Establishment (CGE, CLE, CSE)	Established (CGT, CLT, CST)
<1	65	50
1	60	45
2	55	40
3	50	35
4	45	30
5	40	25
6	35	20
7	30	15
8	25	10
9	20	5
10-19	20	0
20-39	10	0
40 or more	0	0

* CNAL Morgan solution.

These recommendations can also be derived using the following set of equations:

For CGE, CLE, and CSE:

If STP = 40, P recommendation = 0 lbs P_2O_5/acre
If STP = 20 but <40, P recommendation = 10 lbs P_2O_5/acre
If STP = 10 but <20, P recommendation = 20 lbs P_2O_5/acre
If STP <10, P recommendation (lbs P_2O_5/acre) = 65 - (5 * STP) [9]

For CGT, CLT and CST:

If STP =10, P recommendation = 0 lbs P_2O_5/acre
If STP <10, P recommendation (lbs P_2O_5/acre) = 50 - (5 * STP) [10]

3.8 Intensively managed grasses, grasses, pasture, pastures with improved grasses, intensively grazed pasture, pasture with native grasses, and pastures with legumes.

Table 8 lists the recommendation for intensively managed grasses (GIE and GIT), grasses (GRE and GRT), pastures with improved grasses (PGE and PGT), intensively grazed pasture (PIE and PGT), and pasture with native grasses (PNT). No distinction is made between requirements for establishment and topdressing. These recommendations can also be derived using the following set of equations:

For GIE, GIT, GRE, GRT, PGE, PGT, PIE, PIT, and PNT:

If STP =10, P recommendation = 0 lbs P_2O_5/acre
If STP <10, P recommendation (lbs P_2O_5/acre) = 50 - (5 * STP) [11]

Table 8: P recommendation for intensively managed grasses (GIE, GIT), grasses (GRE, GRT), pastures with improved grasses (PGE, PGT), intensively grazed pasture (PIE, PIT), and pasture with native grasses (PNT).

Soil test P (lbs P/acre*)	Recommendation (lbs P_2O_5/acre)
<1	50
1	45
2	40
3	35
4	30
5	25
6	20
7	15
8	10
9	5
10 or more	0

* CNAL Morgan solution.

Recommendations for establishing and topdressing pasture with legumes (PLE and PLT) are listed in Table 9. These recommendations can also be derived using the following set of equations:

For PLE:

If STP =40, P recommendation = 0 lbs P_2O_5/acre

If STP <40, P recommendation (lbs P_2O_5/acre) = 85 - (5 * STP) [12]

For PLT:

If STP =10, P recommendation = 0 lbs P_2O_5/acre

If STP <10, P recommendation (lbs P_2O_5/acre) = 50 - (5 * STP) [13]

Table 9: P recommendation for pasture with legumes (PLE, PLT).

Soil test P (lbs P/acre*)	Recommendation (lbs P_2O_5/acre)	
	Establishment (PLE)	Established (PLT)
0	85	50
1	80	45
2	75	40
3	70	35
4	65	30
5	60	25
6	55	20
7	50	15
8	45	10
9	40	5
10-39	40	0
40 or more	0	0

* CNAL Morgan solution.

3.9 Rye cover crops and rye seed production

Recommendations for rye cover crops (RYC) and for rye seed production (RYS) are given in Table 10. Note that the recommendations for seed production are 35 to 40 lbs P_2O_5 higher than those for cover crop growth. These recommendations can also be derived using the following set of equations:

For RYC:

If STP =10, P recommendation = 0 lbs P_2O_5/acre

If STP <10, P recommendation (lbs P_2O_5/acre) = 50 - (5 * STP) [14]

For RYS:

If STP =10, P recommendation = 40 lbs P_2O_5/acre

If STP <10, P recommendation (lbs P_2O_5/acre) = 85 - (5 * STP) [15]

Table 10: P recommendation for rye cover crop (RYC) and seed production (RYS).

Soil test P (lbs P/acre*)	Recommendation (lbs P_2O_5/acre)	
	Cover Crop (RYC)	Seed Production (RYS)
<1	50	85
1	45	80
2	40	75
3	35	70
4	30	65
5	25	60
6	20	55
7	15	50
8	10	45
9	5	40
10 or more	0	40

* CNAL Morgan solution.

3.10 Idle land, Christmas trees, and waterways.

No P is recommended for idle land. Recommendations for Christmas trees and waterways are given in Table 11. These recommendations can also be derived using the following set of equations:

For Christmas trees:

For TRE:

If STP =4, P recommendation = 0 lbs P_2O_5/acre

If STP <4, P recommendation (lbs P_2O_5/acre) = 100 - (25 * STP) [16]

For TRT:

If STP =3, P recommendation = 0 lbs P_2O_5/acre

If STP <3, P recommendation (lbs P_2O_5/acre) = 75 - (25 * STP) [17]

For waterways:

For WPE:
If STP =40, P recommendation = 0 lbs P_2O_5/acre
If STP =10 and <40, P recommendation = 40 lbs P_2O_5/acre
If STP <10, P recommendation (lbs P_2O_5/acre) = 85 - (5 * STP) [18]

For WPT:
If STP =40, P recommendation = 0 lbs P_2O_5/acre
If STP =10 and <40, P recommendation = 40 lbs P_2O_5/acre
If STP <10, P recommendation (lbs P_2O_5/acre) = 90 - (5 * STP) [19]

Table 11: P recommendation for Christmas trees (TRE, TRT) and waterways (WPE, WPT).

Soil test P (lbs P/acre*)	Recommendation (lbs P_2O_5/acre)			
	Christmas Trees		Waterways	
	Establishment (TRE)	Established (TRT)	Establishment (WPE)	Established (WPT)
<1	100	75	85	90
1	75	50	80	85
2	50	25	75	80
3	25	0	70	75
4	0	0	65	70
5	0	0	60	65
6	0	0	55	60
7	0	0	50	55
8	0	0	45	50
9	0	0	40	45
10-39	0	0	40	40
40 or more	0	0	0	0

* CNAL Morgan solution.

4. SOIL TEST CONVERSION EQUATIONS

Cornell University fertilizer recommendations are based on decades of field research in NY showing soil nutrients extracted by Morgan solution (sodium acetate buffered at pH 4.8) are correlated well with nutrient response for the vast array of soil types in NY. However, several private soil-testing laboratories that serve NY producers (i.e., Brookside Laboratories Inc., Spectrum Analytic, Inc., A&L Eastern Laboratories Inc., and A&L Laboratories Canada) use the Mehlich-III extraction solution (an unbuffered solution of acetate, ammonium nitrate, ammonium fluoride, and ethylenediaminetetraacetic acid) for soil test P determination. Another laboratory used by Northern New York growers is the laboratory of the University of Vermont. This laboratory uses the modified Morgan extraction (ammonium acetate buffered at pH 4.8). The same test is also offered (on request) by Spectrum Analytic, Inc. and A&L Eastern Laboratories Inc.

Compliance with USDA-NRCS Nutrient Management Standard 590 requires that comprehensive nutrient management plans be based on land grant recommendations. In New York, this implies that Mehlich-III and modified Morgan soil test results need to be converted to Cornell Morgan equivalents prior to calculating the soil P contribution to the NY P Index and P fertilizer recommendations.

Cornell Cropware allows Mehlich-III inputs from the above mentioned laboratories with a warning that states that the user should realize that conversion equations add uncertainty to the recommendations and that the user assumes all risk. Currently, Cornell Cropware does not currently allow for the use of soil test data from laboratories other than those listed above because it is unknown how those results compare to Cornell University's Nutrient Analysis Laboratory. Additionally, a downloadable MS Excel-based soil test conversion tool as well as a web-based conversion tool were developed. The conversion tool and Cropware can be accessed through the Nutrient Management Spear Program website (http://nmsp.css.cornell.edu). Studies to derive Morgan equivalents for soil test results from other laboratories in the Northeast are ongoing. An article on the initial conversion equation derived for Brookside Laboratory soil test data was published in the December 2002 issue of Soil Science (Ketterings et al., 2002).

4.1 Mehlich-III: conversion for Brookside Laboratories Inc.

Mehlich-III soil test P data from Brookside Laboratories Inc. can be used to estimate Morgan P equivalents in lbs/acre if Mehlich-III Ca, Al, and the pH of the soil are known:

$$\begin{aligned}\text{Morgan STP (lbs P/acre)} = \; & 3.3957 + (1.1705*B\_P) - (0.003799*B\_Ca) - (27.24*pH) + \\ & (0.1218*B\_Al) - (0.00005760*B\_Al^2) + (2.6867*pH^2) + \\ & (0.00009335*B\_P*B\_Ca) - (0.001940*B\_P*B\_Al) + \\ & (0.00000080*B\_P*B\_Al^2)\end{aligned}$$

$$(r^2=0.88,\ n=235) \qquad [20]$$

In this equation *all input data are in ppm.* Morgan STP is Morgan extractable soil test P in lbs P per acre, B_P is Mehlich-III extractable P, B_Al is Mehlich-III extractable Al, B_Ca is Mehlich-III extractable Ca, and pH is the soil pH in water. If the model predicts a negative Morgan equivalent, a value of 2 lbs/acre is assumed. This model predicted 86% of the dataset within 5 ppm (10 lbs/acre) of the measured value.

4.2 Mehlich-III: conversion for Spectrum Analytic Inc.

Soil test results for the same soil sample analyzed for Mehlich-III Ca, P, and Al differ between Brookside Laboratories Inc., A&L Eastern Laboratories Inc., and Spectrum Analytic Inc. due to differences in analytical procedures and reporting. Brookside Laboratories Inc. and A&L Laboratories report a Mehlich-III result while Spectrum Analytic Inc. conducts the Mehlich-III test but reports Bray-1 P equivalents obtained by multiplying the Mehlich-III result by a factor of 0.7. Morgan P equivalents for soil test results *reported* by Spectrum Analytic Inc. can be derived using the following equation:

$$\begin{aligned}\text{Morgan STP (lbs P/acre)} = & -49.2971 + (0.7850*Sp\_P) - (0.002174*Sp\_Ca) - (11.8281*pH) + \\ & (0.1350*Sp\_Al) - (0.00006742*Sp\_Al^2) + (1.5452*pH^2) + \\ & (0.00004146*Sp\_P*Sp\_Ca) - (0.001353*Sp\_P*Sp\_Al) + \\ & (0.00000057*Sp\_P*Sp\_Al^2)\end{aligned}$$

$(r^2=0.88, n=235)$ [21]

In this equation *all input data are in lbs/acre except for Morgan extractable Al* which is reported in ppm on a standard soil test report from Spectrum Analytic Inc. Morgan STP is Cornell University's Morgan extractable soil test P in lbs P per acre, Sp_P and Sp_Ca are soil test P and Ca in lbs/acre as reported by Spectrum Analytic and Sp_Al is Mehlich-III extractable Al (ppm). If the model predicts a negative Morgan equivalent, a value of 2 lbs/acre is assumed.

4.3 Mehlich-III: conversion for A&L Eastern Laboratories Inc.

Mehlich-III soil test P data from A&L Eastern Laboratories Inc. can be used to estimate Morgan P equivalents in lbs/acre if Mehlich-III Ca, Al and the pH of the soil are known:

$$\begin{aligned}\text{Morgan STP (lbs P/acre)} = & 45.52106614 + (1.44109538*AE\_P) - (0.00250878*AE\_Ca) - \\ & (42.04727550*pH) + (0.09744870*AE\_Al) - (0.00003732*AE\_Al^2) + \\ & (4.00344858*pH^2) + (0.00006744*AE\_P*AE\_Ca) - \\ & (0.00220826*AE\_P*AE\_Al) + (0.00000084*AE\_P*AE\_Al^2)\end{aligned}$$

$(r^2=0.88, n=235)$ [22]

In this equation *all input data are in ppm.* Morgan STP is Cornell Morgan extractable soil test P in lbs P per acre, AE_P is Mehlich-III extractable P, AE_Al is Mehlich-III extractable Al, AE_Ca is Mehlich-III extractable Ca, and pH is the soil pH in water. If the model predicts a negative Morgan equivalent, a value of 2 lbs/acre is assumed. This model predicted 86% of the dataset within 5 ppm (10 lbs/acre) of the measured value.

4.4 Mehlich-III: conversion for A&L Canada Laboratories Inc.

Mehlich-III soil test P data from A&L Canada Laboratories Inc. can be used to estimate Morgan P equivalents in lbs/acre if Mehlich-III Ca, Al, and the pH of the soil are known:

$$\begin{aligned}&\text{Morgan STP (lbs P/acre)} = \\ &\quad 41.06969994 + (1.49813232*AC\_P) - (0.00282226*AC\_Ca) - \\ &\quad (45.0073006*pH) + (0.13061109*AC\_Al) - (0.00005684*AC\_Al^2) + \\ &\quad (4.31119254*pH^2) + (0.00007159*AC\_P*AC\_Ca) - \\ &\quad (0.00247840*AC\_P*AC\_Al) + (0.00000102*AC\_P*AC\_Al^2)\end{aligned}$$

$$(r^2=0.89,\ n=228) \qquad [23]$$

In this equation *all input data are in ppm*. Morgan STP is Cornell Morgan extractable soil test P in lbs P per acre, AC_P is Mehlich-III extractable P, AC_Al is Mehlich-III extractable Al, AC_Ca is Mehlich-III extractable Ca, and pH is the soil pH in water. If the model predicts a negative Morgan equivalent, a value of 2 lbs/acre is assumed.

4.5 (Modified) Morgan: conversions for A&L Eastern Laboratories Inc., Spectrum Analytic Inc., and the University of Vermont.

Modified Morgan P extraction data from A&L Eastern Laboratories Inc. (AE_MP in ppm) should be multiplied by 1.8 to obtain Cornell Morgan soil test equivalents prior to deriving fertilizer recommendations:

A&L Eastern Laboratories:

$$\text{Morgan STP (lbs P/acre)} = 1.8*AE\_MP \qquad (n=235,\ r^2=0.97) \qquad [24]$$

Morgan P test results from Spectrum Analytic Inc. can be converted to Cornell Morgan equivalents according to the following equations (Sp_MP is the modified Morgan test result in lbs/acre):

Spectrum Analytic Inc.:

For Sp_MP < 106 lbs P/acre:

$$\text{Morgan STP (lbs P/acre)} = 1.2*Sp\_MP - 8 \qquad (n=64,\ r^2=0.97)$$

For Sp_MP = 53 lbs P/acre:

$$\text{Morgan STP (lbs P/acre)} = 1.5*Sp\_MP - 42 \qquad (n=18,\ r^2=0.65)$$

$$[25]$$

Modified Morgan P test results from the University of Vermont (UVM) can be converted to Cornell Morgan equivalents according to the following equation (UVM_MP is the modified Morgan test result in ppm):

University of Vermont:

$$\text{Morgan STP (lbs P/acre)} = 1.7 * \text{UVM\_MP} - 1 \qquad (n=232,\ r^2=0.92) \qquad [26]$$

If these models predict a negative Morgan equivalent, a value of 2 lbs/acre is assumed.

5. SOURCES OF PHOSPHORUS

5.1 Manure

Manure P is primarily in the organic form and must mineralize to an inorganic form before being available to a crop. Repeated manure applications at rates beyond crop removal will increase soil test P levels. Thus, soil sampling should be done regularly (at least once in 3 years, ideally once every year) to monitor soil test P levels when manure is being applied. Placement of P is important when establishing a crop. Broadcasted manure P cannot be substituted for a banded starter fertilizer P placed in close proximity to the seed. If manure will be applied after the soil test was taken, the following P, K, and micronutrient guidelines are offered:

- For crop establishment:
  - If the P recommendation is less than 25 lbs/acre, apply the entire amount as a band placed starter fertilizer.
  - If the P recommendation exceeds 25 lbs/acre, apply 25 lbs as a band placed starter fertilizer and use manure to supply the rest.

- For topdressing:
  - If the P recommendation is less than 30 lbs/acre, use fertilizer to supply the entire P requirement.
  - If the P recommendation exceeds 30 lbs/acre, apply 30 lbs in a topdressed fertilizer and use manure to supply the rest.

When manure is applied at a rate to supply the needed N, both P and K are likely to be applied in excess of crop requirements. The excess can be used by a later crop in the rotation. However, continuous application of manure to the same field will result in an accumulation of soil P to a high enough level that crops will no longer respond to added manure or fertilizer P. The excessive inputs of P result in a very high soil test value. Further additions of fertilizer P are costly and are not expected to lead to a yield increase. The potential for P loss increases with an increase in the soil P content.

5.2 Phosphorus containing fertilizers

Table 12 lists common P fertilizers. Single super and triple super phosphates contain P in the form of calcium orthophosphate. Ammoniated superphosphate is obtained by reacting superphosphates with anhydrous ammonium. Superphosphates are considered neutral because their application does not appreciably affect the soil pH. Both ammoniated superphosphates and monoammonium phosphate make excellent sources of N and P for band application.

Table 12: Phosphorus containing inorganic fertilizers.

	%N	%P_2O_5	%K_2O	%S
Single superphosphate (SSP)	0	20	0	14
Triple superphosphate* (TSP or CSP)	0	46	0	2
Ammonium polyphosphate	10	34	0	0
Ammoniated superphosphate	5	40	0	12
Monoammonium phosphate (MAP)	13	52	0	2
Diammonium phosphate (DAP)	18	46	0	0
Urea-ammonium phosphate (UAP)	28	28	0	0
Monopotassium phosphate	0	50	40	0

* Also referred to as concentrated superphosphate.

To avoid fertilizer injury, it is recommended that fertilizer band application rates remain lower than: 1) 30 lbs of P_2O_5 from diammonium phosphate; 2) 20-30 lbs of urea N plus N from diammonium phosphate; and 3) 30-40 lbs of ammonium N from all sources in combination with diammonium phosphate.

6. THE NEW YORK PHOSPHORUS RUNOFF INDEX

The NY P Index is designed to assist producers and planners in identifying fields or portions of fields that are at highest risk of contributing phosphorus (P) to lakes and streams. The NY P Index assigns two scores to each field based upon its characteristics and the producer's intended management practices. One of the two scores, the **Dissolved P Index**, addresses the risk of loss of water-soluble P from a field (flow across the field or through the soil profile), while the **Particulate P Index** estimates the risk of loss of P attached to soil particles and manure.

The NY P Index scores will rank a field to determine its susceptibility to P losses. Fields with high or very high site vulnerability should be managed with minimizing P losses in mind. A low or medium ranking implies management can be nitrogen based. The NY P Index score will also indicate whether other management changes such as winter spreading must be addressed. It is, however, important to note that the P Index is not a measure of actual P loss, but rather an indicator of potential loss. A high or very high P Index score is a warning to further examine the causes, and a low P Index score means the risk of phosphorus loss is reduced, but perhaps not eliminated.

The NY P Index is separated into two main parts: potential sources of P ("source score") and potential movement of P ("transport score"). The final score is the multiplication of the source score and the transport score:

Dissolved P index = P Source score * Dissolved P Transport score [27]
Particulate P index = P Source score * Particulate P Transport score [28]

Rankings and management implications for final field scores are listed in Table 13. Both P forms (dissolved and particulate) are a concern for water quality and hence should be managed jointly. Estimates of P concentrations in harvests of field crops are listed in Appendix Table B.

Table 13: NY P Index scores and their rankings and management implications.

Ranking Values	Site Vulnerability	Management
< 50	Low	N based management
50 – 74	Medium	N based management with best management practices
75 – 99	High	P applications limited to crop removal
≥ 100	Very High	No P fertilizer or manure application

6.1 P Index Source Components

Contributing to the source component are soil test P level, as well as manure and fertilizer additions:

P Source Score = Soil Test P + Fertilizer P + Organic P [29]

This is most easily done in four steps. Each step will be explained briefly. For more thorough documentation and users' instructions, see the "New York Phosphorus Runoff Index – User's Guide and Documentation" by K.J. Czymmek, Q.M Ketterings, L.D. Geohring, and G.L. Albrecht (2003). This user's guide is downloadable from the Nutrient Management Spear Program website (http://nmsp.css.cornell.edu). A hardcopy can be obtained from the Department of Crop and Soil Sciences Extension Office: contact Pam Kline by e-mail (pak1@cornell.edu), phone (607-255-2177) or mail (234 Emerson Hall, Department of Crop and Soil Sciences, Cornell University, Ithaca NY 14853). Available from the same website are a downloadable P Index calculator (MS Excel) and a web-based calculator.

Source Score:

Step 1: Calculate the soil test contribution:

Soil Test P Contribution: Soil Test P = 1.25 **x** Morgan P (lbs/acre)*

*see section 4.1 for Mehlich-III soil test data discussion.

Step 2: Calculate the fertilizer P contribution:

Fertilizer P Contribution: Fertilizer P = (P_{fa}) **x** (P_{ft}) **x** (P_{fm})				
Fertilizer P application (P_{fa})	lbs P_2O_5 / acre			
Fertilizer P timing (P_{ft})	May – August 0.4	September – October 0.7	November – January 0.9	February – April 1.0
Fertilizer P method (P_{fm})	Inject or subsurface band 0.2	Broadcast and incorporate within 1-2 days: 0.4 3-5 days: 0.6	Surface apply or broadcast and incorporate >5 days after application 0.8	Surface apply on frozen, snow covered or saturated ground 1.0

Step 3: Calculate the organic (manure) P contribution:

Organic P Contribution: Organic P = (P_{oa}) **x** (P_{ot}) **x** (P_{om})				
Organic P application rate (P_{oa})	0.75 **x** lbs P_2O_5 (in the organic source) applied / acre			
Organic P timing (P_{ot})	May – August 0.4	September – October 0.7	November – January 0.9	February – April 1.0
Organic P method (P_{om})	Inject or subsurface band 0.2	Broadcast and incorporate within 1-2 days: 0.4 3-5 days: 0.6	Surface apply or broadcast and incorporate >5 days after application 0.8	Surface apply on frozen, snow covered or saturated ground 1.0

Step 4: Calculate the total P source factor:

P Source Factor: Soil Test P + Fertilizer P + Organic P

6.2 P Index Transport Components

To assess dissolved P transport, the NY P Index considers soil drainage class, flooding frequency and predominant water flow distance to a stream:

Dissolved P Transport Score =
Soil drainage + Flooding frequency + Flow distance to stream

(if Dissolved P Transport ≥ 1, then Dissolved P Transport = 1) [30]

The soil drainage classification is determined from a soil survey and should not be modified if drainage practices have been installed. The flooding frequency is also determined from the soil survey or sometimes this information may be available on flood hazard boundary maps. The flow distance is the edge of "field" drainage path that excess water takes as it leaves a field and finds it way downhill to a watercourse (blue line stream). This can be estimated by field observation or determined from topographic maps whereby the flow path is perpendicular to the contour lines. The four steps involved in calculating the dissolved P Index are described below.

Dissolved P Transport Score:

Step 1: Determine the soil drainage contribution:

Soil Drainage	Well to excessively well drained 0.1	Moderately well drained 0.3	Somewhat poorly drained 0.7	Poorly or very poorly drained 1.0

Step 2: Determine the flooding frequency contribution:

Flooding Frequency	Rare / Never > 100 years 0	Occasional 10 – 100 years 0.2	Frequent < 10 years 1.0

Step 3: Determine the flow distance contribution:

Flow distance in feet to blue line stream (or equivalent) as depicted on a topographic map and confirmed based on field evaluation	Intermittent Stream >200 feet Perennial Stream >300 feet -------------------- 0	Intermittent Stream 25 to 200 feet Perennial Stream 50 to 300 feet ------------------------ Intermittent Stream 1 – (Distance–25)/175 Perennial Stream 1 – (Distance–50)/250	Intermittent Stream <25 feet Perennial Stream < 50 feet ------------------- 1.0

* Intermittent streams are generally depicted with a dashed blue line on topographic maps and perennial streams are shown with a solid blue line.

Step 4: Determine the dissolved P transport factor:

Dissolved P Transport Factor = Drainage + Flooding Frequency + Flow Distance*

* If the dissolved P transport factor exceeds 1, the value is set to 1.

The particulate P component of the NY P Index is similar to the dissolved P component in that flooding frequency and the predominant water flow distance to a stream are again considered. Additionally, particulate P loss potential is influenced by soil erosion and the presence of concentrated flow paths. Soil erosion rate is estimated using the Universal Soil Loss Equation (USLE) or the Revised Universal Soil Loss Equation (RUSLE). The determination of whether or not concentrated flow paths are present in the field is best done through field observation. The current resolution of contour lines on topographic maps may not be sufficient to indicate whether a concentrated flow path is present.

Particulate P Transport Score =
Soil erosion + Flooding frequency + Flow distance to stream + Concentrated flow

(if Particulate P Transport $\geq$ 1, then Particulate P Transport = 1) [31]

The five steps involved in calculating the particulate P Index are described below.

Particulate P Transport Score:

Step 1: Determine the flooding frequency contribution.

Flooding Frequency	Rare / Never > 100 years 0	Occasional 10 – 100 years 0.2	Frequent < 10 years 1.0

Step 2: Determine the flow distance contribution.

Flow distance in feet to blue line stream (or equivalent) as depicted on a topographic map and confirmed based on field evaluation	Intermittent Stream >200 feet Perennial Stream >300 feet -------------------- 0	Intermittent Stream 25 to 200 feet Perennial Stream 50 to 300 feet ------------------------ Intermittent Stream 1 – (Distance–25)/175 Perennial Stream 1 – (Distance–50)/250	Intermittent Stream <25 feet Perennial Stream < 50 feet ------------------- 1.0

* Intermittent streams are generally depicted with a dashed blue line on topographic maps and perennial streams are shown with a solid blue line.

Step 3: Determine the soil erosion contribution.

Soil erosion (from RUSLE model)	0.1 x RUSLE Erosion rate (tons/acre)

Step 4: Determine the concentrated flow contribution.

Is a concentrated flow present in the field?	No 0	Yes 0.2

Step 5: Determine the particulate P transport factor.

Particulate P Transport Factor = Flooding Frequency + Flow Distance + Soil Erosion + Concentrated Flow*

* If the particulate P transport factor exceeds 1, the value is set to 1.

One should note that both the dissolved and particulate P Transport Scores are set equivalent to 1.0 when the various transport components add to more than one. Thus, the dissolved and particulate P Transport Scores represent a percentage of the P source factor to arrive at the final NY P index risk scores.

CITED REFERENCES

- Czymmek, K.J., Ketterings, Q.M., Geohring, L.D., and Albrecht, G.L. (2003). The New York Phosphorus Runoff Index. User's manual and documentation. Department of Crop and Soil Sciences Extension Publication E03-12. 72 pages.
- Klausner, S. 1997. Nutrient management: crop production and water quality. NRAES 101. Cornell Cooperative Extension, Ithaca NY.
- Ketterings, Q.M., K.J. Czymmek, W.S. Reid and R.F. Wildman (2002). Conversion of modified Morgan and Mehlich-III soil tests to Morgan soil test values. Soil Science 167(12): 830-837.

APPENDIX TABLE A: CORNELL CROP CODES.

Crop Code	Crop Description
	Alfalfa
ABE	Alfalfa trefoil grass, Establishment
ABT	Alfalfa trefoil grass, Established
AGE	Alfalfa grass, Establishment
AGT	Alfalfa grass, Established
ALE	Alfalfa, Establishment
ALT	Alfalfa, Established
	Birdsfoot
BCE	Birdsfoot trefoil clover, Establishment
BCT	Birdsfoot trefoil clover, Established
BGE	Birdsfoot trefoil grass, Establishment
BGT	Birdsfoot trefoil grass, Established
BSE	Birdsfoot trefoil seed, Establishment
BST	Birdsfoot trefoil seed, Established
BTE	Birdsfoot trefoil, Establishment
BTT	Birdsfoot trefoil, Established
	Barley
BSP	Spring barley
BSS	Spring barley with legumes
BUK	Buckwheat
BWI	Winter barley
BWS	Winter barley with legumes
	Clover
CGE	Clover grass, Establishment
CGT	Clover grass, Established
CLE	Clover, Establishment
CLT	Clover, Established
CSE	Clover seed production, Establishment
CST	Clover seed production, Established
	Corn
COG	Corn grain
COS	Corn silage

APPENDIX TABLE A (CONTINUED)

Crop Code	Crop Description
	Grasses, pastures, covercrops
CVE	Crownvetch, Establishment
CVT	Crownvetch
GIE	Grasses intensively managed, Establishment
GIT	Grasses intensively managed, Established
GRE	Grasses, Establishment
GRT	Grasses, Established
PGE	Pasture, Establishment
PGT	Pasture improved grasses, Established
PIE	Pasture intensively grazed, Establishment
PIT	Pasture intensively grazed, Established
PLE	Pasture with legumes, Establishment
PLT	Pasture with legumes, Established
PNT	Pasture native grasses
RYC	Rye cover crop
RYS	Rye seed production
TRP	Triticale peas
	Small grains
MIL	Millet
OAS	Oats with legume
OAT	Oats
SOF	Sorghum forage
SOG	Sorghum grain
SOY	Soybeans
SSH	Sorghum sudangrass hybrid
SUD	Sudangrass
WHS	Wheat with legume
WHT	Wheat
	Others
SUN	Sunflower
TRE	Christmas trees, Establishment
TRT	Christmas trees, Established

APPENDIX TABLE B: PHOSPHORUS CONCENTRATIONS FOR FIELD CROPS AND VEGETABLE CROPS[1].

Field Crops		%P	$\%P_2O_5$	Vegetable Crops*		%P	$\%P_2O_5$
		% of dry matter				% of dry matter	
ALT	Alfalfa	0.33	0.76	ASP	Asparagus	0.71	1.62
AGE/ AGT	Alfalfa-grass mix	0.23	0.53	BDR	Beans – Dry	0.53	1.22
ABE/ ABT	Alfalfa-trefoil-grass	0.23	0.53	BET	Beets	0.34	0.79
BTE/ BTT	Birdsfoot trefoil	0.23	0.53	BNL	Beans – Lima	0.45	1.03
BGE/ BGT	Birdsfoot trefoil-grass	0.23	0.53	BNS	Beans – Snap	0.50	1.14
BCE/ BCT	Birdsfoot trefoil-clover	0.23	0.53	BRP	Broccoli – Transplanted	0.75	1.73
BSE/ BST	Birdsfoot trefoil-seed	0.23	0.53	BRS	Broccoli – Seeded	0.75	1.73
CLE/ CLT	Clover	0.34	0.78	BUS	Brussels Sprouts	0.51	1.17
CGE/ CGT	Clover-grass	0.24	0.55	CAR	Carrots	0.33	0.75
CSE/ CST	Clover-seed production	0.34	0.78	CBP	Cabbage – Transplanted	0.36	0.82
CVE/ CVT	Crownvetch	0.34	0.78	CBS	Cabbage – Seeded	0.36	0.82
GRE/ GRT	Grasses	0.28	0.64	CEL	Celery	0.67	1.52
GIE/ GIT	Grass-intensive management	0.34	0.78	CFP	Cauliflower – Transplanted	0.66	1.52
PIE/ PIT	Pasture-grazing rotational	0.34	0.78	CFS	Cauliflower – Seeded	0.66	1.52

[1] All data on vegetable crops and the data on field crops marked with an asterisk (*) were obtained from the NRCS Plant Database (http://npk.nrcs.usda.gov). All other field crop data were obtained from DairyOne, Inc.

APPENDIX TABLE B (CONTINUED)[2]

Field Crops		%P	%P_2O_5	Vegetable Crops*		%P	%P_2O_5
		% of dry matter				% of dry matter	
PGE/ PGT	Pasture with Improved grass	0.34	0.78	CKP	Cucumber – Transplanted	0.53	1.20
PLE/ PLT	Pasture with legumes	0.24	0.55	CKS	Cucumber – Seeded	0.53	1.20
PNT	Pasture with native grasses	0.34	0.78	EGG	Eggplant	0.31	0.72
WPE/ WPT	Waterways, pond dikes	0.15	0.34	END	Endive	0.45	1.03
BSP	Barley-spring	0.29	0.66	LET	Lettuce	0.60	1.37
BSS	Barley-spring with legume	0.29	0.66	MML	Muskmelon	0.22	0.50
BWI	Barley-winter	0.29	0.66	ONP	Onion – Transplanted	0.30	0.69
BWS	Barley-winter with legume	0.29	0.66	ONS	Onion – Seeded	0.30	0.69
BUK*	Buckwheat	0.36	0.82	PEA	Peas	0.49	1.13
COG	Corn-grain	0.31	0.71	PEP	Peppers	0.34	0.77
COS	Corn-silage	0.27	0.62	POT	Potato	0.24	0.55
MIL*	Millet	0.34	0.78	PSN	Parsnips	0.36	0.83
OAT*	Oats	0.31	0.71	PUM	Pumpkins	0.39	0.90
OAS	Oats-seeded with legume	0.30	0.69	RAD	Radishes	0.44	1.01

[2] All data on vegetable crops and the data on field crops marked with an asterisk (*) were obtained from the NRCS Plant Database (http://npk.nrcs.usda.gov). All other field crop data were obtained from DairyOne, Inc.

APPENDIX TABLE B (CONTINUED)[3]

Field Crops		%P	%P_2O_5	Vegetable Crops*		%P	%P_2O_5
		% of dry matter				% of dry matter	
RYC	Rye-cover crop	0.36	0.82	RHU	Rhubarb	0.23	0.54
RYS	Rye-seed production	0.36	0.82	RUT	Rutabagas	0.41	0.94
SOG	Sorghum-grain	0.22	0.50	SPF	Spinach – Fall	0.54	1.24
SOF	Sorghum-forage	0.22	0.50	SPS	Spinach – Spring	0.54	1.24
SSH	Sorghum-sudan hybrid	0.50	1.15	SQS	Squash – Summer	0.49	1.12
SUD	Sudangrass	0.50	1.15	SQW	Squash – Winter	0.27	0.62
SOY	Soybeans	0.65	1.49	SWC	Sweetcorn	0.38	0.88
SUN	Sunflower	1.02	2.34	TOM	Tomato	0.47	1.08
TRP	Triticale/peas	0.30	0.69	TUR	Turnips	0.37	0.86
WHT	Wheat	0.29	0.66	WAT	Watermelon	0.11	0.26

Downloadable from: http://nmsp.css.cornell.edu/. Last updated: May 19, 2003.

To obtain P_2O_5 removal rates, multiply yield in lbs/acre with dry matter content in % and P_2O_5 concentration in % and divide the final answer by 10,000. Thus, estimated P_2O_5 removal by a 20 ton/acre corn silage harvest at 35% dry matter amounts to 20*2,000*35*0.61/10,000=85.4 lbs P_2O_5 (an estimated 4.3 lbs P_2O_5/ton of silage).

[3] All data on vegetable crops and the data on field crops marked with an asterisk (*) were obtained from the NRCS Plant Database (http://npk.nrcs.usda.gov). All other field crop data were obtained from DairyOne, Inc.

Q.M. Ketterings, K.J. Czymmek and S. D. Klausner (2003). Phosphorus Guidelines for Field Crops in New York. Second Release. Department of Crop and Soil Sciences Extension Series E03-15. Cornell University, Ithaca NY. 35 pages.