PHOSPHORUS RECOMMENDATIONS FOR FIELD CROPS IN NEW YORK

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Picture by Q. M. Ketterings

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1. INTRODUCTION

Phosphorus (P) is a macronutrient belonging to the group of 17 nutrients that are essential for all 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, our genetic code) and ribonucleic acid (RNA, essential in the production of proteins). It 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 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.

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, most of the annual P loss from fields is 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;
    - P attached to clay minerals, iron and aluminum oxides;
    - P incorporated into iron and aluminum oxides;
    - P in soil organisms, active and stable organic matter.

Plants take up dissolved HPO_4^{2-} and $H_2PO_4^-$ and some soluble organic P compounds from the soil. The plant transfers 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 and 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, 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. Soil test levels <1 lbs P/acre are considered "Very Low", 1-3 is classified as "Low", and 4-8 lbs P/acre constitutes "Medium". Yield benefits from applied P are greatest for soils with a low agronomic soil test. Once a high STP reading is reached, minimal P fertilizer 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.

Cornell's P recommendations for NY are based on soil P level extracted with the Morgan solution. Figure 1 shows a distribution diagram for New York agricultural soil submitted to Cornell University's Nutrient Analysis Laboratory. From this diagram it can be seen that out of the 72669 soil samples submitted to the laboratory in the past 5 years, slightly over 50% test high or very high for soil test P. If corn was grown on all these fields, the recommendation on 8% of the fields would have been not to apply any P until soil test P level drop to less than 40 lbs P/acre.

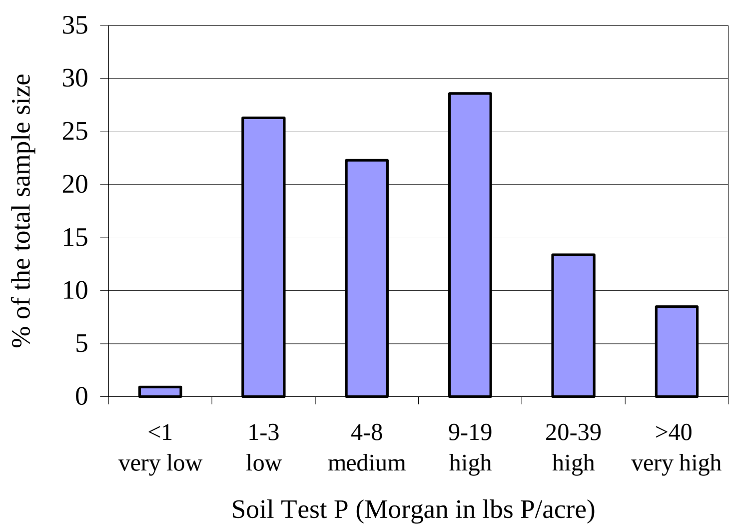

Figure 1: Distribution of soil test P levels (Morgan solution) in New York soils analyzed by Cornell's Nutrient Analysis Laboratory in the past 5 years (72669 samples).

If soil tests are conducted at a laboratory other than Cornell University's Nutrient Analysis Laboratory, soil test P level must be converted to Morgan extraction equivalent value in lbs per acre. 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. One lb of P equals 2.3 lbs of P_2O_5. One lb of P_2O_5 equals 0.44 lb of P.

For all field crops, if the recommendation exceeds 25 lbs of P_2O_5, it is recommended to apply 25 lbs 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 and corn silage on soils with STP's <50 lbs P/acre are presented in Figure 2. Table 1 lists the recommendation for each soil test level as well. The solid line is the "average" recommended fertilizer P application. The dashed lines imply that recommendations are ranges rather than absolute values. Thus, optimum economic recommendations fall with the dashed line for each soil test P level.

Table 1: P recommendations for grain corn (COG) and silage (COS) production in NY.

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.

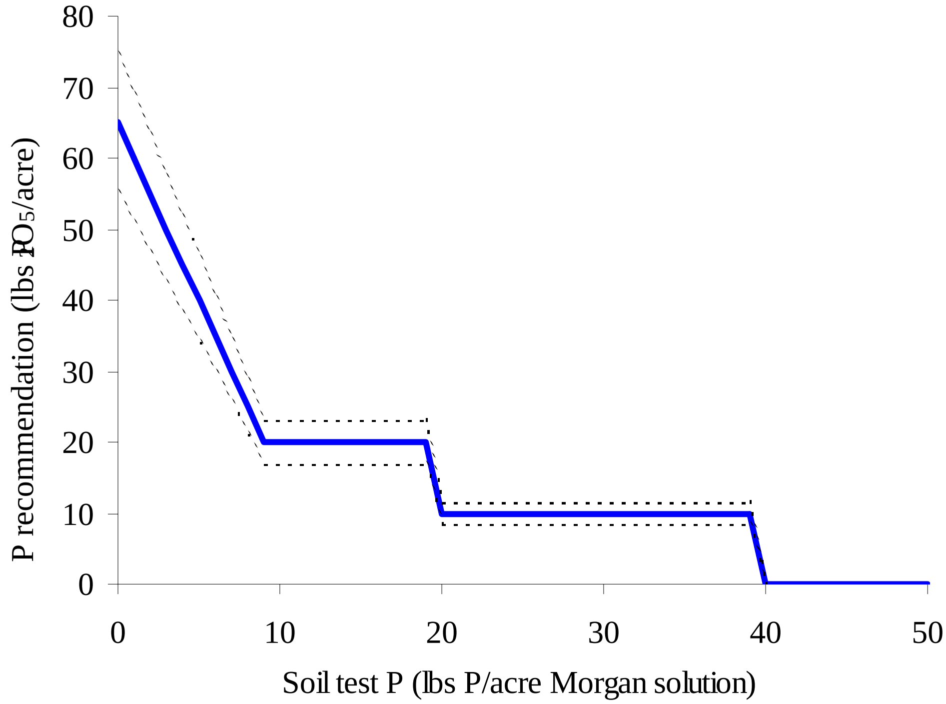

Figure 2: Cornell recommendations for P application. The solid line is the recommendation derived from fertilizer-response curves. Recommendations are optimal when between the dashed lines.

3.2 Alfalfa, alfalfa birdsfoot-trefoil and alfalfa grass

Recommendations for alfalfa, alfalfa birdsfoot-trefoil and alfalfa/grass 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. 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 (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
9-19	40	0
20-39	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, crownvetch, spring or winter barley with legumes, oats with legumes, triticale/peas, wheat with legumes

Phosphorus recommendations for birdsfoot trefoil, birdsfoot trefoil grass, birdsfoot trefoil clover, birdsfoot trefoil seed, crownvetch, spring or winter barley with legumes, oats with legumes, triticale peas, and wheat with legumes 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. 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

Table 3: P recommendation for birdsfoot-trefoil (BTE, BTT), birdsfoot-trefoil/grass (BGE, BGT), birdsfoot-trefoil/clover (BCE, BCT), birdsfoot-trefoil seed (BSE, BST), crownvetch (CVE, CVT), spring barley with legumes (BSS), winter barley with legumes (BWS), oats with legumes (OAS), tritical/peas (TRP), and wheat with legumes (WHS).

Soil test P (lbs P/acre*)	Recommendation (lbs P_2O_5/acre)	
	Establishment (BTE, BGE, BCE, BSE, CVE, BSS, BWS, OAS, TRP, WHS)	Established (BTT, BGT, BCT, BST, CVT, BSS, BWS, OAS, TRP, WHS)
<1	85	50
1	80	45
2	75	40
3	70	35
4	60	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.

3.4 Buckwheat, oats, sorghum forage, soybeans, sorghum sudan hybrid, sudangrass.

Phosphorus recommendations for buckwheat, oats, sorghum forage, soybeans, sorghum/sudan hybrids and sudangrass as a function of soil test P level are listed in Table 4.

Table 4: P recommendation for buckwheat (BUK), oats (OAT), sorghum forage (SOF), soybeans (SOY), sorghum/sudan hybrid (SSH), 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.

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

Phosphorus recommendation for spring and winter barley, millet, sorghum grain, wheat and sunflowers are given in Table 5.

Table 5: P recommendation for spring barley (BSP), winter barley (BWI), millet (MIL), sorghum grain (SOG), sunflowers (SUN) and wheat (WHT).

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.

3.6 Clover, clover grass, and clover seed production

Recommendations for clover, clover grass and clover seed production can be found in Table 6.

Table 6: P recommendation for clover (CLE, CLT), clover grass (CGE, CGT) and clover seed production (CSE, CST).

Soil test P (lbs P/acre*)	Recommendation ($lbs\ P_2O_5/acre$)	
	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
10-20	20	0
21-39	10	0
40 or more	0	0

* CNAL Morgan solution.

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

Table 7 lists the recommendation for intensively managed grasses, grasses, pastures with improved grasses, intensively grazed pasture, pasture with native greases, and rye cover crops. No distinction is made between requirements for establishment and topdressing. Recommendations for establishing and topdressing pasture with legumes are listed in Table 8.

Table 7: 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.

Table 8: 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
9-39	40	5
40 or more	0	0

* CNAL Morgan solution.

3.8 Rye cover crops and rye seed production

Recommendations for rye cover crops and for rye seed production are given in Table 9. Note that the recommendations for seed production are 35 to 40 lbs P_2O_5 higher than those for cover crop growth.

Photo by Q.M. Ketterings

Table 9: P recommendation for rye cover crop (RYC) and see 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.

3.9 Idle land, Christmas trees and waterways.

No P is recommended for idle land. Recommendations for Christmas trees and waterways are given in Table 10.

Table 10: 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	90	95
1	75	50	85	90
2	50	25	80	85
3	25	0	75	80
4	0	0	70	75
5	0	0	65	70
6	0	0	60	65
7	0	0	55	60
8	0	0	50	55
9	0	0	45	50
10	0	0	40	45
11-39	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 use the Mehlich-III extraction solution (an unbuffered solution of acetate, ammonium nitrate, ammonium fluoride, and ethylenediaminetetraacetic acid) for soil test P determination. Other extraction solutions used in the state are Bray-1 (HCl and NH_4F) and modified Morgan (ammonium acetate buffered at pH 4.8).

Compliance with Code 590 (Nutrient Management Standard) developed by US Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS) requires that comprehensive nutrient management plans be based on land grant recommendations. In New York, this implies that Bray-1, Mehlich-III and modified Morgan soil test results need to be converted to Morgan equivalents prior to calculating the soil P contribution to the NY P index and P fertilizer recommendations.

Most NY agricultural soils are analyzed by Cornell University's Nutrient Analysis Laboratory, Brookside Laboratories Inc, A&L Laboratories Inc. or by Spectrum Analytic, Inc. Cornell Cropware allows Mehlich-III inputs from the last three laboratories with a warning that states that the user should realize that conversion equations add uncertainty to the recommendations.

Cornell Cropware does currently not allow for the use of soil test data from any other laboratory because it is unknown how results compare to Cornell University's Nutrient Analysis Laboratory. Studies to derive Morgan equivalents for soil test results from other laboratories in NY and in the Northeast are ongoing. Currently available conversion models and the uncertainty involved in their use are discussed below.

4.1 Conversions for Brookside Laboratories Inc. and A&L Laboratories Mehlich-III input data

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:

$$\begin{aligned}\text{Morgan STP (lbs P/acre)} = \;& 3.3957 + (1.1705*\text{M3P}) - (0.003799*\text{M3Ca}) - (27.24*\text{pH}) + \\ & (0.1218*\text{M3Al}) - (0.00005760*\text{M3Al}^2) + (2.6867*\text{pH}^2) + \\ & (0.00009335*\text{M3P}*\text{M3Ca}) - (0.001940*\text{M3P}*\text{M3Al}) + \\ & (0.00000080*\text{M3P}*\text{M3Al}^2)\} \qquad (r^2=0.88,\ n=235)\end{aligned}$$

In this equation *all input data are in ppm.* Morgan STP is Morgan extractable soil test P in lbs P per acre, M3P is Mehlich-III extractable P, M3Al is Mehlich-III extractable Al, M3Ca 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% within 5 ppm (10 lbs/acre) of the measured value. Because this model accurately predicted Cornell-based corn fertilizer recommendations for 96% of 10,331 fields sampled by staff of Agricultural Consulting Services, Inc. (Ketterings et al., 2001), it can also be used with input data from A&L Laboratories. For further details on this conversion equation, see Ketterings et al. (2001) in "What's Cropping Up? Volume 11 (3) or download a copy from the Nutrient Management Spear Program website: http://www.css.cornell.edu/nutmgmt/index.html (click on articles).

4.2 Conversions for Spectrum Analytic Inc. input data

Soil test results for the same soil sample analyzed for Mehlich-III Ca, P and Al differ between Brookside Laboratories, A&L Laboratories and Spectrum Analytic due to differences in analytical procedures and reporting. For example, in the dataset with 235 soils from all over NY, Spectrum Analytic Inc. soil test P data amounted to 74% of the values reported by Brookside and A&L Laboratories. This difference was due to: 1) Spectrum Analytic Inc. reporting Bray-1 P equivalents for Mehlich-III extractions to clients; Mehlich-III extractions are done but the results are reported as Bray-1 equivalents (a multiplication with a factor 0.7); and 2) differences in analytical procedures. Spectrum Laboratories Inc. reported P levels for the Mehlich-III extraction that were consistently 6% higher than those reported by Brookside Laboratories and A&L Laboratories.

Morgan P equivalents for soil test results *reported* by Spectrum Analytic Inc. can be derived using the following equation:

$$\begin{aligned}\text{Morgan STP (lbs P/acre)} = \; & -49.2971 + (0.7850*SpP) - (0.002174*SpCa) - (11.8281*pH) + \\ & (0.1350*SpAl) - (0.00006742*SpAl^2) + (1.5452*pH^2) + \\ & (0.00004146*SpP*SpCa) - (0.001353*SpP*SpAl) + \\ & (0.00000057*SpP*SpAl^2) \qquad (r^2=0.88,\ n=235)\end{aligned}$$

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, SpP and SpCa are soil test P and Ca in lbs/acre as reported by Spectrum Analytic and SpAl is Mehlich-III extractable Al (ppm). If the model predicts a negative Morgan equivalent, a value of 2 lbs/acre is assumed.

4.3 Conversions for Brookside Laboratories Inc.Bray-1 input data

Bray-1 P tests from Brookside Laboratories Inc. are linearly related to their Mehlich-III results. However, the Mehlich-III solution extracts about 33% more P:

M3P (Brookside, ppm) = 1.33 * Bray1P (Brookside, ppm).

The conversion to Morgan P still requires inputs for Mehlich-III Ca, Al and for pH. Cornell Cropware does not allow for the use of Bray-1 P data from laboratories other than Brookside Laboratories Inc. because it is unknown how results compare to Cornell University's Nutrient Analysis Laboratory.

4.4 Conversion for A&L Laboratories Inc. modified Morgan input data

Modified Morgan P extraction data from A&L Laboratories Inc. should be multiplied by 0.90 to obtain Morgan soil test equivalents prior to deriving fertilizer recommendations. Cornell Cropware does not allow for the use of modified Morgan P data from the other laboratories because it is unknown how results compare to Cornell University's Nutrient Analysis Laboratory. A comparison study with the University of Vermont is currently being conducted.

Picture by Q.M. Ketterings

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/ac, apply the entire amount in a band placed starter fertilizer.
  - If the P recommendation exceeds 25 lbs/ac, apply 25 lbs in band placed starter fertilizer, and use manure to supply the rest.

- For topdressing:
  - If the P recommendation is less than 30 lbs/ac, use fertilizer to supply the entire P requirement.
  - If the P recommendation exceeds 30 lbs/ac, 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 do not increase yield. The potential for P loss increases with an increase in the soil P content.

5.2 Phosphorus containing fertilizers

Table 10 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.

To avoid fertilizer injury, it is recommended that fertilizer band application rates remain lower than:

- 30 lbs of P_2O_5 from diammonium phosphate;
- 20-30 lbs of urea N plus N from diammonium phosphate;
- 30-40 lbs of ammonium N from all sources in combination with diammonium phosphate.

Table 11: Phosphorus containing inorganic fertilizers.

	%N	$\%P_2O_5$	$\%K_2O$	%S
Single superphosphate (SSP)	0	20	0	14
Triple superphosphate* (TSP or CSP)	0	44	0	2
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.

Picture by Q.M. Ketterings

6. THE NEW YORK P RUNOFF INDEX[1]

The NY-PI 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-PI 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-PI 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-PI score will also indicate whether other management changes such as winter spreading must be addressed. It is, however, important to note that the PI is not a measure of actual P loss, but rather an indicator of potential loss. A high or very high PI score is a warning to further examine the causes, and a low PI score means the risk of phosphorus loss is reduced, but perhaps not eliminated.

The NY-PI's are 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
Particulate P index = P Source score * Particulate P Transport score

Rankings and management implications for final field scores are listed in Table 12. Both P forms (dissolved and particulate) are a concern for water quality and hence should be managed jointly.

Table 12: NY-PI 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 to crop removal
≥ 100	Very High	No P fertilizer or manure application

[1] This chapter appeared earlier as an extension article with the same title in What's Cropping Up? Volume 11(4):1-3. The article was written by Karl Czymmek, Larry Geohring and Quirine Ketterings.

6.1 PI 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

The Soil Test P portion of the NY-PI score is obtained by multiplying Morgan soil test P by 1.25:

Soil Test P Score = 1.25 * Morgan's Soil Test P (lbs P/ac)

Soil test P results based on Mehlich-III and modified Morgan must be converted to a Morgan P equivalent (see section 5). The fertilizer and organic P scores are first determined by a multiplication of application rate (lbs P_2O_5/ acre) by the weighing factors for application timing and method (see Tables 13 and 14), and then the scores are added to the Soil Test P score.

Table 13: To obtain the Fertilizer P score for the NY-PI, P_2O_5 application rate, timing and method score need to be multiplied.

<table>
<tr><td colspan="6">Fertilizer P = (P_{fa}) * (P_{ft}) * (P_{fm})</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td>Fertilizer P application rate (P_{fa})</td><td colspan="5">lbs P_2O_5 / acre</td></tr>
<tr><td>Fertilizer P timing (P_{ft})</td><td>May – August
0.4</td><td colspan="2">September – October
0.7</td><td>November – January
0.9</td><td>February – April
1.0</td></tr>
<tr><td>Fertilizer P method (P_{fm})</td><td>Injected or subsurface banded</td><td colspan="2">Broadcast and incorporated within</td><td>Surface applied or broadcast and incorporated >5 days after application</td><td>Surface applied on frozen, snow covered or saturated ground</td></tr>
<tr><td></td><td></td><td>1-2 days</td><td>3-5 days</td><td></td><td></td></tr>
<tr><td></td><td>0.2</td><td>0.4</td><td>0.6</td><td>0.8</td><td>1.0</td></tr>
</table>

Table 14: To obtain the Organic P score for the NY-PI, P_2O_5 application rate from organic sources, timing and method score need to be multiplied.

Organic P = (P_{oa}) * (P_{ot}) * (P_{om})					
Organic P application rate (P_{oa})	0.75 * lbs P_2O_5 / 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})	Injected or subsurface banded 0.2	Broadcast and incorporated within 1-2 days 0.4	3-5 days 0.6	Surface applied or broadcast and incorporated >5 days after application 0.8	Surface applied on frozen, snow covered or saturated ground 1.0

6.*2 PI Transport Components*

To assess dissolved P transport, the NY-PI considers soil drainage class, flooding frequency and predominant water flow distance to a stream (Table 4).

Dissolved P Transport Score =
Soil drainage + Flooding frequency + Flow distance to stream
(if Dissolved P Transport ≥ 1, then Dissolved P Transport = 1)

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.

Table 15: The Dissolved P Transport score is obtained by adding factors for soil drainage, flooding frequency and predominant flow distance to stream.

Dissolved Transport P = D + F + FLD				
Soil Drainage (D)	Well / Excessively well drained 0.1	Moderately -well drained 0.3	Somewhat poorly drained 0.7	Poorly / very poorly drained 1.0
Flooding frequency (F)	Rare / Never > 100 years 0	Occasional 10 - 100 years 0.2		Frequent < 10 years 1.0
Flow distance to blue line stream as depicted on topographic map (or equivalent) Intermittent Stream = dashed blue line. Perennial Stream = solid blue line. (FLD in feet)	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

The particulate P component of the NY-PI is similar to the dissolved P component in that flooding frequency and the predominant water flow distance to a stream are again considered (Table 5). 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 ≥ 1, then Particulate P Transport = 1)

Table 16: The Particulate P Transport Score is obtained by adding factors for soil erosion, flooding frequency, predominant flow distance to stream and the presence or absence of concentrated flow patterns.

Dissolved Transport P = SL + F + FLD + CF			
Soil erosion RUSLE or USLE (SL)	0.1 * Erosion rate (tons/acre)		
Flooding frequency (F)	Rare / Never > 100 years 0	Occasional 10 - 100 years 0.2	Frequent < 10 years 1.0
Flow distance to blue line stream as depicted on topographic map or equivalent Intermittent Stream = dashed blue line. Perennial Stream = solid blue line. (FLD in feet)	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
Is concentrated flow (CF) present?	No 0		Yes 0.2

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-PI risk scores. A spreadsheet calculator of the New York P Runoff Index is available at http://www.css.cornell.edu/nutmgmt/index.html (click on software).

7. PHOSPHORUS REMOVAL

If the NY P index for a particular field is high (75-99), P applications should not exceed P removal by the crop. Estimates of P concentrations in harvests of field crops are listed in Table 16. These data are averages obtained from a large numbers of samples analyzed by DairyOne, Ithaca, NY. 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).

Table 17: P concentrations for field crops analyzed through DairyOne, Inc.

Crop Code	Crop	P (% of dry matter)	P_2O_5 (% of dry matter)
ALT	Alfalfa	0.33	0.75
AGE/AGT	Alfalfa-grass mix	0.23	0.52
ABE/ABT	Alfalfa-trefoil-grass	0.23	0.52
BTE/BTT	Birdsfoot trefoil	0.23	0.52
BGE/BGT	Birdsfoot trefoil-grass	0.23	0.52
BCE/BCT	Birdsfoot trefoil-clover	0.23	0.52
BSE/BST	Birdsfoot trefoil- seed prod.	0.23	0.52
CLE/CLT	Clover	0.34	0.77
CGE/CGT	Clover-grass	0.24	0.55
CSE/CST	Clover-seed production	0.34	0.77
CVE	Crownvetch	0.34	0.77
GRE/GRT	Grasses	0.28	0.64
GIE/GIT	Grass-intensive management	0.34	0.77
PIE/PIT	Pasture-rotational grazing	0.34	0.77
PGE/PGT	Pasture w/ improved grasses	0.34	0.77
PLE/PLT	Pasture with legumes	0.24	0.55
PNT	Pasture w/ native grasses	0.34	0.77
WPE/WPT	Waterways, pond dikes	0.15	0.34
CVT	Crownvetch	0.34	0.77
BSP	Barley-spring	0.29	0.66
BSS	Barley-spring w/ legume	0.29	0.66
BWI	Barley-winter	0.29	0.66
BWS	Barley-winter w/ legume	0.29	0.66

Table 17 (continued): P concentrations for field crops. To obtain P_2O_5 removal rates, multiply yield in tons/acre with dry matter content in % and $\%P_2O_5$.

Crop Code	Crop	P (% of dry matter)	P_2O_5 (% of dry matter)
BDR	Beans-dry	N/A	N/A
BUK	Buckwheat	N/A	N/A
COG	Corn-grain	0.31	0.70
COS	Corn-silage	0.27	0.61
MIL	Millet	N/A	N/A
OAT	Oats	N/A	N/A
OAS	Oats-seeded w/ legume	0.3	0.68
RYC	Rye-cover crop	0.36	0.82
RYS	Rye-seed production	0.36	0.82
SOG	Sorghum-grain	0.22	0.50
SOF	Sorghum-forage	0.22	0.50
SSH	Sorghum-sudan hybrid	0.5	1.14
SUD	Sudangrass	0.5	1.14
SOY	Soybeans	0.65	1.48
SUN	Sunflower	1.02	2.32
TRP	Triticale/peas	0.3	0.68
WHT	Wheat	0.29	0.66

CITED REFERENCES

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- Klausner, S. 1997. Nutrient management: crop production and water quality. NRAES 101. Cornell Cooperative Extension, Ithaca NY.
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APPENDIX

Table A: Crops codes for Cropware.

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

Table A: Crops codes for Cropware (Continued).

Crop Code	Crop Description
	Corn
COG	Corn grain
COS	Corn silage
	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 sudan hybrid
SUD	Sudangrass
WHS	Wheat with legume
WHT	Wheat

Table A: Crops codes for Cropware (Continued).

Crop Code	Crop Description
	Others
SUN	Sunflower
TRE	Christmas trees, Establishment
TRT	Christmas trees, Established
WPE	Waterways, Establishment
WPT	Waterways, Established
IDL	Idle Land
OTH	Blank

Picture by Q.M. Ketterings

Q.M. Ketterings, K.J. Czymmek and S. D. Klausner (2001). Phosphorus Recommendations for Field Crops in New York. Department of Crop and Soil Sciences Extension Series E01-5. Cornell University, Ithaca NY. 32 pages.