PHOPSHORUS RESEARCH IN MASSACHUSETTS

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Large scale field study

In 2001, with funding from the Department of Environmental Protection, a study of six cranberry bogs was initiated in Massachusetts. Two primary questions were posed: 1) How much P (and N) enters and leaves cranberry bog systems on an annual basis?; and 2) How does reduction in P input affect the system, horticulturally and environmentally. In addition, as we developed the nutrient budget, we tried to determine which activities had the most impact on the movement of P.

The six study bogs were assigned as pairs. Each pair had similar soil characteristics and grower management but one from each pair was identified for modification of P input during the project. None of the bogs in this study were 'flow-through', that is, there was no perennial streams passing though the production area. Data collection was conducted from 2002-2004 during which time we measured water volumes and analyzed P and N concentrations in the water. As a result, we could calculate partial budgets for N and P for each 'Cranberry Year' -- May 15 to May 15. These were not complete budgets since we did not collect and analyze groundwater in this study.

The water measurements confirmed that total annual water inputs were in the range of 8-11 acre feet at all sites and years. Between 1/3 and 1/2 of all input was rainfall and 1/4 to 1/2 of inputs were floods. Floods accounted for ~65-75% of all grower-controlled water inputs in the study bogs.

In the second and third year of the study, fertilizer P inputs were reduced at some sites with minimal if any impact on yield (Table 1). To account for possible biennial trends, we compared the yield in the two years of reduced P to that in the prior two years.

Table 1. Yield and fertilizer P at bog study paired sites.

	Average Yield		**Fertilizer P (lb/acre)**		
Site	**2001-2002**	**2003-2004**	**2002**	**2003**	**2004**
EH	111	146	17.8	14.3	5.6
PV	129	158	24.8	22.3	17.3
BEN	131	133	20.0	16.1	17.4
WS	108	101	20.0	18.3	16.7
MK	187	178	28.7	20.0	21.1
ASH	143*	214	35.4	32.3	27.9

*2001 crop as ASH reduced by insects

At the EH and MK sites, P rate was substantially reduced during the project, yet yield remained unaffected. The concentration of P in the discharge outlet water of the bog with the greatest P fertilizer reduction declined after two years of reduction (Table 2).

Table 2. P concentration in samples taken from outlet flumes (average value for all flood discharge samples collected within each year).

	mean ppm P in flood discharges		
Site	**2002**	**2003**	**2004**
EH	0.377	0.424	0.237
PV	0.384	0.439	0.528
BEN	0.291	0.158	0.165
WS	0.296	0.153	0.343
MK	0.100	0.170	0.118
ASH	0.109	0.127	0.147

The sites with the lowest P concentration in flood discharge were the MK and ASH pair. These were mineral soil bogs, while the other 4 sites were older beds on organic (peat) based soils.

In general, on a per acre basis, there was more P in the water leaving the bog than in that entering the bog, opposite from what we found for nitrogen. However, when all inputs (rain, irrigation, floods, fertilizer) and outputs (discharge water, crop, biomass produced) are included in the budget, P output is negative. That is, P is retained in the

Table 3. P budgets for a pair of organic base bogs, one of which had reduced P fertilizer in 2003 and 2004. Data shown are P load in discharge, net discharge (minus incoming load) and the total budget when all inputs are subtracted from all outputs.

	lb/acre/yr				
	phosphate (dissolved)		**Total P**		
Site/year	**in discharge**	**minus incoming**	**in discharge**	**minus incoming**	**Total budget**
EH 2002	1.11	1.02	1.64	1.15	-13.32
EH 2003	1.82	1.78	2.84	2.31	-8.64
EH 2004	0.82	0.74	1.09	0.53	-1.19
PV 2002	3.53	2.67	4.58	2.94	-18.53
PV 2003	3.68	2.99	5.14	3.22	-15.62
PV 2004	3.20	2.62	3.92	2.16	-10.92

system. Table 3 shows a comparison of the water budget and total budget at two organic base sites, one of which had reduced P fertilizer in 2003 and 2004. A comparison of the EH site in 2002 vs. 2004 shows that the net discharge in water decreased by half as fertilizer P inputs were reduced.

A comparison of the mineral soil bog pair is shown in Table 4. At the reduced fertilizer site (MK) in 2004, the P load in the discharge was less than that in incoming water. In general the P discharge from the mineral soil bogs was less than that from the organic bogs. Some of this related to lower water volumes discharged at the surface outlet.

Table 4. P budgets for a pair of mineral soil bogs, one of which had reduced P fertilizer in 2003 and 2004. Data shown are P load in discharge, net discharge (minus incoming load) and the total budget when all inputs are subtracted from all outputs.

	lb/acre/yr				
	phosphate (dissolved)		**Total P**		
Site/year	**in discharge**	**minus incoming**	**in discharge**	**minus incoming**	**Total budget**
MK 2002	0.49	0.35	1.02	0.01	-24.25
MK 2003	0.69	0.32	1.42	0.05	-16.12
MK 2004	0.94	0.01	1.66	-1.10	-17.81
ASH 2002	0.51	0.45	1.09	0.24	-32.32
ASH 2003	0.40	0.26	1.32	-0.56	-29.2
ASH 2004	1.09	0.95	1.97	0.17	-22.86

As mentioned earlier, yield was not affected by fertilizer reduction in this study. A comparison of soil and tissue analyses from the sites showed that soil P remained high at all sites for the duration of the study, while tissue P remained in the mid-normal range (0.13-0.15%). With these results, one would not expect P to be a factor limiting yield. In order to determine that long-term impacts of P reduction. The EH-PV bog pair will continue to receive differential P inputs and the effects on yield and harvest flood quality will be determined.

Plot scale research

Since 2000, research into effects of P rates has been conducted in Massachusetts and Wisconsin. While N and K rates are held constant in the plots, P rates varied from 0 to 30 lb/acre actual P. The rate range for the study was based on previous research. In Wisconsin, Greidanus and Dana (1972) compared rates of 0, 10, and 30 lb/acre with deficiency resulting at 0 and 10 but not at 30 lb/acre. In New Jersey, Eck (1985) compared rates from 5 to 80 lb/acre and showed optimum yield results with rates between 20 and 40 lb/acre. In a study in Massachusetts (DeMoranville and Davenport, 1997), plots receiving no P had significantly lower yield than those receiving 20, 40, or 60 lb/acre but there was no difference among the non-zero rates.

Through the end of the 2005 season, there were no treatment effects of the rate of phosphorus fertilizer applied on total yield in any year in the well established Wisconsin plots (Table 5). Yield varied significantly between years, underscoring the biennial bearing nature of individual cranberry uprights. After 5 years of treatment, tissue P varied in the WI plots with lowest P in the controls and highest in the 30 lb P plots receiving slow release fertilizer. However, all were above 0.1%, the critical level which may account for the lack of yield effects.

Table 5. Yield and tissue P in sand based cranberry beds treated with different rates of phosphorus fertilizer for five years in Wisconsin. n=8 for yield, n=4 for tissue P.

Treatment	Yield (g/ft^2)				
Rate (lb P/a)	***2001***	***2002***	***2003***	***2004***	***2005***
Control	116.7	274.5	215.9	128.7	179.4
5	116.7	248.9	230.1	140.0	226.2
10	112.2	273.3	268.6	117.6	199.1
15	118.9	276.5	221.9	126.2	208.6
20	126.9	242.7	269.4	157.4	224.0
30	130.3	261.6	216.6	131.3	198.7
Significance	ns	ns	ns	ns	ns

Treatment	Tissue P (% dry weight)			
Rate (lb P/a)	***2001***	***2003***	***2004***	***2005***
Control	0.127 f	0.126 f	0.105 d	0.102 b
5	0.143 cdef	0.131 ef	0.127 bc	0.102 b
10	0.144 cdef	0.138 def	0.126 bc	0.112 ab
15	0.145 bcdef	0.157 bcd	0.130 bc	0.120 ab
20	0.147 bcdef	0.142 cdef	0.131 bc	0.124 ab
30	0.170 ab	0.143 cdef	0.142 b	0.121 ab
Within columns, values sharing a letter are NOT statistically different				

In the Massachusetts plots that were treated for 3 years (Table 6), we found year to year variability but no yield differences attributable to P rates. Plants from all plots showed sufficient tissue P at the end of three years and soil P in the high range based on the Bray test. More recent plot studies in Massachusetts are showing similar results as regards yield. However, in 2005, some of the lower rate plots are showing tissue P just below sufficient.

Based on previous research, we know that some P input is better than no P in supporting production. However, in the current plot studies we have found few differences in yield at the P rates applied, including no P. One difficulty has been showing a soil and/or tissue response that increases with increasing P addition. In addition, the controls have not shown deficiency as yet, making calibration impossible using these plots. We continue to study the long-term effects at these sites.

Table 6. Yield, tissue P, and soil P in sand based cranberry beds treated with different rates of phosphorus fertilizer for three years in Massachusetts. n=5.

P rate lb/acre	Location 1 yield (bbl/acre)			Location 2 yield (bbl/acre)		
	2000	***2001***	***2002***	***2000***	***2001***	***2002***
0	239	163	79	344	113	222
2.5	212	146	94	304	93	219
5	263	94	56	326	80	183
10	230	187	93	274	91	244
15	247	150	93	307	95	191
20	278	123	118	343	68	224
30	253	125	69	339	81	193

P rate lb/acre	Location 1 % P in tissue		Location 2 % P in tissue	
	Year 1	***Year 3***	***Year 1***	***Year 3***
0	0.12	0.16	0.13	0.16
2.5	0.11	0.15	0.14	0.16
5	0.11	0.17	0.12	0.16
10	0.11	0.15	0.15	0.18
15	0.12	0.13	0.15	0.17
20	0.12	0.17	0.15	0.17
30	0.14	0.16	0.16	0.16

P rate lb/acre	Location 1 Bray P (ppm)		Location 2 Bray P (ppm)	
	Year 1	***Year 3***	***Year 1***	***Year 3***
0	31	62	31	49
2.5	34	62	51	50
5	38	66	39	50
10	32	83	46	64
15	53	73	39	46
20	37	71	46	58
30	42	69	48	65

Phosphorus interactions with flooding in cranberry production

In the large-scale field study in Massachusetts, we have demonstrated that, at least in the short term, reduction of P to 20 lb/acre on 'Stevens' in mineral soils is possible and that further reductions are possible with native cultivars on organic based soils. More importantly, we found in that study that flood discharges are the primary mode for off-site P export. We looked more closely at flooding practices to determine how flooding impacts water quality.

We observed that during the several days that water sat on the bog following a typical harvest, total P levels declined, presumably due to the settling of particles that were stirred into the water during harvest. This led to an experiment where we had the grower hold the harvest flood for about 2 weeks, then release the water very slowly. While the slowly released water did have less P than that remaining in the bed, we noticed an increase in discharged P over time. After about 12 days, the P load in the water both in the bed and in the discharge, began to rise. An examination of the data showed that inorganic forms of P increased dramatically as the flood was held beyond 12 days (Figure 1). This study indicated that using slow flood discharge to filter particulate P was effective but if the release took too long, inorganic phosphate was released into the flood, presumably from the bog soil.

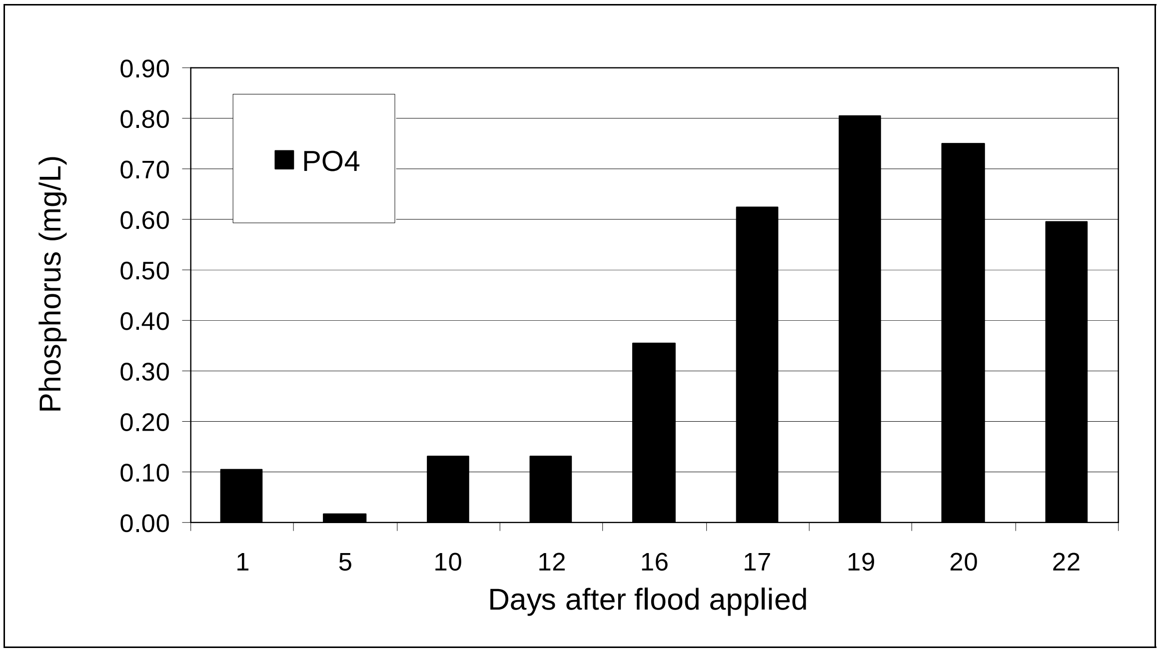

Figure 1. Dissolved phosphate in water samples taken from a prolonged harvest flood.

Other studies confirm that P can be released from the bog soil during floods. In a study of cranberry soils in the laboratory (Davenport et al., 1997), P was released into flooded cranberry soils with the amount released varying by soil type. In a field study of cranberry bogs with a perennial stream running through, the primary discharges of P were during releases of the harvest and winter floods (Howes and Teal, 1995). To further study the interaction of flooding and soil P, we worked with scientists from UMass Dartmouth to conduct a laboratory study. Soil cores were collected from working cranberry bogs and placed in cylinders. Flood water was introduced and the cylinder was sealed. Over time, oxygen and phosphorus content of the water was monitored. Figure 2 shows the change in dissolved P in the flood water as oxygen depleted in the system. All of the soil tested showed similar behavior, whether from abandoned, natural, or high input production areas. Only the magnitude of the phosphate release varied depending on management. This indicates that taking a bog out of production will not prevent P losses to the surrounding environment if the beds are subjected to flooding cycles.

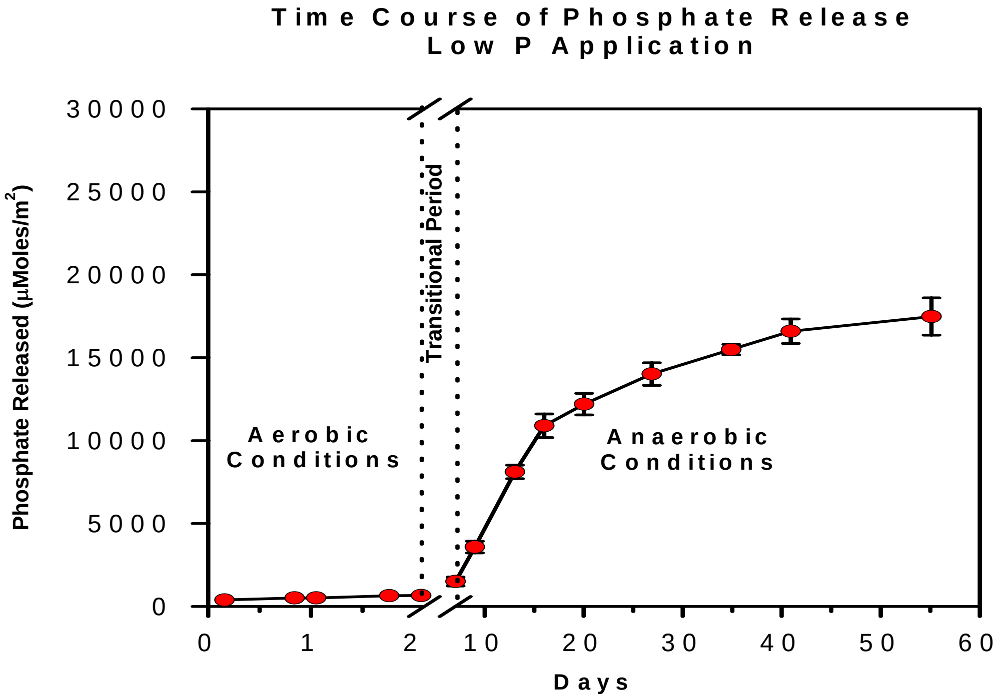

Figure 2. Phosphate in water over cranberry soil. Note the rapid increase after day 10 as the water becomes anoxic. (Schlezinger, Howes and DeMoranville, unpublished data).

Summary

Cranberry bogs, while generally next importers of nitrogen can be exporters of phosphorus. Since most of the P export from bogs was associated with flood discharges, flood management is an area deserving of further study. In order to reduce P output from cranberry systems, an important consideration will be the management of floods to minimize mobilization of soil P. Reduction in P can also be beneficial if managed so as to preserve productivity. In short term studies, fertilizer P reductions were not associated with crop reduction but after two years of reduced P, P load in discharge water was decreased. Long term studies on both plot and bog scale will be needed to determine the actual lowest effective rate for P. At present we recommend using moderate rates with a tissue testing program to monitor results.

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