PHOSPHORUS, POTASSIUM, AND MINOR ELEMENT FERTILIZATION

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The order of topics in the title reflects the relative amounts of knowledge that we have regarding P, K, and minor element fertilization. Extensive studies of P use in cranberry production have been conducted in WI (Greidanus and Dana, 1972) and in Massachusetts (Davenport et al., 1997; DeMoranville and Davenport, 1997). Some research on K fertilizers has been published (DeMoranville and Davenport, 1994) and studies are in progress in MA, WI, and OR. Due to the acid medium in which cranberries grow, minor elements tend to be readily available to the plants. Some research has been done with minor element foliar supplements but the results have been mixed and often vary from year to year on the same bed. Minor element toxicity is of interest due to the extreme availability of metallic minor elements in cranberry soil. Roper and Krueger are investigating nutrient toxicity symptoms in cranberry.

Phosphorus - soil chemistry.

Cranberry soils are high in iron and have low pH. This chemistry leads to conditions where phosphorus (P) is tightly bound in the soil and is to a large extent unavailable to the cranberry plants (Davenport et al., 1997). Cranberry plants with tissue P at or below the critical level are often found growing on soils with high P test values. Most cranberry growers add inorganic P to the soil in N-P-K fertilizer or as triple superphosphate (TSP). When applied to the soil, the P in these materials dissolves in the soil water and quickly becomes bound to iron - only a small percentage of the P remains dissolved in the soil water. Only a portion of that bound P is later released and available for uptake by the plants.

Phosphorus uptake and release in cranberry soils of varying organic matter content was investigated under flooded, dry, and transitional conditions (Davenport et al., 1997). Sand soils readily released P that had been previously applied and bound to the soil. However, the total P holding (and releasing) capacity of these soils was poor indicating a need for low rate applications at frequent intervals. Uptake and release in sand soils was not dependent flooding cycles (aerobic status). However, the results were quite different for peat and layered (sanded cranberry) soils. In the layered soil, P was released from the bound state at the highest rate as the soil moved from the flooded to the seasonal dry state (field capacity). Once the soil reached seasonal dryness, P was only released if a certain threshold amount was present in the soil, indicating the need for fertilizer applications under those conditions. This pattern was even more pronounced in highly organic (peat) soil. Common soil tests for P indicated high P availability under conditions where P was shown to remain bound in our soil studies. We found that if soil iron is high, a test for extractable Fe may be more meaningful than the P soil test for predicting P releasing potential of the soil during the growing season.

To summarize:

In sand soils, P readily attaches to the soil and is completely released for plant use throughout the growing season. However, the total holding capacity of these soils is low, indicating the need for low rate, frequent P applications.

In layered soils, P is available under flooding conditions and during the transition from wet to dry soil conditions (early spring). Fertilizer additions should be delayed until seasonal dryness at which time moderate rates are suitable (very low P additions may be bound to the soil and released poorly).

In organic (peat) soils, P was somewhat available under flooding conditions only. Once the soil begins to dry, additions of P may be beneficial. However, this soil type showed even stronger tendency to bind small additions of P compared to layered soil.

Phosphorus forms, rates, and timing.

Despite cranberry bog soils testing high for P, most cranberry growers continue to use P fertilizer each season. In some annual crops, a yield response to P has been found even in high P test soils, particularly if other production factors are maximized or if soil and climate factors impose plant stress early in the season. Cranberry bogs meet both of those conditions: high yields are common and soils are often cold and waterlogged early in the season. P forms, rates, and timing were studied in a three year field trial at six locations in MA (DeMoranville and Davenport, 1997).

Five P forms and a control receiving no P were compared in field plots (Table 1). The treatments were TSP (0-46-0) phosphoric acid (reagent grade 85%, foliar P), phosphate rock (PR; 0-32-0), half each PR and foliar P, and half each PR and TSP. PR was applied at bud break; TSP and foliar P were split-applied at roughneck, bloom, fruit set, and bud set stages. At the end of three years, yield was similar for all P treatments within each location. Plots receiving no P (control) had significantly lower yield than any of those receiving P (Table 1). Foliar applied phosphoric acid was associated with higher field rot compared to TSP or no P. Among the P treatments, plots treated with foliar P had the highest tissue P levels; those receiving PR the lowest.

Nine P forms and a control receiving no P were compared in field plots (Table 2). PR, Osmocote, and bone meal were applied at bud break; foliar P was split-applied at bloom and fruit set; chicken manure was split-applied at bud break and fruit set; fish was split-applied at bud break, hook stage, fruit set, and bud set; 10-20-10 and 14-14-14 were split-applied at roughneck, bloom, fruit set and bud set stages. Cranberry production in this set of plots seemed to be more dependent on P form than on P rate (Table 2). Yield was lowest in plots receiving no P but yield in the other treatments did not correspond to the three P rate groups. This is illustrated by the individual comparison of 10-20-10 (17.5 lb P/A) with 14-14-14 (8.5 lb P/A) - no difference in yield, although tissue P is higher in the 10-20-10 treatment. The lowest yields in plots receiving P were in those where P was applied in organic fertilizers (fish, chicken manure, and bone meal). Highest yield was in plots receiving PR alone or with added foliar P (but not statistically greater than that in 10-20-10 plots). Slow-release P was no more effective than soluble materials (Osmocote vs. 14-14-14) in promoting productivity but was less effective in raising tissue P content.

Four TSP rates and five split-application timings were compared in field plots (Table 3). The P rates and timing plots received only N and K in the first year and were then treated with the appropriate P rate and timing each year for the following three years. Timing of P application had no effect on cranberry yield, yield components, or soil test P (Table 3). There was no interaction between timing and rate but there were significant rate differences. Plots receiving P at any rate (20, 40, or 60 lb/A) had greater yield and tissue P content than those receiving 0 lb P/A. However, yield among the three P rates was similar - no further gain was achieved by increasing P above the 20 lb/A rate. An individual comparison of 0 lb/A vs. the other P rates was highly significant but there was no linear increase in yield with increasing P rate. However, tissue and soil P did increase with increasing P rate. Plots receiving no P had the fewest flowers per area of bog.

At the six experiment locations, the average soil test P was between 40 and 50 ppm Bray-l P which is greater than the 20-30 ppm recommended by Wisconsin researchers Greidanus and Dana (1972) for maximum vegetative growth of cranberry plants. However, the sites all had cranberry tissue P levels at or below the 0.10% critical level (DeMoranville, 1997). Compared to adding no P fertilizer, cranberries at all locations responded to P rates ranging from 8.5 to 60 lb P/A with increased yield (Tables 1-3). While yield increased with the addition of P compared to adding none, the amount added seemed to have little effect. Regression analysis of the data from the rate study showed no significant relationship between P rate and cranberry yield. Only the comparison of the 0 lb P/A rate to the other rates showed a significant difference. However, increased P rate was associated with increased tissue P (Table 3) confirming the Wisconsin data. Comparison of 8.5 lb P/A to 17.5 lb P/A rates (Table 2, 14-14-14 and 10-20-10 treatments) showed no significant difference in yield, although the higher P rate was associated with higher tissue P values. Cranberries growing on high P soils did respond to the addition of P but there was no advantage to using high rates, the response was a good with low to moderate rates of P - approximately 20 lb/A. Response to added P was the same regardless of application timing (Table 3).

Application of P to cranberry bogs with Bray-l P of 40-50 ppm raised soil P to 70-80 ppm and increased yield. However, tissue P remained below the published critical level (DeMoranville, 1997 and Greidanus and Dana, 1972). It is possible that the available P in these soils was less than that indicated by the Bray-l test due to the presence of citrate/dithionate extractable Fe at interfering levels of greater than 200 ppm (Davenport et al., 1997). It was observed that the two locations where yields were lowest over all treatments were also those with the highest soil P (>100 and >80 ppm).

To summarize:

- Based on this research, P applications of 20 lb/A are recommended for producing cranberry bogs. Higher P rates or foliar P treatments may increase tissue P levels but there is no evidence that yields will improve beyond those with the moderate P rate.
- Foliar P was associated with increased field rot.
- Extreme P loading of the soil may be associated with lower yield.
- P should be split-applied (three or four applications) if a soluble material such as TSP is used to minimize fixation and /or leaching loss. Slow-release or PR may be applied in a single application early in the season. Uptake/ release studies have indicated that P applications should be delayed until soil is at seasonal moisture field capacity - roughneck stage or later.

Potassium.

In the early 1990s, DeMoranville and Davenport (1992) conducted field trials in which K was applied to cranberry in soil or foliar forms at timings designed to increase K during fruiting. Since concentration of K in fruit is significantly higher than in foliage of cranberry, we thought that K might be a limiting factor during fruit set. We found no yield response to our K additions.

We initiated a series of field experiments in 1995 to study several questions related to the use of potassium (K) and phosphorus (P) fertilizers.

Question #1- do high chloride fertilizers have a negative effect on cranberries? After one year of treatment, chloride containing K fertilizers had no adverse effect on yield. However, at the Stevens site, yield was reduced in the treatment receiving $CaCl_2$. High N rates (50-60 lb/A), the other factor studied, were associated with reduced yields and increased rot.

Question #2 - Do P and K fertilizers have a role in the establishment of new cranberry plantings? *We* found that the use of 50 lb P/A at the time of planting increased the percent of coverage by cranberry plants at the end of the first season. The bogs also received 100 lb/A 31-0-0 (IBDU) at the time of planting. After two years of growth, all P treatments had equal vine cover. K applications seemed to have no effect on vining-in. We now recommend 50 lb P/A (100 lb/A triple super phosphate) during vine establishment (at or around the time of planting).

Question #3 - How does a fertilizer schedule including foliar P and K compare to using just 12-24-12? While the differences were not statistically different, yield and weight per berry were greater in the plots receiving an all granular 12-24-12 program at all 4 locations. Conversely, at all locations, field and storage rot was less in the plots receiving the granular/foliar combined program (foliar P+K in the spring, 12-24-12 at bloom, 21-0-0 at fruit set, and foliar P in August). In 1995, two of the locations had higher yields with the granular/foliar combined program (one location significantly greater). This leaves the picture unclear. There may be some benefit in adding foliar P and K applications to a granular fertilizer program at some locations in some years but it is by no means a sure bet.

Question #4 - Does the timing of K application affect the result? K applications, regardless of timing, appeared to have little effect on production after one year of treatment. However, plots receiving no K for the whole season had the highest yield in the second year compared to some of the K treated plots. Timing of K application appeared not to be important in either year of the study. We attempted to study timing of K application and fruit sizing using the Ocean Spray aeroponics system. The experiment was terminated due to high mortality in the study plant material.

Minor element fertilization.

Individual minor element supplements. Joan Davenport conducted three seasons of field studies in WI in which she applied individual minor elements at either hook stage or at early scattered bloom. The elements used were Cu, Zn, Mg, Ca, and B. Results varied from year to year. In the first tow years, some increases in yield were seen. However, in the third year, no treatment was effective. Further, no treatment gave consistent results over time. In two years Ca supplement was associated with yield increase, but the effective timing varied. In addition Ca was sometimes associated with an increase in fruit rot. Mg, B, and Cu had conflicting relationships with yield and quality over the life of the study. Only Zn applied at either timing showed no negative impacts during the study. However, positive impact was only seen in 2 of 3 years. The overall conclusion drawn from these data was that minor element supplements, unless applied to correct specific deficiencies, give at best, mixed results and are unlikely to provide much benefit for the cost involved.

Boron. Boron is essential for flowering and fruiting in higher plants, being involved in the growth of pollen tubes and in the induction of floral buds. We have shown that the addition of a supplement containing calcium and boron during the flowering period led to increased fruit set, presumably due to the effect on pollen tube growth (DeMoranville and Deubert, 1987). There have been reports of increased flowering following fall applications of boron to fruit trees and lowbush blueberry, presumably an effect on bud formation. Calcium-boron sprays during the summer (after bloom) had no effect on cropping that year or the following year. In fact, bloom sprays of CaB appear to be most effective on beds where yield potential is low. High yielding beds are unlikely to benefit from this combination.

Recently, we attempted fall sprays of B alone. Based on reports for other crops, such sprays may increase flower bud production (and crops), particularly on bogs which have shown a low tissue test B. Foliar boron was applied at 3 rates in the fall or spring. We started this project in the fall of 1994, in an attempt to replicate the flower bud stimulation seen in tree fruit crops with fall B (and sometimes spring B) supplements. While boron sprays lead to no statistically significant increase in cranberry production, it appears that there may be some effect on the numbers of berries produced. A 10.5% liquid boron applied to bogs with low tissue boron at 4 pt/A just prior to bud break (early May) was associated with at least 20% increase in number of berries produced at 3 of 5 sites in 1996. When all data from 1995 were combined, that same treatment was associated with more than 10% increase in yield (not statistically significant). *The bottom line:* There may be some benefit of applying boron sprays prior to bud break on bogs with low (30 ppm or less) tissue boron. Our "best" treatment consisted of 4 pt/A of a 10.5% boron liquid applied just prior to bud break in the spring. Use of B supplement sprays remains under investigation.

Minor element 'cocktails'. Foliar nutrient mixtures have been investigated by many researchers around the country. However, no consistent reproducible result has been found. I have made some of these attempts, looking at Zn-B-K, Zn-K-P, CaB, and various N-P-K foliars singly and in combination. The only yield improvements came from CaB or N-P-K additions. The value of additional supply of the major elements is obvious. However, minor element addition for yield improvement remains dubious at best.

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Table 1 - Comparison of soluble, insoluble, and foliar P forms applied to field-grown cranberries. Data collected after three successive years of treatments. All materials were applied each season at the rate of 17.5 lb P/A. Data from six locations combined; treatment comparisons were similar at each location. Within a column, values followed by the same letter are not statistically different.

Treatment	Yield (bbl/A)	Field rot (%)	Soil P (ppm)	Shoot P (%)
Triple super phosphate (TSP)	176a	4.1 b	77	0.088 ab
Phosphoric acid (foliar P)	163 a	6.7 a	70	0.097 a
Phosphate rock (PR)	177a	4.3 ab	71	0.078 b
PR + foliar P	176a	5.7 ab	71	0.084 ab
PR + TSP	183 a	4.8 ab	82	0.088 ab
No P (control)	124b	4.1b	--	--
Initial content			44	0.110
Significance of differences	***	*	*ns*	*

Table 2 - Comparison of inorganic, slow-release, and organic P forms applied to field-grown cranberries. Data collected after three successive years of treatments. Data from six locations combined; treatment comparisons were similar at each location. Within a column, values followed by the same letter are not statistically different.

Treatment	Phosphorus rate (lb/A) per season	Yield (bbl/A)	Soil P (ppm)	Shoot P (%)
Inorganic 10-20-10	17.5	174 ab	69	0.098 a
Fish (2-4-2 liquid)	17.5	137 bc	55	0.083 ab
Phosphate rock (PR)	17.5	194 a	68	0.078 b
Osmocote (slow release)	8.5	174 ab	71	0.071 b
Inorganic (14-14-14)	8.5	164 ab	66	0.084 ab
Chicken manure (3-4-3)	11.6	146 bc	67	0.085 ab
Bone meal (4-12-o)	11.6	160 abc	70	0.081 ab
PR + foliar P	11.6	190 a	70	0.078 b
Osmocote + foliar P	11.6	163 ab	68	0.083 ab
No P	0	124 c	--	--
Initial content			39	0.104
Significance of differences		**	*ns*	**
Individual comparisons				
No P vs. all other treatments		***	--	--
10-20-10 vs. 14-14-14 (rate comparison)		ns	ns	**
Organic vs. 10-20-10		**	ns	**
Osmocote vs. 14-14-14		ns	ns	*
PR vs. PR + foliar P		ns	ns	ns
PR vs. 10-20-10		ns	ns	***

Table 3 - Comparison of four rates and five timings of phosphorus applied to field-grown cranberries. Data collected after three successive years of treatments. Phosphorus was applied as TSP. Data from six locations combined; treatment comparisons were similar at each location. Rate timing interaction was not significant. Within a column, values followed by the same letter are not statistically different.

Treatment	Yield (bbl/A)	Flowers (per ft^2)	Soil P (ppm)	Shoot P (%)
Rates				
0 lb/A	137 b	430 b	54 b	0.123 c
20 lb/A	170a	476 ab	57 b	0.136 b
40 lb/A	157a	440 ab	64 a	0.148 a
60 lb/A	165 a	493 a	67 a	0.152 a
Significance of differences	*	*	**	***
Timings				
RN, BL, ST, BD[z]	161	460	64	
RN, ST, BD	162	451	64	
RN, BL, BD	161	498	62	
RN, BL, ST	169	477	63	
BL, ST, BD	166	462	60	
Significance of differences	*ns*	*ns*	*ns*	

[z]RN = roughneck (1.5 cm growth), BL = bloom, ST = fruit set, BD = bud set