

# Cranberry Best Management Practice Adoption and Conservation Farm Planning in Massachusetts

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**ADDITIONAL INDEX WORDS.** *Vaccinium macrocarpon*, BMP, american cranberry, wetlands, environment, nutrient management, nutrient load, flooding, nutrient discharge

**SUMMARY.** In Massachusetts, cranberry (*Vaccinium macrocarpon*) bogs were historically developed in existing wetlands and new plantings are now established in mineral soils that are converted into constructed wetlands. To streamline the interaction between cranberry farming and wetlands protection, the state has defined "normal agricultural practices" that are exempt from wetlands regulations under certain circumstances. As part of that process and to qualify for the exemption, farmers are required to have a conservation farm plan and demonstrate the use of best management practices (BMPs) on their farms. The University of Massachusetts Amherst Cranberry Experiment Station (UMass Cranberry Station) was engaged to bring together the U.S. Department of Agriculture, Natural Resource Conservation Service (NRCS) and cranberry industry representatives to define BMPs specific to cranberry farming practices. Initially, the documents were reviewed by scientists and regulators for soundness of science and rigor of environmental protection. A grower committee reviewed the proposed BMPs to determine if the BMPs could be implemented on real farms. The next stage of the project consisted of defining areas where more research was needed to formulate good BMPs. In particular, research projects were initiated to study nitrogen and phosphorus nutrition. This research has become the basis for nutrition BMPs, national cranberry nutrition guidelines, and standards used by NRCS for cranberry nutrient management plans. The cranberry BMP project has continued with a regular cycle of revision and additions based on grower-identified needs for horticultural and environmental guidance. This connection to the growers, along with the regulatory link, accounts for the widespread adoption of BMPs in the cranberry industry. Local NRCS estimates that 75% to 80% of Massachusetts cranberry growers have current conservation farm plans that include BMP implementation.

The cranberry is a long-lived woody perennial trailing non-deciduous vine (Roper and Vorsa, 1997). Its native habitat is open bogs, swamps, mires, wet shores, and headlands, and occasionally poorly drained upland meadows. The crop is cultivated in cool, moist, natural or artificial bogs that can be flooded or drained as desired (Vander Kloet, 1988). Historically, cultivation consisted of the management of native cranberry stands, including the installation of drainage structures. Later, cranberry beds were established on wetland soils, characterized primarily as peat bogs, kettle ponds, or former outwash channels (Deubert and Caruso, 1989). Cranberry production in Massachusetts accounts for ~23% of the

national crop, with a farm-gate value of \$47.4 million (National Agricultural Statistics Service, 2006). Production is concentrated in the southeastern area of the state, contributing substantially to the local economy. In Massachusetts, the third most densely populated state in the United States (U.S. Bureau of the Census, 2000), cranberry production is in direct competition with residential users for water and land resources, leading to increased scrutiny of horticultural practices and greater expectations for minimizing environmental impact.

With the advent of wetland

## Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
1233.4819	acre-ft	m <sup>3</sup>	0.0008
2.54	inch(es)	cm	0.3937
1.1209	lb/acre	kg·ha <sup>-1</sup>	0.8922
1	ppm	mg·L <sup>-1</sup>	1

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protection laws and the prohibition of the conversion of natural wetlands into cranberry beds, new cranberry bog construction techniques were introduced (Sandler, 1998). New cranberry bogs are constructed with a slowly permeable confining layer to establish a perched water table, thus creating an artificial wetland setting within a mineral soil (Fig. 1). As these cranberry bogs mature, they function as wetlands and fall under the same regulations as older beds. Activities in wetlands are regulated by state (Commonwealth of Massachusetts, 2005a) and federal agencies. This presents a unique challenge to cranberry growers who, by definition, are carrying out all of their horticultural activities in wetlands. In 1972, Congress enacted legislation that came to be known as the Clean Water Act (CWA). Section 404 of the act prohibited the discharge of fill into wetlands. As amended in 1977, Section 404 defines agricultural activities in wetlands that are regulated, are exempt, or that require a permit from the U.S. Army Corps of Engineers (Sandler, 1998; U.S. Environmental Protection Agency, 2003). Exempt activities included normal agricultural practices on existing farms that did not impair or reduce the reach of a wetland. Under these exemptions, cranberry growers can continue to farm existing wetland bogs as long as they do not expand activities into other wetland areas. New plantings in constructed wetlands fall under these same restrictions once they are established.

## Wetlands Protection Act and conservation farm plans

By the late 1970s, Massachusetts had enacted the Wetlands Protection Act (WPA) (Commonwealth of Massachusetts, 2005b), which prohibited the filling, dredging or altering of land that bordered the waters of the commonwealth. Exceptions were given for "... maintenance of drainage and flooding systems of cranberry bogs, to work performed for normal maintenance or improvement of land in agricultural use or in aquacultural use ... ." The WPA further provided for the Massachusetts Department of Food and Agriculture, with input from a committee consisting of representatives of UMass Extension, NRCS, and farm operators, to establish definitions for the term "normal maintenance or improvement of land in agricultural, or in aquacultural use"

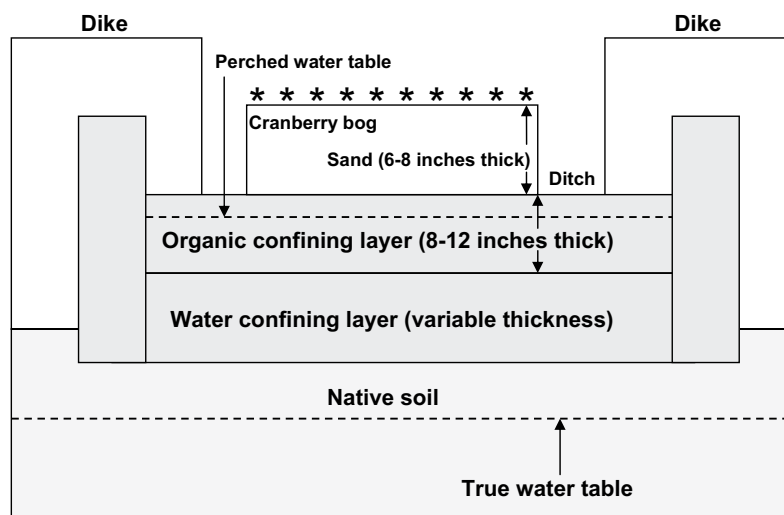


Fig. 1. Cross-section of a cranberry bog constructed in mineral soil, not to scale. Organic and water confining layers create a perched water table (adapted from DeMoranville et al., 2000); 1 inch = 2.54 cm.

(Commonwealth of Massachusetts, 2005b). For the various agricultural enterprises in Massachusetts, a list of normal practices was formulated and became the list of exempt activities in the regulations developed under the WPA.

By the 1990s, the U.S. Army Corps of Engineers had recognized that cranberry farming is a water-dependent activity (U.S. Army Corp of Engineers, 1992) and had adopted the normal cranberry agricultural practices list developed for the WPA as their list of practices exempt from the CWA Section 404 permit process [Cape Cod Cranberry Growers Association (CCCGA), 2003a; Sandler, 1998]. Along with defining normal agricultural practices, the U.S. Army Corps of Engineers developed BMP recommendations that must be followed for some activities to be exempt.

On the state level in Massachusetts, the WPA provided for agricultural exemptions. In the regulations associated with the WPA, the exempt activities that pertained to cranberry farming were defined in two categories, those that were entirely exempt (requiring no action on the part of the farmer) and those that could proceed if the farmer had a conservation farm plan on file with the local conservation commission (CCCGA, 2003b). This provision, combined with the requirement of a farm plan to allow a grower to participate in federal cost-share conservation programs, was the impetus for the conservation farm planning initiative

for Massachusetts cranberry farms. The Plymouth County Conservation District, working with the local NRCS office, began to develop cranberry-specific conservation farm plans.

A conservation farm plan is a tool designed to help farmers manage their land profitably while protecting natural resources on the farm. The plan is developed by a professional planner from the conservation district working with the farmer to identify the resources on the farm, define objectives for the plan, select actions to achieve the objectives, and evaluate the success of the planned activities. The farmer implements the plan. All design specifications in the plan must follow NRCS technical standards (CCCGA, 2003c).

## Cranberry BMPs

As cranberry farm plans were developed and implemented, it became apparent that not all NRCS technical standards developed at the state and federal level were appropriate for the unique cranberry production system. The CCCGA had begun working with the conservation district and NRCS to modify the NRCS technical standards for use in cranberry farm plans. At about that same time, the UMass Cranberry Station was preparing to produce an updated guide to Massachusetts cranberry production practices and Ocean Spray Cranberries, Inc. (Lakeville–Middleboro, Mass.) was beginning the process of providing best management practices guidelines to its growers. All of these

groups came together to identify a unified project that was submitted to the Massachusetts Department of Food and Agriculture Agro-Environmental Technology Program. The *Best Management Practices Guide for Massachusetts Cranberry Production* was the result of that partnership (DeMoranville et al., 2000).

Each section of the guide begins with a description of the part of cranberry production addressed in that BMP. Following the introductory section is a series of recommended practices designed to maximize productivity while preserving the environment. BMPs for the guide were compiled based on existing science and balancing good horticultural production practices and environmental stewardship. The documents were then reviewed by representatives of grower organizations, cranberry handlers, NRCS and the conservation district. Specifically, growers were charged with commenting on the practicality of implementing practices on their farms. By taking this approach, the likelihood of adoption of the BMPs was increased. The use of the BMP guide as part of the farm planning process also encouraged BMP adoption.

The cranberry BMP guide continues to undergo a regular cycle of revision and additions based on grower-identified needs for horticultural and environmental guidance. This connection to the growers, along with the regulatory link, has accounted for the widespread adoption of BMPs by the Massachusetts cranberry industry. The CCCGA has reinforced the need for farm planning and BMP adoption with its members by issuing grower advisories highlighting the advantages of these activities (CCCGA, 2003a, 2003b, 2003c). Local NRCS estimates that 75% to 80% of Massachusetts cranberry growers have current conservation farm plans that include BMP implementation (L. Rinta, personal communication).

## Cranberry nutrient management

As part of the BMP development process, management practices were identified for which knowledge was insufficient for the definition of extensive BMPs. A primary area requiring additional research and synthesis of recommendations was cranberry nutrient management. A mineral nutrition

working group consisting of cranberry research and extension professionals from the growing regions of North America has taken on the challenge of developing nutrient management guidelines for nitrogen (N) and phosphorus (P) use in cranberry production, initiating research projects, and developing publications providing guidance to growers (Hart, 2000; Roper et al., 2004).

Nitrogen management is critical in cranberry crop production. However, the N requirement is modest, between 22 and 67 kg·ha<sup>-1</sup> per year, and high N rates, particularly early in the season, can lead to an abundance of vegetative production at the expense of fruit production (Davenport, 1996; Davenport and Vorsa, 1999; DeMoranville, 1992). Like most ericaceous plants, cranberries preferentially use ammonium N. Although limited quantities of nitrate can be taken up by the plant, nitrate reductase activity in cranberry is extremely limited (Smith, 1993). In addition, populations of nitrifying bacteria are low in acidic cranberry soils (Davenport and DeMoranville, 2004). BMP recommendations for N management include monitoring soil temperature for planning applications, using moderate rates and split applications, maintaining acidic soil pH, and monitoring plant status by evaluating growth and tissue test N (DeMoranville et al., 2000; Hart, 2000).

Phosphorus management recommendations for cranberry were published (Roper et al., 2004) based on completed research studies regarding rates, timing, and soil P testing (Davenport et al., 1997; DeMoranville and Davenport, 1997). These studies identified 22 kg·ha<sup>-1</sup> as a sufficient rate for annual P use in cranberry but did not determine lower effective rates.

The soil testing research identified soil iron as an interfering factor when using the Bray test in cranberry soils but did not identify an alternative test. Current research continues to address these issues.

The effect on water quality from N and P use in cranberry production is a concern in Southeastern Massachusetts where many cranberry farms are located. While nutrient inputs are fairly modest, cranberry production is very water intensive. Cranberry production requires 5 to 10 acre-ft of water from all sources. Production practices, particularly those involving flooding of the beds, can lead to discharges of bog waters through surface water flow directly to streams, ponds or lakes. Recently, a research project to study the output of N and P from cranberry bogs was completed. As part of that project, cranberry growers identified three bog pairs with similar soil characteristics and management within pairs. They agreed to voluntarily reduce P input onto one bog in each pair so that the impact on flood discharge water quality could be evaluated. When N and P load in source waters was compared to that in water leaving the cranberry bogs at these six sites, the bogs were net importers of N and net exporters of P (Table 1). At these sites, P export ranged from >1% to 23% of that applied in fertilizer. At two of the sites (sites 1 and 5), P fertilizer inputs were reduced by at least 35% by the end of the third year (Table 2). At those sites, P discharge declined substantially after two years of reduced rates (Table 1, sites 1 and 5, compare 2002 to 2004). In fact, the bog became a net P importer at site 5. During the period of this study, P fertilizer reduction had no adverse effect on crop yield. Mean yield for the two seasons prior to planned P

**Table 1. Net discharge of phosphorus (P) and nitrogen (N) in cranberry bog water. Net discharge equals gross discharge minus nutrient load in source water.**

Site no. <sup>y</sup>	Total P (kg·ha <sup>-1</sup> per year) <sup>z</sup>			Total N (kg·ha <sup>-1</sup> per year)		
	2002	2003	2004	2002	2003	2004
1	1.29	2.59	0.60	---	-7.24	-9.56
2	3.30	3.62	2.43	---	-7.04	-15.34
3	3.44	1.58	1.03	---	-0.16	-1.92
4	4.15	2.76	4.30	---	-5.80	0.55
5	0.01	0.06	-1.24	---	-9.13	-25.14
6	0.27	-0.63	0.19	---	-15.91	-15.98

<sup>z</sup>1 kg·ha<sup>-1</sup> = 0.8922 lb/acre.

<sup>y</sup>Sites 1 and 5 implemented planned P fertilizer reductions beginning in 2003 (Table 2).

<sup>x</sup>Data not collected.

Table 2. Fertilizer phosphorus (P) and nitrogen (N) inputs applied to cranberry bog study sites from Table 1. Study protocol called for up to 50% P reduction (from 2002 rate) in 2003–04 at sites 1, 3, and 5.

Site no.	Fertilizer P (kg·ha <sup>-1</sup> per year) <sup>z,y</sup>			Fertilizer N (kg·ha <sup>-1</sup> per year)		
	2002	2003	2004	2002	2003	2004
1	20.0	16.1	6.3	35.1	36.4	33.2
2	27.9	25.0	19.4	44.2	36.4	40.7
3	22.4	18.1	19.6	38.7	42.0	29.6
4	22.4	20.6	18.8	42.0	42.0	30.3
5	32.2	22.2	23.7	68.6	38.0	61.1
6	39.8	36.3	31.4	60.6	44.8	53.9

<sup>z</sup>1 kg·ha<sup>-1</sup> = 0.8922 lb/acre.

<sup>y</sup>Extension recommendations for non-deficient cranberry beds call for up to 22 kg·ha<sup>-1</sup> P and 22–67 kg·ha<sup>-1</sup> N per year.

Table 3. Yield at cranberry bog sites from Tables 1 and 2. Planned fertilizer reductions (Table 2) were made in 2003–04.

Site no.	Mean yield (kg·ha <sup>-1</sup> ) <sup>z</sup>	
	2001–02	2003–04
1	12,432	16,352
2	14,448	17,696
3	14,672	14,896
4	12,096	11,312
5	20,944	19,936
6 <sup>y</sup>	16,016	23,968

<sup>z</sup>1 kg·ha<sup>-1</sup> = 0.8922 lb/acre = 0.008922 barrel/acre.

<sup>y</sup>Crop at this site was severely reduced in 2001 due to insect infestation.

reduction was not different from that for the 2 years of modified management (Table 3).

Data indicated that flood discharges were generally the source for the majority of P output from the bog systems. Most cranberry bogs are flooded for harvest and for winter protection. A previous study of a cranberry bog system (Howes and Teal, 1995) also showed that N and P discharge from cranberry bogs was primarily associated with flooding. Therefore, nutrient loads associated with flooding events were more closely examined. Figure 2 shows a typical harvest flood in which the water was held only briefly prior to discharge. Note that the water held on the bog during harvest (day 1 and 2) had an increased nutrient load compared to that in the incoming water and that this load was somewhat reduced by the time of discharge on day 2.5 (Fig. 2). The early flood nutrient increase was likely due to particulates becoming suspended in the water during agitation by the harvest equipment while decreased P concentration in the discharge was likely due to particles settling or being filtered by the outlet flume.

Figure 3 shows data from a harvest flood at site 1 in 2002

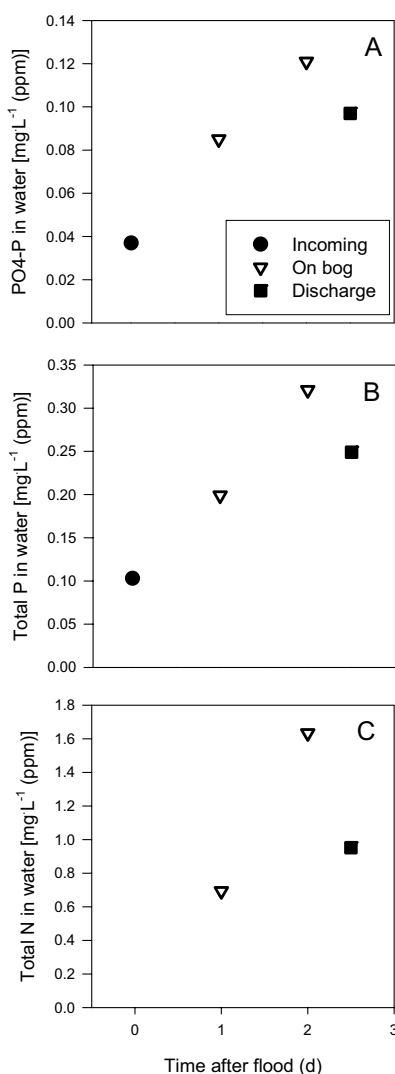


Fig. 2. (A) Inorganic phosphate (PO<sub>4</sub>-P), (B) total phosphorus (P), and (C) total nitrogen (N) concentration in cranberry-bog harvest flood water sampled from site 5 in 2003. Flood release occurred on day 2.5. Data points represent single samples; all project data was collected according to a quality assurance plan that required that duplicate nutrient samples not exceed 20% relative percent difference.

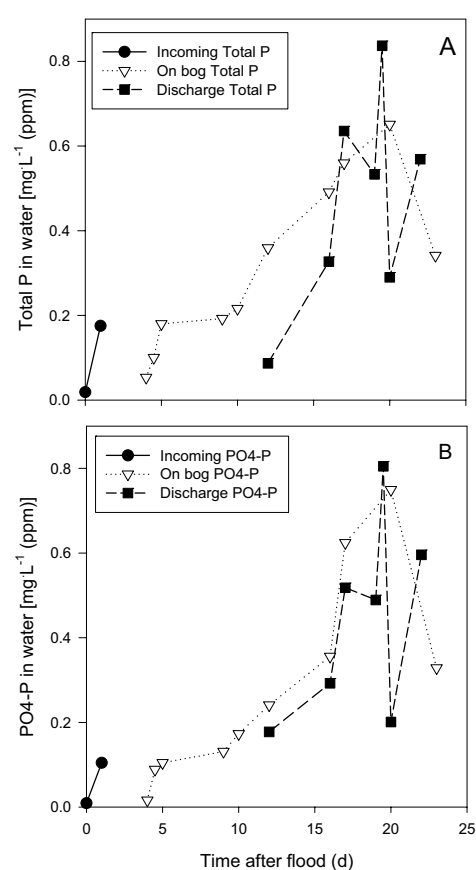


Fig. 3. (A) Total phosphorus (P) and (B) phosphate (PO<sub>4</sub>-P) concentration in cranberry-bog harvest flood water sampled from site 1 in 2002. Flood discharge began on day 12. Data points represent single samples, all project data was collected according to a quality assurance plan that required that duplicate nutrient samples not exceed 20% relative percent difference.



where harvest flood management was modified to test two potential BMP recommendations: 1) P discharge could be reduced if the flood was retained for an extended period after harvester agitation to allow settling of particles; and 2) slowly releasing the flood could reduce P discharge by limiting “churning” of particles into the discharge water. By day 12 of flood retention, total P concentration in the water held over the vines was increasing (Fig. 3A), presumably due to the development of chemically reducing soil conditions that led to the release of phosphate bound to iron and aluminum in the soil (Fig. 3B). As the P in the flood water increased, so too did P in the discharge. This response was seen at several of the study sites if the harvest flood was retained beyond 10–12 d. Slowly releasing the flood did initially result in less total P in the discharge water compared to that over the flooded vines (compare “on bog” to “discharge” on day 12 and 16, Fig. 3A), but this benefit diminished as the last of the water was released. Since holding the flood for an extended period led to increased phosphate in the flood water, slow flood discharge can be counterproductive if extended beyond 10–12 d. In prolonged flood discharge, gains due to particulate organic P settling were offset by increased dissolved P in the flood discharge (compare “discharge” on day 12 and 17 in Fig. 3), indicating that a recommendation to discharge a flood slowly to reduce P output will need to include a definition of the longest effective discharge period (i.e., the time that results in the greatest settling of particulates with minimized movement of phosphate into the flood water). These data point out the need to field test potential nutrient management BMP recommendations.

As a result of current research projects, BMP development for cranberry nutrient management in the near future will focus on P rate reductions and flood management recommendations. Grower involvement in the research and BMP development process will continue to be essential for adoption of those cranberry management practices identified as sustainable for both production and environmental stewardship.

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