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Cranberry Production: A Guide for Massachusetts - Summary Edition

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EXECUTIVE SUMMARY: CP-08
CRANBERRY PRODUCTION: A GUIDE FOR MASSACHUSETTS

Preface

The cranberry industry is important economically and aesthetically to the Commonwealth of Massachusetts. Although cranberry growers currently cultivate ca. 14,000 acres, they own more than 60,000 acres of land in the state. Earnings from the 2007 harvest were valued at ca. 64.6 million dollars for 1.49 million barrels (one barrel =100 pounds of fruit) produced from 13,700 acres. The Massachusetts industry accounted for 23% of the total domestic production (6.4 million barrels) in 2007. Massachusetts and Wisconsin combine to produce over three-fourths of all U.S. cranberries.

Recently, a comprehensive resource document was published through the University entitled, Cranberry Production: A Guide for Massachusetts (CP-08). This 170+ page document is intended for growers or other parties interested in the details of common operations of commercial cranberry production. An extensive bibliography of cranberry research and extension publications is available in CP-08.

This Executive Summary of CP-08 is intended for interested parties, such as public officials, conservation commissioners, and real estate agents, who may only be interested in a brief description of cranberry management practices. The Executive Summary document contains several selected sections from the CP-08 publication. Those interested in more detail may wish to obtain a copy of the full-sized manual through the University of Massachusetts Cranberry Station. Other Extension publications of interest may include:

- Best Management Practices Guide
- Cranberry Chart Book-Management Guide
- Neighbor-to-neighbor brochure

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Introduction

The large American cranberry (*Vaccinium macrocarpon*) is a native American wetland fruit. Its vines thrive on the special combination of soils and hydrology found in the wetlands environment. Natural bogs evolved from glacial deposits that left kettle holes lined with impermeable materials. These kettle bogs became filled with water and decaying matter, creating the ideal environment for cranberries.

Cranberry growers typically own 3-5 acres of uplands or surrounding lands for every acre of producing cranberry bog that they manage. This means Massachusetts cranberry growers are the stewards for more than 60,000 acres of open space. This open space is an important ingredient to the regional character that is so appealing to many residents of Southeastern Massachusetts. The vast cranberry system offers refuge for many plant and animal species. Like all wetlands, the cranberry wetlands system filters groundwater, recharges aquifers, and controls floods by retaining storm water runoff.

Production Statistics. Most of the world's cranberries are produced in the United States on approximately 39,000 acres. The traditional yield unit is the barrel, which is equivalent to 100 pounds. In 2007, the U.S. produced 6.395 million barrels of cranberries. The predominant U.S. production areas are Wisconsin, Massachusetts, New Jersey, Oregon, and Washington. Cranberries are also commercially cultivated in other countries including Canada (ca. 10,000 acres) and Chile (ca. 1,000 acres). Fruit produced outside of the U.S. accounted for 19% of the world's production in 2006.

The cranberry industry is very important economically to Massachusetts, particularly in the southeastern region of the state. Cranberry production is the largest agricultural food commodity in Massachusetts. Cranberries accounted for approximately $75 million in cash farm receipts in the state in 2007.

Payment for crops. Cranberry growers usually enter into a multi-year contract with a company (handler) that will agree to buy their fruit. Growers are paid for their crop in terms of number of barrels. The price per barrel can be paid out to the grower in a variety of ways, depending on the contract. They can receive additional payments if their fruit has good red color (anthocyanin content) and/or excellent quality. Production efficiency is related to the number of barrels produced per acre. Harvest success is usually gauged upon the year-to-year comparison of the number of barrels produced from each particular farm.

Botanical Description. Cranberry belongs to the Ericaceae or heath family, to which plants in the genera *Rhododendron* and *Kalmia* (laurels) also belong. Members of this family prefer acidic soils (pH 4-5) that are moist, well drained and high in organic matter (3-15%). The American or large-fruited cranberry, *V. macrocarpon*, is the most commonly cultivated cranberry. Its native range extends from Maine and the Atlantic Provinces to northern Illinois, and south to Tennessee (at high elevations).

Diagram of the principle parts of the cranberry plant including vegetative uprights, uprights with flowers and fruits, and the woody runner to which the uprights are attached.

The cultivated cranberry is a low-growing, trailing, woody, broadleaf, non-deciduous vine. When the vines successfully colonize an area, they form a thick, continuous mat over the entire surface of a cultivated bed. They are reddish-brown during the dormant season (October through April) and dark green during the growing season. Short vertical branches two to eight inches high, called uprights, are produced on the runners and grow for several years. The cranberry root system is made up of very fine, fibrous roots that develop within the upper three to six inches of soil. Cranberry roots do not have root hairs.

Flowering buds are formed at the tips of the upright. The flowering period begins during the middle of June and lasts from three to six weeks. The first berries are visible in late June or early

July. The curve of the slender flower stem with the ready-to-open blossom is said to resemble the neck and head of a crane, hence suggesting the name, 'craneberry', which is now shortened to cranberry.

Berries are predominantly produced on the uprights. Berries (and flowers) mature from the 'bottom up', so the largest fruits will be found towards the bottom of the upright and the smallest fruits will be towards the top. Berries reach maturity about 80 days after full bloom. Harvesting typically begins around mid-September and continues through early November.

Basic Farm Features. Cranberry bogs in Massachusetts range from less than one acre to more than one hundred acres in size. They tend to be very irregular in shape since they typically follow the contours of kettle hole formations or abandoned iron ore bogs. The farm area is typically the lowest part of the landscape. It is comprised of perimeter and interior drainage ditches and dikes that can readily contain water. Due to the periodic need of flooding, farms are always associated with nearby water bodies such as ponds, rivers, or man-made reservoirs. Irrigation systems consisting of flood gates, flumes, lift pumps, piping, and sprinkler heads are critical components of the working farm. These structures help to flood the beds, impound water, manipulate the water table, and provide drainage.

Sprinkler systems are used for irrigation, evaporative cooling, frost protection, and chemigation (application of chemicals through the irrigation system). Irrigation systems typically consist of buried lateral pipes (PVC or metal) with risers attached at various spacings. Growers typically employ impact-style sprinkler heads. In the past few years, growers have been experimenting with pop-up heads, similar to those used in lawns and golf courses. Almost all growers have adopted the use of sprinklers. Sprinkler systems conserve water and perform the desired tasks much faster than flooding (the historical practice).

Cranberry bog soil is unique because it consists of alternating layers of sand and organic matter. Dead leaves accumulate over the course of time and sand is placed on top of the organic material every two to five years to encourage upright production and maintain productivity. In contrast to regular agricultural soils, cranberry bog soil needs no tilling, remains undisturbed over time, and little mixing of sand and organic matter takes place. Thus, alternating layers of sand and organic matter accumulate producing a 'layer-cake effect'.

Description of Bogs in Massachusetts

Carolyn DeMoranville

Peat-based Bogs. Bogs may form in any location where water collects and organic matter (OM) accumulates. In Massachusetts, bogs formed following the end of the last Ice Age as the glacier that reached as far south as Long Island and Nantucket Island melted and receded. Sometimes blocks of ice that had broken from the glacier were left on or buried in the outwash. As large blocks melted, ponds were created. As smaller blocks melted, pits called kettle holes were formed. Fine-grained sediments in these holes stabilized the water table and aquatic plants began to grow in from the edges, eventually filling the kettle holes. Over time, plants died, decaying plants accumulated, organic sediment layers formed, and a kettle-hole bog was created. Such bogs may consist of an entirely filled kettle hole or a partially filled kettle hole. The later would have the appearance of a bog adjacent to a pond.

When rapid melting of the glacier occurred, outwash channels were cut into the outwash plain. Later, as flow through the channels slowed, vegetation grew along the banks. Over time, plants filled in the channel creating a wetland. These wetlands were of two morphologies, those with streams running through them that ended in an adjacent pond and those where the stream continued on to another wetland and eventually to a pond or the sea. Many Massachusetts bogs are of this type, although this may be hard to recognize due to the construction of adjacent reservoirs built by cranberry growers and the construction of bypass canals to remove the stream flow from within the bog. 'Flow-through' bogs are those with the stream remaining within the bog.

Over many years, plants grew in these wetlands and kettle holes then died and decayed. Organic acids were released during decomposition and so the pH in the bog decreased. Oxygen was

limited in the sediment layers and so decomposition slowed as the sediment layer thickened. The deepest, most decomposed organic layers became sedimentary peat or muck, while the upper layers remained less decomposed fibrous peat.

What are now peat-based cranberry bogs in Massachusetts originated in these peatlands. Under these peat deposits lies an impervious layer that originated at the end of the last Ice Age. This impervious layer, or hardpan, makes it possible to flood these bogs for extended periods. This layer also serves to separate these bogs from the natural water table. Some cranberry bogs in Plymouth County are built on abandoned iron bogs, where the hardpan is a layer of iron oxide materials.

A series of test borings to determine the depth to hardpan in cranberry bogs were conducted by K. Deubert. He pushed half-inch metal tubes, eight feet in length, through the soil in small peat-based cranberry beds in the Sandy Neck Dunes in an attempt to find the depth of peat in the various parts of the beds. In areas of poor productivity, the hardpan was near the surface (less than 2 feet) or missing, while in the productive areas, the depth to hardpan averaged 7 feet. In this setting, the impermeable layer consisted of a yellowish-brown clay.

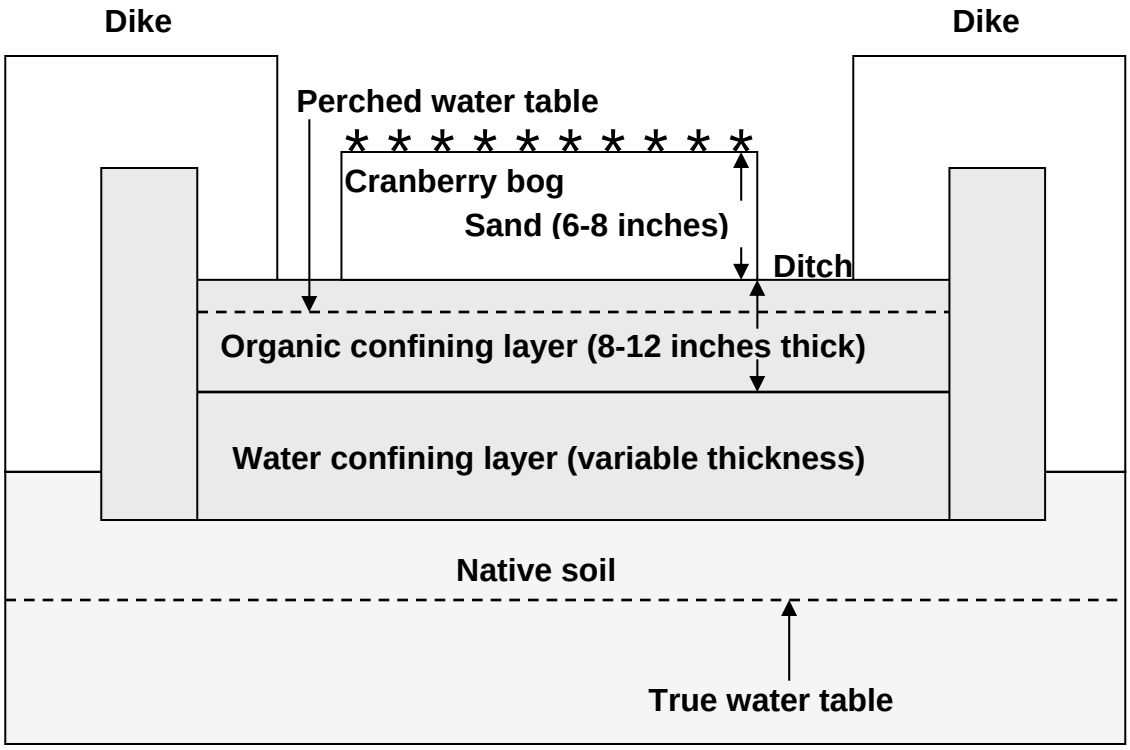
Beginning in the 1990s, the use of ground-penetrating radar (GPR) was implemented to estimate the depth of peat under many Massachusetts cranberry bogs. This device allows the study of bogs much deeper than the 8-foot depth limit of Deubert's study. The GPR method showed that bogs that developed in kettle holes or in outwash channels tend to have shallow layers of peat along the perimeter with substantial depth of peat near the bog centers. The GPR also showed the presence of the impermeable layer under these bogs.

Peat-based cranberry bogs differ from natural bogs in that the upper layers of natural vegetation have been removed, the soil has been modified by the addition of a sand layer, and cranberry plants have been introduced. Not only are the cranberry plants separated from the natural groundwater table by an impervious layer, they are often also separated from the stagnant water in the underlying peat. Thus, cranberry bog soils are subject to desiccation as would be any other agricultural soil. This explains the need for extensive irrigation (0.5-2 acre-inch per week) during drought periods. While manipulation of ditch levels can move water into the upper soil layers, research has shown that during dry periods, the water table in the bed centers (furthest from the ditches) can drop below the ideal 18 inches and plants in the bed centers can suffer drought injury as a result.

Mineral Soil Bogs. Regulatory restrictions on development of new cranberry bogs in wetlands has resulted in a limitation on the sites where new bogs may be constructed. While renovation of existing wetland cranberry bogs is permitted, new acreage is restricted to non-traditional settings, typically uplands. As in the wetland bogs, an ample supply of good quality fresh water, adequate drainage of the bogs, and the ability to hold a flood to cover the cranberry vines are essential to successful cranberry production on mineral soils.

When bogs are constructed on mineral soils, the site is engineered to provide suitable hydrology and soil characteristics to mimic those in traditional wetland settings. Adapting the existing site hydrology to one that supports cranberry production may require manipulation of the water table, soil permeability, soil texture, and soil organic carbon content. The objective is to create a cranberry bog that can be managed using many of the same techniques used on peat-based bogs. In order to accomplish this objective, a slowly permeable subsoil layer (water confining layer) is placed so that a 'perched' water table is created at some distance above the true water table. An organic layer is placed above the confining layer with the sand planting medium on top.

Water confining layer. A continuous, confining layer of sufficient density and thickness to restrict water permeability is constructed below the root zone of the cranberry bog, extending beneath the drainage ditches and into the interior of the dikes. This layer is necessary to flood for winter protection and harvest, to hold soil moisture reserves in the summer, and to minimize leaching. Examples of this layer include compacted fine soils such as clay or relatively impermeable sub-soil such as dense basal glacial till, glacio-fluvial clays, or ironstone ('bog ore') hardpans that may occur naturally on site.



Cross-section of a cranberry bog constructed in mineral soil, not to scale. Organic and water confining layers create a perched water table. Diagram courtesy C. DeMoranville.

Organic confining layer. This layer is placed above the confining layer and is 12 or more inches thick with at least 5% organic carbon (8.5% OM). Its purpose is to confine fertilizers and pesticides within the bog and to facilitate water relations in the perched water table. The best choices for this layer are peat or muck (20% organic carbon). The next best choice is to amend low-organic soil with organic materials containing humus (peat, muck, organic ditch dredgings, renovation sediments, yard compost, decomposed wood waste). Organic debris, including material scalped from the bog surface during renovation, can be composted and re-used as organic liners on new bogs.

Planting medium. The root zone should consist of about 6 inches of coarse sand (>70% in the 0.5-2 mm particle size range) to insure adequate drainage and aeration.

Properties of Bog Soil. Cranberry bog soil, in commercial production, is a man-made substrate consisting primarily of sand. In the root zone of well-established Massachusetts cranberry bogs, OM makes up less than 3.5% of the soil; silt and clay combined may account for as much as another 3%; the remaining particles are sand. In these mature bogs, the soil is stratified or layered, with layers of almost pure sand alternating with organic layers composed of partially decomposed leaf litter and non-functional roots. This layering arises due to the common cultural practice of applying sand to the bogs periodically to improve vigor and control pests.

The stratification in the root zone of the cranberry bog has an impact on the movement of water in the bog soil. In tilled soils, OM is distributed throughout the soil profile and water tends to move almost entirely in a vertical direction. In stratified cranberry soils, water tends to move readily in a horizontal direction within the sand layers. This is of importance for maintaining soil moisture by manipulating the water level in the drainage ditches of the bog.

As mentioned previously, Massachusetts cranberry bog soil is approximately 95% sand (particles varying in size from 0.05 to 2.0 mm in diameter). In comparison to most agricultural soils, ideal cranberry soils are extremely acid (low pH). In an extensive study of cranberry bog soil pH in 1960, scientists found that the average pH was 4.4 (range 3.3 to 5.5). When those sites were re-examined in 1990, the average soil pH was 4.6 (range 3.9 to 5.9). In

both surveys, more than 85% of the sites had soil pH between 4 and 5. Soil pH tends to be lower in well-established bogs. The naturally low soil pH in Massachusetts cranberry bogs is maintained in part by the application of ammonium fertilizers and in part due to low alkalinity in local irrigation water sources.

Soil core showing the alternating layers of sand and organic matter typical of a commercial cranberry farm. Photo courtesy H. Sandler.

Soils have the ability to hold positively charged elements (cations) due to the presence of negative charges on the surface of soil particles. This property is reported as cation exchange capacity (CEC). The negative charges that make up CEC are present on clay and on organic particles in the soil. In cranberry soil, virtually all of the CEC is due to OM. For this reason, mineral soil bogs and other sandy bogs (e.g., recently renovated bogs) have little ability to hold cations such as potassium, magnesium, and calcium. Well-established bogs with an average of 3.5% OM have limited CEC.

As the only active soil constituent, organic matter has a considerable effect on the chemistry and physics of the cranberry bog soil. Decomposed organic material absorbs large quantities of water and slows the flow of water through the soil. In addition to providing sites for holding nutrient elements, OM also traps residues of organic chemicals applied to the bog and supports the growth of soil microorganisms.

The low OM concentration in cranberry bog soils in Massachusetts has advantages and disadvantages when it comes to providing the proper nutritional support for the cranberry plants. Because CEC is low, fertilizer cations are poorly held leading to the need for frequent applications of low rates of fertilizer. However, OM also provides nitrogen though its breakdown by soil microorganisms (mineralization). When cranberry soils have high OM in the root zone (for example the highly decomposed peat soils in Washington), too much nitrogen is often released, leading to excess vegetative growth of the cranberry plants and poor crops. In low OM soils, the grower can supplement the limited amount of nitrogen released by adding nitrogen fertilizer.

Activities on a Cranberry Farm

Hilary A. Sandler

Recent census data indicated that people are moving from urban areas to more rural areas. This is certainly true for the southeastern region of Massachusetts. More people are living in proximity to working cranberry farms and, consequently, have many questions concerning the regular activities relating to cranberry production. This chapter describes many of the management activities that occur on commercial cranberry farms throughout any given year. The activities are presented by season to establish a general chronology, but the reader should bear in mind that some practices may overlap from one season to another.

SPRING

Removal of the Winter Flood. The winter flood is usually drained from the vine canopy anytime from mid-February through mid-March. The vines will slowly break dormancy and begin to grow by mid-April.

Late Water Floods. If growers opt to use this flooding practice, the water will be pumped onto the farm by mid-April and will stay on for at least 30 days (perhaps longer, depending on location). Late water floods provide pest management benefits without the use of chemicals.

Frost Protection. Sprinkler systems are used to protect emerging buds from frost damage. Protecting buds from injury may require growers to run their sprinklers systems from early morning until just past sunrise. Protecting buds from frost injury usually starts in mid-April. Buds are protected at 18°F in early spring but

must be protected from any temperature below 30°F by late May. Frost alerts traditionally run through Memorial Day but may still occur as late as early July.

Weed Management. Preemergence herbicides are applied from late March through mid-June. Herbicides are typically applied by ground rig applicators but newer compounds can be injected through the irrigation system (chemigation). Short (24-48 hr) floods may be held in mid-May for pest management (black-headed fireworm and dodder control).

Fertilizers. Fertilizers can be applied when the soil temperatures warm to at least 50°F, so growers may be applying fertilizer any time from mid-May through late August. Depending on the vines and yield, applications may be made in the fall. Fertilizer may be applied through the irrigation system, by hand-held rotary spreaders, ground rigs, or by helicopter.

Planting New Vines. The best window to plant vines is during the month of May. However, other factors may push the planting date later into the season and perhaps even into the fall. Newly planted vines require frequent irrigation (ca. twice per day for several weeks) until new roots are established.

SUMMER

Irrigation. Cranberries require supplemental water when nature does not provide enough rainfall. Sprinkler systems will be running in the early morning or late at night to minimize loss due to evaporation. On very hot days, growers may opt to run the sprinklers during mid-day to cool the fruit and vines.

Bee Hives. Bees are used to assist in cross-pollination of cranberry flowers. Honeybee hives and bumblebee hives may be present on the farm during June through mid-July.

Scouting. Sweep netting is used to monitor insect populations from May through August. Flowers are counted in June to help time fungicide applications. Pheromone traps are set out by early June and monitored throughout the summer. Berries are inspected July through August for cranberry fruitworm eggs.

Pesticide Applications. Most pesticide applications are made from May through August. The chemicals are used to prevent serious damage to the crop by various insects and fungal pathogens. Most chemical applications are made through the irrigation system.

FALL

Harvest. Depending on weather conditions, harvest begins in September and lasts into early November. Fruit may be dry harvested and sold for fresh market (higher dollar value) or harvested in water and sold as processed fruit. During water harvest, the berries float and are corralled using floating booms. The berries are removed from the flood via a conveyor or vacuum hose. More than 90% of the cranberries in Massachusetts are wet harvested. Due to fruit rot pressure, all wet-harvested berries from Massachusetts must be sold as processed fruit.

Ditch Cleaning. Ditches are needed for moving water through the farm system. Growers will clean their ditches by hand or with machines at various times throughout the season. Mud piles can be removed with a small ATV or by helicopter.

WINTER

Sanding. The preferred method of sand application is on the ice of a flooded bog during the winter months (ice sanding). This prevents vine injury caused by sanding equipment operating on the bog (dry sanding). When the ice melts, the sand sinks slowly to the surface of the bog.

Winter Flood. The cranberry plant is dormant during the winter. The vines become reddish in color after harvest and remain that way until late March-early April. Growers maintain a flood on their cranberry farms during the winter months to prevent winterkill. Winterkill, or winter injury, occurs when the following conditions happen: 1) the root zone is frozen; 2) sub-freezing temperatures prevail day and night; and/or 3) winds of moderate velocity are present. On an unflooded bog, the plant would not be able to absorb water through the roots, and transpiration losses increase. The plants would dry out as if they were in drought conditions.

Monitoring for Oxygen Deficiency. Growers monitor their floods during the winter months to assess oxygen levels. During the winter, vines need oxygen to survive even though they are dormant. Oxygen is made available through photosynthesis, a reaction that is driven by

sunlight. Oxygen levels can be especially critical if the ice on the bog becomes cloudy, or if significant snowfall on top of the ice limits sunshine penetration. When the critical level is reached, water is removed from beneath the ice to allow air to reach the plants.

Equipment Maintenance and Construction. Since cranberries are such a small industry, many equipment companies do not cater to the mechanical needs of cranberry growers. Growers must retrofit and/or manufacture many of the machines and much of the equipment that they use on the farm. Growers use the winter months to maintain or construct equipment.

OTHER ACTIVITIES

Sign Posting. Growers are required to post signs around their property prior to the application of certain pesticides. Sign posting requirements change periodically.

Pumps. Cranberry growers run pumps to operate their irrigation system at various times throughout the year. Most pumps are housed in small sheds near the water resource. The sheds protect the pump from weather and vandalism and help to minimize noise.

Trucks. Large trucks may drive through cranberry properties at various times during the year, but are especially common during harvest and sanding operations.

Regulations of Pesticide Use and Applicator Licenses. All pesticides must be tested and registered for use by the U.S. Environmental Protection Agency and the Commonwealth of Massachusetts. Commercial users of pesticides must be licensed or certified by the Massachusetts Pesticide Bureau. Licensed applicators must attend educational programs to maintain their certifications or licenses. All certified and licensed applicators must report their pesticide usage annually to the Massachusetts Pesticide Bureau.

Water Use in Cranberry Production

Carolyn DeMoranville, Dan Barnett, Jack Heywood, Peter Jeranyama, and Brian Wick

Water is the single most important resource for growing cranberries. Growers rely on a plentiful supply of clean water for the production of their crop. Cranberry growers manage water on their bogs to ensure sufficient moisture and adequate drainage for optimum plant growth. Water management practices on cranberry bogs differ from those used for other forms of agriculture because of the variety of ways that water is used in cranberry culture. Water is used for disease and insect control, frost and heat protection, sanding, harvesting, and protection from winter desiccation and cold injury.

Because of the periodic need for sizable amounts of water, impoundment of water adjacent to the bogs is a normal farming practice in cranberry production. Many cranberry growers have constructed reservoirs adjacent to their bogs to store the water needed for seasonal flooding and irrigation needs.

In addition to storage ponds and sumps, components of a typical water management system for a cranberry bog includes irrigation systems, wells, flood gates and flumes, lift pumps, and drainage ditches and pipes. Growers may construct bypass canals to reroute water that normally flows through the bog. This practice is designed to protect water quality during fertilizer or pesticide applications. Such canals may be part of a tailwater recovery system as well, enhancing water conservation.

Cranberry growers often re-use water, recapturing it through the use of tailwater recovery systems that move water from the bog back to a storage reservoir. In some instances, water is also recycled among growers, particularly at harvest. Therefore, water uses on cranberry bogs are not always consumptive. Newly established bogs, however, do require more irrigation to satisfy the needs of growing vines. Because cranberry culture typically is carried out in moist areas such as wetlands and marshes, irrigation needs are limited and comparatively small.

In a study of evapotranspiration potential in a Massachusetts cranberry bog during the growing season (May through September), it was found that on average, the water demand of the cranberry plants was one inch per week. However, on a weekly basis, demand varied from 0.5 inch (early and late season) and as much as 2 inches per week during the hottest

days in mid-summer. Cranberries can use up to 0.20-0.25 acre-inch of water per day during the hottest, driest, windiest weather. This would amount to one inch in four to five days under the most severe conditions. When rainfall is not sufficient to meet these demands, supplemental irrigation water is applied using sprinklers.

Table 1. Estimated water use in cranberry production in acre-feet. Data from a study of 4 bog systems from 2002-2004. Bogs in the study were fairly well in-grade.

Management Practice	Peat-based bogs	Mineral soil bogs
Winter flood	1.6	1.5
2nd flood (as needed)	0.9	0.8
Frost protection*	0.7	1.1
Chemigation	0.1	0.1
Irrigation	0.5	0.9
Water harvest	1.6	1.6
Total	**5.4**	**6.0**

*Mineral soil bogs tend to be planted with cultivars requiring more frost protection in the spring.
Avg. yearly rainfall (1971-2000) -- 3.9 feet

Table 1 shows estimates of the seasonal water (in acre-feet) needed for cranberry production in peat-based and mineral soil cranberry bogs based on a limited study at 4 sites. As a general rule, growers plan for up to 10 acre-feet of water storage capacity to meet all production, harvesting, and flooding needs even in drought years. The actual required capacity will vary depending on the rate of recharge of the water supply, the extent of water recapture and reuse, and the efficiency of the bog system. With the implementation of appropriate Best Management Practices (BMP), water needs may be reduced substantially.

Water Management Act. The Water Management Act (WMA), M.G.L. Chapter 21G, was enacted in 1985 for the purpose of managing water resources in Massachusetts. The act required consumptive use of water beyond a threshold amount (100,000 gal/day or 9 million gallons within a three-month period) to be registered with the MA Department of Environmental Protection (DEP). Since the only nominal flux in water use attributed to cranberry growing, the DEP regulated the cranberry industry as 'virtually non-consumptive' in order that cranberry growers would be provided the protections of the WMA in regards to rights to use water.

For cranberry growers, rights to water are determined by the following four factors:

1) Registration of historic use (baseline) in 1988 based on previous 5-year water use. Registrations are renewed every 10 years.

2) The threshold volume of water - for cranberries, this is calculated on an acreage basis so that the threshold for cranberries is 4.66 acres based on water use of 10 acre-feet per year. This threshold is increased 9.33 acres for water-conserving 'new style' bogs that meet certain criteria including level surface, tailwater recovery, water control and irrigation designed to Natural Resource Conservation Service (NRCS) specifications, and a farm plan in place. If a grower's acreage within a watershed area remains within these thresholds, no registration or permit is required.

3) Addition of acres to a registration or permit based on conservation credits awarded for the implementation of practices that conserve water.

4) Growers may apply for permits for acres that are not covered under the three items above or for new acres.

Growers report their permitted and registered water use annually and pay an annual fee to maintain the registration or permit.

Water Control Structures. Commercial cranberry management requires the ability to manipulate water during the course of the season. Water control structures are essential to a successful cranberry operation. Among these structures are spillways, and conduits used to temporarily divert water flow, dikes and flumes, and structures fitting the more traditional definition of a dam used to permanently detain water, creating the reservoirs required in the bog system.

Activities that rely on diking systems and water control structures include flooding the beds, impounding water, manipulation of the water table in the bed, and drainage functions. Dikes are also used to separate the cranberry beds into manageable units for flood harvest.

Flumes are water control structures usually constructed of steel, aluminum, or concrete that are installed in a dike to convey water, control the direction of flow, or maintain a required water surface elevation. In cranberry systems,

the primary purpose of the flume is to control discharge, distribution, delivery, or direction of water flow in open channels (ditches, canals) or on the cranberry beds. They are also used for water quality control, holding back sediment and impounding water following pesticide applications.

Proper soil drainage results in healthy vines that reduce the incidence of diseases such as root rot and the need for additional fungicide applications. Proper drainage also improves fertilizer use efficiency resulting in lower fertilizer inputs. Waterlogged soils lead to a poorly aerated root zone and limit the plants' ability to acquire nutrients from the soil. In addition, saturated soil conditions can limit the ability of the cranberry plant to retain fruit.

The drainage system should have the capacity to carry water away from the bog and regulate the water table level as management needs dictate. Cranberry drainage systems may include ditches, subsurface tiles, pumping systems, ponds, sumps, and tailwater recovery.

Sprinkler systems. A sprinkler system is a collection of component devices that, powered by a pump, transports water from either groundwater or surface water (e.g., a small man-made reservoir, or a natural water body like a pond, stream or lake), projects that water into the air, and deposits it onto the surface of the ground. It consists of metal or plastic pipes, which are either horizontal (mains, submains, and laterals) or vertical (risers), and rotating sprinkler heads. Most often, the horizontal components of the cranberry sprinkler system are buried.

Since the 1980's, sprinkler system use has expanded and can be found on nearly every bog in Massachusetts today. As one grower has said, "It is probably our most important tool; we use it for almost everything." Three vital operations performed by sprinklers on cranberry bogs are: irrigation, frost protection, and chemigation.

Irrigation applies supplemental water for plant growth and berry development. Frost protection applies water to prevent damage to buds and berries when they are sensitive to temperatures below freezing. Chemigation is the process of applying chemicals by injecting them into the sprinkler system. This application method is commonly used with many pesticides and some fertilizers used on the bogs.

In order to be used effectively for all three purposes, well-performing cranberry irrigation systems are designed to apply a minimum of 0.1 inch per hour of water in a uniform pattern, meeting a standard of at least 85% uniformity. Recent testing has determined the configurations and sprinkler head types that can deliver this standard of performance on a cranberry bog. Some tested designs delivered >90% uniformity. Based on this research, pop-up heads, designed to be less labor-intensive, have been introduced on cranberry bogs. These heads also allow interchangable nozzles so that water delivery rates can be customized.

Irrigation. Plants maintain hydration and internal temperature through a process called transpiration in which water is moved from the soil, through the roots and shoots and out through pores in the leaves. As this process occurs, moisture is depleted from the soil. If it does not rain, this soil moisture must be replaced through irrigation. Cranberry growers monitor soil moisture in order to determine irrigation needs. Currently, two tools are being used for this purpose. These are water level floats and tensiometers.

In a typical cranberry bog, water can wick up through the soil to the roots of the plants from a water table depth of up to 18 inches. The water level float measures the depth of the water table and allows the grower to adjust that depth to maintain it between the 18-inch limit and 6 inches (the recommended depth to avoid waterlogging in the roots). Depth can be adjusted using the sprinklers or by moving water into the drainage system to water from beneath (subirrigation). Generally, a combination of the two is best.

A tensiometer is a sealed, water-filled tube with a vacuum gauge on the upper end and a porous ceramic tip on the lower end. As the soil around the tensiometer dries out, water is drawn from the tube through the ceramic tip. This creates a vacuum in the tube that can be read on the vacuum gauge. When the soil water is increased, through rainfall or irrigation, water enters the tube through the porous tip, lowering the gauge reading. Growers then schedule irrigation based on those readings.

Irrigation Automation. There has been a growing interest to automate irrigation systems in cranberry production. This technology allows growers to remotely start their irrigation pumps either through an internet or radio based

connection or they can have their pumps start automatically based on pre-set temperature thresholds (current use) or soil moisture level triggers (the focus of current and future research). Temperature triggering is important in frost protection, allowing growers to automatically start their pumps at the proper temperature to prevent a damaging frost event.

Reduced water usage provides the biggest savings with automated systems. Growers are also able to save on fuel, labor, employee safety, mileage and pump longevity.

Frost management. Cranberries, like many other temperate crops, are sensitive to below-freezing temperatures during the active growing season. Additionally, the bogs tend to be much colder than the surrounding lands on clear, calm nights.

Cold air drains from the adjacent high ground into the low-lying bogs on clear, calm nights. In addition, the enormous amount of vegetation present on a cranberry bog is extremely efficient at radiating heat under clear, calm skies -- a process known as radiational cooling. Due to these factors, it is not unusual for bog temperatures to be 10ºF colder than those of nearby non-bog areas. There may be as much as a 20ºF difference in some locations. Prediction of frost temperatures on a cranberry bog must account for these factors. Cranberry-specific predictive formulas are the basis of the frost warning service provided by the Cape Cod Cranberry Growers' Association to its members.

In addition to knowing how cold it will be on the bogs, cranberry growers also need to know the ability of the plants to tolerate freezing temperatures. Cranberry plants will tolerate temperatures slightly below freezing (30ºF) at any time in the season. The ability to tolerate temperatures lower than 30ºF without damage depends on the developmental stage of the cranberry plant.

Injury from cold temperatures can occur throughout the year. However, aside from winter, the most critical times for cold injury are the spring (when flower buds are sensitive to damage) and the fall (when fruit must be protected from freezing damage). Sprinkler irrigation is used to protect these tender tissues.

Preventing frost injury to the flower buds in the spring and to the fruit in the fall is arguably the single most important cultural practice in cranberry production. Frost injury is the only hazard in cranberry production where major crop loss can occur in as little as one hour and total crop loss in one night.

Chemigation. In addition to providing water to the cranberry vines, irrigation systems can be used to apply chemicals (pesticides and fertilizers). Chemigation is the term used to refer to the delivery of chemicals through an irrigation system. An irrigation system that is used for chemigation has several pieces of specialized equipment designed to provide safeguards during chemical applications. These include (but may not be limited to): vacuum relief valve, interlocking pressure switch hookup, injection port, positive displacement pump, interlocking pressure switch, and a back-flow prevention device. It is important that the grower use the appropriate equipment (e.g., screens, part-circle heads) to avoid treating sensitive areas like adjacent wetlands, water bodies, residential areas, public walking trails, the pump house, and roadways. The injection equipment must be in good working order and properly calibrated. This equipment must also meet the backflow prevention requirements of the U.S. Environmental Protection Agency and the Massachusetts Department of Environmental Protection.

Flood management. Cranberries are native to wetland habitats, requiring plentiful water supplies for their cultivation. During most of the season, well-drained soil is required for the development of healthy, functional cranberry root systems. However, evolution in a wetland setting has resulted in the ability of cranberry plants to withstand periodic flooding without harm. In fact, cranberry growers use flooding as a management tool to protect the plants from the cold, drying winds of winter, to harvest and remove fallen leaves, and to control pests. Flooding is so important in cranberry cultivation that bogs where flooding is not possible are no longer considered profitable.

Winter protection. Cranberry vines may be injured or killed by severe winter weather. Injury occurs when moisture lost from the vines due to wind and evaporation cannot be replaced due to freezing in the root zone. Such injury can occur within three days if the root zone is frozen to a depth of four inches, the air temperature is below freezing, and strong drying winds (10 mph or greater) occur. Injury is prevented by protecting the vines with a winter flood, generally about 1 foot deep.

The winter flood may be applied as early as December 1 and should remain on the bog as long as winterkill conditions are present or forecast. Once the flood freezes, removal of water from beneath the ice is standard practice. As wetland plants, cranberries can survive periods of poor oxygenation during flooded conditions. However, this survival comes at a cost to the plants. In order to minimize this stress, the flood is removed from beneath the ice so that oxygen can reach the vines.

Once the water has been removed, the ice may melt during a mid-winter thaw, leaving the vines exposed. Bogs may be left exposed as long as winterkill conditions are not present but must be reflooded when cold conditions return. Thus, in a typical Massachusetts winter, two winter floods are used. Floods are typically removed by March 15.

Late water floods. In the early days of cranberry growing in Massachusetts, growers used flooding for pest control. With the advent of readily available chemical pesticides, such cultural practices were generally abandoned. With the resurgence of interest in farming with minimal pesticide use since the 1990's, interest in these practices has increased.

In modern cranberry production, holding late water (LW) refers to the practice of withdrawing the winter flood in March then reflooding the bog in late April for the period of one month. Study of the use of LW in current cranberry production at the UMass Cranberry Station began in 1990 and has continued into the 21st century. This research has confirmed that LW can play an important role in the management of mites, spring caterpillars, cranberry fruitworm, and cranberry fruit rot disease.

Growers have reported that LW could be used 1 year in 3 without yield reduction, but more frequent use of LW led to elongated uprights with little growth from lateral buds. However, organic producers often use LW yearly since it is an excellent option for controlling many key pests without chemical inputs.

Other pest management floods. Flooding can be used to control insects or reduce weed populations under certain conditions (e.g., a 12-hour flood in mid-May can reduce populations of blossomworm and false armyworm). When such floods are used, the depth of flood and duration of flood are key. Failure to manage these floods properly may result in lack of control or damage to the plants and crop.

Harvest floods. The practice of harvesting cranberries in flood waters began in the late 1960's and now, approximately 90% of the crop is harvested this way. Cranberries harvested in water have limited keeping quality, so berries are cleaned, dried, and either frozen or processed as soon as possible after they are detached from the vines.

Water harvest is a two-stage process. A shallow flood is put onto the bog and 'beaters' move through the vines to knock the berries loose from the plants. The water level is then raised so that the fruit float free of the vine tips and can be moved to an edge of the bed. The berries are then removed from the water using pumps or elevators and into trucks for delivery to the handlers. During this activity, debris (stem pieces, tiny fruit, fallen leaves) that was stirred into the flood during harvest is sorted from the fruit.

Clean-up floods. Water supplies permitting, dry-picked cranberry bogs are flooded immediately after harvest to rehydrate the plants but primarily to remove debris from the field. Dead cranberry leaves, twigs, and any remaining berries float to the surface and are wind-driven to the bog edge where they can be skimmed from the flood for disposal.

Integrated Pest Management

Hilary A. Sandler

Integrated pest management (IPM) was formally introduced to the cranberry industry in 1983 through support of a scouting program by the University of Massachusetts-Amherst. In 2007, estimates indicate private consultants, company personnel, and individual growers combine to scout more than 80% of Massachusetts' cranberries (>10,000 acres). During the past 25 years, IPM has come to mean much more than simply sweep netting for insect pests and installing pheromone traps. Successful modern cranberry growers must have a working knowledge of insect biology, weed ecology, plant physiology, and disease life cycles. They

must know how to apply products with novel chemistry, have proficiency with several pesticide-delivery systems, integrate traditional cultural practices into modern horticulture, select new varieties, cost-effectively renovate out-dated farms, and adjust to the pressures stemming from the encroachment of urbanization.

IPM in Massachusetts. In Massachusetts cranberry production, IPM involves pest monitoring by using sweep nets, pheromone traps, and visual inspection. Cultural, chemical, and biological control strategies are used to develop a broad-based approach to controlling the most economically threatening pests. Cultural practices, such as flooding, the application of a thin layer of sand, and the use of resistant varieties, can reduce the severity of a pest problem. Pesticides remain a vital part of cranberry IPM programs, tempered by their compatibility with other control measures and their consistency with IPM philosophy. Although economical and logistical constraints often hamper wide-scale adoption, biological controls can be successfully utilized to manage pests in specific situations.

A basic cranberry IPM program consists of: sweep net sampling for 6-10 weeks; use of pheromone traps for *Sparganothis* fruitworm, cranberry girdler, and black-headed fireworm moths to aid in the timing of insecticide sprays; inspection of berries in July-August for cranberry fruitworm (CFW) eggs; scouting for dodder seedlings to time management strategies; use of soil and plant tissue analyses to determine fertilizer applications; determination of crop phenology for fungicide and insecticide applications; and mapping of weeds. Maintaining proper sanitation, judicious use of irrigation, planting resistant varieties, and use of various cultural techniques are additional examples of the many components found in an integrated management program for cranberries.

A grower survey conducted in 1999 indicated that 80% of Massachusetts cranberry growers identified themselves as frequent IPM practitioners and 16% as occasional practitioners. Most growers practiced IPM because they agreed with IPM philosophy (80%) and believed it had environmental benefits (73%). More than half of all growers who returned surveys were satisfied with its effectiveness and believed that IPM saved money. More than 90% agreed that the use of IPM could reduce pesticide residue in food and the environment and protect beneficial insects.

Using a sweep net to monitor for insects. Courtesy J. Mason.

Managing Cranberry Pests in Massachusetts. The principle challenge for managing pests in cranberries is simply the vast number of organisms that can cause damage to the vine or the fruit or both. Over 20 insects cause injury to the cranberry and three are direct fruit pests. Fruit rot is the most serious yield-limiting disease problem for Massachusetts and is associated with more than 10 causal agents. The large number of pathogens makes understanding the biology of this disease complex challenging. More than 80 species of weeds have been described by several cranberry researchers.

Although many other factors come into consideration, monitoring continues to be the tool by which growers collect information to determine when control decisions should be made. The use of sweep nets, pheromone traps and visual inspections are the main methods by which growers monitor insect populations. Action thresholds (AT) are available for many cranberry insects. The action threshold is a practical estimate of the economic threshold, the density at which control measures should be applied to prevent an increasing pest population from reaching the economic injury level. AT are typically based upon the average number of insects gathered at a particular sampling time. Examples of AT currently established for insect pests in cranberry production include: 4.5 cutworms, 4.5 cranberry weevils, and 18 spanworms per set of 25 sweeps.

AT do not exist for weed and disease pests. However, cranberry growers use phenology and other biological indicators to make pest management decisions. For example, weeds are prioritized based on their ability to spread, reduce yield, and susceptibility to control measures. Growers can then make decisions based on the assigned priority level. Weed mapping provides a historical catalogue of weed location, growth, and control over the years. For fruit rot management, growers make fungicide applications based on the percentage of open bloom as well as the keeping quality forecast (KQF). A strong relationship between various weather factors and the quality of fruit was documented in the late 1940's and the KQF procedure has been used to recommend fungicide applications ever since.

Chemical control is a critical component of pest management for cranberries. According to a recent summary report, 32 different pesticides were used in Massachusetts in 2003. These included seven fungicides, nine herbicides, and 16 insecticides. Chlorothalonil was the most widely used fungicide (in terms of producing acres that received at least one application), followed by the ethylenebisdithiocarbamate (EBDC) fungicides and the copper fungicides. For postemergence herbicides, glyphosate was the most widely used. The top two preemergence herbicides used were pronamide and dichlobenil. Diazinon was the most widely applied insecticide, followed by carbaryl and thiamethoxam.

Chemigation remains the delivery mechanism of choice for insecticides and fungicides in Massachusetts. However, cranberry growers are not reliant solely upon chemical pesticides. Other pest management options are biological control, pheromones, cultural management, and nutrient management. Many options require the application of a material, even if it is a biological product, such as beneficial nematodes, stomach poisons for caterpillars, or fungi for dodder control. The value of these options will be impacted not only by the products' efficacy but by the precision of the delivery system (e.g., chemigation, boom applicator) and cost.

Research Involving Development of New Pest Management Practices. Massachusetts cranberry industry and research scientists have good relationships with several chemical manufacturers as well as federal and state agencies that regulate and register new pesticides. These relationships are critical for the maintenance of currently registered compounds and well as future registrations. The cranberry industry has been very successful over the past decade in securing Specific and Crisis Exemptions (called Section 18 permits) from EPA. Section 18 permits enable growers to manage pests, such as cranberry weevil, dodder, and *Phytophthora cinnamomi*, with pesticides that have not yet completed the full EPA registration process. UMass Cranberry Station scientists have also obtained special local needs (SLN or 24c) labeling by conducting field trials to demonstrate efficacy, and subsequently working with state officials and registrants to incorporate the needed label changes.

Biological Products. *Bacillus thuringiensis* (B.t.) Products. Several products containing the bacterium, *Bacillus thuringiensis* (B.t.), have been registered to control lepidopteran pests of cranberries. These products are effective for control of the small larval (caterpillar) stages of cutworms, spanworms, and gypsy moths. These insect pests feed primarily on the leaves and buds of cranberry vines. B.t. products are very low in mammalian toxicity, specific to caterpillars and are not harmful to bees, wildlife, or beneficial insects. Growers can apply these products by air or chemigation. A recent survey indicated B.t. products were not frequently used by Massachusetts growers at the close of the 20th century. In fact, less than 10% of the respondents said they frequently used B.t. products while over 50% never used them.

Beneficial Nematodes. Biological control of black vine weevil, strawberry root weevil, and cranberry girdler is possible with use of beneficial nematodes. Nematodes are microscopic worms that parasitize and kill the larval (immature) stages of the above-mentioned cranberry pests. Beneficial nematodes target specific soil-inhabiting insects and should not be confused with the plant-parasitic nematodes, which are considered plant pathogens. Commercial availability of beneficial nematodes in the Northeast has been sporadic over the years and has reduced growers' ability to fully incorporate this strategy into standard IPM programs in Massachusetts.

Pathogens. *Alternaria destrucens* has been identified as a pathogen of dodder. The commercial availability of this mycoherbicide has been hampered by many production problems over the past 20 years. However in 2006, a manufacturer in Pennsylvania registered

the product, Smolder, for dodder control on cranberries in Massachusetts. Two formulations were registered: a preemergence granular and a postemergence wettable powder. Early results indicated that timing and application procedures need to be more clearly defined to maximize the performance of Smolder. *Colletrotrichum gloeosporioides* has also been identified as a pathogen of dodder, but no attempts have been made to commercialize this fungus.

Predators and Parasitoids. Published research on the potential use of parasites and parasitoids in cranberry production has focused on those infecting blackheaded fireworm (BHF) and CFW. Indigenous *Trichogramma sibericum* and, to a lesser extent, *T. minutum*, parasitize BHF eggs. Other species (a tachinid fly and several parasitic wasps) have been reared from BHF larvae. It has been noted that spiders will prey on BHF moths in field cages and on certain larvae of known cranberry pests.

Pheromone, Traps, and Mating Disruption. Research on the identification of sex pheromones for several cranberry pests has led to the incorporation and adoption of pheromone traps into standard IPM programs as monitoring tools. Traps are regularly used by more than half of the Massachusetts growers. Trap catches are monitored to determine the beginning of the moth flight or peak flight, after which sprays can then be timed.

Cultural Controls. Flooding. Cranberries evolved in a wetland setting and as such are able to withstand periodic flooding without sustaining injury. Growers use flooding for many management purposes including harvesting, frost protection, and winter protection. Holding a late water flood (i.e., reflooding the bog from mid-April to mid-May) can decrease the inoculum potential of the fruit rot fungi, cause a general reduction of annual weeds, suppress the spread of dewberries as well as suppress populations of certain insects and mites. Short spring floods can control BHF and dodder. Short (3 to 7 days) late summer floods can also be used for management of cranberry girdler, and longer floods (held for 3-4 weeks after harvest of the fruit) can reduce CFW emergence from hibernacula and suppress growth of dewberries.

Flooding, even if successful in reducing pest populations, carries a certain degree of risk to the vines. Until the early 2000's, flooding was primarily viewed through the lens of pest management only. Recent research has shown that flooding at different times of year for various lengths of time can impact the total nonstructural carbohydrate (TNSC) concentration of the vines. TNSC are the energy currency of the plant. Scientists report that TNSC were generally unaffected by late water floods, winter floods, and short-term spring floods. However, fall floods often resulted in decreased TNSC. Thus, the use of fall floods for pest management may carry the risk of yield reduction.

Sanding. Sanding, i.e., the application of a thin (0.5 to 2 inches) layer of sand on the production surface at 2 to 5 year intervals, is a common cultural practice in Massachusetts. Sanding can suppress fruit rot inoculum by burying infected leaves. Uniform applications of sand on a regular interval may reduce infestations of cranberry girdler and green spanworm. Research is on-going to determine the impact of sanding on CFW. Uniform sand applications can also inhibit emergence of dodder seedlings.

Sanding may not always have positive pest management outcomes. Sand as the surface layer may shorten herbicide longevity. Weed seeds of problematic plants can actually be introduced by the application of sand to the vines, increasing weed problems. Pest control (e.g., cranberry girdler, dodder) often depends on the deposition of uniform layers of sand. Growers will strive to apply a certain target depth, but recent research reported that the majority of measurements of sand depths actually deposited to the bog floor were much lower than the target depth.

Pruning. Pruning has indirect effects on pest populations but provides overall benefits to vine vigor and is an important cultural practice. Periodic pruning of vines improves aeration in the vine canopy and makes the environment unfavorable for fruit rot infection. Pruning is becoming more important to Massachusetts growers as local sand (available on-site) resources decrease and the cost of sand increases.

Other cultural practices. Sanitation (removal of leaf trash after harvest) is very important for minimizing fruit rot inoculum. Proper use of water is important to successful disease management and overall vine health. Improving drainage can help mitigate *Phytophthora* root rot. Proper maintenance and calibration of the sprinkler system and other equipment are important procedures that are practiced by

cranberry growers. Adequate pressure and clean nozzles are critical to ensure that proper amounts of chemicals are delivered to the target area.

The age of the planting can influence the pest complex that must be managed. Newly planted bogs typically need less fungicide and insect inputs; but should be intensively managed for weed pests. As vines age, additional pests may become established. Scouting should be performed routinely, and the process of integrating cultural, biological, and chemical controls becomes part of the regular pest management program.

Nutrient Management. Nutrient management is important when considering pest management in terms of the overall health of the plant. Sustainable nutrient practices have positive impacts on the environment as well as the plant. BMPs for nutrient management recommend that growers use moderate application of nitrogen fertilizers. From a pest management perspective, this practice helps in two ways. Using appropriate amounts of nitrogen limits overgrowth of vines that can encourage infection from fruit rot organisms. Secondly, lush vine growth can provide a suitable habitat for tipworm and flea beetle infestations. Growers can reduce pest problems through judicious use of fertilizer.

Conclusions. Integrated pest management implies more than the application of chemicals at the appropriate time against the correct target pest. Knowledge of the pest's life cycle, symptoms, as well as the conditions that predispose the cranberry to infection or infestation contributes to effective management of cranberry pest problems. Implementing cultural practices, such as flooding and sanding, broaden the baseline defense against crop loss due to pest pressures. Many biological control opportunities exist for cranberry pest management but logistical obstacles, such as problematic production and distribution of reliable commercial compounds, has prevented widespread incorporation of these strategies.

Cranberry Nutrition and Fertilizers

Carolyn DeMoranville

All plants require certain essential mineral elements in certain quantities to complete growth and development. These same nutrient elements are required by cranberry plants for the production of vegetation (new leaves and stems), roots, and fruit (crop). Cranberry plants get these nutrients from the soil, from water, or from fertilizers added to the bog. Additionally, as a perennial crop plant, cranberries have the capacity to store and reuse nutrients in old leaves, wood, and roots.

Cranberries are adapted through evolution for growth on acid, sandy soils. These soils have little nutrient content and the plants such as cranberries and blueberries that evolved on them have correspondingly low nutrient needs. So while cranberries require the same nutrients as other plants, they are unique in that the *amounts* required are much smaller than for most crop plants. Table 1 shows a comparison of plant tissue nutrient concentrations for three important minerals in cranberry and other crop plants. Nitrogen (N) and potassium (K) concentrations in cranberry and blueberry leaves are substantially lower than those in other fruit and agronomic crops. Phosphorus (P) in cranberry and blueberry tissue is also lower than that in many crops.

Why cranberries need fertilizer. Each season nutrients are removed from the bog during harvest and detrashing (removal of fallen leaves from the bog surface). When the fruit is harvested, the elements removed in the largest quantities are nitrogen, potassium, and calcium. The amount of nutrient removal increases with increasing crop load and is less when crops are small. In addition, hybrid cultivars tend to have larger leaves and thicker stems so that more nutrients are used to produce plant parts and more are removed with the fallen leaves. In a 200 barrel per acre crop of Early Black cranberries (including the fallen leaves and stems removed during harvest) 23.6 lbs N, 4.3 lbs P, 20.8 lbs K, and 15.8 lbs calcium per acre are removed from the bog.

It is to compensate for nutrient removal that cranberry growers add fertilizer to their bogs. Most fertilizer added to producing cranberry bogs contains nitrogen, phosphorus, and potassium (N-P-K fertilizer). While P removal is low, some P is included in the mixture to

maintain nutrient balance and because much of the P in cranberry bog soil is not available to the plants at crucial growth stages. Table 2 compares the N, P, and K recommendations for cranberry production to those for other fruit and agronomic crops. In general, cranberry production requires less fertilizer than that of other crops.

However, during establishment of a new planting or renovation, the recommended rates for N and P are higher than those for a producing cranberry bog. At planting, 20 lb/acre P and 20-30 lb/acre slow-release N are applied to the fresh sand to encourage plant rooting. During the first season of a new planting, N is applied at the rate of 5-10 lbs per acre every two to three weeks until late in the summer, alternating N-only products with N-P-K products with a 1:1:1 ratio. This regimen stimulates robust growth and the production of runners that spread quickly to cover the soil surface. Rapid filling-in of cranberry plants discourages weed infestations.

Fertilizers used on cranberries. As noted above, the predominant fertilizers applied to cranberries are complete N-P-K materials with varying ratios of the three elements. Growers apply these fertilizers based on seasonal N requirements. During the season, 20-60 lbs N per acre are applied depending on cultivar and weather conditions. N-P-K materials are chosen so that no more than 20 lb P per acre is applied. K application rates in N-P-K products are generally 1-2 times the rate of N. Additional K may be applied supplementally. N, P, and K will be discussed further below.

While cranberries require many other mineral elements, often these are in sufficient supply in the soil to satisfy the plant needs. When testing shows that these other elements are lacking in the plants or in the soil, they are then applied as needed.

Nitrogen (N). The single most important nutrient element in cranberry production is N. N is required by cranberry plants for the production of vegetation (new leaves and stems), roots, and fruit (crop). As a critical constituent of protein, N is a controlling element in the plant's nutrition. The production of the protein, chlorophyll, the green pigment essential to photosynthesis, is regulated in part by the availability of N.

Average organic matter in the root zone of MA cranberry soils, and therefore available for plant use, is less than 3.5%. While soil N is an important resource to the cranberry, it is not present in sufficient quantity (particularly if the bog soil is very sandy) to meet the demands of plant growth and fruit formation during the most active portion of the growing season.

Nutrient demand tends to be driven by production of plant biomass. In cranberry, this would correspond to extension of new growth in the spring (mid-May to mid-June), fruit formation and filling (July-Sep), initiation of floral buds (July and August), and root turnover. Root production occurs after the first flush of new vegetative growth and late in August after vegetative growth has ceased for the season.

Table 1. Standard concentrations of nitrogen, phosphorus, and potassium in leaf tissue of several crops. Data for cranberries provided by DeMoranville, other fruit crop data by Chuntanaparb and Cummings, and agronomic crop data by Vitosh.

Crop	Nitrogen(%)	Phosphorus (%)	Potassium (%)
Cranberry	0.9-1.1%	0.10-0.20%	0.40-0.75%
Blueberry	1.0-1.5%	0.10%	0.60%
Apple	2.0-2.5%	0.15%	3.0-3.5%
Peach	2.5-3.0%	0.20%	3.0-3.5%
Grape	2.5%	0.30%	2.0%
Corn	2.9-3.5%	0.3-0.5%	1.19-2.50%
Soybean	4.25-5.5%	0.3-0.5%	2.01-2.50%
Wheat	2.59-4.00%	0.21-0.5%	1.51-3.00%

Seasonal N is split-applied to coincide with these periods of demand. Split timing allows for in-season rate adjustment as conditions warrant. Additional N fertilizer should be added if the cranberry plants show signs of N deficiency - poor growth, loss of leaf greenness, and/or low nitrogen content in the leaf tissue.

Cranberries use the ammonium form of N efficiently. Ammonium-N is recommended for that reason and to limit concerns regarding nitrate leaching. In addition to standard soluble granular ammonium fertilizers, organic fertilizers, urea, and many slow release fertilizers can be used to provide ammonium-N.

The average recommended seasonal rate of N for producing cranberry beds in MA varies from 10-60 lb/A depending on plant vigor and variety. N must be used with caution as applications of excessively high N rates promote vegetative growth at the expense of yield. Excess vegetative growth may increase susceptibility to disease, spring frost, or insect feeding. High N rates may also lead to poor fruit quality and delay fruit color development. High N rates can have adverse carry-over effects in following years as stored excess N is remobilized.

Phosphorus (P). P is involved in energy transfer, is a primary constituent of the genetic material (DNA), plays a regulatory role in photosynthesis and starch synthesis, and is critical for flower formation.

While only modest amounts of P are removed from cranberry bogs in fallen leaves and fruit, it is essential that soil P be available to the cranberry plants to support seasonal growth and flowering. Common characteristics of cranberry bog soil affect P availability.
Cranberry soils are high in iron and have low pH. This leads to conditions where P is tightly bound in the soil and is to a large extent unavailable to the cranberry plants during the growing season. Cranberry plants with tissue P at or below the critical level (0.1%) are often found growing on soils with high P test values.

Despite the presence of bound P in the soil, research has shown that cranberry yield increases in response to the addition of P fertilizer. However the response is not linear. While yield was greater with the addition of 20 lb P per acre per season (compared to no P), higher rates did not significantly improve the response above that with the 20 lb rate. Further research with a broader P rate range in Wisconsin and Massachusetts has confirmed that there is no experimental evidence for a cranberry yield response to P rates above 20 lb acre and in many cases, good yield response was found with even lower rates. *The addition of more than 20 lb P per acre in a season is only justified if tissue P is <0.1% or during the establishment of new or renovated plantings.*

Since P is added in N-P-K materials and the material rate is selected based on N requirement, the N:P ratio in the fertilizer is critical if no more than 20 lb P per acre is to be applied. For beds with sufficient tissue P (0.1-0.2%), the recommended ratio of N:P (on the fertilizer bag) is no greater than 1:2 with 1:1 or 1:<1 preferred if high N rates are required. Note that due to fertilizer conventions, the percentages in the bag analysis are not the actual percentages of P and K. Actual P and K are calculated by multiplying the second number by 0.44 and the third number by 0.83 respectively.

Table 2. Standard recommendations (lb/acre/year) for fertilizer N, P, and K rates for several crops. Recommendations for cranberry from UMass, for agronomic crops from Ohio State, for tree fruit/blueberry from Michigan State.

Crop	Nitrogen	Phosphorus	Potassium
Cranberry	20-60	no more than 20	40-120
Blueberry	45-65	35-45	40-80
Apple	50-60	85-175*	125-250*
Peach	80	85-175*	125-250*
Corn	160-200	25-65**	87-120**
Wheat	75-110	45-80**	70-110**

*when required based on soil and tissue tests, every 3-5 years; **based on potential yield and soil test.

Potassium (K). K is the only major element with no structural role in the plant. However, K is involved in the movement of sugars and starch in the plant and may play a role in resistance to disease, drought, and cold temperatures. K also has a major role in plant water relations (hydration). Cranberries have a much higher %K in the fruit and seeds than in the leaf tissue. As a result, seasonal removal of K in crop and fallen leaves is about equal to removal of N.

K fertilizer is added to cranberry bogs when vines are brittle and dry, most often in the spring. Otherwise, K is generally added in the N-P-K fertilizer applied to satisfy N needs. Common cranberry fertilizers supply K in a 1:1 ratio with N. Seasonal rates of K applied to cranberry bogs are in the range of 40-120 lb/A. Field plot research did not show any measurable benefit to the addition of higher K rates.

FERTILIZER USE

This section covers how growers decide on fertilizer rates and timing, how fertilizer is applied, and the interaction of fertilizers and water quality.

Fertilizer use decisions. As noted above, most cranberry fertilizer rate decisions are based on N requirements. Aside from taking varietal differences into account, decisions regarding fertilizer N rate are based in part on length and density of uprights. Other factors that are considered include bog history (previous crops and response to fertilizer), results of soil and tissue tests, and weather conditions.

Fertilizer application timing. The timing of N and P applications is an important factor affecting the potential for fertilizer loss to the environment. The greater the time between application and plant uptake, the greater the chance for loss to ground or surface water. It is best to time fertilizer applications based on the stage of plant growth. Applications should be delayed when spring temperatures are cold. Cranberry plants respond to nutritional support during initial leaf expansion in the spring, during bloom, during fruit set, and during bud development for the following season. Fall application of N should be minimized.

Application methods. Fertilizer is applied to cranberry bogs using ground rigs (spreaders and seeders), helicopters (aerial application), and the sprinkler system (fertigation). Fertilizer is applied in split doses if water-soluble materials are used. As previously mentioned, the rate for the total season is split over 3-4 applications. This lessens the potential for leaching of the material below the root zone. For a soil-applied fertilizer to be used by the plants, it must be taken up by the roots. Cranberries are shallow-rooted. This, combined with the limited ability of cranberry soils to hold nutrients, makes split applications essential. Overloading of soluble materials would be unsound economically as well as ecologically.

Nutrition Decision Making in Cranberry Production

Many factors, including temperature, moisture, pH, and soil type can play a part in the availability of nutrients and the ability of the plant to acquire them. How then can one decide what to supply to cranberries in the form of fertilizer? The following tips are provided for cranberry growers:

1. Observe growth and flowering. Adjust fertilizer based on the appearance of the plants and the potential for cropping. Pay particular attention to upright length and growth above the fruit.

2. Healthy cranberry plants with adequate N are deep, bright green. Fading to yellow is an indication the N may be insufficient.

3. Test the soil to determine the organic matter content. This will supply information regarding the potential for mineralization. Soil pH information can be gathered at the same time. Soil testing every three-five years should be sufficient.

4. Adjust spring fertilizer applications based on soil temperature. Apply only after soil has warmed and decrease N applications if spring has been warm and dry.

5. Do not apply P to wet soils – P is being released under these conditions. Do not apply more than 20 lb P per acre each season.

6. Adjust N rate based on cultivar and crop potential. Cultivars that crop heavily generally require more N compared to native selections.

7. Finally, keep good records of your management and observations, look for patterns, and learn how each bed responds to the addition of fertilizer.

As an alternative to split applications of soluble materials, some growers use fish fertilizer (organic N) or inorganic slow-release materials. Fish fertilizer remains available over an extended period due to the fact that the material adheres to soil particles where the organic nitrogen can be slowly released and become available to the cranberry plants. Inorganic slow-release materials depend on their low solubility to prevent being washed down below the root zone. This is generally achieved by a slowly dissolving coating or a chemical structure that requires breakdown by soil bacteria.

Liquid or foliar fertilizers are also used when a quick response (generally to correct problems) is desired. These are low-analysis materials designed to be taken up quickly by the plants. When used at the recommended rates, they have little potential for movement into water supplies. Due to nonuniform application with irrigation systems, only low rates of fertilizer are applied by this method. Otherwise, the plant stand grows unevenly, leading to difficulties in harvesting and other management tasks.

Interaction with water management. Moisture and aeration in the soil can determine nutrient availability. Plants take up nutrients dissolved in the soil water. If soil is too dry, minerals cannot dissolve and move to the roots and uptake cannot take place. Conversely, if soil is waterlogged, the oxygen the plant needs for root respiration to drive active uptake will be limited.

Proper soil drainage improves fertilizer efficiency so that less fertilizer is required. Soil moisture should be monitored and at minimum checked twice a week. Soil should be moist but not saturated in the root zone.

Environmental considerations. Fertilizer N and P can be environmental pollutants. N is of particular concern in estuarine waters, while P is primarily associated with degradation of water quality in inland, fresh water systems. When excess P is provided in such systems, algal blooms (eutrophication) can result. As the algal population peaks and the algae die, oxygen in the water is depleted, often resulting in fish kills.

Downward leaching of nutrients is minimized by the layered structure of cranberry bog soil. Layers of sand are added to the bogs every 2-5 years leading to alternating sandy and organic layers. The organic layers are comprised of decaying roots and leaves.

Fertilizer Best Management Practices for Cranberry

- Apply N only when the plant can use it (active growth and fruit production). Use ammonium N.
- Apply seasonal fertilizer in split applications. Adjust rates based on observations of growth and plant appearance.
- Reduce fertilizer applications in response to insect infestations that impact potential crop, frost damage, pruning or sanding, and following the use of late water.
- Use tissue testing as a tool to help determine required fertilizer rates. Use soil testing to monitor soil pH and soil organic matter.
- Avoid N applications if the soil is cold (<55ºF) and limit applications if soil temperature is 75ºF or greater.
- Avoid excessive N application to prevent excess vegetative growth and poor cropping but do not starve the plants of N early in the season as this will lead to poor growth and reduced ability to size and retain fruit.
- Limit P applications to no more than 20 lb per acre per season, use less if tissue tests are well above the critical level of 0.1%.
- Do not apply P to saturated soil.
- Monitor soil moisture – soil in the root zone should be moist but not saturated.
- Minimize water in drainage ditches during fertilizer applications.
- Limit flow from bogs during the growing season – use tailwater recovery if possible.
- Hold harvest floods long enough for settling (~3 days) then discharge slowly to minimize particulate discharge. Complete discharge before day 10 to avoid flushing of P from the soil as oxygen depletes.

Nutrient leaching is also minimized in peat-based soils by trapping in the high organic matter content of the subsoil. Further, the low pH of bog soils limits the conversion of ammonium N (the form recommended for cranberry fertilization) to the more leachable nitrate form and P is bound to iron in acid conditions. While leaching is of minimal

concern in cranberry fertilizer management, the potential for movement of N and P in surface water should be taken into account in management decisions.

Cranberries are grown in wetland soils, either natural wetlands converted to cranberry production or manufactured cranberry wetlands. While wetlands are generally perceived to improve water quality, primarily due to their ability to retain sediments, their capacity to retain nutrients may change over time and with continued loading may actually reverse so that they become nutrient exporters. Since managed cranberry wetlands are receiving fertilizer on a regular basis, there is a strong possibility that they may act as nutrient exporters.

A study in Massachusetts by Howes and Teal that included careful mass balance calculations, documented N and P release from established cranberry bogs to Buzzards Bay. In that study, N losses were similar to those in surface water-dominated vegetated wetlands. P output was shown to be minimal with the exception of certain seasonal occurrences, associated with the release of flood waters.

Cranberry growers have a horticultural disincentive to overapply N fertilizer. Too much N quickly promotes vegetative growth and this growth comes at the expense of fruit production. As mentioned above, the ammonium N used in cranberry fertilizers is less susceptible to leaching than nitrate N. The adoption of Best Management Practices can assure that N movement out of the bog is minimized. See the sidebar on the previous page.

Cranberry soil chemistry, particularly the high iron and aluminum associated with acidic soils, leads to extensive binding of P as iron and aluminum phosphates in the soil. However, it has been shown in rice that P can be released from such compounds when flooded soils become anaerobic. A similar phenomenon occurs in pond sediments during anaerobic events. In the absence of oxygen, iron and aluminum change chemical state and no longer strongly bind P. It is likely that the spikes of P associated with flood release found in the Howes and Teal study were related to change in aerobic state of the cranberry soils during the flooded intervals.

Data from several recent studies indicate that native cranberry wetland soils can act as sinks for P under aerobic conditions. However, under commercial management with P fertilizer applications, cranberry soils no longer removed P from water and when fertilizer P applications exceeded 20 lb per acre, P moved from the bog soil into flood water even under aerobic conditions. As bogs were held in flooded conditions the soil became anaerobic after ~10 days and P was released into the water regardless of bog management. However, the magnitude to P release from the soil was proportional to previous fertilizer P additions.

At a field site, fertilizer P application was reduced. After 3 seasons of P reduction, P concentration in flood discharge water was reduced by more than 2/3, providing evidence that the potential for P release from cranberry bogs into flood waters can be reduced with reduction in applied P. Current research efforts are underway to determine if additional management practices can be developed to further reduce the P levels in flood discharges.

Sign Posting and Description of Zone II Regulations

Jeff LaFleur and Brian Wick

Sign Posting. Both state and federal agencies regulate the posting of pesticide application warning signs. The requirement depends on the product being used and the location of the application. In all cases, the label of the product contains the wording that will trigger sign posting. **STATE RESTRICTED USE PESTICIDES** carrying the label "**Danger**" that are **applied within 50 feet of a public way** *(road, trail, walkway or any other land over which the public is likely to pass)* require posting of an EPA Worker Protection Standards sign with the words: DANGER PESTICIDES, KEEP OUT.

- Post signs every 200 feet along the area facing the public way and at every principle entrance facing the public way.
- Post signs between 2 and 24 hours prior to the application.
- Remove signs no sooner than 48 hours after the application and no sooner than the expiration

of any Restricted Entry Interval (REI) stated on the label instructions.

- Remove signs no later than 48 hours after the expiration of the REI stated on the label instructions under the heading "Agricultural Use Requirements".

AERIAL APPLICATIONS of all Pesticides within 500 feet of a protected area *(residential, business, public way, school, park, playground etc.)* require posting of an EPA Worker Protection Standards sign with the words: DANGER PESTICIDES, KEEP OUT.

- Post signs at conspicuous points no less than 200 feet away from one another at every principle entrance fronting a public road.
- Post signs between 2 and 24 hours prior to application.
- Remove signs no sooner than 48 hours after the application and no sooner than the expiration of any REI stated on the label instructions.
- Signs should be removed no later than 48 hours after the expiration of the REI stated on the label instructions under the heading "Agricultural Use Requirements".

FEDERAL RESTRICTED USE PESTICIDES within 300 feet of a sensitive area (residential, business, hospital, or public area) require posting of a federal chemigation sign that states: STOP, KEEP OUT, PESTICIDES IN IRRIGATION WATER.

- Post signs at all usual points of entry. If there are no usual points of entry, post at corners of treated area.
- Signs must be posted no sooner than 24 hours before the scheduled application.
- Signs must be removed within 3 days after the end of the application and any REI and before agricultural-worker entry is permitted.

Protection of Groundwater Sources of Public Drinking Water (Zone II). The Groundwater Protection Regulations from the Massachusetts Department of Agricultural Resources (MDAR) are intended to prevent contamination of public drinking water supply wells through regulating the application of pesticide products on the Groundwater Protection List (GPL) within primary recharge areas. A primary recharge area is either an Interim Wellhead Protection Area (IWPA) or a 'Zone II'. Primary Recharge Areas are updated yearly by the state. The pesticide groundwater protection regulations ONLY apply to public drinking water wells that pump greater than 100,000 gallons of water/day.

MDAR publishes a GPL of those pesticides subject to the regulations. The GPL refers to a list of pesticide active ingredients that could potentially impact groundwater due to their chemical characteristics and toxicological profile. As a result, a product containing any of these active ingredients is regulated if, and only if, it is to be used within the primary recharge area of a public well.

Any applicator who is in a Primary Recharge Area and is planning to apply a pesticide on the GPL must use an alternative pesticide that is not on the GPL for the particular pest they are seeking to control. If an alternative pesticide is not available, then the applicator must either follow an MDAR approved Integrated Pest Management Plan or file a Pesticide Management Plan with MDAR in addition to practicing IPM.

Primary Recharge Area maps are updated yearly and sent to every town in the Commonwealth by the Department of Environmental Protection. These maps are also available online at both the Massachusetts Geographic Information System and MDAR web sites.

Pesticide Registration, Licenses, Application, and Storage

Hilary A. Sandler

Pesticide Registration. All pesticides used in cranberry production must go through rigorous testing, which are ultimately evaluated and regulated by the U.S. Environmental Protection Agency (EPA). It may take 10-20 years to go from discovery of a new compound to registration of a commercialized product and cost millions of dollars.

Minor Crop Registration. Many pesticides used in cranberry production are registered with the assistance of a specialty crop (minor use) pesticide registration program known as the IR-4

Project. This program is specifically designed to supply specialty crops with pest management tools by developing research data to support new EPA tolerances and labeled product uses.

Specific and Crisis Exemptions. Pesticides may also become available for use for specific time periods under specific circumstances against a specific pest(s) via a permit request process (called Section 18 permits). These permits are requested when a compound is in the registration process but has not yet been approved for full label use by the EPA (i.e., it is still technically unregistered). It must be shown that pesticides that once provided control for a particular pest are no longer available, due to resistance of the pest to the compound or loss of product(s) through de-registration. For Specific and Crisis Exemptions, significant economic loss by the industry without the use of the requested compound must be clearly demonstrated. In either case, the exemption is granted for a limited time period (usually several months) and must be approved annually.

Special Local Needs. States may register an additional use of a federally registered pesticide product, or a new end-use product to meet special local needs (called 24c). EPA reviews these registrations and must give final approval. The state will then approve the 24(c).

Pesticide Licenses for Applicators. Massachusetts pesticide law requires that all persons who apply pesticides in public areas and private places used for human occupation and habitation must be in possession of a valid license or certification issued by the Massachusetts Department of Agricultural Resources (MDAR). In accordance with the Massachusetts Pesticide Control Act and the current pesticide regulations, MDAR conducts written examinations to measure competency to use, sell, and apply pesticides in Massachusetts.

Four types of licenses are offered by MDAR. Most cranberry growers who apply pesticides to their own bogs have Private Applicator Certification. Private certification is for applicators who use or supervise the use of restricted use or state-limited use pesticides on property owned or rented by the grower or their employer. A Commercial Applicator License permits individuals to use general use pesticides, or any restricted-use pesticide under the direct supervision of a certified applicator, for hire or compensation. The third category is Commercial Applicator Certification, which is for someone who uses or supervises the use of a restricted use pesticide for hire or compensation. The fourth license type covers those wishing to sell restricted-use or state-limited pesticides; they must obtain a Dealer License.

Application of Chemicals. Pesticides can be applied to Massachusetts cranberry bogs in several ways: chemigation (application through the sprinkler system), ground application, wiper application, and aerial application.

Chemigation, or application of chemicals through a solid-set irrigation system, is the most common method of pesticide delivery. Insecticides, fungicides, herbicides, and fertilizers may be applied through the irrigation system. Growers often use a specialized piece of equipment, a chemigation injection unit, to mix the pesticide with water in the irrigation system. Injection systems must provide backflow prevention through the inclusion of various check valves. Growers are encouraged to contact chemigation specialists prior to purchasing injection equipment.

The application rate of a chemical applied by chemigation is dictated by the label and is typically applied in 300-500 gallons of water/A. The effectiveness of many pesticides, especially the newer chemistries, may be affected by the amount of time needed for water to move from the first head to last head in the irrigation system (wash-off time). The layout of a system as well as the type and height of the sprinkler heads, can affect the performance of an irrigation system. Growers routinely clean and inspect their systems for signs of leaks and excessive wear. Many factors can affect the coefficient of uniformity (CU) of an irrigation system, which ultimately impacts the delivery of water, pesticides, and fertilizers onto the farm.

Growers may employ several types of ground applicators to apply preemergence and postemergence herbicides and granular fertilizers. Most growers use motor-powered herbicide rigs (e.g., Gephardt) to apply granular preemergence herbicides in the spring. During the growing season, growers may need to apply fertilizers or spot-treat weeds with herbicides. Typical ground applications may involve the use of various hand-held devices to apply postemergence herbicide solutions (as wipes or sprays), machines that use a large roller to apply (as a wipe) postemergence herbicides, or hand-crank rotary spreaders for the application of granular fertilizers. More recently, growers are

incorporating the use of boom sprayers as another type of ground application equipment.

Aerial applications of pesticides are made by specially equipped helicopters. Even though helicopters are most often used to perform other normal agricultural practices (e.g., removal of harvested fruit or ditch debris), certain pesticides and fertilizers may be applied by air. A typical aerial application uses approximately 5-25 gallons of water per acre. Aerial application is more expensive than other methods of application. Growers decide whether to use aerial application based on efficacy of the product, cost of the application, proximity to abutters, and available labor and time. Most aerial applications are of granular fertilizers.

Pesticide Storage. Growers may purchase quantities of pesticides in the spring in anticipation of their use during the growing season. These pesticides should be stored in well-ventilated and secured storage facilities. It is recommended to avoid carry-over of extra pesticides. Growers should always try to buy only what they will need for the current season. Pesticides should be sorted by type within the facility and stored in their original container. Dry pesticides (granulars, powders) should be stored in a cool, dry place. In general, liquid or emulsified materials should not be stored at temperatures below 45°F nor at temperatures that consistently exceed 100°F.

Material Safety Data Sheets (MSDS) should be read for current disposal information. Empty containers should be kept in a safe place until disposal. Empty bags and triple-rinsed liquid containers can be placed in sanitary landfills or incinerated, or if permitted by local authorities, by local burning. Empty liquid containers should be triple-rinsed and offered for recycling or reconditioning, if available.

Breakdown and Movement of Pesticides

Hilary A. Sandler

The movement of a pesticide in the soil is influenced by the properties of the soil and the properties of the chemical. Once added to the soil, a pesticide is degraded by biological, physical, and chemical processes that influence its behavior in the soil environment. The following discussion outlines the principle factors that affect the movement and breakdown of chemicals applied to the soil.

PROPERTIES OF THE SOIL

Soil Texture and Bog Structure. The relative amounts of sand, silt, and clay in a soil are collectively known as soil texture. Sand is a very prominent component of most cranberry soils, sometimes accounting for as much as 98% of the soil mineral matter. Many cranberry growers in Massachusetts use the cultural practice of sanding every 2-5 years. Sanding stimulates vine growth by encouraging shoot production and improving soil aeration. The occasional application of a 0.5 to 2.0 inches layer of sand over the layer of leaves that have naturally fallen off the vines creates a unique soil situation called stratification. These events and activities, which are repeated over time, result in layers of organic matter interspersed with layers of sand in the upper profile of cranberry bog soil.

Commercial bogs built on the contours of iron ore bogs will have a stratified soil profile in the uppermost layers (the thickness will vary depending on the age of the bog), typically followed by a substratum of peat. This substratum may be 10-30 feet thick. Pesticides are largely retained in the upper layers of the organic component of the stratified bog soil, though some may be retained in the peat substratum. Additionally, a natural restrictive layer may occur beneath the peat layer of the bog. The presence of this restrictive layer would further separate chemicals applied to the cranberry bog from the groundwater.

Current best management practices (BMP) recommend that bogs constructed on upland soils utilize a perched water table above the natural water table. Below the perched water table is an organic-confining layer followed by a water-confining layer (an impermeable layer that mimics the natural restrictive layer found underneath many traditional bogs). These layers are constructed to enable the grower to hold floodwaters for harvest and pest management activities and to minimize leaching. The natural water table lies beneath all of these layers.

The clay fraction can be very important in influencing the behavior of chemicals in some soils. However, typical cranberry soils contain

less than 1.0% clay, an amount that does not significantly improve the adsorption capacity of a bog soil. The clay fraction is thus considered to play a very minor role affecting the breakdown and movement of pesticides in Massachusetts cranberry bogs.

Organic Matter. Organic matter content is the most influential factor affecting the fate of a soil-applied pesticide. Even though it may only comprise 1-2% of the soil composition (as in Massachusetts bogs), the importance of organic matter must be emphasized. Its large surface area adsorbs cations and organic compounds in the soil solution. Soils high in organic matter have a low potential for pesticide leaching. Research indicates that compounds applied to cranberry bogs are retained in the top 0-4 inches of soil.

The flow of water through the cranberry root zone is slowed by the presence of organic matter. Chemicals can then have time to react with the organic matter. In addition, nutrients can be retained in the root zone long enough to be taken up by the plant. Organic matter also acts as a nutrient reservoir, and supports microorganisms that are associated with the breakdown of plant material and chemicals that are introduced to the environment.

Soil Moisture. The natural setting of a cranberry bog ensures that soil water is not physically far away from the vines. However, in the cranberry system, a high soil moisture content does not guarantee that water is accessible to the roots. Water that contributes to the soil moisture content may be held tenaciously by the peat fraction and is unavailable for plant uptake. The movement of water downward is impeded by the mat of fine, fibrous roots produced by the cranberry vines, and by layers of organic matter. Stratification encourages the horizontal movement of water within cranberry bogs.

The movement of water and chemicals through the soil may not be the same; the pesticide may be slowed due to its adsorption to organic matter. Research indicated that pesticides are primarily retained in the top two inches of bog soil. Since the degradative activities of soil microorganisms are also dependent upon the availability of water, pesticides tend to break down more rapidly in moist soils.

Contrary to a common misconception, cranberries are not grown in a constantly flooded state. Cranberries need a consistent source of water to grow properly, but the root system cannot grow in saturated soil. Well-maintained bogs will have the ability to provide adequate water on a regular basis coupled with good soil drainage. Good soil drainage is important for providing a favorable environment for pesticide degradation.

PROPERTIES OF THE PESTICIDE

Soil Adsorption. K_{OC} is a measure of soil adsorption, the tendency for pesticides to become attached to organic particles. High K_{OC} values indicate that a pesticide is strongly adsorbed to the soil surface and therefore is not easily moved, unless soil erosion occurs. Chemicals with low K_{OC} values have a greater tendency to be moved with water, thus may be moved away from the area of application either by run-off or leaching. The degree of adsorption is dependent upon the chemical structure and concentration of the pesticide in the soil water and on the organic matter content.

Solubility. The maximum amount of a substance that can be dissolved in water at a given temperature is a measure of its solubility. Generally, compounds that have low solubility tend to remain on the soil surface and not leach through the soil profile. Compounds with high solubilities are more likely to be moved with water through the soil. However, there are exceptions to the principle of highly soluble compounds being more apt to move through the soil, as other environmental factors can decrease the probability of leaching and always need to be considered.

Persistence. Used only as a relative indicator of persistence, the half-life of a compound refers to the time required for a chemical to degrade to one-half of its original concentration. In general, the longer the half-life, the greater the potential for pesticide movement within the environment. The compound may resist degradation long enough to be moved into the groundwater or carried from the application site by run-off. Half-life values are greatly dependent upon other parameters such as soil moisture, temperature, oxygen status, soil pH, concentration of the chemical, application method, presence of microbial populations, etc. Half-life values for any compound can be variable and should be used only as a general guideline and/or in conjunction with other known chemical properties. In general, modern

chemicals have significantly shorter half-lives than pesticides that were used 30 years ago.

Odor. Some pesticides or their carriers have strong odors that some people may find offensive. The odor may be a warning agent added to the pesticide to signal that a chemical has been recently applied or it may be an aromatic organic solvent specifically added to facilitate dissolution of the pesticide.

Application of a strong-smelling pesticide when the humidity is high and the air is very still may increase the likelihood detecting a strong odor. This does not mean that the pesticide has drifted off the bog. It is a misconception to assume that if one smells a pesticide odor that the chemical has drifted off of the bog.

Many pesticide odors are formulated fragrances and not part of the active ingredients. Because they are fragrances, odors will carry much farther than the actual droplet portions of a pesticide spray. However, the odors will be more likely to carry in the humid air. This principle is similar to the odor often associated with the ocean's low tide. Often during a humid day in the summer, one can smell the odor of mud and salt from the exposed earth long before the ocean is seen.

PROCESSES AFFECTING DEGRADATION AND MOVEMENT

The primary processes involved in degradation or movement of a pesticide applied to the soil are documented below. The significance of these processes in determining the persistence or breakdown of any chemical is dependent upon many interrelated factors (e.g., soil and pesticide properties). Despite the development of complex mathematical models, predicting the exact behavior of a chemical in the dynamic soil ecosystem is still very difficult.

Pesticide Adsorption and Desorption. The tendency for chemicals to adhere to the soil surface is a continuous, reversible process. The more organic matter that is present, the more adsorption may occur. Adsorption is inversely related to soil moisture content, water movement, and solubility.

As the soil moisture increases and the amount of material dissolved in water increases, adsorption decreases. The effect of temperature can be variable, but temperature is directly related to solubility. Therefore, as the temperature rises, the adsorption of the compound tends to decrease. The compound would tend to move with water through the soil profile.

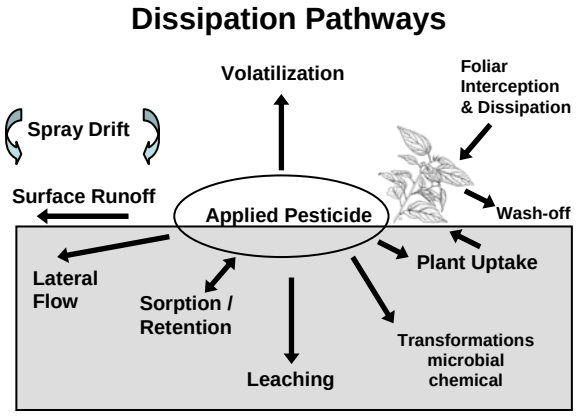


Illustration of the many processes associated with the breakdown of a pesticide courtesy http://www.epa.gov. Plant drawing courtesy http://aquat1.ifas.ufl.edu/drawlist.html

Leaching. The process by which materials are washed through the soil by the movement of water is known as leaching. Plants with dense root systems, such as cranberries, tend to lower the leaching potential of pesticides due to increased soil aeration and larger microbial populations that tend to be associated with the root zone. Generally, the amount leached is directly related to its solubility. The higher the solubility, the less likely the compound will be adsorbed to the soil, and the greater its potential to be leached. The intensity and frequency of rainfall, as well as any use of the irrigation system, affects the amount of the chemical that is leached as well as the depth to which a material is leached.

Plant Uptake. The uptake and movement of a chemical into a plant is affected by the age of the plant, climatic factors, pesticide formulation, and mode of application. Uptake occurs to both target and non-target plants. The persistence of any chemical in the plant is directly related to the rate of the metabolism of the plant.

Evaporation. According to its tendency to vaporize, a compound will evaporate when in contact with air or moisture. The rate of evaporation is directly related to the soil moisture content and temperature. However, when more organic matter is present, the potential for adsorption of the compound is increased and the potential for evaporation is decreased.

Microbial Decomposition. Degradation by microorganisms depends on many factors including the chemical structure and concentration of the pesticide, temperature, soil organic matter content, pH, available water, and nutrients. Most microorganisms are found in the root zone; if a material is moved quickly past the roots, degradation by microbial activity is significantly reduced. Often, pesticide degradation is an incidental event for many microorganisms, i.e., the chemical is not used as an energy or nutrient source by the organism.

Chemical Degradation. Hydrolysis, the breakdown of a compound by water, is an important pathway of chemical degradation. The rate of these reactions is temperature and pH-dependent. Many pesticides react with water to produce compounds that are usually less toxic than the parent compounds.

Photodecomposition. Sunlight may break down organic compounds, causing them to lose their effectiveness. Pesticides applied to plant surfaces are more subject to photodecomposition than those that are incorporated or injected into the soil. This factor is generally of minor importance relative to other factors that affect pesticide degradation and movement.

CONCLUSION

Due to the influence of organic matter in cranberry soils and the dense root systems of the cranberry vines, the potential for movement of pesticides to groundwater is low. Penetration into lower soil layers is inhibited due to the retention of organic chemical in the top 0-4 inches of the soil. Stratification provides a reservoir of adsorption sites that are found in the uppermost portions of cranberry soil profiles. These alternating layers of sand and organic matter facilitate the horizontal movement of water; downward flow is impeded. The organic matter content serves as a substrate for microbial population that actively degrades pesticides.

Concentrated in the upper 2-4 inches of the soil, the dense fibrous root system of the cranberry vines slows the downward movement of water and serves as an additional deterrent to leaching. Furthermore, cranberry vines may be separated from the groundwater by the presence of a restrictive layer under the peat (as in Massachusetts bogs) and stagnant bog water. Currently, it is recommended to hold water within the bog system for variable time periods to allow for degradation (see Cranberry Chart Book for specific times). Thus, the potential for groundwater and surface contamination is reduced further in these situations.

When pesticides are used properly and judiciously, the cranberry system contains a suitable contingent of biological and chemical properties that buffer the potential movement of compounds into water and land resources.

Normal Agricultural Practices for Maintenance or Improvement of Cranberry Bogs

Cape Cod Cranberry Growers' Association

The practices set forth below are based on a number of important agricultural and environmental principles. In many cases, the activities are predicated by research results published from major agricultural and academic institutions. Under certain circumstances, some of the activities may require a permit. Regulations that may be triggered by agricultural activities are listed at the end of this chapter. Growers should contact the CCCGA or the appropriate authority (see “Directory of Agencies”) if they are unsure if a particular activity falls under the jurisdiction of one or more of these regulations.

Brush Cutting and Tree Clearing. Removal of brush and trees around the perimeter of the bog is necessary for promoting air movement that helps reduce frost risk. Air movement on the bog also minimizes potential for fungal infection; removing plants that may serve as hosts for certain insects and minimizes weed incursion; and encouraging sunlight to reach the vine canopy. Although the area to be kept clear depends upon the slope, type of vegetation present, and the direction of the sun, this area is generally at least 50 feet.

Burning. Growers cut brush adjacent to the bogs to improve sunlight and air circulation for their bogs. An efficient method of

disposing of the light brush is to burn it on-site. Agricultural burning is done primarily during the winter months under damp or snowy conditions to minimize damage to surrounding woodlands.

Cleaning and Dredging Reservoirs and Water Storage Systems. Reservoirs and water storage systems lose holding capacity because of vegetation growth and siltation, reducing the availability of water for frost protection, irrigation, and harvest. Storage systems must be cleaned and dredged routinely to maintain water availability. Usually a small area of the reservoir is dredged (~6-10 feet) and volume needed is based on one week's pumping. Shallow water supplies need to be cleaned and deepened for many reasons, including but not limited to: to insure movement of water to pumps/control structures; to control vegetation growth that clogs pump suction; and to insure water availability when ice forms.

Clearing Land in Preparation for Sand Pits. Periodic sanding of cranberry vines is important to cranberry cultivation. Cranberry growers must either purchase sand or use sand deposits located on their property. These sand deposits, usually located in the hills surrounding the bogs, require that the trees and brush be cleared and the top soil removed to allow removal of sand deposits. Screening of the sand is frequently required.

Construction and Maintenance of Buildings. Structures that house/protect equipment used for harvest, sanding, and other production operations are built near bogs to provide efficient access. General maintenance of the structures includes painting, replacement of damaged parts, roofing, siding, etc.

Construction and Maintenance of Pump Houses. Pump houses are built to protect irrigation/pumping equipment from weather and possible vandalism. Pump houses are built next to the water source for efficient access. General upkeep would include painting, re-roofing, new siding, and replacement of decayed timbers.

Ditch Cleaning. Ditches facilitate flooding and draining of the bog, and keep the water table close to the root zone during the growing season. Ditch cleaning is necessary to keep water moving and to reduce fungicide use. It also manages weeds that grow in excessively wet conditions, thus reducing herbicide use. Excessive flooding at bloom will devastate a cranberry crop; thus, free-running ditches are necessary. Removal of excess ditch material may be done by truck or helicopter.

Fertilizer and Pesticide Application. Fertilizers are applied to cranberry bogs to replace nutrients necessary for growth. Applications may occur from spring through fall; time and rate varies by bog. However, growers strive to maximize plant uptake. Fertilizers can be applied aerially by helicopters, or on the ground through irrigation systems, rotary spreaders, or motorized vehicles.

Pesticides are a necessary component of cranberry agriculture to minimize damage to the cranberry plant by various pests. During the season, each grower scouts the cranberry bogs for pests (e.g., insects, weeds, and disease). If the pest population reaches a predetermined economic threshold, the grower decides which management strategy is needed to bring the population below the threshold. Chemicals are applied to the cranberry bog using chemigation systems, helicopters, and portable spray units. Herbicides are applied in the spring as broadcast applications to prevent weed emergence and as postemergence sprays or wipes during the summer to control weeds growing above the vine level.

Flooding and Flood Release. Cranberry growers flood their bogs primarily for three reasons: 1) water harvesting in September-November; 2) protection from winter injury during December-March; and 3) enhancement of fruit quality by holding a flood from mid-April to mid-May (late water). Flooding can also be used as a cultural practice to reduce insect damage. For some insects, it is the only known control. When flooding the bogs, growers take advantage of portable pumps and/or stationary lift pumps.

Gate and Fence Construction. Gates are normally built to control access to a bog to minimize vandalism and theft. Construction and maintenance is ongoing throughout the year.

General Maintenance of Pumps and Equipment. The irrigation pump is the grower's lifeline between success and failure. This pump must provide water to protect the vines and berries during spring and fall frost time, respectively, and during the summer heat. Many chemicals and fertilizers are applied through the sprinkler system, powered by either an internal combustion or electric

motor. These motors must be able to start on a moment's notice and run without fail for 10-12 hours. Proper maintenance of these units is essential. Growers test and maintain the pumps on a regular basis. Equipment is used for many phases of production, including but not limited to: 1) harvesting, 2) sanding, and 3) ditch cleaning. This equipment is constructed and maintained in buildings adjacent to bogs.

Harvesting. Cranberry harvest takes place once a year from mid-September through early November. Two methods are employed: dry harvesting, which involves using machines to rake the berries off the vines into boxes or bags and then berries are removed from the bog either by bog vehicles or helicopters; and wet harvesting, which involves flooding the bog with up to one foot of water and mechanically removing the berries from the vines. Berries are then corralled and removed from the bog by pumps or conveyors. Nearly 90% of the crop is wet-harvested.

Irrigation Systems. Low-volume sprinkler systems are essential for applying water for frost protection and irrigation, as well as for applying pesticides and fertilizers in modern cranberry cultivation. It is common for the main and lateral lines to be buried.

When the new bogs are constructed, before vines are set out, a sprinkler system is set in place. Many systems are now being replaced or upgraded as new technology develops. The proper spacing and sizing of the modern systems provides uniform distribution of irrigation water, which leads to a more conservative use of water. For most of the year, only the sprinkler heads are seen but following harvest, these heads are removed. They are again put into place in early spring. Currently, many growers are also installing pop-up heads instead of traditional impact sprinkler heads. Pop-up heads do not need to be removed each year since they sit flush with the ground and distribute a more uniform spray of water, thereby increasing efficiencies.

Maintaining Dikes and Flumes. Since most cranberry bog dikes were built by hand and are not wide or strong enough to accommodate large vehicles, they need to be repaired and widened. In addition, animals continuously bore holes in dikes causing structural damage. Wind action and heavy rains deteriorate the dikes, making graveling and re-sloping necessary. Maintained dikes provide storm water protection.

Water control flumes were mostly made of wood or concrete, and over time, replacement with new metal ones is necessary. It may be necessary to enlarge them to improve water management efficiency. Faulty, leaking flumes result in lost water, making flume replacement a water conservation practice.

Mowing. Upland areas adjacent to cranberry beds are periodically mowed during the growing season to prevent weed seeds from moving onto the bog and to minimize the risk of fire. Underbrush is also cut and removed at different times throughout the year.

Pollination. Cranberries are normally in bloom from mid-June to mid-July. Hives of bees are brought to the bogs during this period. One to two hives of bees are generally necessary to pollinate one acre of bog. Bees may be brought to the bog on trucks during evening or night hours since that is the time when all bees are in the hive. Once the cranberries are pollinated, bees may be removed to pollinate other crops. Generally, bees are present on cranberry bogs for about one month. Many growers who own and rent hives keep them on the property year-round.

Pond Construction. Construction of water-holding facilities for irrigation/water use is a common practice. Existing small ponds may be expanded or ponds can be excavated in suitable adjacent areas.

Pruning Vines. Pruning vines removes the woody portion of the cranberry plant. Pruning enables the plant to put more resources into the flowering uprights, thus increasing production. Pruning also eliminates the heavy vine growth that promotes the development of fruit rot. Pruning may be done during dry harvest with machines that prune as they pick. It may also be done after harvest, or in the spring before the vines break dormancy.

Regulating Water Flow. Many growers utilize water from lakes and ponds and control the dams and flumes that allow water to be released. Most growers hold deeded water rights. Fluctuations in water levels may occur during flooding and flood release associated with harvesting, winter protection, and late water floods.

Road Maintenance. Bog road maintenance is a year-round activity consisting of grading, filling in pot holes, fixing washouts, mowing

back brush along roadsides, and pruning of tree branches.

Sanding. Every few years, 0.5-1 inch of sand is applied to cranberry bogs as an essential part of good bog management. Sanding is usually applied directly to the vines in the spring or fall or applied directly on the ice during the winter. Most growers use specialized sanders that they have built themselves.

Squaring Off Bogs. Many bogs were constructed in the early 1900's by hand labor. Modern equipment, including excavators and bulldozers, straighten crooked edges and odd-shaped pieces. Straightening edges make many production practices much more efficient.

Stripping and Replanting. A bog is stripped and replanted for the following reasons: the bog is out of grade, requiring excessive quantities of water to flood; the variety is low yielding and/or prone to rot; or perennial weeds have overtaken the vines.

Tailwater Recovery and Bypass Canals. Tailwater recovery is one of the most important management practices used by cranberry growers. Basically, it is a recycling of discharge water, conserving needed supplies and minimizing the risk of chemicals leaving the bog. As a water conservation measure, tailwater recovery is an economically sound way of maintaining an adequate water supply. Bypass canals are normally used as a temporary diversion when a moving stream bisects a bog area. The canal diverts the stream to the perimeter of the bog area and out of the area where pesticides might be applied.

Trapping. Burrowing animals pose serious threat to cranberry bogs and water management systems. These animals tunnel into beds, causing the muck soil to collapse and rendering the bed unusable. They also damage dikes and flumes, which can cause major washouts that damage property and endanger human lives. Only if all 'non-lethal techniques' have been used to control an animal without any success, can a grower apply to their local Board of Health for an emergency permit. The emergency permit is for a conibear, box or cage-type trap.

Upgrading Drainage System. Changes in drainage can reduce disease in the cranberry bogs. Maintaining existing ditches and building new lateral ditches helps to improve drainage. Adding crushed stones or installing drainage tiles may be used for better drainage after filling in ditches.

Normal agricultural activities may fall under the jurisdiction of one or more of the following:

Clean Water Act (Federal - Section 404; wetlands activities)
Dam Safety (M.G.L. c253 302 CMR 10.00)
Massachusetts Environmental Policy Act (M.G.L. c30 301 CMR 11.00)
Open Burning Laws (310 CMR 7.07 and 527 CMR 10.22)
Pesticide Control Act (M.G.L. c132B 333 CMR 1.00-13.00)
Public Waterfront Act (M.G.L. c91 310 CMR 9.00)
Water Management Act (M.G.L. c21G 310 CMR 36.00)
Water Quality Certification (Federal - Section 401; State jurisdiction: M.G.L. c21 314 CMR 4.00)
Wetlands Protection Act (M.G.L. c131 310 CMR 10.00)
Zoning Act (M.G.L. c40A)

Growers should contact the CCCGA or the appropriate authority if they are unsure if an activity falls under one or more of these regulations. Further details on many of the above regulations are available as Grower Advisories on the CCCGA web site at http://www.cranberries.org/growers/advisories.html.

Conservation Planning for Cranberry Farming

Linda Rinta

A Conservation Plan is a tool to help growers manage their lands profitably while protecting the natural resources on and around the farm. It is used to schedule improvements, document conservation practices, and provide access to USDA cost share programs.

Plans are written with the assistance of a USDA trained farm planner or a qualified technical service provider certified by USDA. However, the management decisions recorded in the plan are made by the landowner.

Typically a conservation plan contains the following components:

1. Maps showing the property's location, soil information, proximity to area resource concerns and regulated zones.
2. Practice assessments identifying conditions on the farm needing conservation treatment.
3. Record of decisions indicating a combination of conservation practices that are planned and a schedule of improvements.

In addition, the following documentation of the planning process may also be included:

4. Job sheets explaining how to implement the practices.
5. Conservation plan map to scale showing where practices will be installed.
6. Environmental evaluations and cultural resource considerations addressing the ecological and cultural resource impacts.
7. Cooperator assistance notes indicating the type of assistance provided.
8. Other information including engineering designs, Best Management Practices (BMPs) and Grower Advisories pertinent to the property.

More than the document itself, the process of developing a farm plan is an exercise in reviewing one's farming practices against a standard for resource protection and industry accepted Best Management Practices (BMPs).

Planning occurs through a series of site visits and landowner interviews and discussions. Planners follow a 9-step decision-making process universally employed by USDA throughout the country. These steps include: gathering locational data, identify goals and objectives, evaluate natural and cultural resources, investigate and evaluate various solutions and alternatives, develop and implement a schedule of practices, and ultimately re-evaluate and adjust as needed.

Planning is a dynamic and systematic way of constantly re-evaluating and improving one's farming practices.

Use of Farm Plans as Compliance Documents. Sometimes a Farm Plan is requested as a demonstration of compliance for a number of regulated and non-regulated activities. These may include water supply protection, water conservation, fisheries and wildlife concerns, gravel removal permitting and wetlands projects. In most cases, it is the participation in the planning process that is required.

There are only four situations in which a grower *must* provide a Town Conservation Commission a portion of their approved farm plan. These all involve improvement practices that will impact wetlands. See the Cape Cod Cranberry Growers' Association Grower Advisory on the Agricultural Exemption of the Wetlands Protection Act for more information at: www.cranberries.org/growers/advisories.html.

SPECIAL NOTE: *Some proposed new projects involve regulatory review and/or permits. The planning process does NOT exempt activities from local, state and federal review.*

Wetlands Functions of Cranberry Beds

Garrett G. Hollands

Are Commercial Cranberry Beds Wetlands? This basic question must first be answered before a discussion of how cranberry beds function as wetlands can be conducted. In 1990, the St. Paul District of the U.S. Army Corps of Engineers issued a draft entitled, "Analysis Regarding Section 404 Review of Commercial Cranberry Operations". The draft analysis was the result of long debate between the cranberry industry, the Wisconsin Department of Natural Resources, Region 5 of the USEPA, and the U.S. Army Corps of Engineers concerning expansion of cranberry beds into natural wetlands. This first analysis reached the conclusion that commercial cranberry beds were not wetlands per the federal definition of wetlands defined in either 1987 or 1989 federal delineation manuals.

The draft analysis was reviewed in detail by the cranberry industry, and a scientific report was issued that countered many conclusions of the draft analysis. After considerable debate and public meetings, the Corps of Engineers found that commercial cranberry beds are indeed federal

wetlands because they meet the necessary field test as prescribed in the Federal Wetland Delineation Manual. Also, commercial cranberry beds were determined to be "water dependent", that is, they must occur in "waters of the USA" in order to be economically viable. The Corps issued a Regulatory Guidance Letter (RGL) 92-2 to clarify this issue.

This series of events led to the issuance of Nationwide Permit 34 (not ratified in MA), which allows for limited expansion of cranberry beds into natural wetlands as an activity believed not to result in significant environmental damage to wetlands (since the conversion) to commercial beds does not change the area to uplands. The area remains a wetland with modified wetland hydrology, hydric soils, and wetland vegetation. These areas have not been converted to uplands and when abandoned, quickly revert to natural wetland vegetation communities. Even cranberry beds created from upland are federal wetlands. Therefore, if an area, no matter how altered, is a wetland and when abandoned continues to be a wetland, it must function as a wetland.

Statutory Functions of Commercial Cranberry Beds. The Massachusetts Wetlands Protection Act (MGL Chapter 131, section 40) regulates activities that alter the function of wetlands. These functions or statutory interests are flood control, storm damage prevention, prevention of pollution, public or private water supply, ground water supply, land containing shellfish, fisheries, and wildlife habitat.

The Regulations (310 CMR 10.00) expand upon the Act. Wetlands are defined in the Act to include vegetative communities consisting of "bogs", "coastal wetlands", "swamps", "wet meadows", and "marshes". Cranberry bogs meet the definition of "bog" in the Act. Neither the Act nor its Regulations differentiate in any manner between natural and man-made wetlands. It is extremely difficult to define "natural" vs. "man-made" wetlands. Dr. John Lukins of the Rhode Island School of Design, in conjunction with Interdisciplinary Environmental Planning, Inc. (IEP) in the late 1970's, attempted to define artificial vs. natural wetlands. He found that in many regions, the majority of wetlands have either been inadvertently created by man, or so highly impacted by man that they no longer could be considered "natural" wetlands. My personal inventory of wetlands over the past 22 years, which has included thousands of square miles of Massachusetts wetlands, has shown that there are no wetlands in Massachusetts that have not been altered by man. "Altered" means man has raised or lowered water levels, constricted stream flows and outlets, increased stream flow, changed the vegetative community, etc.

Wetlands are dynamic features of the landscape. What you see today most probably is not what was there 100 years ago, and will not be the same 100 years into the future. The primary cause of these dynamics is man's land use practices. In a rapidly growing region such as southern New England, urbanization of the uplands, even when wetlands are avoided, results in major impacts to the wetlands.

Thus, if only "natural" wetlands were regulated, few of our valuable wetlands would fall under that definition. Some special interest groups might take advantage of the term, "artificial" wetlands, resulting in the destruction of much of the Commonwealth's wetlands.

The regulations (310 CMR 10.00) presume that **all** wetlands have one or more of the eight statutory interests. The Regulations define wetlands as: Wetland resource Areas; Land Under Water Ways or Water Bodies, Banks, Bordering Vegetated Wetlands, and Land Subject to Flooding. Most cranberry bogs contain all of these wetland resource areas. The Regulation in 310 CMR 10.54 through 10.57 define these Resource Areas and the functions that they are presumed to have. Only those wetlands that are not significant for any of the eight functions are not subject to the performance standards, nor worthy of protection. The person desiring to destroy wetland resource areas must prove with credible evidence that the wetlands in question have no function, that is, are not significant for any of the eight values. This is a formidable task.

The regulations in 310 CMR 10.04 Definitions states that Significant means "plays a role". A resource area is significant to an interest identified in the Act when it plays a role in the provision or protection, as appropriate, of that interest. The Regulations do not say "play a small role"; the regulations say "plays a role". This means any role, no matter how small. None of the wetlands assessment methods presently available that rate wetlands as having low, medium, or high values can be used here, as even a "low" value adds up to be a collective large value. To prove that a wetland has any one of the eight interests, all one has to do is to prove that the wetland has the necessary "parts" or elements to give rise to that value. The basic general parts of a wetland are plants, soils, hydrology, and topography. One can

view a wetland similar to an automobile. All automobiles, when they contain the necessary working parts, provide transportation, which is their primary function. Some do so with basic and cheap parts, others do so with great expense and luxury, but they all provide the function of transportation. The increased complexity of an auto only adds to its ability to provide other functions as well as transportation.

The use of wetland parts to define function and significance is relatively simple. Let's take a typical cranberry bog as an example. Although a typical cranberry bog is difficult to define as they occur in a great variety of hydrologic settings, for illustrative purposes, the following description is used:

> The bog was created from a wood swamp. The bog is a groundwater discharge wetland, having an inflowing stream, bog ditches, and an outlet stream. The bog is surrounded by dikes and the outlet is structured to include flash boards. The cranberry plants grow as a thick monoculture on sandy soils overlying organic wetlands soils.

Applying the Regulations, we find that the bog contains Land Under a Waterway (stream), Banks (ditch banks), Bordering Vegetated Wetland (cranberry bog) and Bordering Land Subject to Flooding (100-year flood plain). This bog is presumed to be significant for all statutory values except Land Containing Shellfish. If we test these presumptions with the following examples, we find the following:

Flood Control. The topography and the outlet structure create a volume of water that is stored in the wetland up to the 100-year flood stage. The bog is part of a stream system, receiving and storing inflowing waters, and metering its release downstream through the outlet. It has flood control value since it has the necessary parts and a volume can be computed. If the bog is shown on a FIRM flood plain map as A or V zone, there is no doubt it has flood control value. In the Final Decision of the David Mann Case (DEQE wetland File 57-147), the DEQE (Department of Environmental Quality and Engineering) found that the Mann bogs did contain a flood storage of an average elevation of 2.3 inches for the 100-year flood. This volume of water was required to be compensated for by the Department of Public Works (DPW) proposed detention basin.

Prevention of Pollution. The wetland contains wetland plants and soils capable of removing nutrients, heavy metals and other contaminants from inflowing water. The inflowing water is periodically spread over the plants and soils allowing interaction of water, plants, and soil to remove contaminants. Thus, since the parts occur and are allowed to interact (function), significance is proven.

Again, in the Mann case, the DEQE found since wetlands plants and soils occurred in the bogs, they were significant for prevention of pollution. The DEQE position in the Superseding Order of Conditions was that the bogs were not significant since they did not "respond to natural conditions" as do "naturally occurring" wetlands, and that pesticides and fertilizers were placed into the bog. The Final Order disagreed with this position. The following is quoted from Pages 22 and 23 of the Final Order:

> "I reach this conclusion for two related reasons. First, I note that there is no evidence suggesting that the pollution attenuation capacity of the taken bogs has in any sense been 'used up' by the role that it may have played in taking up agricultural chemicals. Second, while Mr. Hartley has remarked in this testimony that he was not aware of the Department ever requiring replication of a cranberry bog, it is also true that it has not been the Department's policy, under either the Old or the New regulations, to conclude that compensatory measures were not required because a wetland that was being destroyed was already degraded or polluted. While it would be possible to rank wetlands and treat those of 'medium' pollution prevention value as subject to less restriction than those of 'high' value, that is not the regulatory framework which has been adopted in Massachusetts. Rather, the New regulations, codifying prior Departmental policy, have made it clear that the functions performed by Bordering Vegetated Wetlands are subject to protection unless they are wholly without significance to the interest of the Act.
>
> I therefore conclude that wetlands replication must be required in this case because of the destruction of a wetland with pollution-prevention capacity. Since I have not found that any of the unique characteristics of cranberry bogs make a particular contribution to pollution prevention, and since I have concluded that the protectable recharge and flood control function of the taken bogs are adequately accounted for by other means, I

find no basis for requiring that the replicated wetland be in the form of a cranberry bog.

Accordingly, the Final Order of Conditions accompanying this decision requires the establishment of a nine-acre area of shallow marsh to replace the bog area being destroyed."

Other Statutory Interests. Specific bogs may exist that qualify as being significant for the other interests: Public and Private Water Supply, Storm Damage Prevention, Fisheries, and Wildlife Habitat. One only needs to gather the data to show that the wetland has the necessary parts and that these parts occur in such a manner to function for a given interest. The Mann Case shows in the example of "Prevention of Pollution" that any function, any role, no matter how small, is protectable.

In summary, cranberry bogs have functions that are significant to the statutory interest of the Act. Any alteration of a bog that does not meet 310 CMR 10.54-57 is not permitted unless **all** of the presumptions of significance can be overturned (likely to be impossible). In light of the Mann Case, it is probable that all cranberry bogs are significant for "Prevention of Pollution" value. Thus, destruction of existing bogs requires replication in the form of new wetlands of equal size to the area destroyed.

Wildlife Utilization on Commercial Cranberry Wetlands Systems

Steven Ellsworth and Donald Schall

Commercial cranberry bogs were created in moist lowlands and scrub/forested wetlands for over 150 years. These natural wetland systems were utilized by cranberry growers because of readily available water sources, low pH and high iron soils with a base of peat. These are the basic requirements for various cranberry cultivation practices. In the case of some of the earliest beds, the presence of natural wild cranberry vines in the vegetative community encouraged their conversion to commercial cranberry bogs. After 1986, any new cranberry bed establishment needs to be conducted in upland soils, replicating a traditional wetland cranberry bog environment as much as possible.

Despite the long history of cranberry cultivation and the number of acres under cultivation, the ecology of commercial cranberry wetland systems, and in particular, their value to wildlife is only recently being inventoried and studied. A baseline ecological assessment of three commercial cranberry wetland systems in eastern Massachusetts was conducted by Interdisciplinary Environmental Planning (IEP), Inc., in the late Spring of 1990 with the primary focus being the wildlife habitat value and wildlife utilization.

Our studies of wildlife utilization of cranberry wetland systems in eastern Massachusetts incorporated several wildlife sampling methods such as transect bird surveys, mist net bird surveys, small mammal trappings, and fish and macroinvertebrate surveys to collect information on the species composition of the wildlife communities that utilized these systems. The field inspections also generated many interesting field observations.

The field surveys documented a diversity of wildlife on cranberry wetland systems that compared favorably to that reported in the literature for certain types of natural wetland systems. Overall, species diversity was closely tied to the number and variety of habitats found within the cranberry wetland system. During the field investigations, 11 species of mammals, 65 species of birds, 6 species of reptiles, 6 species of amphibians, and 11 species of fish were recorded. Species common to New England were well represented, but several of the region's wildlife species listed as "threatened" or "endangered" by the Commonwealth were also observed.

From an agricultural viewpoint, cranberry beds are monocultures of the large-fruited cranberry. As such, the diversity of plants life forms (e.g., herbs, shrubs, trees), which provide vertical structural diversity in a plant community, is limited on cranberry beds. Increased structural diversity correlates closely with higher wildlife diversity and utilization. Mammalian species found to utilize active cranberry beds in the study areas include white-tailed deer, red fox, and meadow voles. Trapping data documented inhabitation of the cranberry beds by meadow voles. However, trapping success was greater in adjacent disturbed areas and adjacent wetlands. Active beds were also utilized by waterfowl (ducks and geese) and raptors (hawks and owls). Shorebirds and herons

fed along the banks of the irrigation ditches, while swallows and flycatchers hunted for insects above the vines.

Although the cranberry beds themselves appear to be utilized by a relatively low number of species, adjacent managed habitats such as reservoirs, drainage channels, irrigation ditches, low brush communities, and disturbed areas provide breeding areas, cover habitats, and feeding sites for many additional species. The water supply systems and land use management practices are an integral part of the operation of a cranberry bog, and they contribute to the overall diversity of the wetland system.

Construction and maintenance of cranberry wetland systems creates some excellent wildlife habitats such as reservoirs, ponds, and transition zones between adjacent uplands and undisturbed wetlands. The reservoirs often provide habitat for the more aquatic avian species such as double-breasted cormorant, great blue heron, green-backed heron, black-crowned night heron, mute swan, Canada goose, mallard, black duck, wood chuck, osprey, and belted kingfisher, where none previously existed. Permanent water bodies are utilized by various mammals, such as white-tailed deer, raccoons, and muskrats, as well as providing excellent habitat for turtles, frogs, and fish. The reservoir edge was particularly attractive as habitat for a number of avian species. Some of the more commonly observed species in this reservoir edge habitat were Eastern kingbird, gray catbird, yellow warbler, common yellowthroat, red-winged blackbird, and common grackle.

Herbaceous and scrub/shrub areas adjacent to the cranberry beds, in general, had high productivity (abundance). Cottontail rabbit, woodchuck, white-footed mouse, and meadow vole are mammal species that commonly used these habitats. White-tailed deer and red fox also used them. Red-shouldered and red-tailed hawks were seen foraging over these areas on a number of occasions. Bobwhite quail were also frequently observed. Among the more common song birds observed in these habitats were gray catbird, Northern mockingbird, brown thrasher, blue-winged and prairie warblers, Northern cardinals, rufous-sided towhees, and song sparrows. Snapping turtles and painted turtles, which must leave aquatic habitats to deposit their eggs in open, sandy areas were observed depositing eggs in sandy road banks and sand piles in the study areas. Open sand banks, which are maintained as part of the cranberry operation, create habitat for nesting turtles.

The diversity and abundance of wildlife species utilizing both wetland and upland habitats in the study areas were, in all probability, increased by their proximity to the reservoirs, cranberry beds, and disturbed areas of the cranberry operations. This edge effect contributed to ecological diversity. The value of habitats, particularly forested habitats, was improved for most wildlife species when they were adjacent to open areas.

Osprey building a nest atop a pole erected next to a cranberry bog. Photo courtesy J. Mason.

Although wildlife diversity is relatively low in the cranberry beds, diversity within the overall system is high, when compensation from the other habitats is taken into consideration. The study was conducted during a brief 16-day period in May-June, 1990. If a longer study were conducted, the number of species that actually used these wetland systems over the course of an entire year would be increased significantly.
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