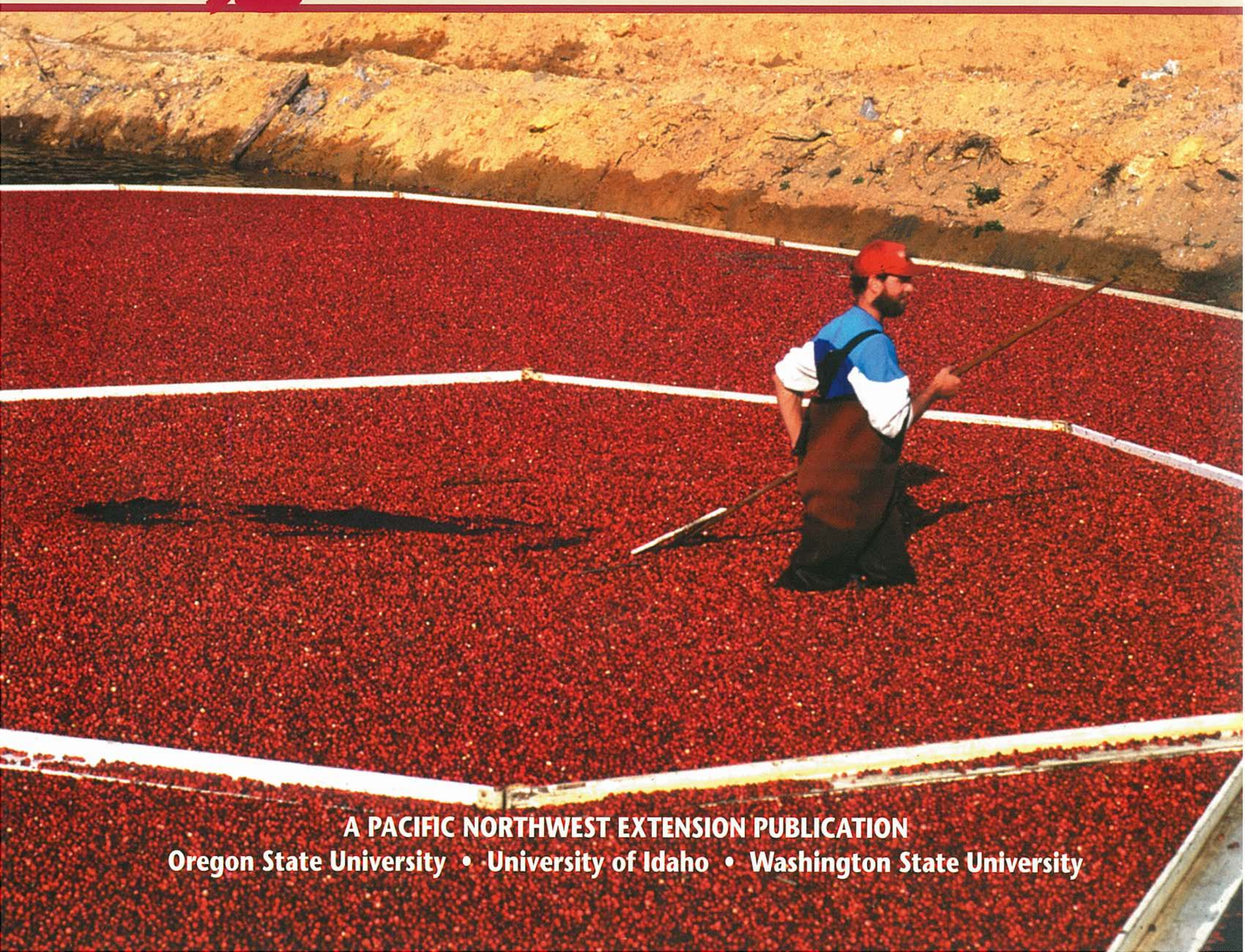
PNW 247 • Revised May 2002

CRANBERRY PRODUCTION IN THE PACIFIC NORTHWEST



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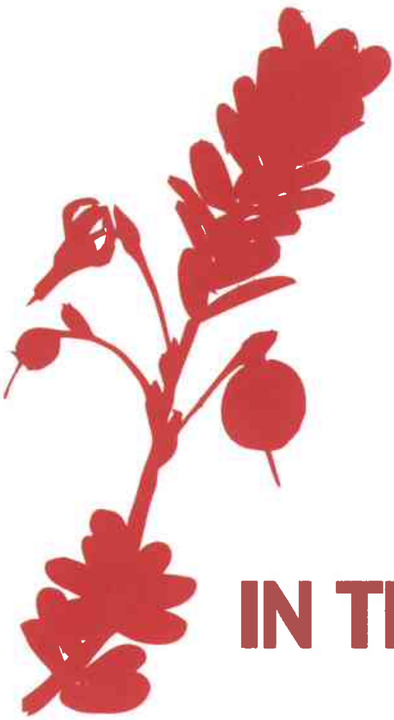

CRANBERRY PRODUCTION IN THE PACIFIC NORTHWEST

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We appreciate the information on British Columbia production provided by Geoffrey Sirois.

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The Cranberry Industry

1

The large-fruited American cranberry (*Vaccinium macrocarpon* Ait.) first was cultivated near Cape Cod, Massachusetts, around 1820. The crop did not become commercially significant until about 1850.

The first cranberry bed in the Pacific Northwest was established by Charles Dexter McFarlin, who came to Coos County, Oregon, from Cape Cod in 1885 and set out vines he obtained from Massachusetts. Mr. McFarlin took great pride in propagating the best strains of berries. He and his brother Thomas are thought to have developed the 'McFarlin' cultivar grown today after finding it growing on their farm in Massachusetts. (See Chapter 3, "Cultivars.")

Today, Oregon cranberries are grown mainly near the coast in Coos and Curry counties. Some beds are located in Clatsop and Tillamook counties.

The first plantings in the state of Washington were made by A. Chabot, who planted 35 acres at the north side of the mouth of the Columbia River shortly after McFarlin started his plantings in Coos County. Chabot also brought cuttings from bogs in the eastern United States. Today, Washington cranberries are grown mainly in the coastal area of southwest Washington, with some plantings in Whatcom County in northwest Washington.

In British Columbia, the cranberry industry began in the 1930s, when vines were planted on small acreages that had been mined for sphagnum peat moss. Arthur Smith first imported American vines to a field "the size of a city block" in 1932. From the 1930s through the early 1970s, cranberry production expanded throughout the peat-mined and peat-rich areas of Richmond, south of Vancouver. Some of the cranberry "pioneers" brought expertise directly from Massachusetts, while others were influenced by growers in Washington.

Today, the leading cranberry-growing regions in North America (in order of acres harvested) are Massachusetts, Wisconsin, New Jersey, British Columbia, Oregon, Washington, and Quebec. Other states or provinces with commercial harvest of fewer than 500 acres in 1997 included Ontario, New Brunswick, Nova Scotia, New York, Michigan, and Maine.

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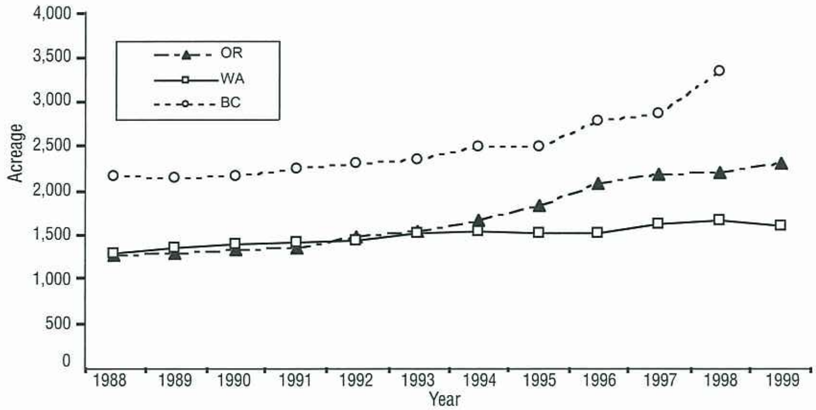

Figure 1.—Acreage of cranberries in the Pacific Northwest (Oregon, Washington, and British Columbia), 1988–1999.

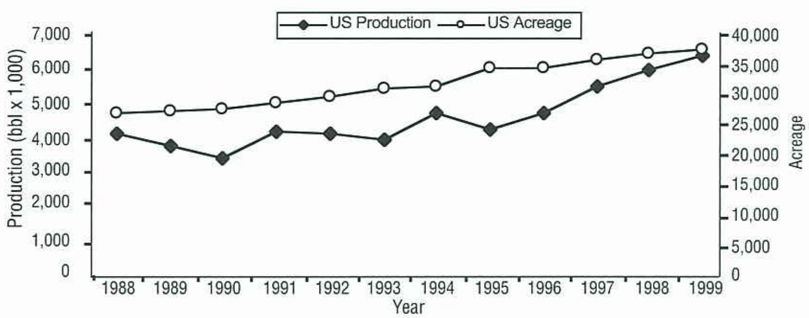

Figure 2.—Production and acreage of cranberries in the U.S., 1988–1999.

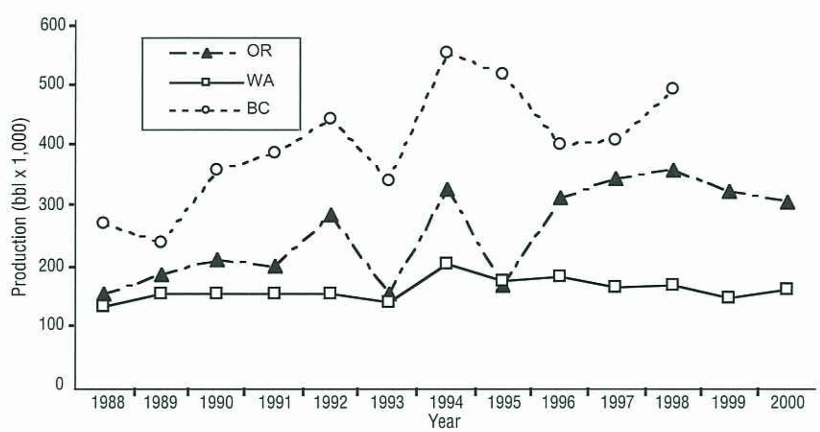

Figure 3.—Total production of cranberries in the Pacific Northwest (Oregon, Washington, and British Columbia), 1988–2000.

Growth of production

The United States produces most of the world supply of cranberries (90 percent in 1998). Cranberry production in most U.S. regions grew very quickly in the early 20th century. By 1927, there were 14,000 acres in Massachusetts, 13,000 acres in New Jersey, 2,000 acres in Wisconsin, 500 acres in Washington, 275 acres in Long Island, NY, 130 acres in Oregon, and 200 acres in other states. Since then, acreage has decreased considerably in New Jersey and a little in Massachusetts, but has increased tremendously in Wisconsin and steadily in the Pacific Northwest.

In the Pacific Northwest cranberry-growing region (Oregon, Washington, and British Columbia, see Figure 1) and in the United States (Figure 2), acreage has increased in the past 10 years. During this time, commercial production essentially has come from Massachusetts, Wisconsin, New Jersey, Oregon, and Washington, but new plantings are being established in New York and Michigan.

About 80 percent of Canada's acreage is in British Columbia, with about 4,000 acres in 2001. More than 98 percent of British Columbia's cranberry production is in the Lower Fraser Valley (Richmond, Delta, Pitt Meadows, and Fort Langley). The remainder is on Vancouver Island. The size of individual cranberry farms ranges from a few to 350 acres.

Cranberries also are grown in Ontario (2 percent of Canadian acreage), Quebec (16 percent), and Nova Scotia (1 percent). In 1997, producing acreage in Quebec was 702 acres, up 29 percent from 1996, with an additional 598 nonbearing acres. In 1997, the harvested cranberry acreage in Canada was 3,671 acres—a 42 percent increase from 1994.

Production in the Pacific Northwest also has increased over the past 10 years (Figure 3).

Yield per acre in barrels (bbl) has remained relatively steady, although production varies from year to year (Figure 4).

Price per barrel increased from 1988 through 1998 due to high demand for cranberries (Figure 5); Americans were consuming the fresh-weight equivalent of 1.6 pounds of cranberries per person. As U.S. acreage and production increased (Figure 2), demand did not keep up with supply; in 1998 lower demand and a large supply caused prices to drop drastically (Figure 5).

In 2000, USDA regulated the crop to 85 percent of production in the highest 4 of the most recent 6 years for growers of all but fresh or organic cranberries. However, price per barrel to growers still is estimated to be in the low teens. A marketing order (volume regulation) of 65 percent of previous crop sales history was set in 2001. Prices to growers look relatively low for at least the next several years.

Cranberry acreage is increasing worldwide. In recent years, plantings have been established in Chile. New Zealand, Ireland, Poland, Belarus, Russia, and Lithuania are testing this crop for commercial potential.

Production and marketing

Cranberry harvest in North America begins in early September. By the end of October, most berries have been harvested.

From 25 to 33 percent of the Washington crop is dry harvested for fresh market, while less than 2 percent of the

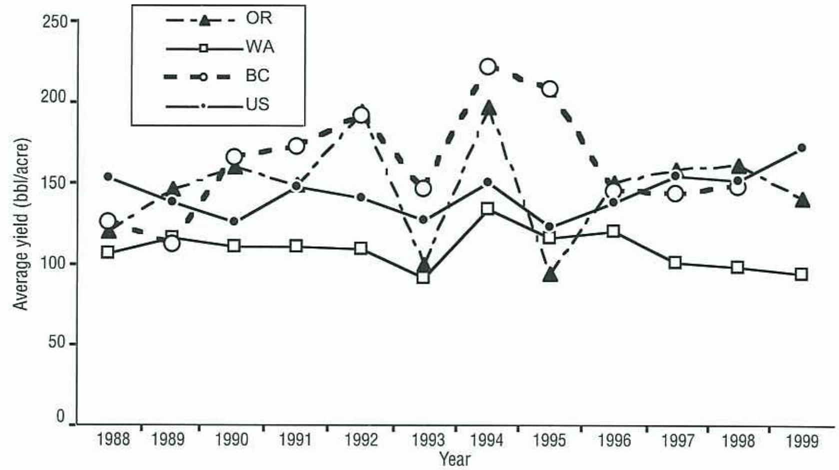

Figure 4.—Average yield per acre in barrels (1 bbl=100 lb) of cranberries in the Pacific Northwest (Oregon, Washington, and British Columbia) and the United States, 1988–1999.

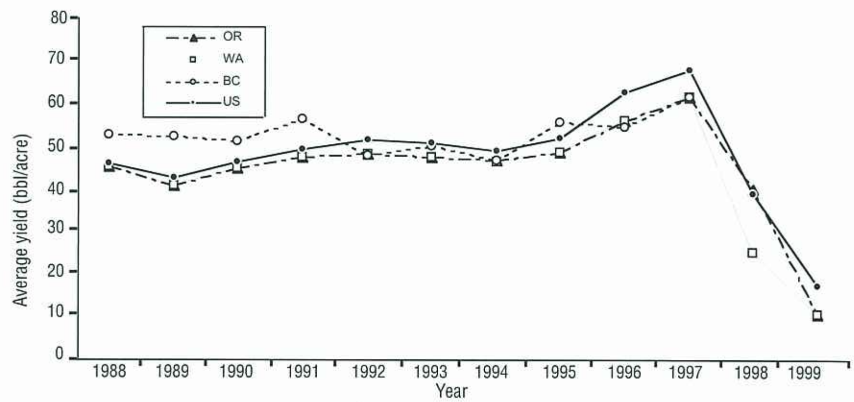

Figure 5.—Average value (US$ per barrel; 1 bbl=100 lb) of cranberries in the Pacific Northwest (Oregon, Washington, and British Columbia) and the United States, 1988–1999.

British Columbia and Oregon crop is sold for fresh market.

Fresh berries are exported from the U.S. to Canada for the Canadian Thanksgiving holiday in October. Fresh berries for the U.S. Thanksgiving holiday remain in refrigerated storage and are sorted and packed later.

In North America, 85 to 95 percent of the cranberry crop is processed. The industry estimates that 90 percent of processed berries go to juice, and the remainder go to sauce and other products such as sweetened, dried cranberries.

Ocean Spray, the large grower cooperative, is credited with lifting the cranberry from its minor role as a sauce to accompany turkey to its current identity as a year-round food. In the 1950s, Ocean Spray introduced cranberry juice cocktail. Demand for cranberry juice increased after an article in the *Journal of the American Medical Association* confirmed in 1994 that drinking cranberry juice helps prevent urinary tract infections.

The Ocean Spray cooperative dominates the industry, with members in the U.S., Canada, and Chile. Growers have renewable 3-year marketing contracts with Ocean Spray for purchase of product from a specified number of acres. Ocean Spray growers can produce additional acres, but they must market the product through other channels.

In the mid-1980s, Ocean Spray controlled 85 percent of U.S. cranberry production. Although Ocean Spray still controls the majority of the U.S. cranberry crop, its share has declined. Over time, high returns have led to a growth in production outside the cooperative and to more competition from independent processors.

In British Columbia, cranberry growers must have a production quota (production forecast or limit) to market cranberries. Cranberry quota is administered by the British Columbia Cranberry Marketing Board. This board has authorized two agencies to market cranberries in British Columbia: Ocean Spray Cranberries, Inc. and Lucerne Foods, Ltd. Most growers are members of Ocean Spray.

The long-term future of the cranberry industry seems promising, since this fruit generates so many by-products and is popular for its nutritional and medicinal value. However, the profitability of the cranberry market is questionable for the near future.

For more information

Growers in the Pacific Northwest can contact grower organizations and the Extension Service (where applicable) for guidance. Check with your local Extension Service for contact information.

- **British Columbia**

  The British Columbia Cranberry Growers' Association

- **Washington**

  The Washington State Cranberry Commission

  The Washington Cranberry Growers' Alliance

  The Pacific Coast Cranberry Research Foundation (also accepts memberships from other regions in the Pacific Northwest)

- **Oregon**

  The Oregon Cranberry Growers' Association

  The Oregon Cranberry Farmers' Alliance

Botanical and Physiological Characteristics

2

The large-fruited American cranberry (*Vaccinium macrocarpon* Ait.) is a low-growing, trailing, woody, broadleaf, nondeciduous vine. It is native to eastern North America, although there are some introduced "wild" plantings on the Pacific coast. More than 30 percent of commercial cranberry acreage consists of selections of *V. macrocarpon* from the wild.

The small-fruited cranberry (*Vaccinium oxycoccus* L.) is native to the Pacific Northwest. It is not cultivated commercially in North America.

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Roots

The cranberry root system is made up of very fine, fibrous roots that develop in the upper 4 inches of soil. Cranberry roots do not have root hairs; they absorb nutrients through association with mycorrhizal fungi in a symbiotic (mutually beneficial) relationship.

Shoots

Runners

Runners are horizontal stems ranging from 1 to 6 feet long. They spread profusely and form a thick mat over the entire surface of a cultivated bed (Figure 1). (Not all cranberries are cultivated on peat bogs; thus, the term "bed" is used to describe a cranberry planting.) Leaves located along the runners are spaced relatively far apart.

Figure 1.—Cranberry runner growth on the surface of the canopy.

Uprights

Uprights are short, vertical branches, distinguished from runners by the whorled arrangement of their leaves and their vertical growth habit. They originate from axillary buds (where a leaf joins a stem) on the runners or from older uprights. Uprights typically are 2 to 3 inches high; their length is affected by light intensity and nutrition. They grow for several years.

New growth originates from uprights and can be either fruiting and vegetative (mixed, Figure 2) or vegetative (no flowers).

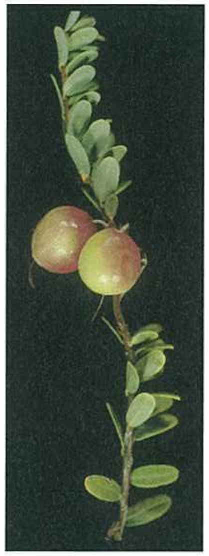

Figure 2.—A cranberry fruiting upright showing set fruit.

Leaves

Leaves are either oblong or oval shaped, 1/3 to 1/2 inch long and 1/8 inch wide. Leaves remain on the plant for up to 2 years before senescing (dropping). During the growing season, the top surface of the leaves is dark green and glossy, turning reddish-brown during the dormant season. The lower leaf surface is pale green.

Buds

Cranberry uprights produce one of two types of buds at their tip: flowering (fruit) or vegetative. *Flowering buds,* also known as "mixed buds" because they contain flowers and vegetative growth, are recognized easily by their large size and plump appearance. The rosette of leaves enclosing a fruit bud is saucer shaped.

Vegetative buds are more pointed. The leaves are more upright and tend to envelop the bud. The bud scales tend to look loose. Vegetative buds often are smaller than mixed buds.

Mixed buds form at the tips of uprights and are easy to see in late summer and fall. Each mixed bud contains from two to seven flowers as well as leaves and a growing point.

A count of mixed buds per unit area gives the earliest prediction of next year's approximate yield. In the Pacific Northwest, 150 to 700 uprights per square foot have been documented in 'Stevens' cranberry beds, with 10 to 65 percent of these being fruiting uprights.

Axillary buds are located at leaf nodes, either on runners or on uprights. They are the source of new uprights and runners. Axillary buds tend to break (develop) when the terminal bud is damaged by cold, insects, or pruning or when the shoot is bent over (as often happens when a cranberry bed is sanded). In these cases, the terminal bud's *apical dominance* is lost; it no longer produces hormones that suppress the development of buds below it on the stem.

Flowers

Each flower is borne individually on its own pedicel (stem), which is slightly curved in a normal flower. There are two to seven flowers per upright (Figure 3).

A normal flower consists of an inferior ovary (located below the calyx), a calyx of four sepals, and a corolla of four petals, which are pinkish-white in color and deeply cleft. The petals curve back when the flower is fully open. Eight stamens surround the pistil in a whorl and shed pollen grains from a pore at the tip of the anther (Figure 4).

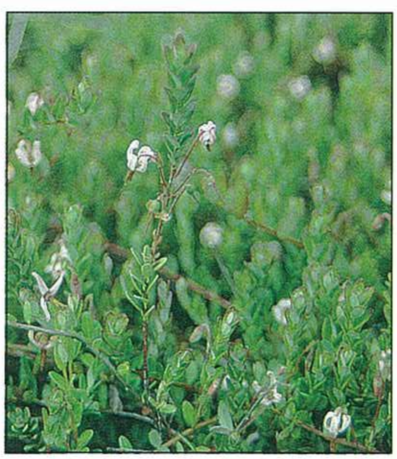

Figure 3.—A fruiting upright in bloom.

Figure 4.—A cranberry flower.

Normally, vegetative growth continues beyond the flowers. Sometimes, however, the upright forms an "umbrella" bloom and terminates with flowers. Umbrella blooms can result from insufficient chilling, frost damage, or insect damage.

Fruit

If an ovule is fertilized (see "Pollination and fruit set," page 8), the ovary and calyx fuse to form a true berry that varies in shape and color. The berry consists of a relatively thin skin enclosing four rather large chambers (*locules*) containing from 0 to 50 seeds, depending on set. In the Pacific Northwest, a typical fruit weighs about 1 to 1.5 grams.

A waxy cuticle covering the skin contributes to the cranberry's ability to resist moisture loss after harvest. Although the thickness of this waxy cuticle differs among cultivars, it is not related to the keeping quality of the fruit.

Fruit growth is optimum at temperatures from 61 to 86°F and tends to occur at a linear rate through the season. Compared to eastern production regions, average daily temperatures are lower in the Pacific Northwest, and growth rates are slower, but a longer growing season makes up for the cooler weather.

Cranberry fruits go through several stages of color development, from green to white to red. The berry's pigments—predominantly red anthocyanin, yellow flavonol, and carotene—become dominant as the fruit matures. These pigments are concentrated in the epidermis (skin) and subepidermal layers of the fruit.

Anthocyanin content is affected by cultivar, climate (cooler nights tend to promote more color development), light intensity (shading or dense canopies reduce color), and perhaps berry size (smaller fruit, which has a higher skin-to-pulp ratio than larger fruit, might have more color).

The chemical composition of the cranberry is shown in Table 1. Fruit composition is affected by cultivar, growing region, and cultural practices.

Table 1.—Average chemical composition of fresh cranberry fruit, per 100 g.

Chemical composition (%)	
Moisture	88.00
Reducing sugars	4.20
Acids (as citric)	2.40
Pectin	1.20
Fat (ether extract)	0.40
Protein	0.20
Ash	0.25
Fiber	1.60
Undetermined	1.80
Mineral content (ppm)	
Potassium	530
Sodium	20
Calcium	130
Phosphorus	80
Magnesium	55
Iodine	0.05
Sulfur	50
Chlorine	40
Iron	4
Manganese	6
Copper	4
Alkalinity of ash	2.2 cc*
Energy value (kcal)	
Fresh berries	26
Sauce	125 **
Vitamin content	
Vitamin A	40 I.U.
Vitamin C	7.5–10.5 mg
Thiamine (B_1)	13.5 mcg***
Riboflavin (B_2)	3.0 mcg
Nicotinic acid	33.0 mcg
Pantothenic acid	25.0 mcg
Pyridoxine (B_6)	10.0 mcg
Biotin	trace
Acid content (%)	
Citric	1.10
Malic	0.26
Quinic	0.5–1.0
Benzoic	0.065

*cc is a measure of alkalinity—the ml of HCl concentration needed to neutralize the residual base in the ash
**Approximately 100 kcal from added syrup
***Microgram
Source: Fellers and Esselen, Cranberries and Cranberry Products, *Bulletin 481 (Massachusetts Agricultural Experiment Station, 1955).*

Growing cycle

The cranberry bud goes through several physical stages before bud break (Figures 5–7). Typically, bud break (Figure 8) is in early April, depending on weather conditions and vine nutrition. In April and May, some vegetative growth occurs, including development of new leaves (Figures 9 and 10).

At the "hook" stage (Figure 11), when the flower pedicels (stems) are visible, it is easy to distinguish a flower bud from a vegetative bud. At this stage, the curve of the slender flower stem with its ready-to-open blossom resembles the neck and head of a crane, suggesting the name "craneberry," now shortened to cranberry.

Bloom (Figure 12) begins around the first part of June and lasts 3 to 6 weeks. Blossoms and fruit usually are borne on uprights, but under certain conditions, some cultivars produce blossoms and fruit on runners. The first berries are visible in late June or early July.

Vegetative growth on uprights and runners continues through the summer. During the long days of mid- to late summer, flower bud initiation for next year's crop begins at the end of some uprights. Uprights tend to bear biennially; if they flower and fruit one year, they are more likely to be vegetative the following year.

Table 2 gives a calendar of cranberry development (phenological) stages in the Pacific Northwest.

Berries reach physiological maturity about 80 days after fruit set. Harvest typically begins in late September and continues through early November, depending on location. Harvest often is delayed past physiological maturity so that berries develop more anthocyanin (red pigment). Better color commands a higher price.

After harvest, the vine begins its acclimation process before entering dormancy in the winter. A chilling requirement (about 1,000 hours of cold between 32 and 45°F) must be satisfied before normal growth resumes the following spring. We do not have conclusive data regarding the chilling requirement of cranberry, but we know that cultivars differ in their chilling requirement and that the regional macroclimate also might be important. Cold hardiness of cranberry is affected by the stage of dormancy or growth.

Pollination and fruit set

In addition to the number of fruiting uprights per unit area, yield depends on percent fruit set. The formation of the cranberry fruit depends on successful fertilization of the ovules within the cranberry flower and subsequent formation of one or more seeds. The number of seeds per fruit is related to berry size; more seeds typically mean larger fruit. Although seedless cranberry fruits do occur, they generally are very small and of no commercial value.

Pollination, the transfer of pollen from an anther to the stigma of the same or a different flower, is a prerequisite to fertilization and seed formation. Agitation of the cranberry flower by wind is inadequate to produce a commercial crop. Pollination normally is performed by bees. (See Chapter 7, "Pollination.")

The cranberry is self-fertile; that is, the pollen from a given flower can fertilize the ovules of that same flower. However, some evidence indicates that cross-pollination can improve fruit set and berry size. For this reason, it's not unusual to find beds of different varieties on a farm or mixtures of cranberry cultivars in beds.

Pollen is shed from the terminal pores of the anthers when they are agitated. Each pollen grain is composed of four cells (a tetrad), and each cell is capable of germinating a pollen tube. Pollen must adhere to a receptive stigma to germinate. The stigma of the flower becomes receptive to pollen about the time the petals open. Pollen tubes take about 48 hours to travel down the style. Fertilization of the ovule occurs within about 72 hours after pollen grain germination. (See Chapter 7.)

The percentage of blossoms that set fruit is relatively low in cranberry. In Oregon, studies have found fruit set to range from 12 to 57 percent. Unfertilized flowers sometimes hang on to the upright for more than 3 weeks.

Figure 5.—Tight bud ('Stevens').

Figure 6.—Bud swell ('Ben Lear').

Figure 7.—Cabbagehead ('Stevens').

Figure 8.—Bud break ('Ben Lear').

Figure 9.—Bud elongation ('Stevens').

Figure 10.—Roughneck ('Stevens').

Figure 11.—Hook.

Figure 12.—Bloom.

Photographs in this chapter are used with permission from Terminology for Cranberry Bud Development and Growth, *by Beth Ann A. Workmaster, Jiwan P. Palta, and Teryl R. Roper, University of Wisconsin (http://web.hoflin.com/terminology).*

Table 2.—Cranberry phenological stages in the Pacific Northwest. Timing depends on weather conditions and vine nutrition.

	Timing		
Stage of development	**Oregon**	**Washington**	**British Columbia**
Bud break	early April	mid- to late April	early April
Hook stage	late April to May	early to mid-May	May
Begin bloom	May	mid- to late May	late May
End bloom	late June	late June	late June
Berry maturity ('Stevens')	late September	mid-September	late September

Adequate carbohydrates are required for fruit set. In cranberry, photosynthesis during bloom is an important source of these carbohydrates. Research has shown that, in general, each upright can support one or two fruits.

Fruit set can be limited by an overproduction of flowers (which limits the amount of carbohydrates available to each flower), insufficient pollination (inadequate bee activity or cool, wet weather during bloom), spring frost, nutritional imbalance, and application of certain fungicides during bloom.

Photosynthesis

Photosynthesis is a process whereby plants use carbon dioxide (CO_2), water, and the sun's energy to produce carbohydrates. Gas exchange (CO_2 and O_2) in plants occurs through small openings called *stomata*. Water vapor also is lost through stomata in a process called *transpiration*. Cranberry leaves have a relatively high number of stomata on the underside of the leaf surface compared with most other crop plants. There are no stomata on the top of the leaf.

Gas exchange and transpiration occur when stomata are open. The opening and closing of each stoma are controlled by a pair of *guard cells*. Unlike many other crop plants, cranberry guard cells do not shrink and swell readily in response to environmental conditions. As a result, cranberry stomata normally are partially open. Thus, compared to other crop plants, cranberry plants have a high transpiration rate and low water use efficiency; they use a lot of water per unit of carbohydrate produced by photosynthesis.

Cultivars

3

The large-fruited American cranberry (*Vaccinium macrocarpon* Ait.) is native in bogs from Newfoundland south to North Carolina and west to Minnesota. Commercial cultivation began in the 1800s using selections from the wild. (See Chapter 1, "The Cranberry Industry.") As certain selections gained notoriety or popularity, they were given a cultivar (variety) name.

A breeding program was established in 1929 by the United States Department of Agriculture in cooperation with Agricultural Experiment Stations in New Jersey, Massachusetts, and Wisconsin. The main objective was to develop varieties with some resistance to false blossom disease. The first 40 seedlings were selected in 1950. Three of these were named 'Beckwith,' 'Stevens,' and 'Wilcox.'

The breeding program's focus then shifted to increasing yield and berry size. In 1961, three more seedlings were named: 'Bergman,' 'Franklin,' and 'Pilgrim.'

In the early 1940s, Washington state initiated a breeding program, which was supervised by D.J. Crowley. It was revived in the 1960s. One of the original seedlings was named 'Crowley' and was released by Washington State University in 1970.

The only formal cranberry breeding programs active today are at the Rutgers Blueberry and Cranberry Research Center in Chatsworth, New Jersey, and at the University of Wisconsin in Madison, Wisconsin.

All cranberry cultivars are self-fertile and self-fruitful; only one cultivar is needed for fruit production. (See Chapter 2, "Botanical and Physiological Characteristics.") However, it's not unusual to find "off types" growing alongside the desired cultivar in commercial cranberry beds. Since cranberry beds are established from cuttings of hundreds (if not thousands) of plants, there is potential to lose genetic uniformity when the bed is planted.

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Also, it's possible that seeds from fruit left in the duff layer (the organic layer in a cranberry bed, Figure 1) after harvest might germinate, producing seedlings that are not like the parent plant. Over time, these seedlings might change the genetic makeup of the bed.

Many cultivars are preserved at the National Clonal Germplasm Repository in Corvallis, Oregon, and at the Rutgers Blueberry and Cranberry Research Center in Chatsworth, New Jersey. They have undergone DNA testing to confirm genetic identity. It is important to preserve the genetic resources of this crop plant for breeding material.

Figure 1.—A section of a cranberry bed showing the duff (organic) layer.

Obtaining vines

Unlike other berry plants, cranberries are not available in true genetic stock from nurseries. Most cranberry beds are established using vines (cuttings) from elsewhere on the property or from other growers. Cuttings are made either from prunings (reel prunings on wet-harvested beds and Furford prunings on dry-harvested beds) or from mowings (bed renovation, Figure 2). See Chapter 10, "Harvesting," for more information.

Figure 2.—Bed renovation can provide a source for new vine material.

Tissue-cultured plants or plugs are an alternative source of vines, although they have not yet been widely used or tested. For genetic material that is difficult to obtain, tissue-cultured plants or vegetatively propagated plugs (one plant per square foot) are an option.

Visit the cranberry bed from which you plan to get cuttings/prunings. This allows you to determine the uniformity of the cultivar (or the percentage of unproductive or vegetative vines) and which weeds, insects, and diseases might be introduced into the new planting. (See Chapters 11, 12, and 14.) You also can determine the vigor of the vines.

Figure 3.—A planting of 'Stevens.'

Careful research into the planting material is essential. Some farmers have invested years and resources to bring fields into production, only to find that the plants were not "true to type." They had to rip out their fields and start over with the desired cultivar.

If you plan to buy vines from out of state, and a site visit is not feasible, be sure to buy them from a reputable grower/handler. In all cases, try to obtain the site's yield records for as many years back as possible. Keep in mind that vines pruned from a bed in one location might not grow or respond the same way when planted in a different location. Vines moved across the U.S.–Canadian border normally need a phytosanitary certificate from your state's or province's department of agriculture.

Keep vines from different sources separate in the field. (Do not mix bales.) This allows easier removal of "off types" if there is a problem with the plant material.

You can have vines tested using DNA fingerprinting to determine their true genetic identity (cultivar). The test is only as good as the sampling, so take as representative a sample as possible. This service is available from the Blueberry and Cranberry Research Center, Rutgers University, Chatsworth, New Jersey, for a fee (http://aesop.rutgers.edu/~bluecran/cranby/cranby.htm).

Recent research has found 15 different DNA fingerprints of 'McFarlin' from 64 clonal accessions (samples). In seven accessions of 'Howes,' five were different. Many plantings have been found that are not "true" 'Stevens.' These results show that cranberry cultivars actually might be composed of several genetic variants. It also raises the question: What is a true 'McFarlin'? The true cultivar identities or genetics of many cultivars, including 'Crowley,' 'Searles,' 'Bergman,' and 'Beckwith,' still need to be sorted out.

Storing vines

Because pruning often is done around January and vines are planted any time from January to May (see Chapter 4, "Establishing the Cranberry Bed"), you usually must store vines before planting. In the Pacific Northwest, vines usually are stored in piles in a shady location with good air circulation and are kept moist by periodic sprinkler irrigation.

Do not store vines in tight bales for any length of time. Loosen the bales and turn the piles periodically to promote good vine health.

Cultivars

Many cultivars of cranberry are known, but most of the U.S. crop is produced by relatively few. In the Pacific Northwest, 'Stevens' is the leading cultivar. 'Bergman,' 'McFarlin,' 'Pilgrim,' 'Crowley,' and 'Ben Lear' also are planted. In the past 5 years, most new beds have been planted to 'Stevens.'

'Stevens'

A cross of 'Potter' and 'McFarlin' introduced in 1950 (Figure 3). Ripens midseason (compared to other cultivars).

Fruit: Large (50 to 60 per cup); shape is round-oval; skin color is deep red with relatively little bloom (waxy coating on the surface of the fruit); flesh is firm; juice yield is good.

Storage: Keeping quality is very good; fairly resistant to fruit rot; only fair coloring in storage.

Vine: Vigorous, coarse, very productive.

Remarks: "Off types" are present in the industry.

'Bergman'

A cross of 'Early Black' and 'Searles' introduced in 1961. Ripens midseason.

Fruit: Medium (65 to 80 per cup); short, pear-shaped; skin color is red with no bloom (glossy); juice yield is average.

Storage: Keeping quality is good to excellent; little shrinkage in storage; good coloring in storage.

Vine: Moderate vigor with few runners; production is high; susceptible to field rot, but less so than 'Early Black' or 'Howes'; resistant to feeding by leafhopper vector of false blossom disease.

Remarks: More common in British Columbia than elsewhere. 'Bergman' beds have been shown to be quite heterogenous (consisting of more than one cultivar).

'McFarlin'

Selected in 1874 from the wild in Massachusetts by T.H. McFarlin. Ripens late (2 weeks later than 'Stevens').

Fruit: Medium to large (60 to 80 per cup); shape is round-oblong, irregular, with the calyx end rounded with medium-sized lobes; skin color is deep red with heavy bloom; flesh is firm; berry is frost resistant.

Storage: Keeping quality is fair to good; poor coloring in storage.

Vine: Vigorous; productive; abundant runnering; uprights are short; vines are less upright and need mechanical training for dry harvest; resistant to feeding by leafhopper vector of false blossom disease.

Remarks: "Off types" are present in the industry.

'Pilgrim'

A cross of 'McFarlin' and 'Prolific' introduced in 1961. Ripens late.

Fruit: Large (43 to 66 per cup); shape is long, oval; skin color is purplish-red with yellow undercolor and moderate to heavy bloom; juice yield is high.

Storage: Keeping quality is good; good coloring in storage.

Vine: Moderate vigor; very productive; susceptible to field rot; resistant to feeding by leafhopper vector of false blossom disease; might have some frost resistance.

Remarks: Most beds have an "off-type" that occurs in low, but consistent, frequency.

'Crowley'

A cross of 'McFarlin' and 'Prolific' introduced in 1961. Ripens early.

Fruit: Medium to large (60 to 70 per cup); shape is round-oblate with calyx end flattened; skin color is medium to dark red with a slight bloom; skin has high anthocyanin content; flesh is white; berry has low astringency; juice yield is medium to good.

Storage: Keeping quality is poor; good coloring in storage.

Vine: Moderate to high vigor; productive; susceptible to field rot.

Remarks: Either 'Crowley' is not a single genotype, or it is becoming lost as a distinct cultivar.

'Ben Lear'

Selected in 1900 from the wild by D.R. Burr. Blooms and ripens early.

Fruit: Medium (70 to 90 per cup); long, pear-shaped with a pointed stem end; skin color is deep red with light to medium bloom.

Storage: Keeping quality is poor; good coloring in storage.

Vine: Moderate vigor; very productive.

The following cultivars are uncommon in the Pacific Northwest.

'Early Black'

Selected around 1835 from the wild in Massachusetts by N. Robbins. Ripens very early.

Fruit: Small (90 to 130 per cup); pear-shaped with a pointed stem end; skin color is blackish-red with no bloom.

Storage: Keeping quality is good to very good; good coloring in storage.

Vine: Low to moderate vigor; productive.

Remarks: Accounts for about half of the acreage in Massachusetts and New Jersey.

'Howes'

Selected in 1843 from the wild in Massachusetts by E. Howes. Ripens late.

Fruit: Small (80 to 115 per cup); shape is oblong-oval; skin color is medium-red with no bloom; fruit is resistant to frost.

Storage: Keeping quality is excellent; good coloring in storage; fruit has high pectin content.

Vine: Vigorous; productive.

Remarks: Accounts for about a third of the acreage in Massachusetts.

'Searles'

Selected in 1893 from the wild in Wisconsin by A. Searles. Ripens midseason.

Fruit: Medium to large (50 to 85 per cup); shape is round-oval; skin color is deep red with no bloom.

Storage: Keeping quality is poor to fair; good coloring in storage.

Vine: Vigorous; very productive. Susceptible to field rot.

Remarks: This is a common cultivar in Wisconsin but is being replaced by 'Stevens.' 'Searles' actually might be several cultivars.

Others

Many other cultivars or selections, including 'Grygleski,' No. 35, 'Franklin,' and 'Cropper,' have been tested in the Pacific Northwest. For information on yield, disease resistance, and fruit quality of various cultivars in Long Beach, Washington, check the World Wide Web at http://www.puyallup.wsu.edu/wsulongbeach/

Establishing the Cranberry Bed

4

B. Larson, K. Patten, and B. Strik

Site selection

Site location is one of the most important factors determining success of a cranberry bed. There are many criteria for site selection, including the following:

- Climate
- Soil type and pH
- Drainage
- Water availability and quality
- Proximity to potential contamination from pests
- Proximity to markets
- Regulatory issues (e.g., wetland and water quality considerations)

Climate

Cranberries do best in a moderate climate. A cool, wet pollination period (late May and June) can suppress yields. A warm summer can help fruit growth, but heat damage is common if temperatures exceed 85°F.

Soil type and pH

Cranberries can be grown equally well on pure sand or pure peat, as long as growers manage them appropriately. The most common soil-related problems in new and established plantings are poor drainage, poor weed control, and/or excessive herbicide damage. Herbicide damage occurs more frequently on poorly drained soil or when the application rate is inappropriate for the soil texture.

For sanded beds, coarse sand is better than fine sand. See Chapter 9, "Sanding," for more information on sand quality. Note that surface sand might contain weed seeds.

In British Columbia, most cranberry farms are located on peat or muck soils. Peat soils, because of their structure, generally have favorable air–water relations that require relatively little special management. Growers farming on mineral soils tend to plant into sawdust or sandy gravel that has been brought onto the farm.

In Washington, cranberries traditionally were planted on muck or peat soils. Although some new plantings still are made on these types of soil, the current trend is to use a thick layer of sand (4 to 12 inches) over an organic soil layer.

In Oregon, most cranberry farms are located in coastal areas and are constructed on mineral soils. Local sand is layered over high-organic-matter or clay subgrade soil.

Sites with too high a soil pH are a serious problem. Avoid sites with a pH above 5.5. Cranberries can grow in mineral soils with a pH in the low 6s, but they don't grow well. Also, cranberries often show nutritional problems in organic soils with a high pH. Many weed species do not grow well at a pH below 5.5.

Drainage

Inadequate drainage is the most common problem associated with poor establishment and production. Areas that are low or have standing water for more than a few hours during the growing season usually fail to grow vigorous vines. Cranberry plants do not like "wet feet"; water from irrigation, rain, or flooding at harvest must be drained off the fields. Removing excess water improves nutrient uptake, increases vigor, controls weeds, and decreases the likelihood of disease.

Water availability and quality

Water requirements vary with management practices and often are expressed in acre-feet. One acre-foot is the water needed to cover an acre to a depth of 1 foot (about 330,000 gallons). Estimates for annual water use in cranberry beds on the West Coast range from about 3 to 6 acre-feet for every acre of bed.

The amount of available water partially determines whether you will wet or dry harvest your crop. Wet harvest requires a substantial, dependable water supply in late September/early October (1 to 2 acre-feet) and a soil substratum that holds the water for several days after flooding. Dry-harvested beds, on the other hand, require water only for irrigation and frost protection, although some growers also use flooding to control black vine weevil (about 1 acre-foot after harvest).

Figure 1.—A water reservoir for cranberry production.

Plan on having a water reservoir of 6 to 8 acre-feet for every acre of farm (Figure 1). If beds and reservoirs are designed to recycle water (tailwater recovery), actual water use can be reduced. Growers often cycle water from bed to bed during harvest in order to reuse it. Many growers dig sumps, which are recharged with groundwater. This method often provides adequate water in areas with a high water table.

Water quality is important. Not all water is suitable for flooding or irrigation of cranberries. Hard water—water that contains calcium, iron, and magnesium ions—can react with certain pesticides to inactivate them or to cause precipitate, which can leave undesirable residues on fruit and leaves. Desirable water quality characteristics are as follows:

- pH: less than 6.5
- Salinity: less than 0.3 mmho
- Chloride: less than 100 ppm
- Sodium: less than 40 ppm

Proximity to potential contamination from pests

If you want to produce organic cranberries, seek a site isolated from other cranberry farms and from fields that are sources of wind-borne weed seeds.

Proximity to markets

The distance to deliver processed or fresh-market fruit to the receiving station can significantly affect the economics of cranberry farming. If you wish to develop niche markets for fresh fruit, you also need to include travel cost to major metropolitan areas in your budget.

Regulatory issues

Access to water from lakes, rivers, streams, and groundwater (wells) requires permits and/or water rights. Discharge permits also might be required if the temperature and chemistry of the water released changes during flooding. Permit requirements and processes vary considerably between the United States and Canada.

The U.S. Army Corps of Engineers regulates the creation and expansion of new cranberry operations in U.S. wetlands under section 404 of the Clean Water Act. Recently, the Corps has increased its requirements for compensatory mitigation for cranberry plantings in wetlands. For every acre of wetland converted to cranberries or filled for dikes, a given number of acres of wetlands (usually from 1 to 6) must be restored, preserved, enhanced, or created. Prior to any new planting in wetlands, U.S. growers should contact the Corps for advice and to learn how much mitigation, if any, is required. In Canada, check with the provincial government for regulations.

Designing new beds

Cranberries are grown on earthen structures called "beds." The beds are surrounded by perimeter ditches and dike systems with adjacent water-storage areas. These all are connected to irrigation systems that provide frost protection to new spring growth and irrigation during the growing season.

Detailed planning is required when designing new beds. Take into account the following factors.

Efficient land use

Use drawings to determine how to maximize land-use efficiency. The greater the land mass in actual cranberry production, the greater the returns.

Size of beds

Bed size ranges from small (1 to 2 acres) to large (10 to 50 acres). Topographic variations in land might dictate the use of smaller beds. Water availability also determines bed size, as very large beds might not be flooded adequately for harvest if the water supply is limited.

Harvest method

Consider the planned harvest method when designing beds. (See Chapter 10, "Harvesting.") To optimize efficiency in dry-harvested beds, minimize the number of direction changes made by the harvester. Rectangular patterns work best.

Sanding

If sanding is desired, it's critical to consider your method of sanding when designing the cranberry beds. If beds are too large, hydrosanding might not be effective. See Chapter 9, "Sanding," and Chapter 14, "Insects," for more information. Also, on-site availability of suitable sand is an advantage when selecting new sites.

Drainage

Beds that are 200 feet wide or less can be crowned in the center (raised by 4 to 6 inches or more) to allow drainage into the perimeter ditches. If the bed size is greater than 200 feet across, crowning would create a distinct grade variation between the center of the bed and the perimeter ditches. This would complicate flood harvesting and require higher than normal dikes to hold the water.

In wider beds, drains alone can be crowned in the soil, leaving the field grade level. This can be accomplished by the use of a laser leveler when the drains are put in. Flooding is achieved with a lower volume (depth) of water on level beds.

The minimum depth of drains should be 18 inches. Spacing depends on depth and soil type; the shallower the drains, the more drains required. Growers often lay drains at or near the surface, but these drains tend to plug easily, reducing their effectiveness.

Water recovery

Systems must be in place to remove and conserve excess water from the perimeter ditches. The most desirable are gravity-feed or lift-pump systems to return the water back into the reservoirs. These tailwater recovery systems recirculate on-farm water, thereby maximizing water-use efficiency and preventing potential contamination of off-site surface water. To increase water-use efficiency, beds can be terraced to facilitate the movement of water from bed to bed; this practice is relatively common in Oregon.

Irrigation layout

Cranberries require irrigation for four purposes:

- *Irrigation* in a cranberry bed refers to the addition of supplemental water for plant growth and development ("crop water").
- *Frost protection* refers to the addition of water during freezing weather to prevent damage to buds and berries when they are sensitive to temperatures at or below freezing.
- *Chemigation* refers to the process of applying chemicals through the irrigation system. Chemigation commonly is used with many pesticides and some fertilizers (generally called "fertigation"). It is convenient and effective and reduces human exposure to pesticides.
- *Cooling*—Some growers irrigate during periods of high temperatures to cool the plants and prevent heat stress.

Designing an irrigation system is one of the most important decisions associated with planning a cranberry field. Clarify all water requirements as they relate to pump specifications and capacities. The pump specifications should limit excessive pressure losses and excess water pressure. See Chapter 5, "Irrigation," for more information on sprinkler spacing/efficiency.

Power requirements

Most irrigation systems require 3-phase power, which runs at 600 volts/60 cycle. This is the most efficient low-voltage system. For some remote sites, the cost to bring in 3-phase power is prohibitive. Diesel- or propane-powered systems are other cost-effective ways to deliver power.

Fertilizer placement

Helicopters, fixed-wing aircraft, ground applicators (seeders or spreaders), and fertigation (sprinkler system) can apply fertilizer to cranberry beds. Bed design can affect your options for fertilizer application, so it's recommended that you choose an application method when designing the beds. Growers with small acreage or acreage "tucked" among trees often find aerial application too expensive or unavailable. Ground application is an effective alternative that can provide excellent application if the beds are designed in a simple manner.

Fertigation should not be your primary application method. Use fertigation only as a way to quickly correct problems and use only low rates of fertilizer. The nonuniform application of fertilizer through the irrigation system will result in uneven growth.

Constructing the bed

The general procedures for bed construction involve clearing, leveling, building drainage systems, sanding, and installing irrigation. These procedures vary somewhat, depending on whether the bed is on organic soils or mineral soils.

Figure 2.—Clearing land for cranberry bed construction.

Disturbing large areas of land carries the risk of erosion. Develop an erosion control plan prior to starting construction. Plan to minimize the amount of land disturbed and to stabilize and protect disturbed areas from runoff. Try to divert channeling water around disturbed areas. Prevent sediment from moving off-site. Recovery ponds, if constructed early, can act as silt basins.

The first step is to clear the land of all natural vegetation (Figure 2). Eliminate all perennial weeds before constructing the beds.

Natural peat bogs require little grading. Minor surface irregularities can be leveled before applying sand or sawdust prior to planting.

Most of the cranberry beds along the Oregon coast are constructed on Blacklock soil. This soil is suited to cranberry production because the subsoil contains one or more semipermeable layers that restrict water movement and make flooding feasible. If the soil does not contain a semi-permeable layer, you'll need to construct a water-confining layer. Contact engineers before proceeding with bed construction.

To construct a cranberry bed on mineral soil, remove the topsoil and subsoil to the more semi-permeable layer after clearing the land. Save the topsoil for later use in completing the bed. The subsoil can be used for dike construction. You then can crown the base of the cranberry bed and install drain tile to improve drainage (see "Drainage," page 19). Next, spread the stockpiled topsoil to a depth of 3 or more inches over the bed base (Figure 3). Then add a 2- to 6-inch layer of clean, coarse sand (Figure 4). See "Sanding," page 19.

The final step in bed construction is installation of irrigation lines, border ditches (Figure 5), and dikes. If drainage is adequate, you can wait to dig border ditches after the bed is stabilized with cranberry roots to minimize soil erosion. Perimeter ditches should be 2 to 3 feet wide and 2 feet deep.

Figure 3.—Leveling returned topsoil on a bed.

Figure 4.—A new bed after addition of sand layer.

Figure 5.—Drainage ditch being leveled with pressure-treated wood and lined.

Figure 6.—A newly constructed bed ready for planting, showing perimeter ditches and dike.

Figure 7.—Keep vine prunings cool and moist prior to planting.

Constructing dikes

Dikes surround each cranberry bed. They are used to contain water during management/ flooding and for moving equipment or vehicles.

In British Columbia, most cranberry farm dikes are built with "hog fuel," a type of sawmill waste. It usually is abundant and economical and provides an all-weather surface on which to drive. Unfortunately, "hog fuel" does not make sound dikes. At harvest time, excellent water management is required to ensure that these dikes do not fail under pressure from water in the beds. In many peat beds, the "hog fuel" dikes are merely "floating," and too much weight on the dike can cause shifting within the beds.

In Washington and Oregon, excavated soil from bed construction is used to make dikes. These dikes are very sound (Figure 6).

If 2 feet or more of water are on the field during water harvest, the pressure from the water can cause dikes to break. Water pressure can build up below ground, pushing dikes outward. It's important to have strong dikes and the ability to flood adjacent fields concurrently to provide back pressure to hold dikes in place.

Dikes should be at least 4 feet wide at the top. Construct dikes to a height of at least 1 foot above normal flood elevation. Allow about 5 percent extra height at construction for settling. Plan dikes with side slopes no greater than 1:1. Steeper slopes are vulnerable to soil erosion and are more difficult to maintain. Dikes can be seeded with grass for stabilization. Construct an area for equipment movement onto each bed. Install flumes (water-control structures) in dikes to control discharge, distribution, delivery, and direction of water flow.

Planting the bed

Obtaining vines

The most common planting material used for establishing new cranberry beds is unrooted "cuttings." Cuttings are obtained from regular pruning of established plantings or from bed renovation. (See Chapter 8, "Pruning.") It is good business to buy vines with a good yield history. There are few specials in the vine sale business. Knowledge of the grower and possible insect, weed, and disease problems is important. Cranberries are not an annual crop, and replanting is not a financially viable alternative. See Chapter 3, "Cultivars," for more information.

Ideally, vines should be pruned one day and planted the next. However, this usually doesn't occur. If vines cannot be planted immediately, they must be stored properly until planting. Keep vines/ prunings moist and cool by storing them in the shade under sprinklers (Figure 7). Don't keep vines in tight bales; loosen them and periodically turn piles to promote good air circulation. Large quantities of vines can be kept in cold storage for an extended period of time.

Planting methods

Scattering unrooted cuttings onto the ground is the most common method of planting. Planting rates of 1.5 to 2 tons of vines per acre generally are used. This planting density ensures rapid vine coverage, leading to less competition from weeds.

There are various ways to incorporate the cuttings into the soil. On small beds, the cuttings can be "stuck" by hand. In sand beds, the best method is to use a disc with dull blades. The disc pushes cuttings into the bed to a depth of 2 to 3 inches. A disc often works on peat beds as well. In sawdust or mineral beds, mechanical transplanters or rototillers give better results.

Recently, rooted plants have become another option for bed establishment. In this case, a rate of one rooted plant per square foot is most common.

Spring is the most common time for planting. However, winter planting is popular for rooted plants, as they have been growing in trays during the summer and are ready to be planted out.

Test the soil before planting to determine the levels of available nutrients. The addition of a high-phosphorus fertilizer (plant starter) is required in mineral, sawdust, and sand beds to promote root growth.

Figure 8.—Irrigating a new cranberry bed.

With spring plantings, apply 5 to 10 lb N per acre every 2 weeks during the first season. In the planting year, do not make the first fertilizer application until the plants have visible roots. For best uptake of fertilizer and production of stocky plants, a complete fertilizer containing N, P, and K is recommended. Slow-release or timed fertilizers can save application costs by reducing the total number of applications, but supplemental granular applications might be required if the slow-release form does not provide enough N at the right time.

Provide adequate water during stand establishment, but do not overwater (Figure 8). During the first 2 to 4 weeks, as roots are being formed, use frequent but short irrigation periods. Manage irrigation to minimize puddles. After the plants are rooted, less frequent but longer irrigation periods are preferred to encourage deeper rooting. After 1 year, rooted cuttings should have produced foot-long runners with well-established roots.

Nitrogen fertilizer applications should be completed by early August (late bud development) in the second year to promote the production of flower buds for the following year. By the end of the second year, vine coverage on the bed should be good. Some fruit production might occur, although year 3 typically is thought of as the first production year. Full production usually starts in year 5.

At the end of the third year, a light layer of sand can be added to anchor runners and promote production of uprights. Once the bed is established, the average upright density should be about 400 to 600 uprights per square foot.

For more information

Sandler, H. *Bog Construction and Renovation Manual* (1998). http://www.umass.edu/umext/programs/agro/cranberries/pubs.html

Irrigation

5

The largest investment in the design and construction of a cranberry bed is the infrastructure to control water for frost protection, irrigation, and flood harvest. Most farms have a basic layout of reservoirs, perimeter ditches, dikes, and sprinklers for moving water through the system.

Growers in British Columbia use a triangular sprinkler grid pattern to provide full coverage with minimal overlap and to provide protection against wind blow-through (Figure 1, page 26). In Oregon and Washington, square patterns are more common.

Ample water is required, as most systems provide 3 to 4 U.S. gallons of water per minute. The system must be designed to optimize recovery of water from beds into ditches and reservoirs.

This chapter discusses irrigation for frost protection, crop water, cooling, and chemical delivery. See Chapter 10, "Harvesting," for information on irrigation for water harvest.

Irrigation for frost protection

Sprinklers are used to protect plants from spring frosts. Most growers use automated systems that carefully monitor temperature and dew point. (The dew point is the temperature at which dew or frost condenses out of the atmosphere as the temperature falls on a clear, calm night.) The sprinklers can be set to operate automatically when the temperature drops low enough to cause frost damage.

Automated sprinklers provide a uniform film of water over the vines. Ice forms steadily, but the latent heat of fusion prevents the surface temperature from falling below freezing (0°C, 32°F). The sprinklers continue to operate as long as the temperature is low enough to cause frost damage.

Test your irrigation system in early March before bud break occurs.

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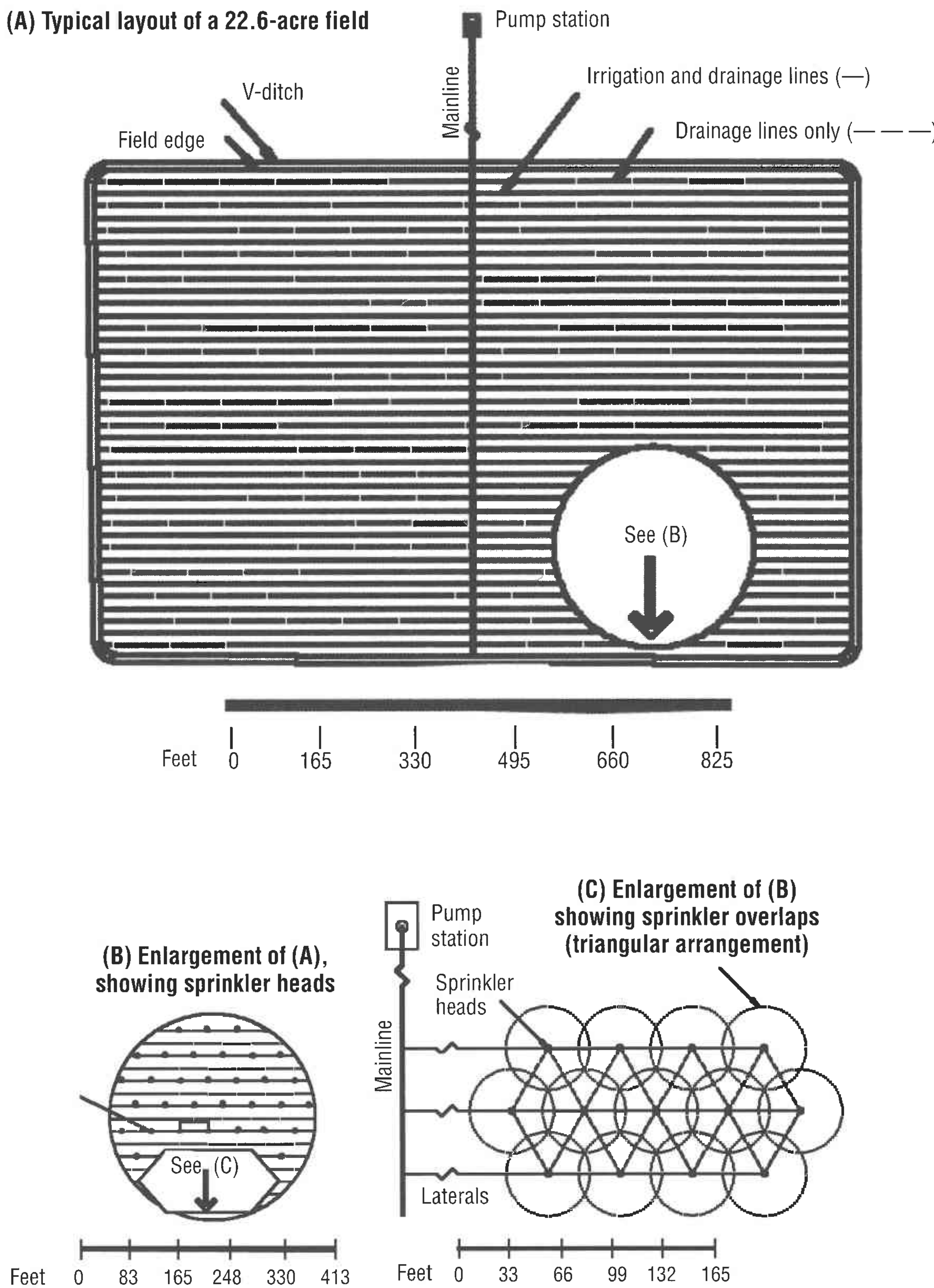

Figure 1.—A typical irrigation system layout. Systems are either square or triangular (staggered). Spacing often is 30 x 30 feet to 45 x 55 feet with ½-inch PVC and ⅛-inch nozzles, or 55 x 55 feet to 55 x 60 feet with ¾-inch PVC and $^{9}/_{64}$-inch nozzles.

Irrigation for crop water

Crop water requirements are determined by three things:

- *The rate of evapotranspiration (ET)*—the amount used by the plant and lost through evaporation, also known as *consumptive use*
- *Effective rainfall*—the amount of rainfall that becomes available to plants, usually about 70 percent of measured rainfall (example: 0.81 inch measured in the rain gauge x 0.70 = 0.57 inch effective rainfall)
- *Efficiency of irrigation application*

There are two reasons for estimating ET for cranberries. First, it is used in designing irrigation systems and for preseason planning of water use. Second, it is important for in-season irrigation management (i.e., deciding exactly when to irrigate and how much water to apply).

Average daily consumptive use rates for cranberry on the Oregon coast typically are about 0.11 to 0.15 inch. In Washington, use rates range from 0.02 to 0.26 inch per day and typically are 0.04 to 0.08 inch per day. Peak rates occur in July on sunny days with low humidity. Under these conditions, daily consumptive use ranges from about 0.16 inch in sheltered areas to about 0.18 inch in areas exposed to winds. On cloudy, cool days, the rate falls to about 0.05 to 0.1 inch.

Consumptive use rates can be viewed as the daily net water requirement—the amount of water that must be made available to the plants, either through rainfall or irrigation. If there is no rain, the entire requirement must be met through irrigation. If it rains, irrigation is reduced by effective rainfall.

The allowable moisture depletion from the shallow, sandy root zones typical of the Pacific Northwest cranberry-growing regions is about the same amount as that used during 1 day of peak-rate consumptive use. Consequently, during peak water-use periods, the crop should be irrigated daily.

The *net* application (the amount of irrigation water that becomes available to the plants) should equal daily consumptive use—about 0.16 to 0.18 inches. The *gross* water application, that is, the amount you should apply to a field, must be greater than the net requirement to account for system inefficiencies, including spray and evaporation losses, and drainage of excess water beyond the reach of the roots.

The application efficiency of properly designed solid-set sprinkler systems ranges from about 70 percent under low wind conditions (typical of much of the coastal area) to about 50 percent under the extreme wind conditions seen in exposed coastal areas. If winds are high, a significant fraction of the water is lost through wind drift, evaporation, and uneven distribution of water. If winds are moderate, these losses are less.

Based on these efficiencies, the *peak daily gross application rate* ranges from about 0.25 inch per day in moderate wind areas to about 0.33 inch per day in extremely windy areas.

Preseason planning

Table 1 shows estimates of average daily water requirements for irrigation of cranberries on the southern Oregon coast. The table contains data for a 30 x 30 foot sprinkler spacing. These estimates are intended primarily for preseason planning and design purposes. Incorporate peak rates into the design of your irrigation system so that it will be able to deliver enough water during peak use periods.

To use the table, find the dates of interest in the left-hand column. Column 2 shows the estimated daily consumptive water use (ET) for cranberries on those dates (inches per day).

Columns 3 and 4 show the estimated gross water requirement, i.e., the number of inches of water that must be applied to replace water consumed by the crop. This amount depends partly on wind conditions during irrigation. Use column 3 if the wind is expected to be moderate *on the day the irrigation is to take place.* Use column 4 if winds are likely to be high that day.

Note that the units in columns 3 and 4 are inches of water per day, i.e., the amount of water that must be applied for each day that has passed since the last irrigation. To determine the total water that must be applied, multiply the number in column 3 or 4 by the number of days since the last irrigation. Subtract from that the cumulative effective rainfall since the last irrigation. The balance is the amount that should be applied.

Table 1.—Gross daily water requirements for cranberries on the southern Oregon coast.

		Gross water requirements	
Date	Average ET (inches/day)	Low/moderate winds (inches/day)	High winds (inches/day)
March 20–31	0.049	0.072	0.089
April 1–10	0.067	0.099	0.122
April 11–20	0.080	0.118	0.145
April 21–30	0.093	0.137	0.169
May 1–10	0.106	0.156	0.193
May 11–20	0.110	0.162	0.200
May 21–31	0.120	0.176	0.218
June 1–10	0.126	0.185	0.229
June 11–20	0.131	0.193	0.238
June 21–30	0.130	0.191	0.236
July 1–10	0.143	0.210	0.260
July 11–20	0.140	0.206	0.255
July 21–31	0.130	0.191	0.236
August 1–10	0.130	0.191	0.236
August 11–20	0.118	0.174	0.215
August 21–31	0.113	0.166	0.205
September 1–10	0.106	0.156	0.193
September 11–20	0.095	0.140	0.173
September 21–30	0.083	0.122	0.151
October 1–10	0.073	0.107	0.133

Sprinkler spacing: 30 x 30 feet
Efficiency: Low/moderate winds: 68%
High winds: 55%

In-season management

Although you can use Table 1 for in-season irrigation management, it is better to use a Web site such as Agrimet (http://mac1.pn.usbr.gov/agrimet/index.html) in Oregon. Agrimet contains up-to-date estimates of ET during the preceding 4 days. In Washington, growers can use the Washington Irrigation Scheduling Expert, WISE (http://wise.prosser.wsu.edu).

These estimates are more accurate than those in Table 1, which represents 10-year average values. The actual crop water use and gross irrigation requirement on any given day rarely equal the long-term average. In fact, they can fluctuate widely from one day to the next and easily can be 15 percent above or below average.

From the Agrimet home page, choose *Crop water use information.* Then, under *crop water use charts,* select your state and location. The resulting table will show estimated crop water use for several crops during the preceding 4 days. Cranberry water use is shown in the row labeled CRAN.

The first column shows the starting date on which ET calculations were initiated in the current year. The next four columns show the estimated ET for the preceding 4 days. The dates are shown at the top of each column. The next column is the estimated ET for the current day. Subsequent columns give the estimated date when the crop is expected to reach maximum ET rates, the last day of the year for which ET will be estimated, the cumulative ET for the season to date, and the cumulative ET for the past 7 and 14 days.

Use the total estimated ET for each of the days since the most recent irrigation to determine the consumptive use. Then divide that ET by the estimated application efficiency for the day on which the next irrigation will take place, and multiply by 100. Estimated efficiencies for different spacing and wind conditions are shown in Table 2.

Example: Suppose a bed is irrigated every other day, and the ET for the past 2 days was 0.10 and 0.11 inches. The next irrigation is to take place on the current day, and winds are expected to be moderate. The sprinkler spacing is 34 x 31 feet. You would calculate the amount of water to be applied as follows:

Table 2.—Estimated irrigation efficiencies for various sprinkler spacings and wind conditions.

Sprinkler spacing (feet)	Moderate winds (%)	High winds (%)
30 x 30	68	55
30 x 35	66	53
35 x 35	65	53
30 x 40	60	46
40 x 40	56	35
40 x 50	53	21

The cumulative ET is 0.10 + 0.11, or a total of 0.21 inches. You could use a 30 x 35 spacing to estimate sprinkler efficiency, which would be 66 percent for the moderate wind conditions that are expected. The gross water requirement would be:

0.21 inch ÷ 0.66 = 0.32 inch

Irrigation time

To determine the time needed to apply the recommended gross amount of water, divide the application amount by your system's application rate (inches per hour):

0.32 inch ÷ 0.16 inch per hour = 2.0 hours

You can determine your application rate from the total amount of water applied (gallons) in a given amount of time and the area irrigated (square feet). First, calculate the application depth:

Depth applied (inches) =
(Application [gal] ÷ Area [ft^2]) x 1.6

Now, divide the depth by the number of hours the irrigation system was running to find the application rate in inches per hour.

Example: If you apply 85,000 gallons of water in 3 hours to a field that measures 250 x 500 feet, the application depth is:

(85,000 ÷ [250 x 500]) x 1.6 = 1.088 inches

and the rate of application is:

1.088 ÷ 3 = 0.36 inch per hour

Sprinkler systems typically apply about 0.15 to 0.35 inch per hour, depending on the nozzle size, pressure, and spacing.

When irrigating, keep the following factors in mind:

- Take care to avoid too much water pooling at one time. Excess water decreases vine vigor.
- Irrigate in the early morning. This allows plants to dry quickly, thus reducing the possibility of disease.

Irrigation for cooling

Some growers irrigate during periods of high temperatures to cool the plants and prevent heat stress. The normal practice is to irrigate 15 minutes on and 15 minutes off. Again, avoid pooling, which can decrease the plants' vigor. See Chapter 15, "Physiological Disorders (Noninfectious)," for more information.

Water quality

It's important to test your irrigation water for pH, salts, chloride, and nitrate. Most growers in British Columbia rely on the Fraser River for water. In Oregon and Washington, growers generally use well, pond, or river water.

Wells, in most cases, do not supply the output required for proper frost protection or harvesting.

Chemigation

Injecting agricultural chemicals such as fertilizers (usually called fertigation), herbicides, fungicides, and insecticides into an irrigation system is called *chemigation*. Chemigation provides relatively uniform chemical distribution, is cheap and safe to the applicator, and results in less crop damage than does application with ground equipment.

However, chemigation does have the potential to contaminate groundwater and surface water. Therefore, a certified system to prevent backflow is required by law. In the U.S., each state might have its own laws requiring specific devices for a chemigation system, in addition to U.S. Environmental Protection Agency (EPA) standards.

In general, the minimum equipment for protecting water resources is:

- A backflow prevention device (usually consisting of a check valve, vacuum relief valve, and low-pressure drain)
- An interlock control to shut off the chemical injection device automatically when the water pump stops
- A chemical injection line check valve
- A metering chemical injection pump fitted into the interlock system
- A normally closed, solenoid-operated valve on the intake side of the chemical injection pump

Injecting chemicals into an irrigation line gives poor results unless the following requirements are met:

- The irrigation system is free of leaks.
- All sprinkler nozzles are the same size, and part-circle heads are sized to deliver 50 percent of the amount delivered by full-circle heads.
- Worn nozzles are replaced.
- The operating pressure is at least 45 psi at the pump.
- The pressure drop across the system from the first to the last head does not exceed 15 percent.
- The uniformity coefficient (UC) of the irrigation system is greater than 70 percent. A UC denotes differences in the spatial distribution of water in the field and is determined by a catch can test.

Temporal patterns of chemigation differ substantially among and within beds and can result in poor pest control. To resolve this, all chemigation systems should be calibrated. A calibrated system lets you know how long to run the system to assure that the chemical has been applied to all parts of the field and that minimal wash-off has occurred. (Wash-off can occur because the system must be run long enough for the chemical to reach the final sprinkler; by that time, the chemical might have been washed off the plants near the first sprinkler by fresh water. The longer the time needed for the chemical to move through the system, the greater the risk of wash-off.)

To calibrate, inject an inert blue dye into the set sprinkler system according to normal operating procedures. Position three or four observers at different parts of the farm and have them note the appearance and disappearance of the dye at several sprinkler heads. The wash-off time is that measured from when the dye clears the first sprinkler to when it clears the last sprinkler. The length of time it takes to clear the last sprinkler is how long the system must run to assure full coverage.

Follow these additional environmental guidelines when chemigating:

- No pesticide may be applied through an irrigation system unless its registration label contains a statement specifically permitting this means of application.
- Minimize applications to nontarget areas by using screens, part-circle sprinkler heads or gear-driven sprinkler heads.
- Do not allow sprinkler heads to spray across open water unless the water can be held for the required time specified on the pesticide label. Water-control structures must be in place and free of leaks to hold ditch water containing pesticide for the required time.
- Do not use chemigation to apply pesticide if your sprinkler system is not very uniform or has leaky underground pipe.

For more information

For more specific information on chemigation, see:

- *Chemigation in the Pacific Northwest,* PNW 360 (Oregon State University, reprinted 1992).
- Solomon, K.H. and D.F. Zoldoske, *Backflow Prevention and Safety Devices for Chemigation,* Publication 981201 (California Agricultural Technical Institute, 1998). http://cati.csufresno.edu/cit/rese/98/981201/index.html
- Washington State Chemigation and Fertigation laws (WAC 16-228-232 & WAC 16-200-742)
- The Washington or Oregon state departments of agriculture

Maintaining the Bed
Nutrition

6

The nutrient management information in this chapter is specific to producing cranberry beds in the Pacific Northwest. It is appropriate for various soil types, including:

- Sandy soil over peat or clay subgrade (Oregon)
- Peat and sanded peat soil (Washington and British Columbia)
- Mineral soil or sawdust beds with clay subgrade (British Columbia)

If you have a newer bed established in Washington on sand or mineral soil or a bed outside the traditional coastal region, you might wish to contact your local Extension Service for more information than is provided in this chapter.

The goal of nutrient application to cranberries, as for any high-value crop, is to remove limitations to yield and quality by supplying the crop with ample nutrition in advance of demand. Apply fertilizer based on yield or quality response, experience, and economics. Determine the need for fertilizer through soil and leaf analyses in conjunction with weather records, crop yield, vine growth, upright length, fruit quality, and an assessment of pest problems. Also consider production costs, environmental stewardship, and government regulations.

Consider the fertilizer needs of each cranberry bed rather than treating your entire acreage the same way. If nutrition is adequate, fertilizing is an unnecessary expense and potentially detrimental to both crop yield and the environment.

Plants indicate low nutrient supply through reduced growth, reduced yield, and often through visible symptoms of deficiency. However, insufficient nutrition is only one possible cause of reduced yields. Other causes include saturated or dry soil; high temperature; frost; shading; weed, insect, or disease pressure; or herbicide injury. Application of nutrients does not compensate for these problems.

Also note that terminal leaves on flowering uprights turn from a healthy green color to pale yellowish green during fruit set and sizing. Terminal leaf margins turn red, while leaf bases and midribs remain green. These signals of stress indicate normal nutrient flow from current-season growth to developing fruit and do not indicate a need for fertilization. Recent research supports these observations.

Contents

J. Hart, A. Poole, J. Davenport, K. Patten, and B. Larson

Growers practice foliar fertilization (leaf feeding) of cranberries with little evidence to support its benefits with regard to application of macronutrients. Although nutrients can be absorbed through leaves, little information is available about how leaf feeding compares to soil application. As with other crops, foliar feeding should be viewed as a supplement to soil application of nutrients. Foliar feeding is most appropriate for application of micronutrients.

Using soil and tissue tests

Nutrient supply below crop demand can lead to visible nutrient deficiency symptoms. Routine collection and analysis of soil and tissue samples will help you detect low nutrient concentration before visible symptoms and yield reduction occur.

Routinely monitor soil for pH, phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), boron (B), and zinc (Zn). Test cranberry tissue annually for total nitrogen (N), P, K, Ca, Mg, sulfur (S), B, Zn, copper (Cu), and manganese (Mn). Tissue tests help to evaluate past nutrient management and to plan nutrient applications for the next growing season.

Many laboratories also provide analyses for other micronutrients, such as iron (Fe). These analyses might be helpful in problem or "troubleshooting" situations, but they are difficult to interpret from routine sampling.

Soil and tissue tests are most useful for evaluating a fertilization program over the course of several years. The effect of fertilization on a perennial crop such as cranberries might not show in tissue analysis levels for 1 to 2 years after application. Therefore, record-keeping is vital for interpreting soil and tissue analyses correctly. Record data on fertilizer applications, weather, fruit set, fruitful and nonfruitful upright numbers, and yield.

Tissue and soil sampling

Collect tissue samples from mid-August to mid-September, prior to harvest. Clip current-season growth from a mixture of fruit-bearing and nonfruiting uprights (Figure 1). Take 20 tips from each of 10 locations representative of the bed, making a total sample of 200 tips per bed. Do not wash or separate leaves and stems before submitting the sample to the laboratory.

See EM 8610, *Cranberry Tissue Testing for Producing Beds in North America,* for additional information about tissue testing. For information on laboratories that offer soil and tissue testing services, see EM 8677, *Analytical Laboratories Serving Oregon.* See "For more information," page 42.

Obtain soil samples during the dormant season after flood management and before bud break. Take 10 to 12 cores from the same area where you collected tissue samples. Sampling depth should be 4 inches on new or young beds or 6 inches, including surface duff, on mature, well-established beds.

Avoid poorly drained areas, high spots, or other nonrepresentative areas. Sample problem areas separately.

Interpreting test results

Cranberry tissue test values are divided into "below normal," "normal," and "above normal"

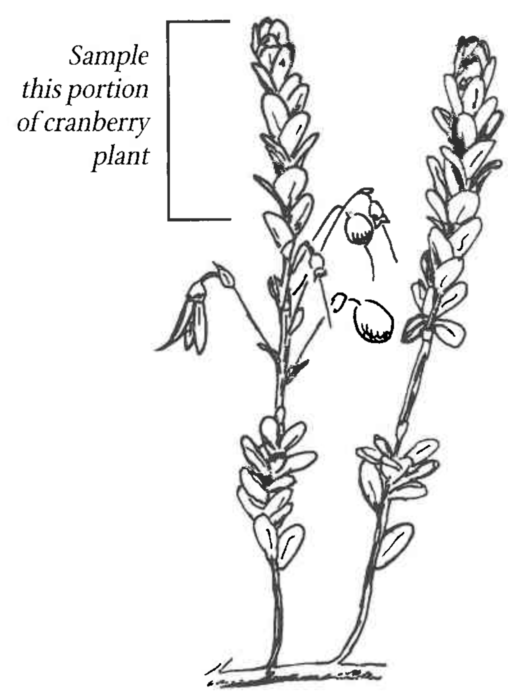

Figure 1.—Obtain tissue samples from the area shown.

categories. These categories are based on nutrient ranges from all North American growing areas, grower observations, cranberry tissue analyses, and field trials. If a tissue concentration is deficient ("below normal"), fertilization with the appropriate nutrient is recommended. Soil and tissue analyses do not identify an exact amount of fertilizer to apply.

The following are standard fertilization schemes. Modify them as needed based on soil and tissue analyses, vigor, and crop performance.

Nitrogen (N)

Bearing beds

Dried cranberry leaves contain approximately 1 percent N, and dried cranberry fruit about 0.5 percent N. This might seem a small amount, but N is the most abundant mineral element in cranberry plants. Adequate tissue N levels are necessary to maintain growth, crop production, and flower bud development for next year's crop.

Too much N causes excessive vegetative growth, which restricts flower bud formation and delays fruit maturity. Beds with high N content also are prone to increased fruit rot, poor keeping quality of fresh fruit, and increased problems with insects. In dry-harvested beds, overgrowth created by excess N makes harvest difficult and increases the possibility of removing fruiting tips in the harvest process.

Nitrogen fertilizer rates are based on field observation and plant analysis. Tissue analysis alone does not indicate whether N fertilizer is required, but it can be used with an assessment of plant growth and productivity to determine N status. Soil testing for N is not a reliable indicator of perennial crop N status.

Normal growth for flowering uprights is 2 to 4 inches per year above the bud break point. Flowering upright growth of less than 2 inches is below normal, and greater than 4 inches is above normal. Cranberry beds with normal growth have runners, but more than a few runners indicates a possible excess of N.

Table 1.—Percent leaf N on a dry-weight basis for mature beds, August–September. Standards are combined for 'McFarlin,' 'Stevens,' and 'Crowley' cultivars.

Leaf N (%)	Status
Below 0.90	Below normal
0.90–1.10	Normal
Above 1.10	Above normal

Above-normal tissue N and high vigor indicate overuse of N fertilizer. Below-normal tissue N and low vigor indicate a need for more N. Above-normal tissue N and low vigor suggest that some other factor, such as poor drainage, is limiting growth. Below-normal tissue N and high vigor can occur in beds with little or no fruit production.

Table 1 provides a guide to cranberry N tissue concentrations.

Detailed knowledge about each bed's response to N is critical to optimize production. When planning N management for each bed, you must consider the rate of N, timing of application, method of application, and source of material. For example, nitrogen applied early in the season or an application of N combined with release of N from peat soil causes excess growth, which frequently leads to poor production.

Rate

The rate of N fertilizer application varies according to crop potential, weather, soil type, and stress conditions such as herbicide use, frost injury, and poor drainage. Warm soils might stimulate release of N from duff in established beds. Nitrogen applications on peat soils should be lower than those on sand-based beds.

Depending on local conditions, apply a total of 10 to 60 lb N/a in increments of 5 to 20 lb N/a throughout the growing season, as described below.

Timing

Nitrogen applied between bud break and early bloom often produces excessive growth, especially during the cloudy or rainy periods common during May and June in the Pacific Northwest.

For most beds, optimum timing of N for fruit set, berry size, and bud initiation seems to be from the time the last flower petal falls until berries are pea-sized, a period of 3 to 4 weeks. Research has shown that little N is taken up after fruit is set and sized. Use bee activity during bloom to help determine N timing. Make final N applications 1 to 3 weeks after bee activity stops.

Method of application

Broadcast applications of dry materials usually are spread more evenly than applications made through sprinkler systems. To avoid plant injury, apply materials to dry vines, then rinse with irrigation water.

Source

Cranberries use ammonium-N efficiently and nitrate-N inefficiently. Urea, ammonium sulfate, ammonium phosphate, and fish hydrolosate are materials that supply the ammonium form of N.

Management summary

For established plantings of 'Crowley' and 'McFarlin' in mineral soil, if the bed is not overly vegetative, apply 5 to 10 lb N/a at late hook/early bloom stage, as shown in Table 10, page 41. (See Chapter 2, "Botanical and Physiological Characteristics," for an explanation of developmental stages.)

Do not apply N between bud break and early bloom to cranberries growing on organic soil in Washington. Nitrogen is released from organic soil in sufficient quantities to adequately supply cranberries' N requirement during this time.

Nitrogen application from bud break to early bloom on cranberries planted in organic soil in British Columbia also produces a risk of overgrowth. If the bed is not overly vegetative, apply 1 to 5 lb N/a.

Withhold further N until berries are pea- or marble-sized throughout the field, then apply 10 to 20 lb N/a. A final application of 10 to 20 lb N/a may be applied in late July or early August to maintain plant vigor and to encourage further bud development (Table 10).

Some cultivars require slightly different N fertilizer management. For 'Bergman,' use a similar application schedule, but apply 25 lb N/a per season, split into three or four applications.

For 'Stevens,' wait until pea-sized berry stage before beginning N fertilization. Apply 10 to 20 lb N/a every 7 to 14 days until berry sizing seems complete. Or, apply 20 lb N/a twice at 2-week intervals during fruit sizing. A final application of 5 to 10 lb N/a may be applied in late July or early August to maintain plant vigor and encourage further bud development.

Adjustment of N application rates

If vines are weak or stressed, a postharvest application of up to 5 lb N/a might be helpful. However, heavy applications of N late in the season encourage berry rot, delay ripening and color development, and stimulate bud growth, increasing the risk of winter injury. Determine the cause of the stress to cranberry vines before applying additional N.

Vines suffering from inadequate drainage do not grow or yield adequately until drainage is improved. Additional N applied to poorly drained areas does not improve growth.

Vines suffering from herbicide injury often lack sufficient root systems to assure adequate nutrient uptake. Sometimes, vines injured by herbicides benefit from higher-than-normal N rates. Frequent, light N applications probably are of greater benefit than a few large applications, especially on sandy soils.

Some adjustment of the N rate might be required if cool, wet early-season weather causes low berry set or crop load. A slightly lower N rate might be logical in this circumstance. Conversely, a very high yield (approximately 400 bbl/a) might increase the need for N. Some university personnel recommend additional N in high-yielding situations as a precaution to avoid alternate-year bearing.

Adjust rates cautiously. Doubling the N rate for a high yield is not recommended. Fruit in a 200 bbl/a crop contains about 15 lb N/a, so doubling the yield of a bed from 200 to 400 bbl/a would require only an additional 15 lb N/a.

For further information about N and cranberry production, consult *Nitrogen for Bearing Cranberries in North America.* (See "For more information," page 42.)

Nitrogen for new plantings

Fertilization of new beds encourages rapid soil coverage and root growth for early establishment, which decreases weed competition. For new plantings (first year), apply 5 to 10 lb N/a after roots are established and you can see 1/4 inch of new growth. After that, apply a maximum of 10 lb N/a no more often than every other week until September or until appropriate vigor and runner growth are achieved. Use lower rates for new plantings in peat.

Uniform irrigation is essential for optimum cranberry growth. Irrigate to maintain a moist but not wet soil environment. Cranberries can die or lose vigor if they constantly stand in water. If water puddles consistently, adjust sprinklers, reduce irrigation amounts, or improve drainage.

Establishment is achieved when runners produce uprights with terminal buds uniformly across the bed. When the bed is completely covered with plants supporting uprights and buds, apply N according to the scheme outlined for bearing beds.

Phosphorus (P)

Tissue testing is the best way to determine the need for P fertilizer. Soil testing is not as useful. Although soil test P below 15 ppm usually produces cranberries with below-normal tissue P (below 0.10 percent), soil test P above 15 ppm does not ensure the production of cranberries with normal tissue P. Therefore, tissue testing better indicates cranberry P status.

Soil tests can be useful to help determine the reason for low tissue test results. For example, a soil test can confirm a low amount of soil P or, if there is adequate P in the soil, indicate that another problem is limiting P uptake by the plant (for example, root disease).

Recent work in Massachusetts showed that application rates ranging from 45 to 120 lb P_2O_5/a performed equally well in providing P to established P-deficient cranberries. No definitive data exist to indicate whether single or multiple applications of P are superior.

Agricultural applications of P fertilizer are being examined for their potential adverse impact on surface water quality. Because cranberry production systems are water-intensive, this concern is an additional reason for caution with P fertilizer application rates.

Make single applications of P at or before the roughneck development stage. In established beds, apply P according to Tables 2 and 10. If vines are weak, a postharvest application of 10 to 20 lb P_2O_5/a might be helpful.

Table 2.—Phosphorus sufficiency and fertilizer recommendations for cranberry based on tissue and soil tests.

If plant P in Aug.–Sept. is (%)	If the Bray soil test for P is (ppm)*	Status
Below 0.10	0–15	Below normal
0.10–0.20	15–30	Normal
Above 0.20	Above 30	Above normal
If cranberry P status is	**Broadcast this amount of P_2O_5 (lb/a)**	
Below normal	40–80	
Normal	0–40	
Above normal	0	

**If a tissue test is not possible or as additional information.*

Phosphorus for new plantings

Efficient use of P fertilizer depends on fertilizer placement in the root zone, as P is not mobile in soil. The fibrous root system of cranberry develops in the top 1 to 3 inches of soil. By applying one-third to two-thirds of the P fertilizer just before vines are scattered and disked, you will place the P where the roots can use it. Apply the remaining P at midseason.

If vines already have been planted, split the P applications in the first year, applying half as growth starts and half at midseason.

Potassium (K)

An adequate supply of K is needed for the high K requirement of young leaves and berries. Multiple applications of K fertilizer are recommended. If you apply dry K fertilizers, rinse the material from foliage with irrigation to prevent fertilizer burn. See Tables 3 and 10 for K fertilizer recommendations.

If K is required, apply 25 percent of the total at cabbagehead/bud break stage in late March or early April, 25 percent at hook stage in May, 25 percent at fruit set stage in June to early July, and 25 percent after fruit set in late July to early August. If vines are weak, a postharvest application of 10 to 20 lb K_2O/a might be helpful.

Sulfur (S)

Plant tissue analysis is used for prediction of cranberry S needs, as shown in Table 4.

Fertilizer materials used to supply other nutrients normally contain more than enough S, at least 10 to 20 lb/a. Therefore, separate applications of S are not recommended. An exception occurs in sawdust beds, where sulfur deficiencies have been reported. Applying 250 lb/a of elemental S before planting usually corrects the problem.

Lowering soil pH with elemental sulfur

Cranberries grow best when soil pH is between 4.0 and 5.5. If soil pH is higher, lowering it can help control some leguminous weeds, slow conversion of N to unavailable forms, and provide optimal micronutrient availability.

In British Columbia and Washington, where the pH is above the optimal range, elemental sulfur can be used to lower soil pH. The average decrease is approximately 1 unit for every 1,000 lb/a of elemental sulfur applied. Suggested rates are 200 to 400 lb/a for each application, with at least 4 weeks between applications.

Use caution when applying elemental S, as it can be toxic to cranberries. Apply elemental S only when the soil is relatively dry, and especially do not apply it to any standing water or after mid-August. Even low rates of elemental S (200 lb/a) can cause crop damage or death if applied in standing water. High rates of elemental S (more than 1,000 lb/a) in a single application can be toxic even in dry soil.

Table 3.—Potassium sufficiency and fertilizer recommendations for cranberry based on soil and tissue analysis.

If soil test for K is (ppm)	If plant K in Aug.–Sept. is (%)	Status
0–50	Below 0.40	Below normal
50–100	0.40–0.75	Normal
Above 100	Above 0.75	Above normal

If cranberry status is	Broadcast this amount of K_2O (lb/a)
Below normal	60–100
Normal	0–60
Above normal	0

Table 4.—Sulfur sufficiency in cranberry based on tissue analysis.

If plant S in Aug.–Sept. is (%)	Status
Below 0.08	Below normal
0.08–0.25	Normal
Above 0.25	Above normal

Calcium (Ca)

Cranberries, like all acid-adapted plants, require little Ca. If tissue tests indicate a Ca deficiency, Ca can be supplied with gypsum (calcium sulfate) or foliar Ca materials. Apply Ca as gypsum between cabbagehead/bud break and roughneck stages according to Tables 5 and 10. Gypsum does not improve soil drainage in cranberry beds. Apply foliar Ca according to the product label, usually between late hook and early bloom stages. Sufficient Ca also can be supplied by 0-45-0 (12 to 14 percent Ca) fertilizer or Bordeaux fungicide.

Caution: Excess soil calcium can encourage unwanted legumes to invade cranberry beds.

Magnesium (Mg)

In the Pacific Northwest, cranberries routinely are fertilized with Mg. However, according to Eck in *The American Cranberry* (see "For more information," page 42), no published reports have indicated yield or growth increases due to Mg applications.

Eck also reports that blueberries grown on the same soil as cranberries sometimes exhibit Mg deficiency symptoms. The limited growth of cranberries compared to blueberries might be one factor in the lower Mg requirement of cranberries. Also, cranberries are nondeciduous, which might allow Mg to be translocated from old to new growth.

Little is known about Mg nutrition of cranberries. However, 0.15 to 0.25 percent tissue Mg in a late summer sampling is considered normal based on tissue analysis summaries from various North American growing regions. Analyses of Oregon cranberry tissue from 1974 to 1988 showed that 98 percent of samples were within this range. Where Mg is deficient, a greater range of tissue Mg concentration would be expected.

Low tissue Mg can be caused by Ca and K fertilization. If Mg is deficient, and tissue levels of Ca and K are high, reduce Ca and K applications. If Mg fertilizer is needed, apply it at cabbagehead/bud break stage, as recommended in Tables 6 and 10.

Table 5.—Calcium sufficiency and fertilizer recommendations for cranberry based on soil and tissue analysis.

If the Ca soil test is (meq/100 g)	If plant Ca in Aug.–Sept. is (%)	Apply this amount of gypsum (lb/a)
Below 0.50	Below 0.30	100
	0.30–0.80	0–100
	Above 0.80	0

Table 6.—Magnesium sufficiency and fertilizer recommendations for cranberry based on soil and tissue analysis.

If the Mg soil test is (meq/100g)	If plant Mg in Aug.–Sept. is (%)	Broadcast this amount of Mg (lb/a)
Below 0.30	Below 0.15	20
	0.15–0.25	0–20
	Above 0.25	0

Boron (B)

Apply boron only when the need is indicated by soil or plant analysis. You can supply boron either as an addition to an early-season granular fertilizer or as a liquid. If you apply B as a liquid, broadcast a soluble form by sprayer or sprinkler. Do not mix B with copper materials. Apply between roughneck and early bloom at the rates and times given in Tables 7 and 10.

Copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn)

Soil and tissue tests for Cu and Fe are difficult to interpret. Analysis for Fe is not recommended, because cranberry leaf tissue often is contaminated with iron from water or soil dust.

Fungicides commonly contain one or more micronutrients that contaminate a tissue sample. This contamination causes tissue micronutrient levels to read extremely high, thus making tissue analyses for these nutrients useless.

Repeated annual applications of copper-supplemented granular fertilizers in addition to fungicides containing Cu can result in Cu toxicity on peat soil. Conversely, if no copper fungicides are used, and Cu tissue analyses are low, an application of copper is recommended (Tables 8 and 10). Apply Cu either as a supplement to spring fertilizers or by substituting a Cu fungicide in your disease management program.

High levels of manganese (Mn) are common in cranberry tissue. If you have not used fungicides containing Mn, and tissue concentration of Mn exceeds 300 ppm, soil drainage might be inadequate.

Soluble forms of zinc, such as zinc sulfate or chelate, can be applied by sprayer or sprinkler. Apply only when needed between roughneck and early bloom, as shown in Tables 9 and 10.

Table 7.—Boron sufficiency and fertilizer recommendations for cranberry based on soil and tissue analysis.

If the B soil test is (ppm)	If plant B in Aug.–Sept. is (ppm)	Apply this amount of B (lb/a)
Below 0.50	Below 15	1
	15–60	0–1
	Above 60	0

Table 8.—Copper sufficiency and fertilizer recommendations for cranberry based on tissue analysis.

If plant Cu in Aug.–Sept. is (ppm)	Apply this amount of Cu (lb/a)
Below 4	0.5–1
4–10	0–0.5
Above 10	0

Table 9.—Zinc sufficiency and fertilizer recommendations for cranberry based on soil and tissue analysis.

If the DTPA* soil test for Zn is (ppm)	If plant Zn in Aug.–Sept. is (ppm)	Apply this amount of Zn (lb/a)
Below 0.80	Below 15	1–2
	15–30	0–1
	Above 30	0

*The standard method for extracting Zn from soil

Table 10.—Guide to timing of cranberry fertilization in bearing beds. [a]

Nutrient	Cabbagehead/ bud break	Roughneck	Late hook/ early bloom	Fruit set	Late fruit set to early bud development	Post-harvest
	lb/a					
Nitrogen (N)	[b]	0–5	5–10	10–20	10–20	0–5[c]
Phosphorus (P_2O_5)	0–80[d]					0–20[c]
Potassium (K_2O)	0–25		0–25	0–25	0–25	0–20[c]
Calcium (Ca)	0–100[e]	[f]				
Magnesium (Mg)	0–20					
Boron (B)		0–1[g]				
Copper (Cu)		0–2[g]				
Zinc (Zn)		0–1[g]				

[a]*See Chapter 2, "Botanical and Physiological Characteristics," for an explanation of developmental stages.*

[b]*Apply 5 to 10 lb N/a if vines are weak. Excess growth can occur in warm, wet weather in beds with duff buildup. Avoid early N treatments in second-year beds if first-year growth was abundant. Also, avoid early N use on 'Stevens.'*

[c]*Postharvest fertilization usually is not needed. However, apply immediately after harvest if vines are weak.*

[d]*No definite data exist to indicate whether single or multiple applications of P are superior. Single applications should be made at or before roughneck development stage.*

[e]*Apply 100 lb calcium sulfate (gypsum)/a if needed. Gypsum contains 19 to 23 percent calcium.*

[f]*Apply foliar calcium between late hook and early bloom according to product label.*

[g]*Apply during the period marked with shading or according to the product label. Postbloom applications are not recommended.*

For more information

Analytical Laboratories Serving Oregon, EM 8677 (Oregon State University, revised 2002).

Cranberries (South Coastal Oregon) Nutrient Management Guide, EM 8672 (Oregon State University, 1997).

Cranberry Tissue Testing for Producing Beds in North America, EM 8610 (Oregon State University, 1997).

Eck, P. *The American Cranberry* (Rutgers University Press, New Brunswick, NJ, 1990).

Nitrogen for Bearing Cranberries in North America, EM 8741 (Oregon State University, 2000).

Maintaining the Bed

Pollination

7

Floral biology

Cranberries are self-fertile and self-fruitful; only one cultivar is needed for fruit production. However, insect foraging is required for fruit set, to transfer pollen from the anthers to the receptive stigmas. Because the pollen is heavy and remains viable only a few hours after being shed, very little cranberry pollination occurs from wind dissemination.

Several events must occur in rapid sequence for good fruit set: viable pollen must be transferred to a receptive stigma, the germinating pollen must grow down the style, and the pollen must fertilize a viable ovule. Table 1 outlines the time frames during which these events can occur for cranberries.

A lack of pollinators often is to blame in years when there are significant reductions in cranberry crops in the Pacific Northwest. Achieving a healthy population of pollinators in the field is not easy because of wet weather and cold temperatures, the preference of honeybees for resources other than cranberries, and sparse bumblebee populations. The challenge for the grower, therefore, is to assure sufficient pollinating agents at the right time.

Table 1.—Average time frames for successful cranberry pollination and fruit set.

Event	Average time frame across cultivars
Stigma receptive to pollen	From 3 to 20 days after flower opening
Period of ovule viability	From 0 to 14 days after flower opening
Length of pollen viability in the flower	12 days after flower opening
Length of pollen viability after shed from flower	6 to 8 hours
Length of time for pollen tube growth down style	2 days
Time period for maximum fruit set	7 to 10 days after flower opening
Optimal pollination window	3 to 10 days after flower opening

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Assessing pollination needs

To understand the conditions that can limit pollination, evaluate the following:

- Pollination history of your farm
- Pollination requirements (flowering upright density, cultivar, expected crop load)
- Pollinator numbers and quality (surrounding habitat for competing forage, amount of adjacent cranberries, native bumblebee density, honeybee hive quality, and number of rented colonies)
- Expected bloom time (start and finish)
- Need for an insecticide during bloom

By assessing these factors, you can decide whether to rent hives, when to place and remove them, where to locate them, and whether you need alternative pollinators (e.g., purchased bumblebees).

Pollination history

If you have experienced poor yield, you should determine whether it was due to pollination problems. Compare your previous cropping records to your neighbors' records, examine state or province averages, consider the weather, and record your observations of yearly bumblebee populations on the beds. If beds with good flowering upright density have yielded poor crops despite good bloom and weather, if other farmers in the area have obtained good yields, and if there are low bumblebee densities, then pollination probably is a significant factor in limiting yield.

Pollination requirements

The historical recommendation of one hive per acre for cranberries was adequate for yields of 100 bbl per acre. Modern, more productive cultivars, with high upright density and capacity for yields of 200 to 400 bbl per acre, require greater hive density. An extremely productive 'Stevens' bed, for example, can support three or four colonies per acre in years when other conditions exist for high yields.

Pollinator numbers and quality

All bee hives are not created equal. Larger, stronger hives are more effective. One colony of 30,000 bees might pollinate one and a half times more than two colonies of 15,000 bees. A strong hive must have an actively laying queen, which creates a high demand for pollen to feed the larvae. Weak or queenless colonies are useless for pollination purposes.

Frequently check the number of foraging bees entering and exiting hives. A good pollinating colony should have 100 incoming bees per minute during ideal weather (over 65°F with little wind). On average, one-quarter to one-third of incoming bees should have pollen sacs on their legs. If few or none do, the colony might be queenless.

States require certain standards for rental hives. The Washington standard is six frames that are two-thirds covered with bees at a temperature of 65°F.

Do not attempt to conduct in-hive inspections without permission of the beekeeper. If hives show little consistent activity, especially during good foraging weather, notify the beekeeper.

Since honeybees usually prefer to forage on flowers other than cranberries, colony density must be adequate to saturate forage resources at least one-half mile from the farm. If your beds are surrounded by floral habitat that is favored by honeybees, you must bring in enough bees to saturate both the surrounding flora and the cranberries. For example, if the only resource within miles is gorse (*Ulex europaeus*), you might not need any additional hives, but if acres of wild blackberries are blooming adjacent to cranberry beds, several extra colonies per acre are required.

One way to determine the seriousness of forage competition is by observing the type of pollen gathered by the bees. Cranberry pollen is very light tan. If most incoming bees are carrying a different colored pollen, then competition from surrounding resources is a problem. Evaluate pollen color several times during the season (from behind the safety of a car window).

Table 2.—Comparisons of pollen collected by honeybees used for cranberry pollination.

Growing area	Cranberry %	Blackberry (*Rubus* spp.) %	Clover (*Trifolium* spp.) %	False dandelion (*Hypochaeris* spp.) %	Other %
S coastal Oregon	60	13	3	3	21
SW Washington	22	42	3	18	15
British Columbia	14	45	24	1	16

Based on 5 years of pollen trap data from bee colonies in Oregon, Washington, and British Columbia, the major forage resource competitors of cranberries are blackberry, clovers, and false dandelion (Table 2).

Bees do not pay attention to property lines. If an adjacent farm has inadequate bee strength, it is likely to draw bees away from your field and onto the neighboring cranberries. Good rapport among neighbors is important to assure that the burden of pollination is shared equally.

Bloom time

Early-blooming cultivars such as 'Stevens' and 'Pilgrim' require hive placement before 'McFarlin' and also finish blooming earlier. Some 'McFarlin' can continue to bloom well past the time of bee removal. This is true especially when June weather is cooler than normal. Some of the late-blooming flowers on 'McFarlin' can set fruit if pollinated and contribute slightly to yield.

The best time to place hives is when the cranberries are at about 10 percent bloom. Sometimes, the greatest difficulty with timing hive placement and removal is that you must make decisions based on the beekeeper's schedule and the requirements of area growers as a whole. Thus, effective timing of hive placement can be difficult if you have all early or late bloom. Special arrangements might be required.

Using insecticides during bloom

Honeybees are very susceptible to most insecticides. They can be killed by direct application or through contacting insecticides while foraging. Insecticide carried back to the hive diminishes hive quality or even kills entire hives. Insecticides sprayed on nearby fields and those that contaminate water sources also can lead to hive decline. In addition to bee kill, some insecticides interfere with pollination by repelling bees.

The length of residue hazard can vary from hours to days. For more information, see *Pollinator Protection Update for Small Fruit.*

Fireworm control often is necessary during bloom, especially if poor control was achieved during the first generation. (See Chapter 14, "Insects.") If sweep or visual sampling indicates that larvae populations are high enough to warrant control, use only insecticides with reduced toxicity for honeybees.

An additional consideration is protection of native pollinators. Bumblebees are likely to forage in early- and late-blooming cranberry flowers when insecticides are in use, which might cause severe, long-term damage to their populations. Therefore, it is important to make pesticide applications at night, even after honeybee colonies have been removed, to avoid poisoning bumblebees.

Hive placement

Although much of hive management is the responsibility of the beekeeper, growers can determine the best locations to place hives on their farm. The location of hives around the bed can make a huge difference in their performance. For example, exposing the hive entrance to full sun increases working hours. Placing hives so that entrances are directly accessible to the cranberry beds keeps workers from drifting into other hives.

High winds can prevent a large number of workers from returning or cause them to drift into other hives. Placing wind breaks around the colonies might help prevent these losses and improve pollination.

Other commercially available pollinator species

There are two species of bumblebee colonies available from commercial suppliers, *Bombus impatiens* and *Bombus occidentalis. B. impatiens* is not available in the Pacific Northwest, as it cannot be sold west of the Rocky Mountains. Suppliers have had difficulties with hive quality of *B. occidentalis,* so its availability is not reliable.

Unlike honeybees, bumblebees forage and are effective pollinators in cold, wet weather. However, bumblebee colonies are expensive (approximately $80 to $100 per hive), short lived (1 to 2 months), and contain only a small fraction (less than 1 percent) of the foraging population of a honeybee colony. Therefore, unless the weather during bloom is *very* unfavorable to honeybees, buying bumblebee colonies is not as cost effective as renting honeybee hives.

A few species of *Osmia* and *Megachile* bees have been commercialized and shown to work cranberries in some areas of the Midwest and Canada. *Osmia lignaria* (Mason bee) is touted as useful for pollinating orchards in the Pacific Northwest. However, due to problems with cost, availability, wet weather during bloom, and the lack of synchrony between bee emergence and bloom, none of these solitary nesting species has been shown to be effective for pollinating cranberries in the Pacific Northwest.

Building up native pollinator populations

Extensive surveys of Pacific Northwest cranberry beds during bloom found that *Bombus occidentalis* and *B. mixtus* species of bumblebees were common. (Other solitary nesting bee species also were observed, but in such low frequency that they can be considered insignificant for cranberry pollination.) These surveys also found that some cranberry beds had a very high average bumblebee population (greater than 1 per 100 sq ft), while others had none. Quality of habitat (food resources and nesting sites) adjacent to the farms accounted for the differences in populations.

Large cranberry fields surrounded by poor-quality food sources (dairy pasture, gorse, Scotch broom, willow) supported low resident populations of foraging bumblebees (less than 1 per 1,000 sq ft). Cranberry beds with high populations of bumblebees were small (less than 5 acres), isolated, and bordered by undisturbed, well-drained scrub/shrub/forest land (important for hibernating queens and nest sites). Spring flora included a high population of blooming evergreen huckleberry (*Vaccinium ovatum*), blackberry (*Rubus lacinatus* and *Rubus armenicus*), dewberry (*Rubus ursinus*), fireweed (*Epilobium angustifolium*), white clover (*Trifolium repens*), springbank clover (*Trifolium wormskjoldii*), white sweet clover (*Melilotus alba*), or rhododendron (*Rhododendron* spp.). In the summer and fall, blooming lotus (*Lotus corniculatus*), clover (*Trifolium* spp.), and goldenrod (*Solidago canadensis*) were in flower.

Research indicates that growers can improve bumblebee habitat by establishing plantings of winter-blooming heather species such as *Erica x darleyensis* ('Alba,' 'Darley Dale,' and 'Furzey') and *Erica carnea* ('Springwood Pink' and 'Springwood

White') near their beds. These plants provide a sequence of bloom attractive to newly emerging queens and young colonies from late winter to late spring.

In some sites that lack undisturbed natural habitat, good nesting places for bumblebees might be scarce. Providing nest boxes for bumblebees might help build populations.

For more information

Evaluating Honey Bee Colonies for Pollination—A Guide for Growers and Beekeepers, PNW 245 (Washington State University, 1993).

Pollinator Protection Update for Small Fruit (Washington State Department of Agriculture, Pesticide Management Division). P.O. Box 42589, Olympia, WA 98504-2589 (phone: 360-902-2010).

Maintaining the Bed

Pruning

8

Pruning is an important practice for balancing vegetative and fruiting growth in cranberry. Cranberries are pruned to remove excessive vegetative growth, particularly excess runners and old, long upright shoots, which create a dense canopy that limits light penetration. Improved light exposure in the canopy promotes increased fruit color and flower bud initiation (for next year's crop). Research in Oregon found that fruit set and fruit color (anthocyanin) were improved by pruning. Light pruning (removing about 0.8 ton of vines per acre) every other year resulted in the highest yield and best fruit color.

Pruning also provides the following benefits:

- Production of uprights is stimulated.
- Flowers are more accessible to pollinators (bees); thus, the percentage of fruit set might improve.
- Fruit rot disease pressure might be reduced, as fruit rot fungi flourish in the moist microclimate created by the dense canopy in unpruned beds.
- Harvesting (wet or dry) is more efficient because runners are kept to a minimum and because pruning trains vines for harvest.
- The prunings can be used to plant new areas, or they can be sold.

Disadvantages of pruning include:

- Vines can be damaged by pruning equipment.
- Heavy pruning (removal of too many uprights) can reduce yield the following year.

Research in Oregon has shown that the proportion of nonfruiting uprights increased the following season as pruning severity increased, thus reducing yield that year. On the other hand, because individual uprights tend to bear fruit biennially (see Chapter 2, "Botanical and Physiological Characteristics"), stimulating the production of nonfruiting uprights can offer advantages the second year after pruning.

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Severe pruning (removal of about 1 to 2 tons of vines per acre in Oregon conditions) also reduced yield the following season due to the removal of uprights bearing flower buds. Severe pruning two winters in a row intensified the effects.

When to prune

Delay pruning cranberry beds until a relatively vigorous canopy has been established (year 3).

On wet-harvested beds, as long as vines are pruned sometime between late fall (after fruit harvest) and late winter, timing of pruning is not critical in the Pacific Northwest. In Oregon research, the timing of pruning had no effect on yield or fruit quality when pruning was done in early December or early March. Avoid pruning when vines are frozen.

Cranberries that are dry harvested using a Furford picker are pruned during fruit harvest.

Pruning methods

Pruning machines for wet-harvested cranberries usually consist of a head with a series of knife blades set at an angle to the direction of movement (often vertical) and spaced at about 1-foot intervals on a rotating frame mounted on a motorized piece of equipment. These machines often are called "reel" pruners (Figure 1). The severity of pruning is determined by knife spacing and speed of operation. Pruning patterns should follow harvest beating patterns.

In some cases, water pickers (harvesters) have been modified to accept a pruning head. Some growers follow machine pruning with hand pruning, using a special rake set with pruning blades.

Take care not to damage vines by pruning too severely or by using equipment incorrectly.

Bed renovation

Old cranberry beds that have become overly vegetative or weedy might require heavy pruning (renovation) to reduce canopy density and bring them back into production. Plantings usually are renovated by mowing most of the top growth to just above the duff layer. You can use mowings to establish new beds or you can sell them, provided they are a good cultivar. Renovation also might involve redesigning the irrigation system and leveling the bed surface.

There will be no crop the year following mowing. By the third year, the bed should be in full production.

To change cultivars, first mow and/or scalp the old vines. Then add about 6 inches of coarse sand to the bed surface and replant. (See Chapter 4, "Establishing the Cranberry Bed.")

Figure 1.—A "reel" pruner used to prune wet-harvested beds.

Maintaining the Bed
Sanding

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Sanding was one of the first cultural practices used in cranberry production. It originated from an observation made in 1816 by Henry Hall in Cape Cod, Massachusetts, who noted that sand blown onto his wild cranberry vines improved growth. Since then, it has become a common practice in all United States cranberry-producing regions to apply sand to cranberry beds. The usual practice is to apply ½ to 1 inch every 3 to 5 years. Historically, sanding is practiced irregularly or not at all by Pacific Northwest growers.

Some of the effects of sanding are similar to those of pruning, so you should not prune and sand in the same year. The effects of sanding also might be observed for several years after application.

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Benefits of sanding

The following are observed benefits of sanding; unfortunately, for many of these, no good research data are available to give quantitative measures of the benefits.

Plant growth improves due to increased breakdown of soil organic matter, stimulation of root growth, and improved aeration in the root zone. Sanding also improves soil drainage. For this reason, N fertilizer needs generally are reduced by 5 or more pounds per acre the growing season following sand application.

Sanding strengthens peat soils physically so that mechanical operations on the bed are easier. On very light peat beds, which cannot be flooded due to floating peat, sanding might allow you to flood a bed by "tacking" down the peat.

Production of new uprights and roots is stimulated when the exposed portions at the base of old upright stems and runners are covered with sand. This response is similar to that stimulated by mechanical pruning.

Sanding can level low spots in fields for smoother dry harvesting and can be used to rejuvenate weak spots in beds. However, spot sanding can have unintended consequences. (See "Possible disadvantages of sanding," page 52.)

Sanding alters the microclimate and habitat for pests on the floor of the cranberry bed. A regular sanding program is important in the management of the cranberry girdler. (See Chapter 14, "Insects.") Cranberry girdler larvae live in and just below the organic or duff layer on the surface of the bed. Sanding covers this duff layer, and when cranberry girdlers lay their eggs on the sand layer, the newly hatched larvae die for lack of soft, vegetative food. If sanding is used as a direct control measure, fall or winter sanding is more effective than sanding in the spring.

Sanding also might suppress tipworm populations temporarily.

Sanding might suppress the germination of certain weed seeds. In order to be effective, the sand layer must be uniformly 1 inch deep. Sanding also might synchronize weed emergence, enhancing control by herbicides.

On the other hand, sand might provide ideal conditions for weed seed germination. Sanding affects perennial weeds much the same as it does cranberries and might actually enhance their growth.

Sand must be free of weed seeds, or new weeds will be introduced to the cranberry bed.

Sanding removes inoculum of several plant pathogens by burying old leaves.

Sanded beds are less likely to suffer frost damage than unsanded beds, as shown by experience in eastern production regions. Sand warms faster than organic matter. Compared to beds with a thick duff layer, temperatures on a newly sanded bed are at least 2°F higher if the sand is wet.

Possible disadvantages of sanding

Research on sanding 'Stevens' cranberry beds in Oregon showed that sanding younger beds might decrease yield in the year of sanding, especially with heavy applications (1 inch deep). A lighter sanding (½ inch deep) improved yield in an older bed with a thick duff layer.

Heavy sanding on deep, peat-based beds can lead to uneven settling of the subsoil (compression), leaving the bed out of grade or even causing sinkholes. Spot sanding (applying sand to a single location within a bed) is not recommended on peat beds.

Use herbicides with caution on sanded beds, as the sand layer might enhance their effectiveness. Also, roots developing in sand might be more sensitive to herbicides.

Type of sand to use

Growers in the Pacific Northwest use sand from various sources, depending on availability and convenience. Oregon growers commonly use on-farm coastal dune sand. In British Columbia, river-bottom sand usually is most available. Washington growers usually use beach sand.

Sand with few fine particles (fine sand, silt, and clay) gives the best results. Fine particles are the most likely to remain suspended in water and to move away from the target area during barge sanding or hydrosanding. (See "Methods of sanding," page 53.) Coarse sand with particle sizes between 0.5 and 2 mm promotes proper drainage and increases root growth. The following particle size mixture is recommended: 3 to 7 percent very coarse, 25 to 32 percent coarse, 36 to 42 percent medium, 20 to 27 percent fine, 1 to 4 percent very fine. Laboratories that test soil should be able to perform an analysis of particle size.

Avoid using gravel. Screen sand to remove gravel before application.

Amount of sand to apply

Very little is known about the optimal depth of sanding. Practices are based on experience and practicality. Results vary depending on the type of cranberry bed construction (peat or sand) and the age of the bed (perhaps because bed age affects the depth of the duff layer). Also, the amount of sand to apply depends on how recently you last sanded and the sanding depth and method used.

Applying heavy sand layers on deep peat beds can cause compression of the peat and uneven settling of the bed. Applying extra sand to low areas on deep, peat bogs only raises the soil surface temporarily and might cause the soil to sink later.

Research in Oregon has shown that ½ inch of sand often provides better results than 1 inch (Figure 1). However, when you barge sand, it is difficult to apply only ½ inch uniformly.

To achieve a 1-inch depth on 1 acre, apply 134 cubic yards of sand. For a ½-inch depth, use 67 cubic yards.

Frequency of sanding

There is no research information on how often to sand. In eastern production regions, growers sand every 3 to 5 years. In British Columbia, sanding still is relatively uncommon. In Oregon and Washington, sanding has become a more common cultural practice and can be done every 3 to 5 years.

Methods of sanding

There are several methods of sanding. In colder regions of eastern North America, growers can apply sand onto the ice used for winter protection. As the ice melts in the spring, the sand settles onto the duff layer.

In warmer regions, where an ice layer cannot be maintained or winter cold protection is not necessary, other methods of sanding are used. These include barge sanding (flooding beds and dropping sand through the water), hydro- or aqua-sanding (spraying a sand-water slurry), and applying dry sand directly to the vines using ground rigs or helicopters. See Figures 2 and 3.

When you barge sand, you must keep the flood on the bed long enough to allow particles to settle before discharging the water. Because warm water (above 65°F) held on a cranberry bed for extended periods damages plants, use this method only when the temperature is no higher than 65°F.

When you choose a sanding method, consider the following:

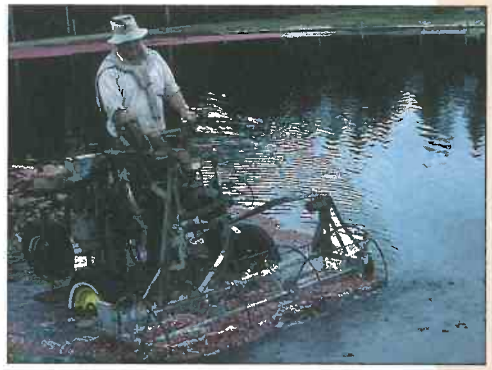
- Barge sanding might not anchor runners well and therefore might stimulate less growth.
- Hydrosanding can cause mechanical damage, especially if the vines are not dormant at the time of sanding.
- Dry sanding can damage vines and cause reduced yield, especially in the year of sanding.
- Methods differ in ease of application and cost.

Figure 1.—A section of a cranberry bed showing the results of adding ½ inch of sand (arrow) on top of the duff layer.

Figure 2.—Barge sander.

Figure 3.—Hydrosanding established cranberry beds.

Harvesting



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Ideally, cranberry fruit is harvested at full maturity with good color (anthocyanin content), but before fruit becomes overripe.

Cranberries can be harvested in two ways. Water harvest (also called wet harvest) involves flooding the bed, agitating fruit off the vine, and removing the fruit from the floodwater. It takes advantage of the fact that cranberries contain large air spaces, so they float. Dry harvest involves removing the fruit directly from the vine into a container and then moving it off the bed.

In general, fruit that is dry harvested is used for fresh market, while water-harvested fruit is used for processed cranberry products. Wet-harvested fruit does not store well for the fresh market due to rough handling and exposure to spores of rot organisms.

Water harvest has a number of advantages over dry harvest:

- Beds reach full production faster in water-harvest systems (4 to 5 years) than in dry-harvest systems (8 years).
- The entire harvest process is much faster, allowing management of larger farms and lower labor costs.
- To dry harvest you need dry weather, whereas water harvest is possible in inclement weather.

Most growers would choose water harvest over dry harvest; however, dry harvest has two unique advantages over water harvest:

- Fruit quality is maintained sufficiently to allow marketing of fresh berries at Thanksgiving and Christmas. This affords growers a premium price.
- Water is not necessary, making dry harvest the only option if harvest water is not available or if construction of dikes is regulation- or cost-prohibitive.

If the premium for fresh fruit is 20 to 30 percent above the price of fruit for processing, and if restrictions on establishing dikes on wetlands become more stringent, dry harvest might be the appropriate choice for a new bed.

Other economic factors (e.g., equipment needs, pruning processes) also differ between the two systems. The following sections describe the two harvest

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systems, how they work, and what to consider when choosing a harvest method.

Water harvest

Water harvest dates to the 1920s and was mechanized in the mid-1950s. Before harvest, beds are flooded until a shallow layer of water covers the vines. Depending on the size of the operation and the amount of water available, either a single bed or multiple beds can be flooded. Floodwater generally is reused for more than one bed and is moved with a combination of pumping and gravity. (See Chapter 4, "Establishing the Cranberry Bed.")

The harvest process involves several stages: flooding the beds, knocking the fruit from the vines, corralling the fruit, washing the fruit, and loading it. On large farms, several stages of the harvest process might occur simultaneously.

The mechanical harvest process begins after the bed is flooded (Figure 1). Mechanical harvesting devices are called water reels and consist of a series of flat, horizontal bars on round heads that rotate as the picker moves through the water. The movement of the bars causes turbulence, which breaks the delicate pedicel holding the berry to the upright—a procedure known as knocking off the fruit. The berry then floats to the surface.

Water reels are driven by mechanized devices that typically are set up for a rider. Some, however, are self-propelled; the operator walks behind and controls the unit. You can buy water harvest equipment ready-made, but much of it is custom made with water reel lengths specific to individual operations. New water harvesters can be quite sophisticated and can cost up to $20,000. Note that only food-grade grease and oils should be used in wet-harvest equipment in case of leaks.

Generally, several water reels operate in a bed at the same time, following circular paths around the bed until all the fruit is knocked off the vines. The fruit then is corralled in a corner of the field using floatable booms. Usually, the direction fruit moves to the corral corresponds to wind direction. Large paddles also are used to help move the fruit to the desired area.

Figure 1.—Water harvest.

Figure 2.—Using a stepped conveyor belt to move berries from the water into harvest containers.

After the fruit has been corralled, it is loaded into truck beds or other motorized transport containers that move the fruit away from the field. Traditionally, a flighted (stepped) conveyor belt moves fruit from the floodwater into the container; the flights keep berries from rolling back down the belt (Figure 2). Some belts have water nozzles to spray off trash (leaves, stems, and rotted fruit). Fruit loaded using less sophisticated systems is washed at the edge of the field or taken to a washing device elsewhere before being trucked off-site.

An alternative to the conveyor belt is the berry pump. It originally was designed and developed in Massachusetts and has become popular in other growing areas. A low-pressure pump sucks the fruit up through a hose sitting in a pan in the flood water to an inclined metal grate, where the fruit is washed to remove trash and then rolled directly into the harvest container. The berry pump is less labor intensive than the conveyor system and is easier to move from bed to bed.

After the fruit is removed from the bed and cleaned, it is transported in one of two ways, depending on the receiving facility. Fruit either is loaded into 10-barrel bins (1,000 lb of fruit) or bulk loaded into a truck.

Dry harvest

The tools for dry harvest have evolved from the hand scoops used in the early 1900s, to suction pickers, to small combine-like machines used currently, called Furford harvesters. There are only a few types of dry harvesters available commercially.

Furford harvesters have been the standard on the West Coast for many years and are readily available (Figure 3). They are 22 inches wide and have a harvest speed of 0.25 to 1 mph, depending on the gearing. Typically, it takes 2 days to harvest an acre. Furford harvesters can be modified, for example by adding softer pads, to reduce the amount of damage to the fruit. New machines are hydraulic rather than chain driven and can cost up to $10,000.

Once the fruit is harvested, vines, leaves, weeds, and small fruit must be removed. Several types of "deviners" or "sorters" are used; all rely on a screen, shaker, blower, and conveyor belt elevator system (Figure 4). Berries often are injured or bruised during the sorting and cleaning process, so good sorting systems that minimize both drop height and number of drops are important.

Field heat must be removed as soon as possible by cooling the fruit. To maintain keeping quality, sacks of fruit should not be manhandled or piled more than two or three sacks high.

Dry harvesting is affected greatly by weather, land uniformity, vine growth, and weeds. Fresh fruit keeping quality is impaired if fruit is harvested when it is wet. Therefore, long periods of rainy weather can delay or prevent harvest if fresh fruit is the goal.

Settling of land over time can cause undulating topography, also making dry harvesting difficult.

Excessive vine growth is a severe problem on some fields. It can be caused by over-fertilization or rich soil that releases too much nitrogen. Excessive growth reduces fruit keeping quality, thus preventing the crop from being used for fresh fruit.

Figure 3.—A Furford dry harvester.

Figure 4.—A cranberry sorting machine.

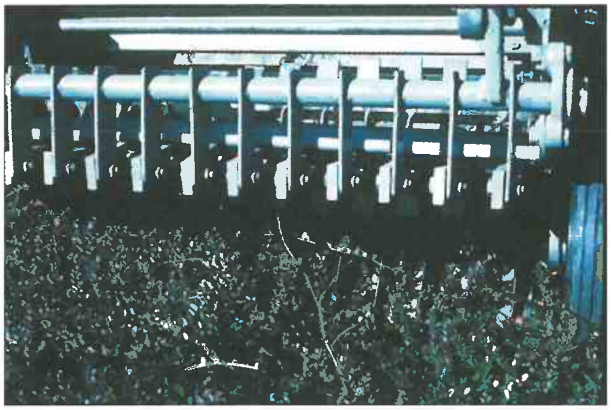

Figure 5.—A closeup of harvesting with a Furford picker.

Figure 6.—Dry harvesting of cranberries.

Moreover, because a Furford harvester prunes while harvesting, it will remove the excess vegetation, thus removing the following year's fruit buds and causing more vigor the subsequent year (Figure 5). This leads to a cycle of vine overgrowth for many years.

Weedy fields are not well suited for fresh fruit. Many weed species plug the harvest head of a dry harvester, causing increased mechanical damage to fruit, which reduces keeping quality.

Once you have made the commitment to dry harvest, three additional decisions must be made for new plantings: cultivar selection, bed design and vine training, and mode of transport.

Cultivar

The cultivar you select should bear good yields, be easy to dry harvest (fruit needs to set up high on the vine), have good fresh fruit keeping quality, and ripen when market prices are premium. For most purposes, 'Stevens' meets these requirements. 'Bergman' is preferred for dry harvest in British Columbia. 'Pilgrim' is high-yielding, but it is difficult to pick because the fruit lies close to the ground. Young or poorly established beds in which fruit-laden uprights are not held upright by adjacent plant growth also are difficult to pick.

Newer cultivars have yet to be fully evaluated in the Pacific Northwest for their dry harvest potential.

Bed design and vine training

Ideally, dry harvest beds are long and narrow to minimize the area of direction change (training pattern) in the middle of a production area, because a dry harvester, unlike a wet harvester, cannot follow a circular pattern on the beds (Figure 6). Fruit cannot be harvested in the narrow strips between direction changes. Instead, direction changes should be associated with railroad tracks or road beds, or the beds should be trained in one direction only and the harvester transported back to start with each pass.

It takes several years to train dry-harvested vines for the specific bed design or harvest pattern. Training usually starts in the fall or winter of the first or second year of growth, before the canopy becomes excessively dense. The harvester, a combination pruner and scoop, combs the vines, selectively removing vines and runners and eventually establishing a clear pattern of vine growth in one direction.

By the second or third year, some fruit can be harvested; however, you will lose much of the fruit in the canopy until the vines are completely trained. It takes 7 or 8 years to train a canopy completely for minimal fruit loss from a dry harvester, compared to 3 or 4 years for a wet-harvested bed.

Mode of transport

Once fruit is harvested, there must be a quick, efficient method of removing hundreds of 40- to 80-lb sacks off the bed (Figure 7). Carts on narrow-gauge railroad tracks down the middle of the bed are most common (Figure 8), but they are very expensive to install. Some growers lay narrow roads and use vehicles with low-pressure tires to collect sacks of fruit. Some use a second harvesting method (suction pick or hand scoop) to recover berries from between the railroad tracks and along ditch banks.

Figure 7.—Sack of dry-harvested fruit and prunings.

Figure 8.—Collecting dry-harvested berries using railroad carts.

Pest Management

Weeds

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K. Patten

Weed control in cranberries is more difficult than in almost any other crop. Herbaceous perennial weeds in cranberry are highly productive and are difficult to control with registered herbicides. The potential production loss caused by weeds in cranberries is estimated to be 15 percent, among the highest of any agricultural commodity. Crop loss in cranberries due to weeds is greater than for all other pests combined. The most important weeds in West Coast cranberry beds are shown in Figures 1 through 19 (pages 65 and 66).

The 1994 National Agricultural Pesticide Impact Assessment Program Report on the "Biologic and Economic Assessment of Pesticide Usage on Cranberry" states that loss of herbicide registrations in cranberries would result in a $65 million short-run economic loss in the United States. This is threefold the loss that would occur if all cranberry insecticide registrations were canceled and almost double that expected for the loss of fungicide registrations.

The impact of weeds on cranberry production makes attention to details in land preparation and early weed control essential to the economic viability of a new cranberry farm.

Land preparation

Eliminating weeds

To prepare the land adequately, make sure all perennial weeds are killed prior to bed construction. If sand is used on the bed, make sure it is free of weed seeds (especially perennial weeds) and that it is deep enough (at least 4 inches) to prevent germination of seeds in the soil underneath.

In some cases, it might be necessary to fumigate the surface soil to kill weed seeds and the vegetative propagules (root rhizomes) of perennials, for which there is zero tolerance in cranberry beds. Fumigate early enough to allow the soil to aerate adequately (release all the fumigant) prior to planting. Minimize land disturbance after fumigation.

Examine the surrounding habitat for sources of weed seeds. If beds are planted next to fields with asters, thistles, or willows, wind-blown seeds can be a problem.

If possible, control these potential sources of infestation prior to planting or avoid these sites.

Drainage

Equally important to removing potential sources of weeds is to make sure the site has good water drainage. Without question, weed problems occur most frequently on poorly drained beds. Therefore, drain lines across the beds and deep ditches around the bed perimeters are recommended for most new bed construction. Making beds narrow or giving them a slight crown (making them higher in the middle than at the edges) also improves drainage. Areas of the beds that have standing water for longer than several hours probably have drainage problems.

All low spots in beds, even if they are well drained, are likely to cause weed-control problems because there is a tendency for some herbicides to move into low areas and accumulate in higher than recommended amounts. As a result, cranberry plants in the low area might suffer herbicide damage, while there is poor weed control elsewhere in the bed.

Many soils tend to settle after beds have been prepared, especially in places where large stumps have been removed. Allow adequate time (a few weeks to a month) between bed preparation and planting for settling to occur, and then adjust uneven areas as needed.

Another common symptom of beds that are too wet or overirrigated is an overabundance of moisture-loving plant species such as mosses, St. Johnswort (*Hypericum anagalloides, Hypericum virginicum,* and *Hypericum formosum*), rushes (*Juncus* spp.), and sedges (*Carex* spp.). A large population of fungus gnats is another sign.

Ditch banks

Ditch bank preparation is another key to weed control. Seed the banks with a low-growing but competitive grass species that keeps out other weeds. Select grass that is not vigorous enough to require multiple mowings per month or to become a weed itself. Several dwarf perennial ryegrass varieties are suitable for ditch banks. Use hydroseeding or erosion control blankets to help ensure a good stand of grass on steep banks. However, grass might be a host for cranberry girdler. (See Chapter 14, "Insects.")

Mow dikes often enough to prevent seeding of unwanted weeds. Shape beds to accommodate mowing equipment.

Soil pH

The last consideration for land preparation is soil pH. Cranberries can tolerate a lower pH than most common weed species; therefore, lowering the soil pH will help control the vigor and diversity of weeds in a bed. If soil pH is above 6.0, use elemental sulfur to lower pH before planting. A predominance of upland weed species such as dandelions and legumes in a cranberry bed suggests that pH might be too high. Check pH with a soil test.

Soil pH adjustment can cause other problems and must be done cautiously. (See Chapter 6, "Nutrition.")

Vines

All of the above efforts are for naught if you plant vines that contain weed seeds. Most difficult-to-control weeds come as freeloaders on vines. Take care to determine that the vines you purchase are free of weed seeds. The easiest way to do this is to inspect beds in the fall prior to harvest to ascertain the level of potential weed seeds or pieces of weeds that could propagate vegetatively. If you know which weed seeds are in the vines, you can design a weed-control program specifically for that weed species.

New plantings

Mosses and liverworts can be a nuisance on new beds. They usually are symptoms of overirrigation or poor drainage, so moisture control usually is the first step in moss control. Once mosses and liverworts have become established, it usually is difficult to get rid of them during the growing season. For chemical control of these weeds, check the appropriate weed management guides.

There are several successful strategies for weed control in new plantings. The most successful combines all of the following methods:

- Use a heavy rate (greater than 1 ton per acre) of vines at planting to establish quick vining-over and crowd out weeds.
- Use low rates of preemergent herbicides to prevent major infestations of weeds from seeds. Overapplication of herbicides in an attempt to ensure weed-free beds is an expensive mistake that can set back vine growth for a year or two.
- Use a zealous program of hand pulling and herbicide wiping to remove all perennial weeds that are difficult to eradicate once they become established.

Because there are few herbicides available for use in cranberries, it is important to maximize their effectiveness by choosing the best combinations and using proper application timing and rates. There are preemergent and postemergent herbicide options. Recommendations are always site-specific, so only general principles are mentioned here. You must check the current labels for all products to ensure proper and legal use.

The key to using any pre- or postemergent herbicide is to use the right herbicide for the right weed. For example, cranberry beds are full of broadleaf weeds, as well as sedges, rushes, and grass look-alikes. Although many of these plants are called grasses, they are not. Grass herbicides work only on true grass species, so do not use them on any of these pseudo-grasses. An easy way to tell the difference between grasses, sedges, and rushes is that grasses have nodes (ringlike swellings on the stem), sedges have edges (stems usually are triangular), and rushes are round (stems are round and, unlike the hollow stems of grasses, are filled with a white, spongy matter called pith).

Several good books on plant identification are available, including *Plants of the Pacific Northwest Coast,* by Jim Pojar and Andy MacKinnon ("For more information," page 65). Several common cranberry weeds are shown in Figures 1 to 19 (pages 65 and 66).

Using preemergent herbicides

Preemergent herbicides have little effect on emerged seedlings or existing plants, so they must be applied prior to the main emergence of weeds on a bed. The ideal timing of these herbicides is after planting and after the vines have rooted but prior to weed seedling emergence. The most prudent way to time herbicide applications is to wait until the *very first signs* of weed seed germination before applying. This maximizes the time vines have in an herbicide-free environment.

In rare cases, a bed with little weed pressure might not need preemergent herbicides. Keep in mind that large seedlings or perennials emerging from overwintering root structures are not controlled by preemergent herbicides.

Recommended application rates of preemergent herbicides are highly dependent on soil type. Herbicide behavior in soil follows fundamental laws of physical chemistry. Herbicides differ in how easily they bind to organic carbon. The higher an herbicide's binding affinity, the greater its propensity to be tied up in the soil matrix.

Because of herbicides' tendency to bind with organic carbon, weed control on peat, which is high in organic matter, requires much higher rates of herbicide than it does on pure sand. Also, herbicide half-life diminishes greatly the less organic matter is in the soil; herbicides might last for several years on a peat soil and only months on a sand soil.

A knowledge of the organic matter content in your cranberry bed is vital to achieve a balance between good weed control and minor crop damage. On sand beds, use the lowest label rate of herbicides and consider multiple applications over time. Better weed control with less crop damage can be achieved when herbicides are applied in two or more small applications, spaced 3 to 5 weeks apart, instead of in a single, large dose.

Preemergent herbicides must be incorporated by rain or irrigation to be effective. Loss of herbicide effectiveness and greater crop damage occur unless products are incorporated shortly after application.

Using postemergent herbicides

Postemergent herbicides include those that are specific to grasses, those specific to a few species of broadleaf weeds, and those that kill all plants. Grass herbicides and selective broadleaf herbicides can be broadcast over cranberry vines to the target weeds. Broad-spectrum, postemergent herbicides must be target-applied to the weeds by wiping the weed canopy as it extends above the vines.

All postemergent herbicides can damage cranberries if used improperly or at the wrong time of year. Follow label instructions carefully.

You can control grasses with postemergent herbicides only if you apply them when grasses are growing actively. Once they have a seed head, control is minimal. If the grass is a perennial and very tall, more than one application might be necessary.

Not all grass species are controlled with all grass herbicides. Bluegrass (*Poa* spp.) and fescues (*Festuca* spp.) require a specific postemergent herbicide for control.

All grass herbicides require the addition of a crop oil. Cranberries can be sensitive to crop oil when it is not used according to label instructions. When growers complain about crop damage from a grass herbicide, it usually is due to the crop oil, not the herbicide. To avoid crop oil damage, adopt the following practices:

- Follow the label directions.
- Use the lower rates.
- Spray to wet leaves, not to runoff (i.e., don't use spray volumes greater than 100 gallons per acre).
- Don't spray when the temperature is above 80°F.

For broad-spectrum, postemergent herbicides, timing usually is not the critical factor for success. Instead, the more of the weed leaf surface area covered by the wipe, the better the success. This is particularly true for a weed that has multiple shoots. To help assure complete coverage, use a dye in the herbicide tank mix.

Multiple applications usually are necessary for the most persistent weeds. Avoid overzealous applications, as vines are damaged easily by these herbicides. Also, avoid walking over weeds that have been wiped recently, as you will transfer the herbicide from the weeds to the cranberries by way of your shoes (another reason to use a dye in the tank mix).

Established plantings

Strategies for weed control in the second year and beyond change only slightly. Higher herbicide rates can be used in the second year when vines have a good root system.

As with new plantings, you first must identify the weeds and then gather information about effective control measures and the level of tolerance for a specific weed in the cranberry bed. Select herbicides and rates of application based on which weed species are present. Use spray guides and labels to help with the selection process.

Some weeds are controlled easily and have little effect on yield. Applying maximum rates of herbicides to these weeds is foolish.

Make maps detailing the precise locations of different weeds. This allows you to make spot applications of herbicides. You still must remove perennial weeds by hand. Aim to remove all perennial weeds that are deep rooted and difficult to control once established.

Even with the best of plans, vine stress caused by overapplication of herbicides is common. It is essential to calibrate all application equipment annually.

The effects of herbicide stress are slow vine growth and dead spots that must be replanted. Nonstressed vines are flexible and bend when walked on. Herbicide-stressed vines are brittle and will "crunch" when walked on. Improving drainage and applying extra fertilizer (especially phosphorus and nitrogen) usually are essential to improve vigor of weak vines.

Rooted plantings or plugs are highly recommended for replanting dead areas. The 'Pilgrim' cultivar tends to have more vigor for this purpose. To improve the growth of rooted cuttings, consider using a slow-release fertilizer beneath the plugs. This gives them a competitive advantage over weeds.

If areas of the beds are contaminated with excess herbicides to the extent that vines do not grow, soil removal or the use of activated charcoal is an option. Charcoal binds to and inactivates residual herbicides in the root zone.

Once a bed is free of weed problems, it is important to keep it clean. Move equipment carefully between beds at harvest to avoid transferring weed seeds. Also, use care when transferring water used for harvest between beds. Passive screen systems are available to filter out seeds carried in harvest water.

For more information

Aquatic Vegetation Management and Control, PNW 224 (Washington State University, 1987).

Pacific Northwest Weed Management Handbook (Oregon State University, revised annually).

Pojar, J. and A. MacKinnon. *Plants of the Pacific Northwest Coast* (British Columbia Ministry of Forests and Lone Pine Publishing, 1994).

Photographs in this chapter are courtesy of Kim Patten, Washington State University.

Figure 1.—Annual bluegrass, *Poa annua.*

Figure 2.—Arrowgrass, *Triglochin palustris.*

Figure 3.—Beggars tick, *Bidens frondosa.*

Figure 4.—Creeping bentgrass, *Agrostis stolonifera.*

Figure 5.—Creeping buttercup, *Ranunculus repens.*

Figure 6.—False lily-of-the-valley, *Maianthemum dilatatum.*

Figure 7.—Horsetail, *Equisetum arvense.*

Figure 8.—Bog St. Johnswort, *Hypericum anagalloides.*

Figure 9.—Lotus, *Lotus corniculatus.*

Figure 10.—Purple aster, *Aster subspicatus.*

Figure 11.—Salt grass, *Distichlis spicata* var. 'spicata.'

Figure 12.—Silverleaf, *Potentilla pacifica.*

Figure 13.—Smartweed, *Polygonum persicaria.*

Figure 14.—Sour weed, *Rumex acetosella.*

Figure 15.—Toad rush, *Juncus bufonius.*

Figure 16.—Tussock, *Juncus effusus.*

Figure 17.—Sweet vernal grass, *Anthoxanthum odoratum.*

Figure 18.—Purple-leaved willowherb, *Epilobium ciliatum.*

Figure 19.—Yellow weed, *Lysimachia terrestris.*

Pest Management

Diseases

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P. Bristow and J. Pscheidt

Most of the diseases affecting cranberries in the Pacific Northwest are caused by fungi. Fortunately, only a few have the potential to cause significant losses if not controlled. These include fruit rots, twig blight, rose bloom, and Phytophthora root and runner rot. Table 1 lists the plant parts affected by disease-causing fungi.

Table 1.—Parts of the cranberry plant where symptoms of various diseases are found.

	Affected plant part				
Disease	**Roots**	**Stems**[a]	**Leaves**	**Flowers**	**Berries**
Phytophthora root rot	X	X			
Rose bloom		X	X		
Red leaf spot		X	X		
Red shoot		X	X		
Twig blight		X	X		
Upright dieback		X	X		
Black spot (secondary infection with red leaf spot)		X			
Protoventuria leaf spot			X		
Pyrenobotrys leaf spot			X		
Fruit rots					
Early rot			X	X	X
Bitter rot					X
Blotch rot			X		X
Cottonball (hard rot)		X	X		X
Ripe rot			X		X
Viscid rot					X
Yellow rot					X
Black rot					X
End rot					X
Botryosphaeria rot			X		X
False blossom (not caused by a fungus)		X		X	

[a]Includes runners.

Specific recommendations for chemical control are not included here because of the frequent changes in approved materials and directions for their use. See the *Pacific Northwest Plant Disease Management Handbook* ("For more information," page 79).

Fruit rots

A number of fungi infect developing and ripening berries, and at least one fungus infects during bloom, but the incidence of fruit rot before harvest usually is low in the Pacific Northwest. Considerable losses can occur after harvest when fresh berries are held in refrigerated storage. Berries destined to become juice, sauce, or other processed products are frozen immediately after they are harvested and sorted, so they suffer no additional losses from fruit rots.

Symptoms and disease cycle

Symptoms on fruit infected by the different fungi are very similar, making it nearly impossible to distinguish one rot from another based on symptoms alone. Moreover, these fungi infect green berries and establish latent infections (the fungus penetrates the berry, but no symptoms appear until later), so control measures must be implemented well before symptoms develop.

Historically, fruit rots have been divided into two categories depending on when symptoms appear (Table 2). However, there is considerable variability as to when symptoms of a particular fruit rot first develop.

Control

Fungicides are used to control fruit rots. Generally, two or three applications are required. Treatment begins at the end of bloom to protect berries during the early stage of development. Broad-spectrum fungicides are used because more than one fungus might be present in a given bed or area. One exception is cottonball, which requires specific fungicides for control.

Some fruit-rotting fungi might be controlled better if fungicides could be applied closer to harvest than current labels allow. In the future, new chemicals with lower risks and shorter preharvest intervals might become available.

Several cultural practices influence the incidence of fruit rots. See "Cultural factors affecting disease development," page 78, for more information.

Table 2.—Types of fruit rots.

Early rots (usually develop in the field or early in storage)

Disease	Fungus
Early rot	*Phyllosticta vaccinii*
Bitter rot	*Glomerella cingulata*
Blotch rot	*Physalospora vaccinii*
Cottonball (hard rot)	*Monilinia oxycocci*

Late rots (usually develop after harvest, during storage)

Disease	Fungus
Ripe rot	*Coleophoma empetri*
Viscid rot	*Phomopsis vaccinii*
Yellow rot	*Botrytis cinerea*
Black rot	*Strasseria geniculata* *Allantophomopsis lycopodina* *Allantophomopsis cytosporea*
End rot	*Fusicoccum putrefaciens*
Botryosphaeria rot	*Phyllosticta elongata*

Figure 1.—Twig blight. Brown and tan discoloration of blighted uprights in early spring.

Figure 2.—Twig blight. Bleached-tan leaves on infected uprights.

Figure 3.—Twig blight. Patch of blighted uprights in early spring before healthy uprights turn green.

Twig blight

Twig blight is caused by the fungus *Lophodermium oxycocci* and possibly *L. hypophyllum.*

Twig blight has the greatest potential to cause loss of any disease in the Pacific Northwest. Significant losses have occurred in both Oregon and Washington. If left unchecked, 100 percent of the uprights in a bed can be blighted and the entire crop lost. Currently, fungicides provide excellent control, and the disease is observed only occasionally.

Symptoms and disease cycle

Although uprights become infected during the summer, symptoms do not appear until winter or, more commonly, early spring of the following year. Leaves on the newest growth (1-year-old wood) first turn brown, then dull tan (Figure 1) and eventually silvery-gray (Figure 2). The fungus cannot grow into 2-year-old wood; thus, only 1-year-old wood is killed.

The disease initially appears on scattered uprights or in patches (Figure 3). In severe outbreaks, large areas or entire beds can be blighted.

In spring, small black spots appear on the lower surface of some, but not all, blighted leaves. These spots eventually develop into fungal fruiting

Figure 4.—Twig blight. Fully opened fruiting bodies of Lophodermium oxycocci *on the lower surface of an infected leaf.*

bodies. (A fruiting body is a fungal structure in which spores are produced.) As the season progresses, they become football-shaped with a median ridge that runs the length of the structure.

When the fruiting body matures, the ridge becomes a slitlike opening with light gray edges or lips. Moisture from dew, rain, or irrigation causes the slit to open, exposing the spore-bearing layer inside (Figure 4). As the fruiting body dries slightly, ascospores are discharged forcibly into the air, where they are disseminated by wind currents.

Ascospores are present from mid-June through harvest (October), but infection occurs only during a 4- to 6-week period in summer. The onset of the infection period varies from year to year, but it is related to when ascospores mature. Monitoring the development of the fruiting bodies as part of an Integrated Pest Management (IPM) program permits timely applications of fungicides, usually resulting in fewer applications needed.

Control

Control is based on protecting new growth with fungicides during the infection period. Both chlorothalonil and mancozeb are very effective; wettable sulfur also has some activity. Cultural practices seem to have little impact on this disease.

When you establish new plantings, select vine cuttings only from beds you know are free of the disease. Be sure to scout new beds for the disease in the second year. If you find it, initiate a control program. New beds with twig blight vine over slowly and take longer to come into production if the disease is not controlled.

Phytophthora root and runner rot

This disease is caused by the fungus *Phytophthora cinnamomi* and possibly other species of *Phytophthora.*

This disease is the most important root disease of cranberry. It is particularly serious in Massachusetts and New Jersey, but it also has been detected in a few beds in Washington and Oregon.

Symptoms and disease cycle

In the early stages of the disease, vines in affected areas are weak and might be brittle. Affected areas within a bed might appear off-color in the spring as healthy vines begin to turn green. The current season's growth is stunted (shorter uprights with fewer and smaller leaves), and the foliage might turn red prematurely in the fall. Later, discrete patches in the beds are devoid of vine growth (Figure 5).

Below ground, there are few, if any, fine, fibrous feeder roots. Infected vines can be pulled easily from the soil. If you cut into the runner, you might find that the internal tissues are olive green to dark brown in color. In healthy runners, these tissues are cream to light tan in color.

The fungus survives in the soil for many years and is favored by prolonged saturated soil conditions.

Control

Managing soil moisture is the key to an integrated control program. Avoid excessive irrigation. Maintain ditches and drains. When constructing new beds, be sure the crown is high enough for water to drain to the surrounding ditches.

Sand low areas to bring them up to grade. (See Chapter 9, "Sanding.") If necessary, replant after sanding. Maintain fertilization to stimulate new root growth.

The effect of chemical treatments has been inconsistent. They are most effective when used in combination with cultural practices to manage soil moisture. The effectiveness of soil fumigation has not been tested.

Rose bloom

This very conspicuous disease is caused by the fungus *Exobasidium oxycocci.* A cool, moist environment favors the disease. All cranberry varieties are susceptible.

Symptoms and disease cycle

From late April through mid-June, infected axillary (lateral) buds produce an abnormal branch

Figure 5.—Damage caused by Phytophthora root and runner rot.

Figure 6.—Rose bloom. Abnormal branch caused by Exobasidium oxycocci.

with thickened, rose-colored leaves (Figure 6). (Healthy axillary buds normally do not break dormancy and grow out.) The pink, abnormal branch looks like a miniature rose blossom, which gives the disease its common name. More than one infected branch might develop on an infected upright.

The surface of the branch takes on a whitish cast when the fungus begins to produce spores on the surface of the swollen leaves (Figure 7). The spores are ejected forcibly into the air, where they are dispersed by wind currents. It is thought that the spores germinate and infect healthy buds on new shoot growth.

By mid-June, the fleshy, abnormal growths begin to shrivel and turn gray. They collapse more rapidly during warm weather, when the demand for water exceeds the ability of the upright to provide it. Eventually, the growths become hard, brittle, and dark brown-black. The remnants break off the upright and fall into the duff layer.

Most newly infected buds remain dormant until the following spring, when they become active and produce an abnormal branch. However, a few might break dormancy later in the summer (late July through August) and form the typical pink, swollen branches on the current year's growth.

It is not known whether spores produced in late summer can infect buds. It is believed that they do not, except possibly the terminal bud, as pink,

Figure 7.—Rose bloom. Spores of E. oxycocci *give a whitish cast to the surface of the swollen leaves.*

abnormal branches occasionally develop from terminal buds the following spring.

Abnormal branches contain little chlorophyll and depend on energy from the rest of the vine in order to grow. The swollen leaves lose water at a rate several times faster than healthy leaves. Thus, the abnormal branches compete with the rest of the upright for both water and energy resources.

Yield on infected uprights is lowered by one-third through a combination of reduced flower number, fruit set, and weight per berry. The following year's crop also is impacted, as infected uprights are less likely to set a mixed bud for the next crop year.

Despite the stress on infected uprights, flowers on infected uprights are no more sensitive to frost during bloom than flowers on healthy uprights.

Control

Control is based on protecting new upright growth during late spring, when spores are being produced. The first fungicide application corresponds with the appearance of spores on the surface of the fleshy, pink leaves. The need for protection ends when the abnormal branches shrivel and no longer produce spores.

Red leaf spot

The fungus causing this showy but occasional disease is *Exobasidium vaccinii*, which is related to the one that causes rose bloom. The disease occurs sporadically and is associated with beds where the nitrogen level is very high and vines are extremely vigorous.

Although the fungus usually infects leaves, it sometimes also infects flowers and berries. Little crop is lost to this disease, unless the fungus infects the upright stem and the infected tissues are invaded by a secondary fungus (*Mycosphaerella nigromaculans*), which causes the disease called black spot.

Symptoms and disease cycle

As the name of the disease suggests, the primary symptom is a red spot on the upper surface of the current season's leaves (Figure 8). The spots are slightly raised and glossy. They vary in size up to 5 mm in diameter, and more than one might form on a leaf. When more than one spot forms, they can merge into an irregularly shaped spot. A dusty tan spot forms on the lower surface of the leaf directly below the red spot. The color comes from the developing spores.

The fungus can spread from the leaves through the petiole into the succulent stem. Infected stems become red and swollen (Figure 9). A secondary fungus, *M. nigromaculans,* can colonize leaf spots and infected stems, turning the tissues black

Figure 8.—Red leaf spot. Glossy red spots on the upper surface of infected leaves (top row). Spores of the fungus are produced on the lower surface of leaves (bottom row). Leaf on the left end of each row is healthy.

Figure 9.—Red leaf spot. Swelling and reddening of the stem.

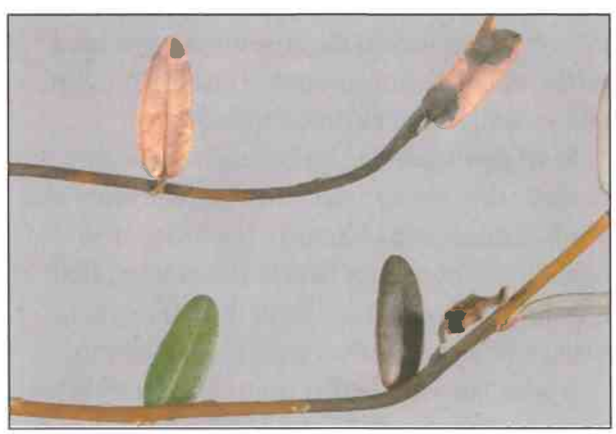

Figure 10.—Colonization of infected leaf and stem tissues by the fungus Mycosphaerella nigromaculans.

(Figure 10). The most serious damage occurs when *M. nigromaculans* invades infected stems and causes the death of uprights that would have set fruit buds for next year's crop.

It is unknown where *E. vaccinii* overwinters or whether the primary inoculum that gives rise to the red spots comes from sexual or asexual spores.

Control

Red leaf spot is a minor disease and generally does not warrant control, unless disease incidence is extremely high. Fungicides normally applied for control of fruit rot keep red leaf spot in check.

Red shoot

This rather rare disease is caused by a third species of *Exobasidium, E. perenne*. It has been found in beds in both Washington and Oregon, but it has not been of any economic importance.

Symptoms and disease cycle

Symptoms appear on current-season shoots. Infected uprights are most noticeable in the spring prior to bloom, when their bright red color contrasts with the green of surrounding healthy uprights (Figure 11).

Affected shoots arise singly (Figure 12) or in clusters (Figure 13). Infected uprights typically have spindly stems and bright red leaves (upper surface) that are enlarged but not greatly thickened. Infected leaves might be cupped downward. The lower surface of the red leaves is whitish and covered with a powdery mass of spores. Diseased leaves wither and drop prematurely.

Control

No control is necessary.

Figure 11.—Red shoot. Uprights infected by Exobasidium perenne.

Figure 12.—Red shoot. Individual infected uprights.

Figure 13.—Red shoot. A cluster of infected uprights.

Figure 14.—Cottonball. Growth of cottony fungal mycelium in the seed cavity of infected berries. Berries on the left end of each row are healthy.

Cottonball

This twig and fruit disease is caused by the fungus *Monilinia oxycocci*. The disease affects young shoots, flowers, and berries. The common name of the disease comes from the white, cottony mass of fungal hyphae surrounding seeds in infected berries (Figure 14).

Cottonball was an important disease in Washington during the 1920s and 1930s but is rarely found there today. The disease is of economic importance now only in Wisconsin and British Columbia.

Cottonball recently was detected in all 16 varieties in an experimental variety planting at the Pacific Coast Cranberry Research Foundation farm and on several commercial beds in Long Beach, WA. This finding suggests that there is little resistance to this disease in varieties that are adapted to this region. In British Columbia, cottonball is most common on 'Pilgrim' and 'Bergman.' These two varieties are being planted with increasing frequency in Washington and Oregon, so the disease might become more important in the future.

Symptoms and disease cycle

Cottonball has two distinct infection stages: (1) tip blight of young shoots, and (2) fruit rot (Figure 15). The fruit rot stage also is called "hard

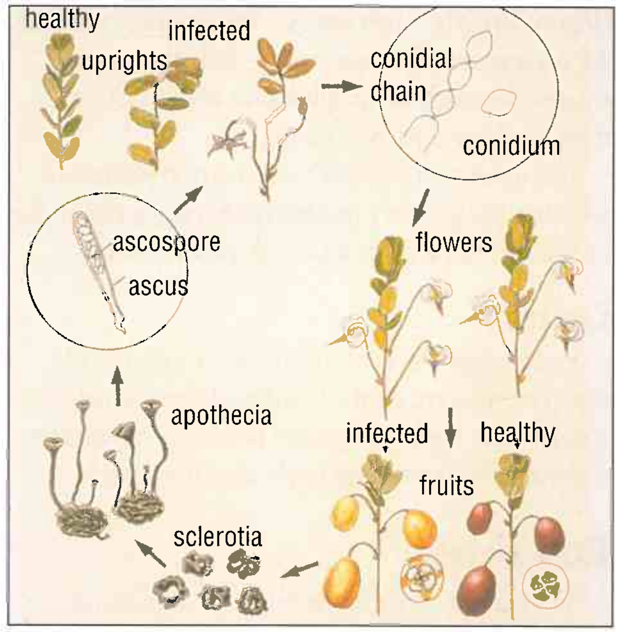

Figure 15.—Cottonball. Disease cycle of Monilinia oxycocci *on cranberry. (Courtesy of P.S. McManus, University of Wisconsin-Madison)*

Figure 16.—Cottonball. The "tip blight" stage of the disease. Note the whitish-gray fungal growth on the stem.

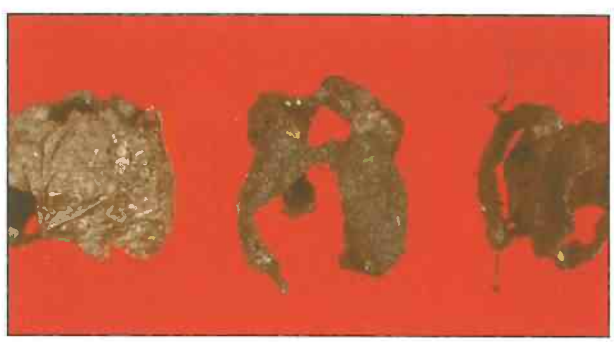

Figure 17.—Cottonball. Sclerotia of M. oxycocci.

Figure 18.—Cottonball. Apothecia arising from a sclerotium of M. oxycocci.

rot." Each infection stage is caused by a different type of spore produced by the fungus. Both stages reduce fruit yield and quality.

Tip blight is the first symptom observed in the spring, and it appears just as flowers are about to open. The tip of new upright growth blights and bends over, and conspicuous grayish-white masses of powdery spores (conidia) form at the crooked portion of the blighted shoots (Figure 16). Leaves on infected shoot tips turn a tan color.

Conidia are present throughout the bloom period. They infect healthy flowers, leading to the fruit rot stage of the disease. There are no external symptoms until late summer, when infested berries stay yellowish-green, while healthy berries are beginning to turn red. Later, tan stripes develop and extend from the flower end of the berry following the four internal (carpel) walls toward the flower stalk. Infected berries remain firm, leading to the name "hard rot."

The overwintering structure of the fungus (sclerotia) forms in some infected berries (Figure 17). These berries eventually become dark brown and shriveled and are called "mummies."

Water harvesting removes many of the sclerotia, but some fall into the duff layer, where they remain until spring. In spring, they germinate to form a cup-shaped structure called an apothecium (Figure 18). A second type of spore (ascospore) forms in the lining of the apothecia. Ascospores are discharged into the air, where they are dispersed by air currents. Ascospores infect emerging shoot growth. Infected shoots crook just prior to bloom, and the cycle begins again.

Control

You can manage cottonball with fungicides. Fungicide timing is based on the development of the plant. Make two applications before bloom, starting at bud break, to control the tip blight phase (protect new growth from infection by ascospores). Make two additional applications during bloom to protect flowers from infection by conidia.

Flood harvesting might aid control by removing mummies from beds, thus reducing spore production the following spring.

Pyrenobotrys leaf spot

The fungus *Pyrenobotrys compacta* causes this disease. This is another leaf disease that is quite conspicuous when disease incidence is high, although it seems to cause little damage.

Symptoms and disease cycle

From harvest through early spring, clusters or rings of discrete, black fruiting bodies appear on the lower leaf surface (Figure 19). Purplish-red lesions with diffuse margins usually form on the

Figure 19.—Pyrenobotrys leaf spot. Fruiting bodies on the lower surface of infected leaves in mid-March.

Figure 20.—Pyrenobotrys leaf spot. Purplish spots on the upper leaf surface (top row) and groups of fungal fruiting bodies on the lower surface of infected leaves (bottom row). A healthy leaf is at the right end of each row.

Figure 21.—Early leaf spot. Dull, reddish-purple spots on the upper surface of infected leaves (top row) and symptoms on the lower surface of infected leaves (bottom row). A healthy leaf is at the left end of each row.

upper leaf surface above the fruiting bodies (Figure 20). By early summer, some of the leaf lesions turn brown, and other leaves turn yellow and drop from the upright.

No symptoms appear on leaves of new growth until the following winter. Spores in the fruiting bodies mature in early summer, and infection of new leaves most likely takes place during summer and/or early fall.

Control

Fungicides applied in July and August to control fruit rots and twig blight also control this leaf disease.

Protoventuria early leaf spot

This leaf disease, caused by the fungus *Protoventuria barriae,* is quite common in Washington and Oregon beds. Its incidence can be high in localized areas within beds. Little is known about its impact on plants or associated losses.

Symptoms and disease cycle

Distinct dark red to purple circles or spots develop on upper leaf surfaces in late winter (Figure 21). On close examination, dark strands of the fungus (hyphae) can be seen radiating from the

Figure 22.—Early leaf spot. Closeup of leaf spots showing the dark fungal strands (hyphae) radiating from the center of the spot.

center of the spots (Figure 22). On the lower leaf surface, the spots are a mottled purple. By summer, the spots on the upper surface darken, and black fruiting bodies form on the surface of the spots. The fungus overwinters as a fine fungal strand just under the cuticle on the upper surface of infected leaves.

Control

No control measures are recommended.

Upright dieback

The fungus *Phomopsis vaccinii* causes this stem (vine) disease. (The same fungus also causes the fruit rot called viscid rot.) Upright dieback appears occasionally in Pacific Northwest beds.

Symptoms and disease cycle

Symptoms first appear as the vines begin to turn green in spring. Leaves on infected uprights take on a yellow cast and later become orange or bronze. Leaves often exhibit a yellow mottling before they turn completely yellow. In most cases, infected uprights die before bloom.

The disease usually appears on scattered uprights but sometimes in patches. Diseased and healthy uprights can be on the same runner. Roots on diseased vines are not affected. Fruiting bodies of *P. vaccinii* form on infected berries. They rarely develop on infected uprights.

Control

Cultural practices that promote rank vine growth, such as excess nitrogen fertilizer, favor this disease. Fungicides are effective if applied shortly after bud break.

False blossom

This disease is caused by a mycoplasma-like organism (MLO) that is transmitted only by the blunt-nosed leafhopper (*Euscelis striatulus*). A mycoplasma, also known as a phytoplasma, is a microscopic, bacteria-like organism that lacks a cell wall.

False blossom first was detected in Wisconsin in the early 1900s and now is present in all North American cranberry-growing regions. The disease was brought into the Pacific Northwest in infected vines from eastern and Midwestern growing areas.

Symptoms of false blossom have been observed in Oregon and Washington, but the disease is not spreading actively because the insect vector is not present in western North America. For this reason, the disease is of only minor importance here. However, even though false blossom is not considered important at this time, all Pacific Northwest cranberry growers should learn to recognize its symptoms in case the vector is introduced and the disease begins to spread.

Symptoms and disease cycle

This disease is diagnosed most easily at bloom, when pedicels (flower stems) on infected plants remain straight rather than becoming hooked (Figure 23). The lobes of the calyx (sepals) become enlarged, and the petals are short and streaked with deep pink, red, or green.

Diseased blossoms usually are sterile and do not produce berries. Branching is stimulated in infected plants, resulting in a "witches'-broom." Also, the foliage on infected plants might redden prematurely in the fall. Diseased vines grow few, if any, runners and tend to die out over time.

Control

Where the blunt-nosed leafhopper is present, controlling this insect vector is the most important part of a program to keep the disease in check. The most effective control program combines insecticides and cultural methods (flooding, sanding, and fertilizing). Remove infected plants to eliminate sources of inoculum.

Figure 23.—False blossom.

Cultural factors affecting disease development

Overgrowth

Excessive vine growth, whether from heavy fertilizer (nitrogen) applications or naturally fertile soil, leads to the following conditions:

- Poor air circulation within the plant canopy
- Periods of prolonged high relative humidity
- Slow drying of vines and berries following rain, irrigation, or heavy dew

A moist plant canopy favors fungal spore germination and infection. Also, there is some indication that excessive rates of nitrogen make the developing berries inherently more susceptible to fruit-rotting fungi.

Plant debris

Old leaves and broken stems can contain fungi that cause fruit rots. This debris or trash serves as a source of inoculum for the following growing season. After water harvest, do not leave trash piles on the side of the bed. Researchers in Massachusetts recommend moving trash piles at least 0.25 mile from the bed, if possible, because spores of several fruit-rotting fungi are disseminated by wind.

Trash removal is not an option if you use a dry harvest system, unless you use a suction picker to harvest berries within the railroad tracks and along the ditch banks.

Irrigation

Run sprinklers for several hours to apply the desired amount of water. Preferably, irrigate in the early morning rather than the early evening. When vines are irrigated in the morning, they can dry in the sun's heat. When they are irrigated in the evening, they might remain wet for an extended period, which maintains favorable conditions for infection by fruit-rotting fungi.

Weeds

Weeds also might create environmental conditions that favor disease buildup. Recent field trials showed that berries harvested from weedy areas by Furford picker-pruners had more storage rot than berries harvested by the same machine from adjacent weed-free areas. Apparently, as weeds pass through the harvester with the berries, they cause additional damage to the harvested fruit, which translates into greater loss in storage.

On the other hand, hand-harvested berries from weedy and nonweedy areas had the same incidence of storage rot.

Flooding

In some cases, flooding beds for 2 or 3 days in late July through early August to control cranberry girdler has significantly increased the incidence of fruit rot at harvest. At this time, little is known about this phenomenon, but it is another point to consider when deciding whether to use flooding for insect control.

Considerations when using fungicides

Pesticide rates and coverage

In beds with a history of fruit rot, consider using the maximum fungicide rates permitted. Conversely, if field and storage rots have been minimal, reduce the number of fungicide applications and/or use the minimum recommended rate. Never use a rate below the lowest recommended rate.

Fungicides generally are more important for berries harvested for the fresh market.

Regardless of the method of application (see "Chemigation," page 79), complete and uniform coverage is important for optimal disease control. Self-propelled boom sprayers must be recalibrated before each growing season. Spraying when it is calm improves uniformity and minimizes pesticide drift. Avoid spraying when wind speed is more than 5 to 7 mph. Do not spray if the spray suspension will not have time to dry before the next rain.

Spreader-stickers

Most fungicide formulations already contain adjuvants to improve coverage. Be sure to check the pesticide label to determine whether the addition of wetting, spreading, and sticking agents might be phytotoxic (cause plant damage) and/or reduce performance of the pesticide. If an adjuvant is required, be sure to add it **after** the pesticide has been mixed completely with water.

Chemigation

When mixing chemicals (liquid or dry) for chemigation, always add part of the total required water to the pesticide tank before adding the chemical. Once the chemical is mixed, add the rest of the water.

For liquids, add 25 to 35 percent of the total water needed, then add the liquid pesticide. Rinse the pesticide container and add the rinse water to the pesticide tank. Finally, add the rest of the water.

For dry formulations, add about 50 percent of the water first, then add the pesticide, using plenty of agitation for complete mixing. Then, add the rest of the water.

Chemigation works best when the irrigation system performs at its optimum level. Uniform application of water is very important for chemigation (as well as for frost and heat protection and water applied to the vines throughout the growing season).

Perform a catch can test to determine the uniformity coefficient for your system. Also, perform a dye test to determine (a) how long to run your pump after the chemical injection is complete, and (b) whether your system finishes the application without excessive wash-off at the sprinkler heads closest to the pump. See "Chemigation," pages 30–31, for more information. Contact your local Cooperative Extension or Ministry of Agriculture, Fisheries, and Food office for details on these two tests.

For more information

Caruso, F.L. and D.C. Ramsdell. (eds.) *Compendium of Blueberry and Cranberry Diseases* (The American Phytopathological Society, St. Paul, MN, 1995).

Cranberry Pest Management Guide, EB 0845 (Washington State University, revised annually).

Maurice, C., C. Bédard, S.M. Fitzpatrick, J. Troubridge, and D. Henderson. *Integrated Pest Management for Cranberries in Western Canada: A Guide to Identification, Monitoring and Decision-making for Pests and Diseases* (Agriculture and Agri-Food Canada, 2000). http://res2.agr.ca/parc-crapac/english/1agassiz/ipm/fitzpatrick/pages/electpubs.html

Northwest U.S. Cranberry Pesticide Chart (Cranberry Institute, revised annually).

Pacific Northwest Plant Disease Management Handbook (Oregon State University, revised annually).

Photographs in this chapter are courtesy of P.R. Bristow, Figures 1–4, 8–13, 17, 19–22; C.C. Kusek, Figure 5; R.S. Byther, Figures 6–7; University of Wisconsin-Madison, Figures 14, 18; P.S. McManus, Figure 15; S.N. Jeffers, Figure 16; and P.V. Oudemans, Figure 23.

13

Pest Management

Nematodes

Plant-parasitic nematodes are microscopic, soil-inhabiting roundworms that feed on and damage plant roots. They are distributed widely in cranberry beds in Massachusetts, New Jersey, Wisconsin, and the Pacific Northwest. Three genera—the ring nematode, *Mesocriconema* spp. (=*Criconemella*); the stubby root nematode, *Paratrichodorus* spp.; and the sheath nematode, *Hemicyclophora* spp.—are most common.

Although it has been reported that these three nematodes reduce runner growth and cause darkened, stunted, or galled roots in greenhouse studies, the role they play in the health of cranberry plants under field conditions is unclear. In a recent USDA-ARS survey of 53 cranberry beds in Oregon and Washington, the incidence and population densities of *Criconemella xenoplax*, *Paratrichodorus* spp., and *Hemicyclophora similis* were slightly higher in weak areas of the beds but not significantly greater than in strong areas. This finding agrees with earlier WSU surveys and observations in other regions, in which pathogenicity of nematodes could not be demonstrated under field conditions.

It has been suggested that nematode parasitism might increase the severity of root rot diseases caused by soil-borne pathogenic fungi, but this relationship has not been demonstrated experimentally.

Most data suggest that control of nematodes is not warranted in mature beds. However, the establishment of new plantings can be impaired on nematode-infested sites. You can collect soil samples for nematode analysis to determine whether population densities might be damaging. Send samples to the Plant Clinic at Oregon State University or to a commercial laboratory for analysis. Soil fumigation might be recommended prior to planting on land with high population densities of plant-parasitic nematodes.

Nematodes spread to new areas on plant material and equipment, which explains their universal distribution in cranberry production. When establishing new plantings, use vine cuttings from beds without populations of plant-parasitic nematodes.

There are no known nematode-resistant cranberry cultivars.

J. Pinkerton

Pest Management

Insects

14

Contents

S. Fitzpatrick, J. DeFrancesco, D. Henderson, A. Broaddus, and G. Fisher

In the Pacific Northwest, there are three major and several occasional insect pests of cranberries. This chapter describes life cycles, provides illustrations, and explains how to monitor and manage the major pests and some of the occasional ones.

For detailed information on registered insecticides and their use, Canadian growers can refer to the *Cranberry Institute's Canada Cranberry Pesticide Chart.* U.S. growers can refer to the *Northwest U.S. Cranberry Pesticide Chart* and the *Pacific Northwest Insect Management Handbook.* See "For more information," page 99.

Mites, which have eight legs (insects have six), sometimes appear in cranberry buds. To date, all mites found on cranberry foliage in the Pacific Northwest are fungus- or detritus-feeders, not pests.

Major pests

Blackheaded fireworm

Description, life cycle, and damage

The blackheaded fireworm, *Rhopobota naevana* Hübner, is a major pest in all areas where cranberries are grown.

The insect overwinters in the egg stage. The overwintering eggs are yellow, less than 1/16 inch (about 1.5 mm) in diameter, and are found on the undersides of cranberry leaves (Figure 1). As the larva (worm) inside the egg develops in the spring, the egg changes to a brighter yellow. A day or two before hatching, a black spot (the head of the larva) can be seen. First-brood hatch usually begins in April (but can be earlier in Oregon), reaches a peak in mid-May, and is completed by about mid-June.

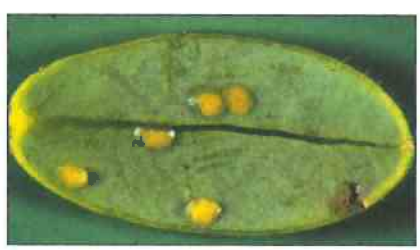

Figure 1.—Blackheaded fireworm eggs on the underside of a leaf.

The newly hatched larvae feed on and mine the underside of the leaf on which they emerge, hidden under brown, grainy frass (excrement) and webbing. As hatching proceeds and the weather becomes warmer, some of the newly emerged larvae move to the growing tips and unopened buds. The presence of frass in the side of an unopened bud indicates that a fireworm larva has entered it. Eventually, all larvae move to the growing tips, where they web leaves or blossoms together to form "tents" and feed until they are fully grown (Figures 2 and 3). It takes about 30 days of feeding to complete larval growth.

The fully grown larva is about 1/3 inch (8 mm) long with a shiny brown head (Figure 4). When fully grown, the larva wraps itself in a silken cocoon in dead leaves and the duff layer beneath the vines (or occasionally in leaves on the vines) and passes through the pupal stage in about 2 weeks.

Moth emergence is determined by temperature. Moths of the first brood usually appear in late May or early June and fly through July. Moths are about 1/4 inch (6 mm) long and grayish-brown. When the moth is at rest on a vine, dark bands are visible across the back (Figure 5). It flies with a characteristic jerky movement, rarely going more than a few feet at a time.

The moths are most active in late afternoons and early evenings, and most mating and egg laying occurs at this time. Daily flight is governed by weather; moths are most active on warm, sunny days.

Second-brood larvae usually start to emerge from eggs from mid-June through early July, but they sometimes appear earlier. Peak egg hatch ranges from the last week of June to the third week of July, depending on the region and the temperature. These larvae rarely mine leaves, but go directly to the new growth (often the runner ends), where they feed within tents and sometimes web uprights and runners together. As larvae grow, they might burrow into the developing fruit.

Because temperatures in summer are warmer than in spring, second-brood larvae develop more rapidly than those of the first brood. A heavy infestation quickly causes serious damage to the current year's berries and to flower buds of the following year's crop.

Damage from second-brood larvae can be seen readily by examining runner tips at ditch banks

Figure 2.—"Tent" made by blackheaded fireworm larva at the tip of an upright.

Figure 3.—Advanced feeding damage by blackheaded fireworm larvae.

Figure 4.—Blackheaded fireworm larva.

Figure 5.—Blackheaded fireworm adult.

and field edges. When injury is severe, the vines become brown as if scorched by fire, whence the name "fireworm."

Moths of the second brood begin flying in mid- to late July, depending on the region and the temperature, and continue until late August or early September. Most of the eggs laid by second-brood moths go into diapause (a hibernation-like state) for winter, but some hatch in August and give rise to a third brood of larvae in August and September if temperatures remain warm. In warm years, third-brood moths might be seen flying as late as December.

Detection, monitoring, and control

Early detection and timely application of treatments are critical for successful control of blackheaded fireworm.

Hatch of overwintering eggs is temperature-dependent and occurs earlier in warm springs than in cool ones. A degree-day model was developed in Wisconsin, but it is not useful for predicting egg hatch in the Pacific Northwest, because the timing and duration of egg hatch varies more here. Therefore, detection and monitoring of this pest in the Pacific Northwest are done by looking for the larvae.

Visual monitoring: Fireworm feeding usually is seen first on new growth overhanging water-filled ditches at the warmest edges of a field, such as those across from the side of a levee (dike) warmed by the afternoon sun. In late April, look closely at runner tips and buds at warm edges of beds for small tents and frass made by newly hatched larvae ($^1/_{16}$ inch or 1.5 mm long). One to 2 weeks after you see larvae, begin more extensive monitoring with a sweep net or with "visual sweeps." (Crouch down to examine areas of about 2 square feet or 0.18 square meters.)

If you use a sweep net, do 2 sets of 20 sweeps on beds less than 1 acre, 3 sets on beds of 1 to 3 acres, 4 sets on beds of 3 to 4 acres, 5 sets on beds of 4 to 6 acres, and 6 sets on beds of 6 to 8 acres (1 acre = 0.4 hectare). Make sure to take some sweep sets along warm edges. Newly hatched larvae up to $^1/_8$ inch (3 mm) long rarely are picked up in sweep nets.

If you're doing a visual search, examine the edges of the bed and known "hot spots" (areas of high densities of larvae) first, doing at least 10 visual sweeps per acre (25 per hectare).

An insecticide treatment is recommended if an average of one larva per visual sweep or sweep set is found. Apply insecticide when most larvae are $^1/_8$ to $^1/_4$ inch (3 to 6 mm) long.

Monitoring with pheromone traps: Regardless of whether you apply insecticide in spring, and especially on farms with a history of fireworm infestations, place pheromone traps for monitoring moth flight in fields in May. Place a minimum of three traps on farms of 10 acres (4 hectares) or less. On larger farms, one trap per 5 acres (2 hectares) is recommended.

When placing lures in traps, use gloves or forceps, and keep the gloves or forceps from touching any other part of the trap. Check traps weekly by counting the number of fireworm moths. Then scrape them off the sticky floor of the trap or replace the trap if necessary. Change lures before the second flight of moths.

Ten days to 2 weeks after the greatest number (peak) of moths is caught, begin checking field edges and hot spots for larvae. Look around sprinklers that might have been plugged or stopped turning during previous insecticide applications. Use the same thresholds and timing as in spring to determine whether and when to apply insecticide. During bloom, do not apply insecticides that are toxic to bees.

Pheromone traps attract male moths. The pattern of trap catches reflects the emergence pattern and activity of fireworm moths, which vary from farm to farm and region to region. In British Columbia, where two distinct flights are seen in summer, the flights on northern Vancouver Island usually begin 2 weeks later than flights in the middle Fraser Valley. In Washington, the second flight might blend into the first flight. In Oregon, a

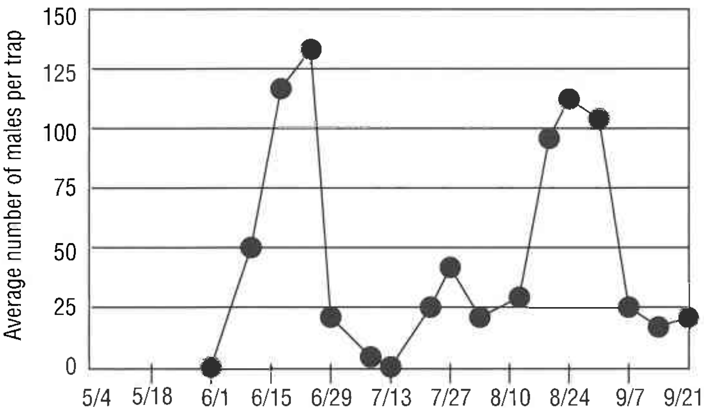

Figure 6.—An example of fireworm flight in a hot year in British Columbia, measured by the number of male fireworm moths caught in wing traps baited with pheromone lures. The pattern shows the first flight in June and the second beginning in mid-July and continuing into September. The timing and number of moths caught vary from farm to farm, region to region, and year to year.

small flight of moths sometimes occurs in late summer. Figure 6 shows an example of the pattern of male moth catches in pheromone traps in British Columbia.

Control using sprayable pheromone: The need for insecticide applications can be reduced or eliminated by using sprayable pheromone that interferes with moth communication and prevents most male fireworm moths from finding and mating with females. When used successfully, this mating disruption technique substantially reduces the number of fertile eggs deposited on leaves and the number of larvae in a bed. If you use this method, it is recommended that you consult a pest management specialist.

Apply sprayable pheromone at the label rate at or just before first moth catch in pheromone traps (based on trap catch records from previous years). Two or three applications at intervals of 2.5 to 3 weeks should reduce mating of the first flight of moths. As or just before the second flight begins, again begin applications of sprayable pheromone, and continue at intervals of 2.5 to 3 weeks until flight ends.

During the first year of sprayable pheromone application, continue insecticide applications against fireworm larvae as usual. During the second and subsequent years, it should be possible to reduce or eliminate summer applications of insecticide against fireworms.

Sprayable pheromone is not toxic to mammals or beneficial insects such as bees.

Mating disruption is most effective if all farms in an area use it. This reduces the possibility that mated fireworm females from an untreated farm might fly into a treated area.

Pheromone trap counts are somewhat reduced in the presence of sprayable pheromone, but the pattern of first catch, peak catch, and diminishing catch are unaltered. ("Decoy-female" pheromone traps can be used to track the efficacy of sprayable pheromone; consult your pest management specialist for further information.)

Sprayable pheromone does not disrupt mating where moth density is high. Pay particular attention to detecting and eliminating hot spots (areas of high density) of larvae, because they will become hot spots of moths.

Control using parasitic wasps: A tiny parasitic wasp, *Trichogramma sibericum*, sometimes is found in beds not treated with insecticides. The wasp lays its eggs in fireworm eggs, and the larvae consume the contents of the host eggs. Fireworm eggs parasitized by *T. sibericum* are black; unparasitized eggs are yellow.

These tiny wasps usually are scarce and are not widely available commercially, but they are so well adapted to parasitize fireworm eggs that there has been much research on rearing them for commercial use. Other *Trichogramma* species are available commercially, but they do not parasitize fireworm eggs to the extent that *T. sibericum* does.

Adult wasps live for only a few days, and a generational cycle can take about 2 weeks in the field, depending on weather. Rainy, cool conditions reduce activity and the number of eggs parasitized by *Trichogramma*. If *Trichogramma* wasps are applied in August, and the weather remains warm, they will cycle through two or more generations before fall.

Research trials in British Columbia have shown that the most effective times to apply *T. sibericum* wasps are during and after the second flight of fireworms. Most eggs laid by second-flight moths enter diapause for the winter, so the *Trichogramma* larvae within have lots of time to develop, consume the contents of the fireworm egg, and emerge as *Trichogramma* adults. In this way, *Trichogramma* wasps reduce the number of fireworm larvae emerging from eggs in spring.

Research has shown that the most effective control of fireworms by *T. sibericum* is achieved by splitting a dose of 800,000 wasps per acre into two halves, applied 7 to 10 days apart. Apply wasps as advanced pupae (i.e., ready to emerge) in host eggs mixed with vermiculite to add bulk. Spread them by hand or with a "belly crank" fertilizer or seed spreader early in the morning of a dry, warm day. *Trichogramma* pupae in vermiculite have been successfully applied to larger fields with a helicopter and fertilizer hopper.

Trichogramma wasps are most effective where fireworm density is high, such as in hot spots and along field edges. In these areas, they can parasitize 80 percent or more of the fireworm eggs. Where fireworm density is low, *Trichogramma* has more difficulty finding eggs. Thus, this biological control agent works well as a companion technique with mating disruption. Wasps parasitize the highest percentage of fireworm eggs in hot spots, and mating disruption is most effective at low fireworm densities. Both techniques are most effective when used with the advice of a pest management specialist.

Cranberry girdler

Description, life cycle, and damage

The cranberry girdler, *Chrysoteuchia topiaria* Zeller, is a serious pest in cranberry beds, turf, and young conifer plantings. Girdler populations and damage vary from year to year, but some beds experience chronic infestation.

There usually is only one generation of cranberry girdler per year, but in warm years a second flight of girdler moths might occur in late summer. This pest is reported to overwinter as a mature larva wrapped in a "hibernaculum"—a silk cocoon covered with soil (Figure 7). Pupation is reported to occur in May and early June.

Most moths emerge from the soil and take flight from early June until mid-July. They are about ½ inch (13 mm) long with straw-colored forewings that are fringed with silver and have three dots along the outer edge. The moth folds its wings close to its body when at rest, giving it a long, slender appearance (Figure 8). It often perches vertically, with its head pointing down.

Figure 7.—Hibernaculum of a cranberry girdler, opened to show pupa.

Eggs are scattered on the duff of cranberry beds during the flight period. The larvae emerge after 4 days to 2 weeks, depending on temperature. Newly hatched larvae are about $^{1}/_{16}$ inch (1.5 mm) long. They feed on soft tissues such as grass crowns, leaves, and roots.

Larvae mature to $^{1}/_{2}$ inch (13 mm) after several weeks (Figure 9) and chew on the bark of roots and underground stems, girdling and severing vines. Mature larvae do most of their damage in late August through early September. The foliage of girdled vines turns orange and then brown in late summer. The presence of patches of dead or dying uprights in late summer and early fall might indicate girdler damage.

Girdler damage (Figure 10) looks somewhat like mouse damage, except that mice nip vines cleanly on an angle without gnawing. Girdler larvae leave characteristic brown to orange, sawdust-like frass.

Detection, monitoring, and control

There is no satisfactory method of detecting larvae in the bed when they are small enough for optimum control. Therefore, pheromone traps and visual observations are used to detect and monitor moths.

Using pheromone traps: Place pheromone traps in beds between mid-May and June 1. Use a minimum of three traps on farms of 10 acres (4 hectares) or less. On larger farms, one trap per 5 acres (2 hectares) is recommended.

When placing lures in traps, use gloves or forceps, and keep the gloves or forceps from touching any other part of the trap. You can place girdler traps side-by-side (but not end-to-end) with fireworm traps. Check traps weekly by counting the number of girdler moths. Then scrape them off the sticky floor of the trap or replace the trap if necessary. Change lures every few weeks during flight, according to the manufacturer's instructions.

Figure 8.—Cranberry girdler adult.

Figure 9.—Cranberry girdler larva.

Figure 10.—Vines damaged by cranberry girdler larvae.

Visual observation: It also is helpful to walk through the beds on a warm afternoon when pheromone trap catches show that girdlers are flying. Count the number of girdler moths that fly up as you walk through the beds. This helps to identify spots where most egg-laying is likely to occur.

An example of cranberry girdler moth emergence and flight in British Columbia, estimated from pheromone traps, is shown in Figure 11. Patterns of trap catch vary from farm to farm and region to region.

In late August through September, inspect damaged areas of the bed for larvae. On a warm afternoon, roll back damaged vines and follow the roots through the top 2 inches of soil, looking for girdled vines, sawdust-like frass, and dirty-white larvae. It often is difficult to find larvae this way, however.

Control methods: In the U.S., insecticides registered for control of the cranberry girdler can be applied at or shortly after peak flight and again 10 to 14 days later. These applications reduce the numbers of egg-laying adults, thus reducing the number of larvae. In all regions, entomopathogenic (insect-attacking) nematodes can be applied 2 to 4 weeks after peak flight to control young larvae.

It also is possible to drown larvae by flooding beds in August. Floodwater should be deep enough to cover the highest weeds, because larvae crawl up them to escape. Leave floodwater on the beds for 24 to 48 hours. Flooding increases the risk of fruit rot on producing beds, but it is a good preventive measure for young or nonproducing beds. See Chapter 15, "Physiological Disorders (Noninfectious)," for cautions regarding flooding. Also, do not apply fertilizer or pesticides just before flooding.

Flood harvesting in early September might kill larvae that have not yet spun their cocoons. (Once protected by a cocoon, a larva is protected from drowning.)

Older beds with a thick duff layer and little sand tend to have the most serious infestations. Regularly sanded beds ($^1/_4$ inch or 6 mm) tend to

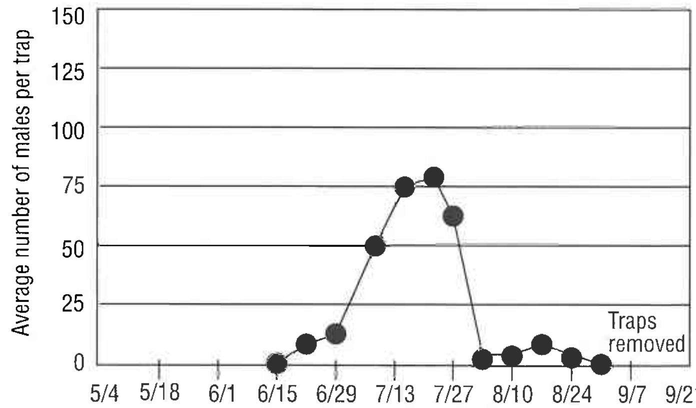

Figure 11.—An example of cranberry girdler flight in a cool year in British Columbia, measured by the number of male girdler moths caught in wing traps baited with pheromone lures. The pattern shows one main flight from mid-June until late July. In a hot year, a second flight might be seen in August. The timing and number of moths caught vary from farm to farm, region to region, and year to year.

have fewer girdler problems, probably because the sand covers fungi, moss, and small plants on which young larvae feed. Sand also might be abrasive and damaging to larvae. Thus, a regular sanding program can help control this pest.

The cranberry girdler also is a pest in lawns and other turf. Observe levees and grassy areas surrounding the beds as a possible source of infestation; treat grassy areas preventively with entomopathogenic nematodes if possible.

When you create new cranberry beds, note the kind of vegetation present before bed construction begins. Girdlers feed on the roots of grasses, conifer seedlings (especially firs), and other plants found in peaty soils. Before you plant your vines, it might be advisable to apply entomopathogenic nematodes to leveled beds and levees to kill larvae remaining in the soil.

Root weevils

Description, life cycle, and damage

Three species of root weevils cause damage in cranberry beds. The most common is the black vine weevil, *Otiorynchus sulcatus* Fabricius. The strawberry root weevil, *O. ovatus* Linnaeus, and the clay-colored weevil, *O. singularis* Linnaeus, can be common, too.

The black vine weevil is a key pest of cranberry beds in Washington and Oregon. In British Columbia, weevil damage usually is restricted to beds that are not flooded regularly for harvest.

The adult black vine weevil is a black snout beetle about $\frac{1}{3}$ inch (8 to 9 mm) long (Figure 12). Adult black vine weevils begin emerging from pupal cells in the soil in late May and early June; some adults live through the winter. Adults feed on foliage for 4 to 6 weeks before laying eggs.

Black vine weevils are all females; there is no mating before egg laying. Eggs are laid in early summer at the soil surface beneath vines, and they hatch within 2 to 3 weeks. The newly emerged larvae descend to feed on rootlets and, later, on the larger roots and root bark. The larvae are white and legless, have brown heads, and often curl their bodies into the shape of the letter C (Figure 13). They feed from the time they hatch until pupation the next spring. They sometimes are inactive during very cold spells in winter.

Strawberry root weevils are about half the size of the black vine weevil and have a similar life cycle.

Clay-colored weevils are intermediate in size between strawberry and black vine weevils and have a mottled, clay-colored exterior that looks black when wet. Clay-colored weevil adults emerge very early in spring, when the other two species still are larvae or pupae; egg laying also precedes that of the other two species. Research on clay-colored weevils in raspberries in Washington suggests that larvae finish feeding in midsummer, pupate, and then spend the winter in the soil as soft, white *(teneral)* adults (Geoff Menzies, personal communication).

Figure 12.—Black vine weevil adult.

Figure 13.—Black vine weevil larva.

Figure 14.—Cranberry bed showing damage by black vine weevil larvae.

Figure 15.—Leaf notching on salal made by black vine weevil adults.

Weevils can girdle roots completely. Weevil-damaged vines look similar to girdler-damaged vines, but lack the frass left by girdler larvae at feeding sites. Symptoms of damage (wilting, weakening, browning, and death) begin to appear in May or June (Figure 14) and intensify through the season.

Detection and monitoring

You can detect weevils at almost any time of the year by observing vegetation in the vicinity of the cranberry bed. If weevils are present, characteristic leaf notching caused by feeding adults is seen readily on plants such as salal (Figure 15). Notching on cranberry leaves is more difficult to see.

In spring and fall, you can monitor the larval population of black vine and strawberry root weevils by rolling back damaged vines and looking through the top 2 inches of soil for girdled roots and C-shaped weevil larvae. Black vine weevil larvae are mature (about ⅓ inch or 8 to 9 mm long) in spring. In fall, they are younger, smaller, and harder to see. You are most likely to detect clay-colored weevil larvae in early to midsummer.

On warm, still nights after dusk, beginning in June (April and May for clay-colored weevils), monitor for adult weevil emergence and population size using a sweep net. Sweep beds once or twice a week until eggs begin to mature within the adult weevils and egg laying begins. To determine the presence and maturity of eggs within adult weevils, pinch the abdomens of about 10 weevils and look for spherical, white eggs. When a weevil is ready to lay eggs, its entire abdomen contains eggs and little else. If more than 5 weevils are found per 10 sweeps, treatment is recommended.

Control methods

Insecticides registered for control of weevils are most effective when applied to the adult stage prior to egg laying. Foliar sprays are most effective when made on a calm, warm evening when adults are feeding on foliage. Treatment of surrounding vegetation might be necessary if it harbors weevils. Baits, which are registered in the U.S., can be applied during the day. They offer the added advantage of being relatively harmless to pollinating insects.

Entomopathogenic nematodes can be applied in fall and spring to target larvae of black vine weevil and strawberry root weevil in the soil. Follow directions on the manufacturer's label. Clay-colored weevils are a new pest, and the optimal application time has not yet been determined. We suggest applying nematodes approximately 4 to 6 weeks after mature eggs are found in adults.

For dry-harvested beds in the U.S., you can use a soil-applied insecticide in the fall to target larvae of black vine weevil and strawberry root weevil. In water-harvested beds, weevil larvae drown.

On dry-pick farms or young, unharvested beds, you can drown weevil larvae and pupae by flooding the beds in the winter. Hold water on the bed for 2 to 4 weeks if plants are relatively dormant. Be mindful that reinfestation can occur by movement of adults when recycling floodwater from one bed to another. See Chapter 15, "Physiological Disorders (Noninfectious)."

Occasional pests

Oystershell scale

Oystershell scale insects (*Lepidosaphes ulmi* Linnaeus) spend the winter as tiny, grayish-white eggs under the miniature oystershell-like covering of a female scale. One female can harbor 50 to 250 eggs, which hatch about the time cranberry vines are in hook or early blossom.

Figure 16.—Oystershell scale.

Figure 17.—Lecanium scale.

The young scales, or nymphs, are tiny and whitish. The females soon attach themselves to the vines and begin to cover themselves with a waxy coating. The coating is white at first, but it turns brown as the insect matures (Figure 16). Winged males emerge in July. After mating, the females lay their eggs and die, leaving the cavity under the scale filled with eggs.

Oystershell scale has been reported as a pest on cranberries in Oregon, but not in British Columbia or Washington.

Lecanium scale

Lecanium scale (*Lecanium corni* Bouche) can be found on many native trees and shrubs in some cranberry-growing areas. It spends the winter as a partially grown insect beneath small, rounded scales (Figure 17). It reaches full size and begins laying eggs in June. The female shrinks as she lays eggs and dies when the process is completed.

The young insects, which resemble yellow mites, emerge in July and August. They migrate to leaves, attach themselves to either side, and feed. When the weather turns cold, they migrate to stems, where they form a brown scale covering for the winter.

Lecanium scale has been reported as a pest on cranberries in Oregon, but not in British Columbia or Washington.

Brown soft scale

Description, life cycle, and damage

The brown soft scale (*Coccus hesperidum* Linnaeus) was first noticed around 1992 in small portions of a few cranberry beds in southwest Oregon. Since then, it has been detected occasionally in other beds in the same area, usually following mild winters.

These insects are small, brownish scales resembling the larger lecanium scale. All sizes of this scale can be found throughout the year. They spend the winter on uprights and leaves.

Infested areas of beds usually are small, crudely shaped circles, ranging from 3 to 20 feet (1 to 7 meters) in diameter. Infested vines are dark green to black during late winter and spring. Spring regrowth is inhibited greatly, as is flower and fruit set on infested uprights. Yield is reduced within the infested area. Natural spread within a bed is slow—just a few feet per year.

Brown soft scale has been reported as a pest on cranberries in Oregon, but not in British Columbia or Washington.

Detection, monitoring, and control

Heavily infested vines turn red in July from the feeding of growing nymphs. Examine vines for scales as you prune.

Scales can hitchhike on infested leaves and vines caught on machinery. After working in infested beds, clean harvesting and pruning equipment with water from a high-pressure hose. Use scale-free plant material when establishing new beds. Inspect vegetation surrounding beds to determine whether scales are infesting other plants. These areas can serve as sources of reinfestation.

Field research in Coos County, Oregon, showed that effective control of scales can be achieved with insecticide applications in late winter. In the U.S., a 2 percent insecticidal soap solution, either alone or combined with an approved organophosphate insecticide labeled for use in cranberries, can be applied to dormant vines. Treat heavy infestations again 7 days later. Use a boom sprayer; sprinkler applications have not been effective.

Cutworms, spanworms, and related pests

Description, life cycle, and damage

The larvae of several species of moths infest cranberry beds from time to time. These pests are found in four families of the order Lepidoptera: *Noctuidae* (armyworms, cutworms, some loopers), *Geometridae* (spanworms and "true loopers"), *Lymantriidae* (tussock moths and relatives), and *Tortricidae* (leafrollers). These insects spend the winter as partially grown larvae, pupae, or adults, depending on the species.

Larvae begin feeding in spring or early summer. Cutworms usually feed nocturnally. They may defoliate uprights and runners, girdle stems, prune tips, and destroy berries. Loopers, spanworms, hairy caterpillars, and leafrollers feed during the day. If present in large numbers, larvae of all four groups can do much damage.

Cutworms and loopers that have been found in cranberries include the following:

- Black cutworm, *Agrotis ipsilon* Hufnagel—Figures 18 and 19
- Alfalfa looper, *Autographa californica* Speyer—Figures 20 and 21

Figure 18.—Black cutworm larva.

Figure 19.—Black cutworm adult.

Figure 20.—Alfalfa looper larva.

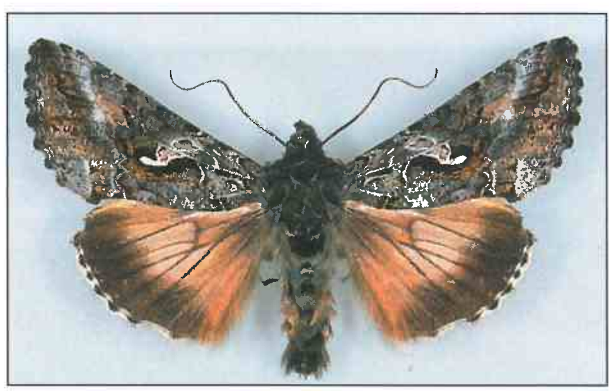

Figure 21.—Alfalfa looper adult.

- Zebra caterpillar, *Melanchra picta* Harris—Figures 22 and 23
- False armyworm, *Xylena nupera* Lintner—Figures 24 and 25
- *Ochropleura implecta* Lafontaine (no common name)—Figures 26 and 27

Zebra caterpillars feed mostly on weeds and rarely damage cranberries enough to warrant treatment.

Spanworms include the Bruce spanworm (*Operophtera bruceata* Hulst, Figures 28 and 29) and the winter moth (*O. brumata* Linneaus, Figure 30).

Hairy caterpillars of the rusty tussock moth (*Orgyia antigua* Linneaus, Figures 31 and 32) have been found on cranberries in British Columbia. To date, there have been no reports of this species in Oregon or Washington.

The leafroller straw-colored tortrix *Clepsis spectrana* Treitschke (Figures 33 and 34), which attacks other fruit crops such as raspberry, strawberry, and currant in the Pacific Northwest, is found occasionally on cranberries in British Columbia. There have been no reports of this species in Oregon or Washington.

Figure 22.—Zebra caterpillar larva.

Figure 23.—Zebra caterpillar adult.

Figure 24.—False armyworm larva.

Figure 25.—False armyworm adult.

*Figure 26.—*Ochropleura implecta *larva.*

*Figure 27.—*Ochropleura implecta *adult.*

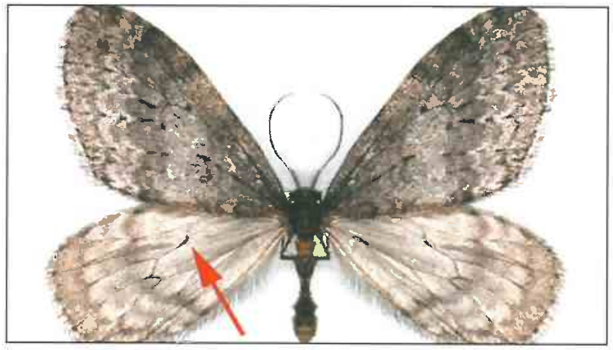

Figure 29.—Bruce spanworm adult, distinguished from winter moth by the scallop pattern on the forewing and a dot (indicated by the arrow) on the hindwing.

Figure 28.—Bruce spanworm larva. Larvae of the winter moth are almost identical.

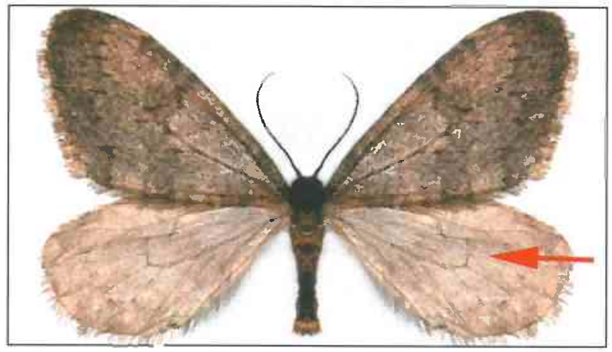

Figure 30.—Winter moth adult. Note absence of the scallop pattern and dot.

Figure 31.—Rusty tussock moth larva.

Figure 32.—Rusty tussock moth adult, male.

Figure 33.—Straw-colored tortrix larva.

Figure 34.—Straw-colored tortrix adult.

Detection, monitoring, and control

Look for larvae of these species while monitoring for blackheaded fireworm larvae or during night sweeps for black vine weevil adults. Cutworm moths also can be attracted to light traps. Moths of the Bruce spanworm and winter moth fly in winter, however, and are not seen in spring.

Light trapping in British Columbia in 1998 showed two flights of *O. implecta*, the first in June and the second in August. Night sweeps first found larvae approximately 2 weeks after peak catch in light traps, but very young larvae likely were present earlier. *O. implecta* also is attracted to pheromone traps for blackheaded fireworm.

Currently, the only way to control the larvae of these four groups is by using a registered insecticide when larvae are detected. Damage is minimized if larvae are detected soon after hatching and, in the case of night-feeding cutworms, if insecticide is applied in the evening. Insecticides used against cutworms are most effective when they are applied by a boom or backpack sprayer when larvae are small. Consider spot-spraying if you can delineate the area of infestation clearly.

Cranberry fruitworm

Description, life cycle, and damage

Cranberry fruitworm, *Acrobasis vaccinii* Riley, feeds only on berries and can be a serious pest. Usually, the larvae are found in green fruit well before harvest. However, in cool, late seasons, larvae might remain in berries at harvest time. Larvae brought to a warehouse in berries continue to feed, often webbing berries together.

The fruitworm spends the winter in the larval stage, wrapped in a hibernaculum of old leaves, sand, and other material under the vines. Pupation occurs in spring, and moths begin to appear in June. Generally, peak flight occurs about the time cranberries are in full bloom and can continue through much of July.

The moths are dark brown with very noticeable white bands on the forewings, and their wingspan is about ⅔ inch (15 mm) (Figure 35). They rest under vines during the day, particularly if the sun is bright. When disturbed, they fly 40 to 50 feet (15 to 17 meters) before coming to rest on a vine. Moths are strong flyers, moving readily between cranberry beds and from alternate hosts such as highbush blueberries.

Eggs usually are laid on the calyx end of the berry. As soon as the larva hatches, it usually moves to the stem end, enters the berry, and seals the entrance with a white, silken web. Only very close inspection reveals that the berry has been attacked.

The larva is pale green with a yellowish head. When fully grown, it is ½ inch (13 cm) long. It rarely leaves a berry until it has eaten all of the pulp and seeds and filled the berry with frass (Figure 36). Then, it usually bores through the side

Figure 35.—Cranberry fruitworm adult.

Figure 36.—Cranberry damaged by cranberry fruitworm larva; note frass.

of the consumed berry and into an adjoining berry. One larva can eat several berries before going into diapause (a hibernation-like state) in the duff for the winter.

Infested green fruits redden prematurely, then shrivel up like raisins.

Detection, monitoring, and control

Male moths can be attracted to traps baited with cranberry fruitworm pheromone. The correlation between trap catch and egg laying has not been established, but it is known that eggs are laid after peak catch. In Massachusetts, egg laying begins when berries have just begun to grow and can continue to late August. Females prefer to lay eggs on berries just larger than pinhead stage.

Work in Massachusetts showed that most eggs are found at the calyx end of berries growing at the edges of beds and ditches, in weedy areas, and above the vine canopy. If possible, examine 25 to 50 berries from these areas under a magnifier or microscope. If you find eggs, apply a registered insecticide. Do not apply insecticides during bloom or against fruitworm larvae, which are protected in the berries.

In Massachusetts, "late water" (a spring reflood done 1 year out of 3) is recommended for fruitworm control, but holding late water is not a practice in the Pacific Northwest.

Cranberry fruitworm is a troublesome pest. Research on biological control and pheromone-mediated mating disruption is underway in eastern Canada and the U.S.

Tipworm

Description, life cycle, and damage

The cranberry tipworm, *Dasyneura oxycoccana* Johnson, is a very small fly similar to a midge (Figure 37). Injury is caused by the maggot (immature stage) and often is mistaken for fireworm injury. The difference is that a tip sealed by fireworm has an angular appearance, while tips attacked by tipworm are cupped and look like they were injured by frost.

The tiny larva (maggot) is clear until the first molt (the stage known as the first instar), then greenish-white (second instar, Figure 38), and finally orange after it molts again (third instar). It has no visible head. As many as four larvae can be found feeding in the same tip. Pupae, which are pink to tan or brown, are enclosed in silk in the damaged tip (Figure 39) or in the duff.

Tipworms have at least two broods in the Pacific Northwest. Damage from the first brood occurs in late May or June. The second brood attacks tips in July. Tipworms are an increasing problem in Washington.

Detection, monitoring, and control

In Massachusetts and Wisconsin, where tipworms are relatively common, there is evidence that cranberry vines usually recover from tipworm attack. Therefore, insecticides rarely are recommended for control of

Figure 37.—Cranberry tipworm adult.

Figure 38.—Cranberry tipworm larva, second instar.

Figure 39.—Cranberry tipworm cocoons.

this pest. However, if tipworms are present, and other factors are stressing vines, insecticidal control might be warranted.

It is best to target control measures, whether at the first or second brood, during the early stages when tipworm larvae are clear or greenish-white. Sprays targeting orange larvae or pupae are too late and are ineffective. Because the typical cupping is not seen until larvae are orange (third instar), vine tips must be dissected under a microscope to find clear or greenish-white larvae in time to apply insecticide.

Observations in the Pacific Northwest suggest that tipworm infestations might be more prevalent on new beds with succulent growth than on mature beds.

Leatherjackets

Leatherjackets are larvae of craneflies, which are large flies ($\frac{3}{4}$ to 1 inch or 14 to 25 mm long) known for their wobbling, ponderous flight (Figure 40). Two species, the European cranefly, *Tipula paludosa* Meigen, and the marsh cranefly, *T. oleracea* Linneaus, have been reported in cranberry beds in the Pacific Northwest. European craneflies emerge, mate, and lay eggs from late August through October; marsh craneflies emerge in April, from late August through October, and possibly at other times of the year. Little else is known about the life history of the marsh cranefly.

The larvae of both species are grayish, cylindrical, and taper at both ends, with no apparent head (Figure 41). European cranefly larvae hatch soon after egg-laying. They feed on roots and plant crowns during periods of mild temperatures in fall, winter, and spring. In June, larvae of the European cranefly measure about $\frac{1}{2}$ to $\frac{3}{4}$ inch (13 to 20 mm), while marsh cranefly larvae are smaller ($\frac{3}{8}$ to $\frac{7}{8}$ inch or 5 to 10 mm). European craneflies pupate in late spring or early summer.

If present in cranberry beds, larvae usually are found in the roots of grasses and sedges. In addition to grasses, European cranefly larvae are known to feed on strawberries, flowers, and vegetable crops; marsh cranefly larvae might feed on conifer seedlings.

Although the larvae of the marsh cranefly and the European cranefly usually are found in or near the roots of grasses and sedges, they are potential cranberry pests. If grassy weeds are removed from young, weedy plantings where larvae are present, larvae might move to cranberries. Therefore, it might be advisable to kill larvae by flooding before controlling grassy weeds.

Figure 40.—Cranefly adult.

Figure 41.—Cranefly larva, known as a leatherjacket.

For more information

Averill, A. and M. Sylvia. *Cranberry Insects of the Northeast* (University of Massachusetts Extension, 1998). Available from Cranberries, P.O. Box 190, Rochester, MA 02770-0190.

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Pacific Northwest Insect Management Handbook (Oregon State University, revised annually).

Most photographs in this chapter were taken by Jim Troubridge (AAFC, Pacific Agri-Food Research Centre, Agassiz, British Columbia, Canada). We thank Wes McDiarmid (formerly of AAFC, Vancouver, British Columbia, Canada) for Figures 3 and 12, and Jean-Francois Landry (AAFC, Eastern Cereals and Oilseeds Research Centre, Ottawa, Ontario, Canada) for Figures 38, 39, and 40. Joe DeFrancesco provided Figure 18. All other figures are from the original version of Cranberry Production in the Pacific Northwest, *PNW 247,*

15

Physiological Disorders (Noninfectious)

Contents

B. Strik and
K. Patten

Effects of weather

Heat injury and sunscald

During the active growth period, temperatures above 86°F with high winds and low humidity can cause heat injury to cranberry plants. Effects of heat injury include desiccated new shoots and leaves (causing upright dieback), suppressed growth, reduced flowering, blossom "blast" (the failure of blossoms to set fruit), and lower productivity.

Heat injury is most common in the following circumstances:

- Vines are weakened from damage by herbicides, cranberry girdlers, or black vine weevils.
- New plantings are made on sand.
- Vines are poorly rooted.
- Vines at the edges of beds receive inadequate sprinkler coverage.

Sunscald or "scalding" refers to fruit injury resulting from exposure to direct sunlight. Large berries at the top of the canopy are most vulnerable. Healthy vines on sand are more sensitive to sunscald than those on peat or muck. Also, vines stressed by the herbicide dichlobenil are more likely to be injured.

Sunscald is most common where vine coverage is thin, especially where sunlight raises soil surface temperatures. Damage can be more severe when high air temperatures are accompanied by wind and low relative humidity.

Sunscald normally occurs only when temperatures are above 90°F. However, in the Pacific Northwest, sunscald can occur at temperatures as low as 79°F when relative humidity is low and there is bright sunshine. Under lightly overcast skies, some sunscald can occur when a lot of sunlight is reflected from the surface of the cranberry bed.

Scalding occurs most often in mid- to late August just as berries begin to color. Circular or oval, soft, light tan lesions form on the shoulder or sides of fruit directly exposed to the sun.

Prevention

To monitor the risk of heat injury and sunscald, position a temperature sensor so it is level with the tips of uprights and exposed to the sun. Do not place sensors in the shade.

Irrigating lowers the temperature of vines and fruit as much as 10°F. Operate sprinklers during periods of high risk, i.e., when the following conditions exist:

- A dew point of 55°F or less during midday and afternoon hours
- Air temperature of approximately 80°F or higher
- Clear or scattered cloud conditions during the day
- Low soil moisture in beds
- Wind speeds of more than 10 mph average
- No rainfall in the past 48 hours

Frost injury

During winter, when cranberry plants are in full dormancy, they are relatively tolerant to cold and can withstand temperatures as low as 0°F. However, once the plants' chilling requirement has been satisfied and they begin to come out of dormancy, cold hardiness decreases.

Research in Massachusetts has determined the relative cold hardiness of various cranberry cultivars. Although cold tolerance at various stages of development might be different in the Pacific Northwest, the critical temperatures for 'Stevens' shown in Table 1 can be used as a guide. (See the calendar of cranberry developmental stages in Chapter 2, "Botanical and Physiological Characteristics," for information on the timing of these stages.)

Frost damage to the terminal bud shows up after 24 hours as a light brown coloration in the center of the bud. After 2 weeks, the color changes to dark brown. Partial cold damage, where only some of the flower buds are damaged, shows as brown spots in the green center of the terminal bud.

Young vegetative growth exposed to frost turns brown and dies. Eventually, the uprights develop side shoots and the dead tissue falls off.

Fruit becomes more frost tolerant as it matures. Table 2 shows thresholds for 'Stevens' in Massachusetts.

Sprinkler irrigation systems can be used effectively to protect against frost injury. (See Chapter 5, "Irrigation.")

Winter injury

Winter injury is not common in the Pacific Northwest, as cranberry plants are relatively cold tolerant in the winter. However, when the soil is

Table 1.—Frost hardiness of 'Stevens' at various developmental stages in Massachusetts.

Stage	Frost hardiness (°F)
Tight bud	20
Bud swell	25
Cabbagehead	27
Bud break	27–29.5
Bud elongation	30
Roughneck	30–31
Hook	30–31
Bloom	30–31

Table 2.—Frost tolerance of 'Stevens' cranberry fruit at various stages of maturity in Massachusetts.

Stage	Temperature threshold (°F)
White to light blush color on fruit	28
Deep blush on exposed surface	27
Deep blush	26
Red	25
Deep red	23
Maroon (1 to 2 weeks later)	22

frozen to a depth of about 4 inches, temperatures remain below 25°F for a few days, and there are strong, drying winds, desiccation (drying) injury can occur. Under these conditions, plants lose water through transpiration faster than they can take it up from the soil.

The terminal bud always is killed first, followed by the upright. There are no records of injury to the root system.

Temporary flooding prior to and during a cold spell can prevent winter injury in areas subject to cold, dry winds.

Data from Massachusetts suggest that use of an antitranspirant (a product that reduces the speed of transpiration, or water loss, from the plant) might prevent desiccation injury. The use of antitranspirants in Pacific Northwest cranberry beds has not been studied.

Hail injury

Hail injury is most serious during the flowering period, when blossoms and flower buds can be severed or battered so severely that fruit set is impaired. Buds between cabbagehead and roughneck stage also can be damaged.

Developing, immature fruit can be bruised, punctured, or detached from the plant if the petioles are broken. Hard, brown scar tissue forms on punctured fruit, making it unsuitable for fresh market.

Leaves also can be damaged by hail, but the plants usually recover.

Lightning injury

Damage to cranberry beds from a lightning strike is not common, but it has been documented. Look for an area of dead or injured plants. Damage is evident both above and below ground. No pathogens or insects are present. Plants tend to be killed in wavy patterns that radiate from a central axis. The central point of the damage usually is a metal sprinkler head.

Nutritional disorders

Cranberry plants, like other crops, require several chemical elements for health and vigor. If one of these elements is not present in the plant in sufficient quantities, growth and development are adversely affected.

Diagnosing nutrient deficiency from visible symptoms alone is difficult, as deficiency symptoms can resemble symptoms of disease, insect attack, pesticide injury, and possibly nutrient toxicity. Many deficiencies are expressed as a reddening of tissue, especially in new growth, and it can be difficult to identify correctly which nutrient is lacking. Moreover, by the time you see symptoms, the deficiency might be so severe that crop production or growth already has been reduced.

Therefore, other diagnostic tools, such as tissue and soil testing, are recommended to assist in maintaining an adequate plant nutrient status. Tissue testing helps to ensure that nutrient levels are within their optimum range and allows you to correct deficiencies before visible symptoms appear. Refer to Chapter 6, "Nutrition," for recommended tissue levels and fertilizer application rates for critical nutrients in cranberry.

Macronutrients

Nitrogen

Nitrogen deficiency in cranberry results in reduced growth and abnormal color development. Runners are shortened, and uprights have small leaves. Leaves are light green with red pigmentation on leaf margins and new stem tissue (Figure 1). Older leaves show symptoms first.

In the Pacific Northwest, excess nitrogen often is more of a problem than nitrogen deficiency. Vine overgrowth caused by excessive nitrogen application can reduce yield and fruit quality of the current and possibly next season's crop. See Chapter 6, "Nutrition."

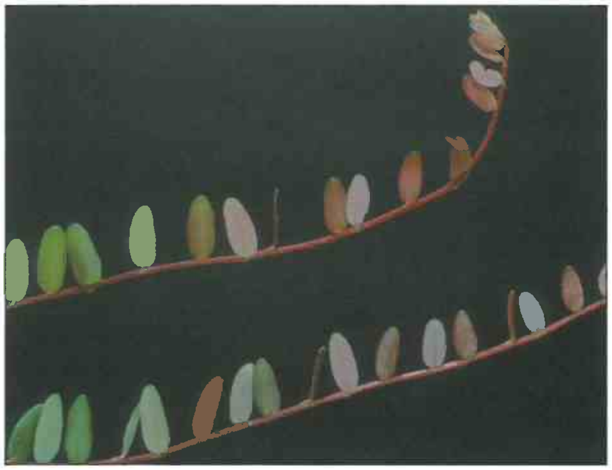

Figure 1.—Nitrogen deficiency symptoms on runners.

Figure 2.—Phosphorus deficiency symptoms on runners.

Figure 3.—Potassium deficiency symptoms on runners.

Phosphorus

Phosphorus deficiency reduces the plant's growth rate and causes dark green leaves and a slight reddening of the stem and leaves of the shoot. Symptoms of phosphorus deficiency are rare in Pacific Northwest cranberry fields and have been observed in greenhouse-grown plants only when the phosphorus supply was limited deliberately (Figure 2).

Potassium

Potassium deficiency symptoms have not been observed under field conditions. Under greenhouse conditions where potassium deficiency has been induced, symptoms first appear as a reddening of the leaf margins at the tip of the upright or runner (Figure 3). Growth is slowed, and eventually leaves die and drop off.

Calcium

Calcium deficiency appears as a marginal reddening of the leaves at the tip of the upright or runner. The discoloration spreads gradually to the whole leaf, which turns brown and dies within a few days. The growing tip dies back about 1 inch in length.

These deficiency symptoms have been induced in a greenhouse (Figure 4). They have not been observed in the field.

Magnesium

No magnesium-associated nutritional disorders have been observed under field conditions in the Pacific Northwest. However, in Massachusetts, drought-induced magnesium deficiency has led to yellow vines. In greenhouse studies, symptoms of magnesium deficiency appear as a dark mottling and distortion of older leaves on the upright or runner, followed by the development of necrotic (dead) spots on the edges of these leaves. In time, the affected leaves drop off. Injury progresses from the base of the shoot to the tip.

Sulfur

Sulfur deficiency is not a common problem in the field, perhaps because several fertilizer materials contain sulfur. Deficiency symptoms are very similar to those for nitrogen (Figure 5).

Sulfur toxicity has been observed on some sites when growers use high rates (1,000 lb/a or more) of elemental sulfur for soil acidification. Vines are killed by the formation of hydrogen sulfide (H_2S), especially in poorly drained areas of the bed.

Micronutrients

The availability of micronutrients to cranberry plants is very closely related to their content in the soil and to soil pH. A decrease in soil pH (increased acidity) increases the availability of copper, zinc, manganese, boron, and iron. Molybdenum, on the other hand, is less available in acidic soils than in soils that are near neutral pH.

Micronutrient toxicities are rare in cranberry. Sometimes, cranberry tissue test results show a high copper content; however, this typically is related to the presence of copper on the outside of the tissue sample (from a copper fungicide application) rather than excessive levels in plant cells. Elevated manganese in cranberry tissue can be an indication of inadequate drainage.

Because acidic soils typically are used in cranberry production, problems with micronutrient deficiencies are not very common. The following micronutrient deficiency symptoms were induced under greenhouse conditions.

Zinc

Deficiency symptoms include mild chlorosis (yellowing) of the youngest leaves and reddening of stem tips, margins of youngest leaves, and roots (Figure 6). Stem tips develop into little rosettes as a result of reduced internode length.

Figure 4.—Calcium deficiency symptoms on uprights.

Figure 5.—Sulfur deficiency symptoms on runners.

Figure 6.—Zinc deficiency symptoms on runners.

Copper

Copper deficiency first appears as a slight chlorosis and reddening of the youngest leaves. As the deficiency progresses, entire runners rapidly die, becoming light tan (Figure 7). Copper deficiency also has been associated with "monkey-faced" berries (fruit with a pinched-in appearance).

Copper toxicity has been observed in the field at tissue levels above 35 ppm. Symptoms include aborted fruit and rosetting and reddening of leaves.

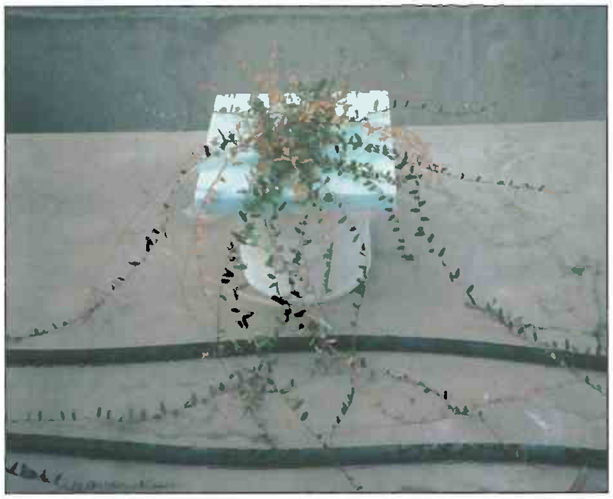

Figure 7.—Copper deficiency symptoms on runners.

Figure 8.—Manganese deficiency symptoms on runner tips.

Boron

Deficiency symptoms appear at the growing point, which eventually dies. Terminal leaves are small and slightly chlorotic, with some reddening of the margins.

Manganese

Deficiency is indicated by distorted, chlorotic, and necrotic leaves beginning about 1 inch from the growing tip (Figure 8).

Manganese toxicity, which sometimes shows as brown spots on older leaves, is more likely than deficiency in cranberry production. Poor drainage contributes to excess manganese. If fungicides containing manganese have not been used, and the tissue concentration of manganese exceeds 300 ppm, the soil drainage probably is inadequate.

Iron

Deficiency appears as a chlorosis of new growth that decreases in intensity from the tip to the base of the shoot.

Pesticide toxicity injury

Not all of the following pesticides are registered for use on cranberry in every region. Always check the label before applying any product.

Herbicide injury

Dichlobenil

Dichlobenil is a strong inhibitor of root and shoot growth in many types of germinating weed seedlings. It also can injure cranberry vines by inhibiting root formation in newly planted cuttings and by reducing root growth in mature plants. Stems become brittle and break easily, and plant growth is stunted. Dichlobenil injury also makes plants more susceptible to sunscald, insect damage, and nutritional stresses.

The most commonly observed symptoms of dichlobenil injury are the reddening of old leaves and unusually small size of developing fruit. Injury in the field often is visible as a swath of red vines in a straight line—a result of overlap of the chemical during application. Damage is more common on sandier soils and in areas of poor drainage.

Frequent applications of small quantities of fertilizer (nitrogen and phosphorus), irrigation, resanding, and reduced herbicide usage can help injured plants recover.

Norflurazon

Norflurazon is a preemergent herbicide that restricts carotenoid pigments, which results in bleaching of chlorophyll by sunlight in susceptible weed species.

Injury symptoms in cranberry plants are very distinctive. First, the stems and leaves of new growth turn bright pink, then the leaves turn white between the veins, and then the leaf margins turn brown. New growth is stunted, and the leaves are close together, forming a witches'-broom.

Injury is more common where water puddles in low areas for several days. The risk of injury is higher if the herbicide is used in consecutive growing seasons. On some sites, norflurazon symptoms recur for several years after application.

Glyphosate

This nonselective herbicide is nonvolatile (it does not vaporize), so vines are injured only if the solution comes in contact with the vines. Injury begins as a yellowing of the leaves followed by necrosis. Damage generally is very localized, and nearby weeds show similar symptoms.

2,4-D

The danger of vine injury from this herbicide arises mainly from its volatility. Do not use 2,4-D in hot, humid conditions.

Affected leaves turn brown very quickly, usually within 48 hours. The stems might grow abnormally or twist as they recover from the injury. Slight damage from 2,4-D appears as small, twisted leaves and a slight twist in the stem. Damage might be visible the following season.

Napropamide

Napropamide damage usually appears as stunted growth. The vines turn maroon in color and stop growing. Symptoms are most common in new plantings that are overwatered or poorly drained.

Copper sulfate

An extreme overdose of copper sulfate (more than 20 lb/a) kills cranberry vines. The usual sign of less severe injury is a bright red color on one or more of the older leaves on an affected upright.

Insecticide injury

Chlorpyrifos

This insecticide normally does not cause injury when applied through a chemigation system. However, if it is applied aerially through a low-volume injection system, it can be deposited in too high a concentration on cranberry vines. After 48 hours, leaves might develop discrete lesions that can coalesce and become necrotic. Developing berries exhibit necrotic areas that russet as the fruit continues to mature.

Fungicide injury

Chlorothalonil

This fungicide can injure fruit when applied in a highly concentrated aerial spray. Injury is more common in hot weather. Symptoms include reddish patterns on young fruit and necrosis of developing berries similar to that described for chlorpyrifos injury.

Salt injury

Cranberry vines are fairly tolerant of salt. In seaside areas, beds that receive brackish water in the drainage ditches from occasional high tides do not show any visible signs of injury, except in extreme cases. However, vines can be injured or killed in low areas where saltwater drains slowly.

Oxygen deficiency injury

Floodwaters often are used for harvest and for insect control at various stages of plant development. (See Chapter 14, "Insects.") Oxygen deficiency injury occurs on flooded beds when the demand for oxygen by cranberry plants exceeds the supply of oxygen dissolved in the floodwater. The exact oxygen level and associated injury to specific parts of the cranberry plant are not well known.

However, a good guideline is to not let the oxygen level drop below 4 mg/liter (40 percent of full oxygenation).

Oxygen deficiency can have the following effects, in order of most to least important:

- Death of stems
- Loss of old leaves (leaf drop)
- Death of terminal buds
- Death of flower buds
- Retarded development of flowers
- Failure of flowers to set fruit
- Generally undersized fruit

Do not hold water on cranberry beds for long unless you ensure that the water remains in motion to keep the oxygen content sufficiently high.

Physiological breakdown (postharvest)

Postharvest losses due to physiological breakdown are a concern only for fresh fruit, because berries harvested for processing are frozen shortly after harvest. Losses vary from year to year, from bed to bed, and even from one section of a bed to another. In some years, postharvest losses of cranberries stored for fresh market are as high as 30 to 40 percent.

Losses during refrigerated storage result from a combination of physiological breakdown and fungal decay. The longer berries remain in floodwater at harvest, the more fungal decay and physiological breakdown occur in storage. Thus, only dry harvest is recommended for fresh-market fruit. Fungal rot is not a problem for dry-harvested fruit in the Pacific Northwest, but physiological breakdown can be.

Figure 9.—Bruise injury on a machine-harvested berry after 2 months in refrigerated storage.

Physiological breakdown also is called sterile breakdown or sterile rot, because no microorganisms (e.g., fungi) can be isolated from the softened berries. Because fungi are not responsible for physiological breakdown, fungicides do not correct the problem. Physiological breakdown includes low-temperature damage, which occurs when berries are stored below 33.8°F.

Fruit that is bruised during harvesting, separating, sorting, or packing breaks down more rapidly in cold storage than undamaged fruit (Figure 9). Thus, the shelf life of bruised berries is reduced greatly.

In the Pacific Northwest, the blossom stage frequently lasts 3 to 6 weeks. Earlier ripening berries tend to be softer at harvest and more sensitive to bruising. Thus, they have a higher incidence of physiological breakdown than later ripening fruit.

The following practices increase the keeping quality of fresh cranberries:

- Avoid excessive use of nitrogen fertilizer, which causes soft fruit.
- Harvest before fruit is overripe.
- Minimize handling to reduce bruising.
- Store fruit as dry as possible.
- Do not run fruit through a sizing or debris-removal screen.
- Maintain a storage temperature of 35.6 to 39.2°F with a relative humidity of about 90 percent.
- Ensure adequate air circulation around fruit and storage containers.
- Pack and repack fruit in a cool room.

Photographs of nutrient deficiencies in this chapter are courtesy of Lloyd Peterson, retired faculty member of the Department of Horticulture at the University of Wisconsin-Madison. To produce the nutrient deficiencies, cranberries were grown in a greenhouse with a single nutrient withheld from a nutrient solution.

Economic Factors

16

Cost of establishment

Significant capital is required to begin cranberry farming, whether to establish a new farm or to purchase an existing farm. In general terms, the cost to establish a new 10-acre cranberry farm and bring it into production (3 to 7 years) ranges from $30,000 to $80,000 an acre. This includes not only a capital outlay, but interest on operating capital and capital assets (including land) and the cost of obtaining permits to fill wetlands or obtain water rights.

Much of the cost is in the initial land preparation. A site requiring extensive alteration (such as removal of large stumps, bringing in large amounts of sand or planting medium, major drainage alterations, or installing railroad tracks or wood-lined drainage ditches) or land that is very expensive requires more capital to develop than a site that is almost ready to plant. If you already own the land, vines, and equipment, and are expanding on a site that is easy to develop, the basic preparation and planting might cost as little as $10,000 to $20,000 an acre.

Dry-harvest beds come into full production later than wet-harvest beds, so they take significantly longer to reach break-even.

The U.S. Army Corps of Engineers regulates the creation and expansion of new cranberry operations in U.S. wetlands under section 404 of the Clean Water Act. Recently, the Corps has increased its requirements for compensatory mitigation for cranberry plantings in wetlands. For every acre of wetland converted to cranberries or filled for dikes, a given number of acres of wetlands (usually from 1 to 6) must be restored, preserved, enhanced, or created. Therefore, to plant 10 acres of cranberries, a grower might incur an additional expense for enhancing or preserving up to 60 acres of wetlands. Prior to any new planting in wetlands, U.S. growers should contact the Corps for advice and to learn how much mitigation, if any, is required.

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Cost of production

Cost of production depends on region, location, and method of harvest. Estimates for various growing regions range from $2,000 to $6,000 per acre. The cost of production per barrel ranges from $30 to $50. Much of the variation is based on the size of the operation (larger farms have economies of scale) and on the degree of modernization. True operating costs should include personal and property taxes, insurance, utilities, labor, repairs, fuel, pump standby charges, equipment, vehicles, and chemicals.

Studies of Massachusetts cranberry farms have shown that, because the expense of growing cranberries is mostly fixed on a per-acre basis, good cultural practices that increase yield are critical to farm profitability.

According to Washington State University publications, average per-acre costs of production in Washington are as follows:

- Variable cost—$2,275
- Fixed cost—$5,882
- Total cost—$8,157

These costs are based on average 1995 values for established wet- and dry-harvested beds. Because most plantings represented by the state average are more than 50 years old, the prorated establishment cost can be omitted. In this case, the average fixed cost is $1,623, and the total cost of production (variable + fixed costs) is $3,898. (For more information, see WSU publications EB 1806 and EB 1805, listed under "For more information," page 111).

Cost of renovation

Existing beds often do not produce enough to justify continued farming. In this case, bed renovation is warranted. (See Chapter 8, "Pruning.") Variable costs to scalp and replant (including labor, equipment, cost of vines, etc.) and fixed costs (see EB 1806) are approximately $9,000 per acre. If you include the average fixed cost of production (without the prorated establishment cost) for 4 years, the total cost might be $15,000 to $20,000 per acre.

Cost of purchase

There always are cranberry farms for sale. The typical price of farms with a low to moderate yield record has ranged from $5,000 to $40,000 per acre. Farms with good yields have ranged from $10,000 to more than $80,000 per acre.

The buyer must work out a plan that covers the cost of the mortgage and the annual production costs and still returns some living expenses. For example, if the cost per acre is $15,000, and a 10-acre farm is purchased with a $50,000 down payment and a $100,000 note for 20 years at 8 percent interest, the farmer must produce more than 200 bbl/a (assuming $25/bbl) just to break even on payments.

In general, low-yielding (less than 100 to 125 bbl/a) farms that sell for $5,000 to $35,000 an acre probably generate an internal rate of return of less than 1 to 4 percent, while higher yielding beds (more than 250 to 300 bbl/a) selling for twice that amount could generate an internal rate of return of greater than 5 to 10 percent. Yield potential and a healthy long-term price ($/bbl) are essential to making a farm profitable.

Cranberry price

Cranberries are like other farm commodities—the price reflects supply and demand. The considerable new acreage planted since 1990 and the oversupply has markedly reduced grower returns. Base your decisions to establish, renovate, or purchase cranberry beds on a conservative price structure.

You can get more information on current and projected supply and demand from the Cranberry Marketing Committee, 266 Main St., Wareham, MA 02571-2172; crnberry@capecod.net.

For more information

You can find full details of cost of establishment and production in Washington in the following publications:

Cranberry Establishment and Production Costs and Returns, Southwestern Washington, Dry Harvest, EB 1805 (Washington State University, 1995).

Cranberry Establishment and Production Costs and Returns, Southwestern Washington, Wet Harvest, EB 1806 (Washington State University, 1995).

The values outlined in these publications vary, depending on time, location, size of operation, method of establishment, and commodity price, but you can use them as a general guideline for calculating costs under different circumstances. All values are given in U.S. dollars.