Crop Profile for Cranberries in Massachusetts

Prepared: Feb., 2001

General Production Information

- The American Cranberry (*Vaccinium macrocarpon* Ericaceae Ait.) is a low-growing, creeping, woody perennial shrub with small, alternate, oval leaves (22). The plant produces trailing stems or runners up to six feet long. The leaves, glossy-green in summer, turn dark red during the dormant season, which is approximately November through April. Short vertical branches two to eight inches tall, called uprights, grow from buds on the runners and produce both vegetative and fruit buds. Each fruit bud may contain as many as seven flowers.
- The cranberry root system is fine and fibrous (25). The roots absorb most of their nutrients through a symbiotic relationship with mycorrhizal fungi (14). In recent Massachusetts measurements, cranberry roots were found to penetrate soil to a depth of no greater than eight centimeters (3¼ inches) (17), although field observations have confirmed rooting depth of approximately five inches and lab studies have shown root growth to a depth of ten inches (Dr. Bruce Lampinen, personal communication, November 1999).
- After emerging from dormancy in May, the vines begin to develop new leaves followed by flowers. Flowering in Massachusetts typically begins mid-June and lasts from three to six weeks. Berries reach maturity approximately 80 days after full bloom and are harvested from early September through early November, depending on season and variety (25). The American Cranberry is native to North America and is found in natural bogs from Minnesota to Newfoundland and south to Illinois, Ohio, Tennessee, and Virginia (22).
- By any agronomic measure, cranberry is a relatively undomesticated crop. Although significant breeding programs are underway in both New Jersey and Wisconsin, the dominant cranberry varieties under cultivation in Massachusetts were selected from native bogs prior to the American Civil War. According to 1998 statistics (23), the dominant varieties grown in Massachusetts are Early Blacks and Howes (See Table 1). The first vines of Early Black originated from Harwich, Massachusetts around 1835 (14). Howes was selected from the wild in East Dennis, Massachusetts, in 1843. Stevens, a relatively new hybrid released in 1950 by USDA, is third in acreage in Massachusetts. The majority of new acreage is being planted to Stevens because of its high-yielding characteristics.

Table 1. Percentage of Total Acreage in Massachusetts by Cultivar, 1998 (23).

Cultivar	Percent
Early Black	42.66
Howes	36.54
Stevens	11.74
Ben Lear	5.06
Other	4.00

- Massachusetts cranberry farms produced 1,874,463 barrels of fruit valued at approximately $70,200,000 in 1998 (15) (See Table 2). This represents 34 percent of U.S. production and thirty one percent of U.S. utilized production value. The USDA National Agricultural Statistics Service projects the 1999 Massachusetts crop to increase 12 percent in 1999 to 2.1 million barrels (15) although preliminary harvest figures indicate harvest at approximately 1.9 million barrels.

Table 2. Cranberry Production, 1998 (15).

Region	Barrels
Wisconsin	2,541,266
Massachusetts	1,874,463
Canada	608,876
New Jersey	534,566

- Massachusetts's crop acreage has been on a steady upward trend. There were 14,400 acres harvested in Massachusetts in 1998, which represented 40 percent of U.S. acreage (15). Average yield per acre in 1998 was 130 barrels, 20 barrels below United States average yield.
- The first attempts to cultivate wild cranberry were made in 1816 by Henry Hall, a Revolutionary War veteran, in the town of Dennis, Massachusetts on Cape Cod (14). While the geographic focus of cranberry production was once Cape Cod, the great majority of cranberry production is now off-Cape in the coastal and inland towns of southeast Massachusetts. According to the Cape Cod Cranberry Growers' Association, cranberry acreage is found in 48 different towns in Plymouth, Bristol, Barnstable, Nantucket, Middlesex and Norfolk counties (Jeff LaFleur, personal communication, August 1999). Five Plymouth County towns (Carver, Wareham, Middleboro, Plymouth, and Rochester) account for approximately 60 percent of Massachusetts cranberry acreage. Carver stands alone as the center of Massachusetts cranberry production with fully 25 percent of all Massachusetts acreage within its boundaries.
- Cranberry beds range in size from less than one acre to over 200 acres in size. Because beds were once planted in natural wetland environments, older fields tend to be irregular in shape, following the historical contours of kettle holes, outwash bogs, or abandoned iron ore bogs (25). This characteristic greatly impacts pesticide application methods and cultural methods. Newly planted beds tend to be rectangular and of a standard width to promote management efficiency.

Cultural Practices

Massachusetts cranberries are grown in beds of varying size and shape that have either been developed in traditional kettle or outwash bogs, abandoned iron bog sites, or, more recently, on non-traditional upland sites (25). Cranberry beds typically have interior and peripheral ditches that are used for drainage during the growing season. This ditch system is also used, with the aid of gates and flumes, to hold water on the beds for flooding. Flooding of bogs typically occurs during harvest (if wet picked), and during winter for cold-temperature protection and barge sanding. Flooding is also used on occasion during the growing season for pest control.

Cranberry production is water-dependent. Growers rely on surface waters, such as farm ponds, reservoirs, rivers, streams, lakes, and, to a lesser degree, ground water, for a reliable high-quality water supply. Aside from flooding, as described above, water is used in Massachusetts for supplemental irrigation, frost protection during spring and fall, heat protection during unusually warm weather, and application of fertilizers and pesticides (through solid set sprinkler systems). The University of Massachusetts estimates that approximately eight acre-feet of water are used annually on a cranberry bed, the majority of which is used for the harvest and winter floods.

Peat-based cranberry beds were historically built by draining, clearing, and covering with sand to level the bed before the crop was planted to selected vines (8). However, due to regulatory restrictions on development of new beds in traditional wetland sites, all new beds are built in "non-traditional" upland sites (11, 25). Upland sites are engineered to provide hydrologic and soil characteristics that mimic traditional wetland sites. Six- to eight-inch lengths of vine cuttings are scattered uniformly over the sand at the rate of approximately one to two tons per acre and are then pushed into the soil with a modified disc harrow to a depth of three to four inches. Full production may be reached within three years from planting.

Important cultural practices for maintaining good productivity of established beds include pruning, sanding, and fertilization. Beds may be pruned after harvest to stimulate the production of uprights and to prevent the runners from becoming matted and reducing productivity (25). Sanding refers to an application of a thin layer of sand (one-half to two inches) over the bed at two to five year intervals (10). Sanding stimulates new root and vine growth, improves soil drainage, reduces danger of frost injury, and aids in pest control (e.g., cranberry girdler). Fertilizers, in granular or liquid formulations, are applied as necessary (following University of Massachusetts recommendations) for optimum growth.

Proper water management is also important in maintaining productivity. Water is used to irrigate the crop during the active growing season. According to conventional wisdom, a typical cranberry bed requires approximately one inch of irrigation per week. At this time no irrigation scheduling program exists that bases irrigation need on actual or predicted evapotranspiration loss. Irrigation is also used to protect the flowers and flower buds during early season frost events and for protecting ripening fruits from freezing temperatures during the fall prior to harvest.

Cranberries are harvested in two ways, depending on the intended crop use: dry or wet harvest. Dry-picked berries are sold primarily for fresh market. Dry harvest utilizes a harvesting machine that combs the berries off the vines. Many dry-pick machines are also equipped with knives to prune the vines (25). Fruit harvested by dry picking in Massachusetts is much less prone to storage rots compared to water harvested fruit.

In Massachusetts, water harvest is used for berries intended exclusively for processing. After the bed is flooded a water-reel knocks the berries off the vines and the buoyant berries rise to the water surface. The floating berries are corralled with floating booms to one corner of the flooded bed and loaded onto trucks by mechanical conveyors or pumps. These fruit, after cleaning, go directly into freezer storage.

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IPM and alternative pest control strategies in Massachusetts

Massachusetts cranberry growers have used Integrated Pest Management (IPM) practices for decades. The University of Massachusetts initiated a formal cranberry IPM program in 1983 (25). IPM practices were developed to improve

the appropriateness and timing of pest control activities. The Massachusetts program, led by Ms. Hilary Sandler, University of Massachusetts Cranberry Experiment Station, has been highly successful. Growers, private IPM scouts, and UMass provide scouting services.

According to Weber and Roskelley (26), results from a commodity-wide assessment of cranberry pest management show that Massachusetts cranberry growers have a high IPM adoption rate. In their comprehensive survey, 94 percent of North American growers said they monitor for pests.

Of those that monitored for pests *in Massachusetts*, 96 percent use sweep netting, 59 percent use pheromone traps to monitor adult insect populations of Sparganothis fruitworm, cranberry girdler, cranberry fruitworm, and/or blackheaded fireworm, and 52 percent of growers construct weed maps. Over 85 percent of all Massachusetts growers utilize action thresholds from insect sweep counts as a decision aid in pesticide control actions.

Implementation of IPM-based alternative practices such as sanding, winter flooding, summer flooding, and "late water" is high. Ninety-eight percent of growers in Massachusetts use sanding, 92 percent use winter flooding, and 18 percent flood for specific species, such as cranberry girdler. Twenty-six percent of all Massachusetts growers have used "late water". Late water is a 30-day spring reflood applied several weeks after the winter flood has been removed and before the plants break dormancy. Late water has been employed for the control of fruit rot, dewberry, Southern red mite, cranberry fruitworm, false armyworm, and gypsy moth (24) and greatly reduces the need for pesticides to control these pests.

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EPA Pesticide Environmental Stewardship Program partnership

The Pesticide Environmental Stewardship Program (PESP) forms partnerships between pesticide users and EPA’s Office of Pesticide Programs. All PESP Partners make a commitment to reduce pesticide risk and to develop a strategy to achieve risk-reduction goals.

According to EPA, the strategy is a concrete statement of the Partner's commitment to reduce risks from the use of pesticides and the actions they will pursue to implement their commitment. The strategy provides the Partner the opportunity to look comprehensively at their pest control issues and to provide that information to federal agencies for furthering the Partnership. In addition, it offers the Partner an opportunity to share their successes and possibly assist others in achieving similar success.

The Cranberry Institute formed a PESP partnership with the EPA in 1995. Our stewardship goals through the PESP partnership include the following:

1. Protect and enhance natural resources while managing viable cranberry operations. Industry organizations will continue to fund research and implement research findings that protect surface and ground water, protect and encourage natural enemies of crop pests, and enhance wildlife utilization of the unique habitats provided by cranberry farms.

2. Strengthen current IPM programs and practices by utilizing newly-registered pheromones and biorational pesticides, new survey techniques, and innovative cultural control measures as they become available.

3. Teach growers the latest research findings and update growers about improved or innovative IPM-strengthening control techniques (through meetings with handler, university, and grower organizations).

4. Provide significant support and funding for research on alternative practices that will strengthen IPM and protect natural resources.

5. Pursue and obtain reduced-risk registrations with the EPA's commitment to assist.

Insect Pests

The definitive source of information regarding Massachusetts cranberry insect pests is *Cranberry Insects of the Northeast*, published in December 1998 (made possible by a PESP grant). Co-authored by Dr. Anne Averill and Ms. Martha Sylvia, University of Massachusetts at Amherst, this well-illustrated book thoroughly describes the identification, biology, and management of cranberry insect pests in the Northeast. This publication is the primary source of information for this section.

According to Averill and Sylvia (2), many insect species are found feeding on cultivated cranberry in the Northeastern United States. They consider cranberry fruitworm to be the most serious and widespread pest in Massachusetts, while Sparganothis fruitworm, cranberry weevil, false armyworm, brown spanworm, cranberry root grub, and cranberry white grub are problematic on many beds. Weber and Roskelley (26) confirm this opinion in their commodity-wide IPM assessment. Oriental beetle, the soil scarab *Hoplia modesta*, and gypsy moth can also be severe pests where they occur.

Cranberry fruitworm [*Acrobasis vaccinii* (Riley)] is the most economically important insect pest of cranberry in Massachusetts. According to Averill and Sylvia, moths occur from late May until September, but peak moth flight is typically from the latter part of June through the first week of July with a smaller peak of emergence at the end of July. Female moths deposit eggs singly at the blossom end (calyx) of berries and the larvae, which feed only on developing berries, consume seeds and pulp before moving to an adjacent fruit. Female moths lay significantly more eggs along bog edges, internal ditches, and in weedy patches. Each larva normally consumes three to six berries. Infested fruits redden prematurely and later dry and shrivel on the vine.

Sparganothis fruitworm [*Sparganothis sulfureana* (Clemens)] is also a primary pest in Massachusetts. Hard to find or absent in wild bogs, this lepidopteran pest is considered an induced pest that tends to be localized. When present it can be very difficult to manage due to suspected organophosphate resistance and the related negative effect of organophosphate applications on natural enemies. The Ben Lear variety appears more suitable to Sparganothis infestation due to fruiting characteristics. The first-generation larvae are indirect pests, feeding on new foliage and flowers, often webbing one or more terminals together. Generally, most of the damage is from the second-generation larvae that bore into the fruit and feed on foliage.

Cranberry weevil [*Anthonomus musculus* (Say)] is a native North American pest that can be very problematic in Massachusetts. The insect overwinters as an adult. Shortly after emergence in early spring the adults feed on wild

blueberries and other upland plants adjacent to bogs. Starting in mid-May, some adults move onto commercial cranberry bogs. By the end of June, all adults have moved onto the bog, where they feed on new foliage, mate and lay eggs in holes drilled into unopened flower blossoms. Infested buds do not open and the larvae develop protected within the buds, which may fall to the ground. After adult emergence, the adult beetles attack immature fruit and young foliage. When abundant, this pest has the potential to destroy much of the crop.

False armyworm [*Xylena nupera* (Linter)] moths overwinter and females lay upwards of six egg masses of one hundred eggs each in late April and early May. The eggs hatch during the second and third week of May. The larvae can do severe damage by eating the hearts out of the terminal buds prior to budbreak in spring. They develop with the new growth and feed more voraciously as they develop, consuming leaves, flower buds, and flowers of new stems. There is a single generation each year.

Brown spanworm [*Ematurga amitaria* (Guenée)] appears on Massachusetts bogs sporadically, but almost always in high numbers. Overwintering as pupae, the brown spanworm adult moth emerges in late May to mid June and is generally active until late June to mid July. The female lays approximately three hundred eggs in irregular groups numbering as many as twenty. Larvae hatch just before and during bloom (late June through early July) and feed on foliage, buds, and blossoms. A severe infestation may result in the loss of all blossoms and under extreme circumstances the bog may turn brown. Infestation is patchy. There is a single generation each year.

Cranberry root grub [*Lichnanthe vulpina* (Hentz)] is found on a number of bogs in Massachusetts and is one of the most difficult pests to control. Overwintering as a pupa, cranberry root grub adults emerge in middle to late June and are active through mid July. Adult beetles do not eat cranberry foliage or fruit. After mating the eggs are laid singly or in pairs through the soil to a depth of about three inches. The grubs feed on roots mostly within three or four inches of the soil surface in the spring and summer and may feed deeper (to ten inches) as the season progresses. Grubs of all sizes can be found during peak feeding times indicating populations established in different years.

Cranberry white grub [*Phyllophaga anxia* (LeConte)] is often found scattered among other scarab beetle infestations and near bog edges or high spots in the bog. The adults, commonly called May beetles or June bugs, have never been reported to feed on cranberry leaves, flowers, stems, or fruit. They emerge in May through June, feed on oak, elm, ash, and other deciduous trees, and mate. The eggs are scattered by the female in the soil within one to eight inches of the soil surface. Most of the eggs are laid in June. The larvae, or grubs, have a three-year life cycle. According to Averill and Sylvia, the grubs are voracious feeders, doing more harm individually than any other type of grub that attacks cranberry. They also appear to travel in the soil, thus causing more damage to larger areas than their numbers would otherwise account for.

Oriental beetle [*Exomala orientalis* (Waterhouse)] is a new pest of Massachusetts cranberry, recorded for the first time in the mid 1990's at several bogs on Cape Cod. As a new, non-native pest, the life cycle of Oriental beetle in cranberry is yet to be fully described. However, samples by Averill indicate a two-year life cycle. The adults, who eat little, feeding mostly on flowers, emerge in June. In turf populations, mating normally occurs within five days and egg laying within four to twenty-one days of emergence. Females lay an average of twenty-five eggs singly at a depth of one to eleven inches. The grubs feed close to the surface on cranberry roots and organic matter.

Hoplia modesta (Haldeman) is a Massachusetts cranberry exclusive. It has not been reported as a pest in any other crop. *Hoplia* overwinter as larvae and Averill and Sylvia suggest a two-year life cycle. The adult scarab beetles emerge during cranberry bloom and form "mass swarms" synchronized with high soil moisture. Grub infestations tend to

escalate quicker with *Hoplia* than with cranberry root grub or cranberry white grub. In infestations, grub populations can reach as high as fifty per square foot.

Gypsy moth [*Lymantria dispar* (L.)] overwinter as eggs which can survive on flooded beds. The larvae normally hatch between the end of April and mid June. Larvae attack the terminal buds first, eating all but the outer scales. As the cranberry plant and caterpillars develop, the larvae consume the new leaves, flower buds, and blossoms. When high populations occur the larvae will move on to consume older foliage. Pupation occurs mid July through mid-August. Adults emerge in late July through August. There is a single generation each year.

Southern red mite [*Oligonychus ilicis* (McGregor)] is a cranberry pest only in Massachusetts. It occurs sporadically, but infestations can be serious (27). The mites overwinter as eggs on cranberry bark and leaves and begin to hatch in mid April through early May. Indications are that the first generation is completed on the old foliage and then the females move to new foliage in late June to early July. Average time from egg hatch to adult emergence (from nymphal stage) is 12 days. Six to eight overlapping generations occur each season and under hot, dry conditions populations can rapidly expand. Mites cause damage by piercing the upper surfaces of leaf and feeding on cell contents. Severe infestations will cause a bronzing of the foliage. The impact of mite population on yield is unknown.

Cranberry flea beetle (also known as red-headed flea beetle) [*Systena frontalis* (F.)] attacks Massachusetts cranberry fields in highly patchy infestations, often in areas of lush vine growth (25), skeletonizing leaves. There is a single generation per year. Eggs laid in August through September overwinter and hatch the following May. While the habits of the larval stage are not fully understood, the adults appear on the bogs in July and remain until mid-September.

Cranberry tipworm [*Dasineura oxycoccana* (Johnson)] is found in many cranberry-producing regions. While a confirmed pest in the short-season production areas, its pest status in Massachusetts is a matter of controversy. Averill and Sylvia state that vigorous vines often recover from the attack of this insect and yield well the following year. After overwintering as pupae, cranberry tipworm adults (flies) appear at bud-break in May. Female tipworm lay eggs at the base of leaves and eggs hatch within a few hours. Generations take approximately two to four weeks to complete; four or five generations occur each season. The larvae damage the tip of cranberry shoots by scraping off the inner surface of the succulent new leaves in the developing bud. Early season damage results in the development of secondary lateral shoots. Late season impact may result in yield losses, but this has occurred infrequently and Averill and Sylvia conclude that concern over late-season damage in Massachusetts has little merit.

Blackheaded fireworm (BHFW) [*Rhopobota naevana* (Hübner)] is a very serious Lepidopteran cranberry pest for all regions except the northeastern U.S. According to Averill and Sylvia, BHFW was once the most prevalent insect pest in Massachusetts until the introduction of chemical insecticides. While some growers in Massachusetts continue to find it a serious pest, BHFW infestations are spotty in nature. The BHFW has two generations per year. The first generation larvae hatch from overwintering eggs in May to early June and mine older leaves prior to moving to new leaves and shoots, feeding for as much as two and one-half weeks. Larvae will web leaf tips and shoots together and feed on the new growth. If uncontrolled, severe feeding damage will cause the field to turn brown as if touched by fire. Second generation larvae may feed on flowers or new fruit, causing significant injury through August. In later hatches BHFW larvae can cause significant damage to the following year’s flower buds. Serious outbreaks of BHFW occur in wild cranberry stands.

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Table 3. Insect Control Ratings, 0 through 10.
100=No Control; 10= 100% Control

Pest	Chlorpyrifos	Acephate	Azinphos methyl	Carbaryl	Diazinon	Tebufenozide	Pyrethrin	B.t. *kurstaki*	Summer flood	Fall flood	Late water	Parasitic Nematodes	Cryolite bait	Natural enemies
Brown spanworm	9	9	9	7	9	--	7	7	--	--	5	--	0	5
Cranberry fleabeetle	9	9	9	9	9	0	?	0	?	?	?	?	0	?
Cranberry Fruitworm	9	9	9	7	9	4	2	0	0	0	9	0	0	4
Cranberry girdler	1	1	1	1	5	?	0	1	10	8	0	4	0	--
Cranberry tipworm	0	0	4	0	5	0	0	0	0	0	0	--	0	4
Cranberry weevil	9	3	2	0	0	0	0	0	0	0	0	0	0	2
False armyworm (and other cutworms)	9	8	4	3	8	8	6	4	0	0	0	0	?	4
Fireworms	9	9	9	7	8	9	8	6	4	0	0	0	0	0
Gypsy moth	10	10	10	8	10	10	8	7	0	0	0	0	0	5
Scarab grubs	0	0	0	0	0	0	0	0	10	0	0	6	0	--
Southern Red Mite	2	0	0	0	0	0	0	0	--	--	10	0	0	3
Sparganothis fruitworm	3	2	2	1	2	8	3	2	7	0	0	0	0	7

Source: Dr. Don Weber, OSC, 1998, unpublished

The majority of insecticides are applied on Massachusetts commercial cranberry farms by chemigation through solid set irrigation systems designed primarily for frost control. According to unpublished 1995 pesticide use statistics (source: Cranberry Institute), 83 percent of all insecticide applications were applied by sprinkler system, 14 percent by air (helicopter), and three percent by ground. Conventional hydraulic boom sprayers are very uncommon in Massachusetts cranberry production.

Table 3, above, rates insect control by compound for all the major cranberry insect pests found in Massachusetts.

The organophosphate insecticides (chlorpyrifos, acephate, azinphos-methyl, and diazinon) are the most important insecticides in Massachusetts, controlling key pests including cranberry fruitworm, Sparganothis fruitworm, brown spanworm, cutworms, blackheaded fireworm, and gypsy moth. Chlorpyrifos is the lone chemical control for cranberry weevil but is no longer the best control for Sparganothis fruitworm. Strong anecdotal evidence exists that some populations of Sparganothis fruitworm in the heart of the Massachusetts growing area are resistant to chlorpyrifos and other organophosphate insecticides (13).

With the cancellation and subsequent tolerance revocation of propargite (Omite®) in 1996, the Massachusetts cranberry growers lost their only chemical control for southern red mite. Handlers and grower leadership agreed to pursue propargite alternatives. This research was funded by the Cranberry Institute and later the USDA-CSREES PMAP program. Several alternative management tools, including pyridaben (Pyramite®), for which a Section 18 Emergency Exemption was obtained for Massachusetts growers in 1998 and 1999. Grower reports indicate excellent control with pyridaben.

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Registered insecticides, target pests, and use in Massachusetts (1, 24)

Table 4. Insecticide Use in Massachusetts, 1996 (7).

Insecticide	**% Acres treated**	**Average pounds active ingredient applied per acre per year in Massachusetts**
Acephate	18	1.28
Azinphos-methyl	26	1.75
Bt	14	--
Carbaryl	42	6.24
Chlorpyrifos	85	1.85
Diazinon	75	4.57
Pyrethrin	30	0.04
Insecticide	**Acres treated**	**Total pounds active ingredient applied in 1996 to Massachusetts cranberry acreage**
Acephate	2,555	3,270
Azinphos-methyl	3,690	6,458
Bt	1,990	--
Carbaryl	5,961	37,200
Chlorpyrifos	12,065	22,320
Diazinon	10,646	48,650
Pyrethrin	4,260	170

Acephate is used in Massachusetts to control gypsy moth, fireworms, spanworms, cutworms (including false armyworm), and Sparganothis fruitworm (acephate is not a reliable control in chlorpyrifos-resistant populations). One pound active ingredient per acre is the labeled rate with two applications permitted each season with a 75-day pre-harvest interval (this is a Orthene® 75W and 75WSP 24[c] label). It should not be applied from ten days prior to the start of bloom until all berries are set. Acephate was applied to approximately 18 percent of Massachusetts cranberry acreage in 1996. Fifteen percent of acreage was treated in 1998 (see Appendix C).

Azinphos-methyl is used to control fireworms and cranberry fruitworm. Azinphos-methyl is only rarely effective against Sparganothis fruitworm and cranberry weevil in Massachusetts. The labeled rate is ½ to one pound active ingredient per acre with a maximum of three applications per year and a 21 day pre-harvest interval. Azinphos-methyl was applied to 26 percent of Massachusetts cranberry acreage in 1996. Eighteen percent of acreage was treated in 1998.

Carbaryl is a broad-spectrum carbamate insecticide used to control fireworms, cranberry fruitworm, cutworms, gypsy moth, striped colaspis (adult), and cranberry flea beetle (adult) in Massachusetts. Several formulations are available for use at the rate of one to two pounds active ingredient per acre. There is a seven-day pre-harvest interval. Forty-six percent of Massachusetts cranberry acreage was treated with carbaryl in 1996. Fifty-one percent of acreage was treated in 1998.

Chlorpyrifos is the most important insecticide utilized by Massachusetts cranberry growers. Chlorpyrifos is also the most widely used insecticide in the United States, applied to 67 percent of the total U.S. cranberry acreage (1998). Its use increased dramatically with the cancellation of ethyl parathion in 1991. Chlorpyrifos is the only insecticide effective against cranberry weevil. Chlorpyrifos is also used to control fireworms, cranberry fruitworm, spanworms, and cutworms. Chlorpyrifos was once the preferred pesticide for control of Sparganothis fruitworm, but this is no longer true because of resistance build-up. It is applied at the rate of 1½ pounds active ingredient per acre with a maximum of two applications per year and a 60-day pre-harvest interval. Eighty-five percent of all cranberry acres in Massachusetts were treated with chlorpyrifos in 1996. Eighty-seven percent of acreage was treated in 1998.

Diazinon is used to control fireworms, cutworms, cranberry fruitworm, and cranberry girdler in Massachusetts. Diazinon is labeled for use at rates from two (fireworm) or three (fruitworm) pounds active ingredient per acre with a seven-day interval before harvest. Diazinon 14G® has a Section 24(c) Special Local Needs label in Massachusetts for control of cranberry girdler larvae applied at three pounds active ingredient per acre. In Massachusetts this granular formulation is limited to two applications per year. In Massachusetts, diazinon use ranks second below chlorpyrifos at 75 percent of acreage treated (1996). Seventy-seven percent of acreage was treated in 1998.

Tebufenozide received a national (Section 3) label in May 1999. It is an insect growth regulator, interfering with molting of Lepidopteran larvae. It is used in Massachusetts against Sparganothis fruitworm, fireworms, false armyworm, gypsy moth, and spanworms. It is applied at a rate of four ounces active ingredient per acre with a seasonal maximum of one pound active ingredient per acre per season. The pre-harvest interval is 30 days. This product is a reduced-risk insecticide. Because this is a new registration, usage information was not available at the time of this report.

Phosmet received a national label in February 2000. EPA is requesting minor label language revisions from the registrant (Gowan) regarding child-resistant packaging before the final label will be issued. Phosmet is an organophosphate insecticide. According to EPA, phosmet poses lower risks to birds compared to other organophosphate insecticides and acute and chronic risk to fish is relatively low. The registration process was initiated in 1996 with a Cranberry Institute grant ($24,000) to IR-4 (minor use pesticide registration program). Cranberry had a

tolerance of 10 ppm on the books for many years, but had never secured a registration. The new tolerance is 1.0 ppm. Imidan is labeled for the control of various lepidopteran larval pests including blackheaded fireworm, gypsy moth, and others.

Pyrethrins are botanical contact insecticides derived from the flowers of *Chrysanthemum cinerariaefolium*. Synergists are necessary to produce rapid knockdown and good kill at an economic level. The most useful combination is 1:2:3.3 parts pyrethrins, the synergists piperonyl butoxide and N-octyl bicycloheptene dicarboximide (Pyrenone Crop Spray®). Pyrenone is registered for control of numerous insects at a rate as high 12 ounces product with a zero day pre-harvest interval. It is often combined in tank mixes with other insecticides for faster and better control. Pyrethrins were used on 30 percent of Massachusetts cranberry acreage in 1996.

Cryolite® is the naturally occurring insecticidal mineral **sodium alumino-fluoride** in a dry apple pumice presscake bait for control of adult black vine weevil and strawberry root weevil registered in Massachusetts, Oregon, and Washington. The labeled rate is four to six pounds active ingredient per acre. Two applications are allowed with a 30-day pre-harvest interval. The bait is broadcast over the bed with a rotary spreader. Because this is a new registration, usage information was not available at the time of this report.

Bacillus thuringiensis* var. *kurstaki (Btk, Dipel ES®, MVP®, MVPII®, Cutlass®, Crymax®, Agree®, Mattch®) and ***Bacillus thuringiensis var. aizawai*** (Bta, Xentari®) are microbial insecticides for control of many Lepidoptera larvae. Depending on the product, Btk and Bta insecticides are used in Massachusetts cranberry for control of spanworms, gypsy moth, cutworms, and armyworms with no harvest restriction. Fourteen percent of the Massachusetts cranberry acres were treated with Bt in 1996.

Neem oil (Trilogy 70EC®) is recommended for use in cranberry at a rate of one to three percent solution in 25 to 250 gallons of water. It is used on a limited basis against southern red mite in Massachusetts. Some success against leafminer has also been reported (Hilary Sandler, personal communication, January 2000). No use data are available.

Insecticidal **Nematodes** are commercially available for use in cranberry beds for control of black vine weevil and strawberry root weevil, and cranberry girdler and are being tested for control of cranberry rootworm (not a Massachusetts pest) and soil scarabs. *Steinernema carpocapsae* are formulated for application at one to three billion per acre. One or two applications are usually sufficient. No use data are available.

Synthetic pheromones, marketed by 3M, for mating disruption of blackheaded fireworm and Sparganothis fruitworm became registered for use in 1998 and 1999, respectively. In 1999 an estimated six hundred acres were treated with Sparganothis pheromone, and ten acres were treated with BHFW pheromone (Don Weber, personal communication, January 2000). Pheromones will likely see greater use in future years and be important components in IPM, particularly with the introduction of new biorational insecticides over the next five to ten years.

Organophosphate and carbamate pesticide use

The most recent pesticide use data on cranberry in the Commonwealth of Massachusetts are found in Table 4, previous page. (See Appendix 3, page 20, for limited 1998 data). These data indicate that chlorpyrifos, diazinon, and carbaryl are the most commonly used insecticides. Combined, these three insecticides represent more than 90 percent of total insecticide use.

Table 5. Insecticide Target Pests and Potential Alternatives

Insecticide	Target Pest	Potential chemical and biological alternative
Acephate	Cranberry fruitworm, fireworms, Sparganothis, fruitworm	Tebufenozide, methoxyfenozide, spinosad, S1812, and emamectin benzoate are all Lepidopteran insecticides. Thiamethoxam has very good potential as an alternative to chlorpyrifos and azinphos-methyl against cranberry weevil. Imidacloprid is underway towards registration for the control of soil insect pests. Mycotrol (*Beauveria bassiana*), spinosad, and thiamethoxam may control tipworm (under investigation). Nematodes and Mycotrol may control cranberry girdler. Efficacy studies are ongoing. Thiamethoxam has shown good efficacy in preliminary field trials against cranberry fleabeetle.
Azinphos-methyl	Cranberry weevil, fireworms, Sparganothis, fruitworm, cranberry fruitworm, cranberry tipworm	
Carbaryl	Gypsy moth, fireworms, cutworms, striped colaspis, fleabeetle, cranberry fruitworm	
Chlorpyrifos	Cranberry weevil, fireworms, spanworms, Sparganothis fruitworm, cutworms, cranberry fruitworm	
Diazinon	Fireworms, cutworms, cranberry flea beetle, cranberry fruitworm, striped colaspis, cranberry girdler, cranberry tipworm, fleabeetle	

Target pests for insecticide use in cranberry are listed in Table 5. Key pests include Sparganothis fruitworm, cranberry weevil, and cranberry fruitworm.

Organophosphate-replacement pesticides recently registered, or progressing towards registration, include Confirm® (tebufenozide; Rohm & Haas; registered for cranberry May 1999), Intrepid® (methoxyfenozide; Rohm & Haas; IR-4 field residue trials conducted in 1999), SpinTor® or Success® (spinosad; Dow Agrosciences; IR-4 residue trials conducted in 1998 and 1999), Actara® (thiamethoxam; Novartis; IR-4 project scheduled for 2000), and Admire® (imidacloprid; Bayer; IR-4 residue trials conducted in 1997). Confirm®, SpinTor®, and Intrepid® are EPA "reduced-risk" insecticides. Actara® is considered a strong candidate for reduced-risk status (3). See Appendix A for pesticide registration status.

Several new insecticides are undergoing advanced testing for use in cranberry. They include emamectin benzoate and indoxacarb.

Emamectin benzoate (Novartis) has been shown to be effective against a wide array of lepidopteran pests in trials across the US. Although it is not a reduced-risk insecticide, emamectin benzoate is applied at extremely low rates, as low as 3.4 grams active ingredient per acre. Emamectin benzoate offers growers a good mode-of-action alternative to the organophosphate insecticides. It is moderately effective against leaf-feeding caterpillars and less effective against fruit-feeding caterpillars such as Sparganothis and cranberry fruitworms.

Indoxacarb (DuPont) is another alternative to organophosphate insecticides for lepidopteran control. Reduced-risk status from EPA is pending (3). Indoxacarb has been shown to be effective in preliminary studies at Rutgers University (Dupont, however, did not provide samples for 1999 testing). This insecticide is at least several years away from consideration for IR-4 project scheduling.

Weeds

Native and introduced plant species are considered weeds when they invade managed cranberry beds. Weeds reduce yield and quality through competition with cranberry vines for light, air, water, and nutrients needed for growth, color, and fruit development (16). Heavy stands of weeds slow harvest operations, and some weeds directly damage fruit skin during harvest (9). One weed (dodder) is directly parasitic on the cranberry plant.

Weeds are numerous and varied in Massachusetts beds. University of Massachusetts weed scientists rank dodder [*Cuscuta gronovii* (Willd.)], bristly and prickly dewberry [*Rubus hispidus and Rubus flagellaris*, respectively], glaucous greenbriar [*Smilax glauca*], wild bean [*Apios americana*], and poison ivy [*Toxicodendron radicans* (L.)] as the Commonwealth's most difficult to control and costly weed pests (24).

Common greenbriar [*Smilax rotundifolia*], yellow loosestrife [*Lysimachia terrestris* (L.)], narrow-leafed goldenrod [*Euthamia tenuifolia*], asters [*Aster spp.*], and blackberry [*Rubus allegheniensis*] are ranked slightly lower as "Priority Two" weed species.

"Priority Three" weed species include chokeberry [*Pyrus melanocarpa*], sheep laurel [*Kalmia angustifolia*], leatherleaf [*Chamaedaphne calyculata*], sedges, rushes [*Juncus spp.*], and perennial grasses.

Mosses [*Polytrichum spp*], red maple and other trees, joe-pye weed [*Euphatorium dubium*], cinquefoil [*Potentilla Canadensis, P. simplex*], meadowsweet and hardhack [*Spirea latifolia and S. tomentosa*, respectively], pitchfork [*Bidens frondosa*], ragweed [*Ambrosia artemisiifolia*] fireweed [*erechtites hieracifolia*], white violet [*Viola lanceolata*], annual grass, ferns, clover and vetch, and other weeds are of least concern and ranked as "Priority Four" weeds.

Woody and herbaceous broadleaf perennial weeds may also be found in the interior and marginal ditches as well as on ditch banks. Controlling weeds on the ditch bank may be useful in reducing the colonization of these weeds onto the bed itself.

Registered herbicides, target pests, and use in Massachusetts (1, 24)

Table 6. Herbicde use in Massachusetts, 1996 (7).

Herbicide	% Acres treated	Average pounds active ingredient applied per acre per year in Massachusetts
Dichlobenil	67	2.05
Glyphosate	80	0.50
Naprpamide	30	6.91
Norflurazon	4	3.07
Sethoxydim	6	0.29

	Acres treated	Total pounds active ingredient applied in 1996 to Massachusetts cranberry acreage
Dichlobenil	9,510	19,500
Glyphosate	11,360	5,680
Napropamide	4,260	29,425
Norflurazon	570	1,740
Sethoxydim	850	245

Hand weeding is used extensively in Massachusetts, but is not always economically feasible, particularly given the current unfavorable cranberry market conditions. Commercial herbicides are very important tools for all cranberry growers, including those in Massachusetts (see Table 6). Dr. Susan Rice Mahr, University of Wisconsin, estimated that the loss of key herbicides in cranberry would have *triple* the economic impact of loss of key insecticides in an economic study published in 1994 (18).

2,4-D formulations are registered for control of numerous annual and perennial broadleaf weeds. The granular formulation should be applied in early spring after removal of the winter flood at ten to twenty pounds product per acre. Weedar 64®, a liquid 2,4-D formulation, is applied as a wipe in a ratio of 1:2 in water. One application is allowed per season. In 1996, 2-4,D was applied to an insignificant percent of Massachusetts acreage. This may be due to the crop injury sometimes associated with the use of 2-4,D. It is recommended for the control of sedges and leatherleaf, although other good herbicide options exist.

Clethodim is a selective postemergence herbicide used to control annual and perennial grasses. Clethodim has no food tolerance, thus may only be applied to cranberry beds that will not bear fruit for at least twelve months. Herbicide rate will depend on the life habit of the weed as well as species. Clethodim is labeled at a rate of 0.095-0.251 pound active ingredient per acre along with a crop oil concentrate. Clethodim is a current IR-4 project. Submission of the petition for tolerance is scheduled for 1999 with EPA review scheduled for 2000.

Clopyralid is a selective, postemergence, broadleaf herbicide used to control wild bean, narrow-leaved goldenrod, asters, clover, ragweed, pitchforks, and other weeds. It received a Section 18 label for use in cranberries in 1999 in the states of Massachusetts, New Jersey, Oregon, Washington, and Wisconsin. It is applied by either spot spray or wiper application at a rate of 0.09375 to 0.25 pound active ingredient per acre. Crop damage will result if application precision is inadequate. 1998 preliminary data suggests approximately ten percent of the acreage received clopyralid applications.

Dichlobenil is the single most important herbicide used in Massachusetts cranberry. It is used as a pre-emergence herbicide to control numerous perennial and annual, broadleaved and grassy weeds, including dodder, yellow loosestrife, narrow-leafed goldenrod, asters, rushes, and sedges. Dichlobenil is applied in early spring or post-harvest, although fall application efficacy has not been documented (6). Multiple applications are allowed with no more than four pounds active ingredient per acre allowed in a twelve-month period. Temporary reddening of cranberry plants may occur with late spring applications or on sandy beds. Dichlobenil is not recommended on beds less than three years old. Diclobenil was used on 67 percent of Massachusetts cranberry acres in 1996. Sixty-five percent of acreage was treated in 1998.

Iron sulfate is a selective post-emergence herbicide for control of sphagnum moss, cinquefoil, asters, and ferns at the rate

of two to three ounces of product (twenty percent active ingredient) per acre. Granules are applied by hand. The University of Massachusetts recommends that iron sulfate should not be applied to new beds or mature vines sanded within 18 months (24). Although 1996 use data do not exist from Massachusetts, 1998 data indicate that iron sulfate use was virtually nonexistent.

Glyphosate is a non-selective, non-residual herbicide, used to control annual and perennial grasses and broadleaf weeds by wiper application or cut-stem treatment only. It is recommended against dewberry, greenbriar, yellow loosestrife, brambles, poison ivy (vine damage possible because of low-growing nature of poison ivy), leatherleaf, spireas, and other tall woody or herbaceous weeds. The University of Massachusetts recommends a ten to twenty percent solution applied above the crop by wick or other wiper applicator anytime weeds are present and no later than thirty days before harvest. Repeat or spot treatment may be necessary where weeds were initially dense or to eliminate weeds that were missed (24). In 1999, application of glyphosate (RoundUp®) to non-flooded ditches by sprayer was added to the label. Glyphosate was applied as a spot treatment on an unknown proportion of approximately eighty percent of Massachusetts cranberry acreage in 1996.

Napropamide is used for the pre-emergence control of sedges, rushes, and wild bean (in combination with dichlobenil) at the rate of up to nine pounds active ingredient per acre. Up to three pounds active ingredient per acre may be applied on newly planted beds. It does not control established weeds. Napropamide was used on 30 percent of the Massachusetts cranberry acres in 1996. Acreage treated was unchanged in 1998.

Norflurazon is a soil-applied, pre-emergence herbicide recommended for the control of annual and perennial grasses, sedges, and rushes. Norflurazon is applied as a single ground or aerial application at four to eight pounds active ingredient per acre in the early spring after removal of winter flood and before weed growth resumes, or in the fall after harvest at least two weeks before winter flood. Application rates vary depending on the weed species present, soil type, and cranberry vine health status. Norflurazon is limited to one application per twelve months, not to exceed four pounds active ingredient in a newly planted bed or eight pounds per acre for established beds. Phytotoxicity is sometimes associated with norflurazon use, particularly due to ponding due to poor drainage after heavy rains. Three percent of the Massachusetts cranberry acres were treated with norflurazon in 1996.

Pronamide (propyzamide) is a pre-emergence herbicide that received a Section 18 label in Massachusetts in 1998 and 1999 for the control of dodder. One application of one-half pound active ingredient per acre was recommended (the 2000 Section 18 submission requests two applications for a total of one pound active ingredient per acre). According to 1998 Massachusetts Department of Food and Agriculture statistics, pronamide was used on 193 acres in 1998 and 3,330 acres in 1999 (Hilary Sandler, personal communication, January 2000).

Simazine is a pre-emergence herbicide registered for control of most annual grasses and broadleaf weeds. Massachusetts growers are allowed to apply up to four pounds active ingredient per acre. Although labeled for fall use, the University of Massachusetts does not recommend it (24). Simazine is used very sparingly in Massachusetts. In 1996 simazine was used on an insignificant number of acres.

Sethoxydim is a postemergence herbicide registered for the control of annual and perennial grasses. It should be applied to actively growing weeds at no more than 0.45 pounds active ingredient per acre with a seasonal maximum of nine pounds. Crop oil concentrate or Dash HC® must be used as a spray adjuvant. Sethoxydim has a 60-day pre-harvest interval. In 1996 six percent of Massachusetts acreage was treated with sethoxydim.

Salt (NaCl) is recommended as a spot treatment for selected weeds including wild bean and rushes at the rate of one pound per gallon in a spray solution and one to three teaspoons per crown, respectively. No use data for salt exist. Salt is a tolerance and registration exempt material. Cranberry plants show an increased sensitivity to salt after a late water flood.

Diseases

Table 7. Cranberry fruit rot organisms (21).

Field rot organisms	Storage rot organisms
Coleophoma empetri	*Allantophomopsis lycopodina*
Colletotrichum acutatum	*Allantophomopsis cytisporea*
Colletotrichum gloeosporiodes	*Coleophoma empetri*
Fusicoccum putrefaciens	*Phyllosticta elongata*
Monilinia oxycocci	*Physalospora vaccinii*
Phomopsis vaccinii	*Strasseria geniculata*
Phyllosticta vaccinii	
Physalospora vaccinii	

Fruit rots, all of which are caused by fungi, are considered the most yield-limiting disease problem in Massachusetts cranberry production (21). Fruit-rotting fungi cause cranberries to rot, either before harvest (collectively called field rots) or after harvest (storage rots). Upright dieback, *Phytophthora* root rot, and fairy ring are also important economic diseases in Massachusetts.

Fruit rot is a serious problem every year in Massachusetts and New Jersey (6). Fruit rot is caused by as many as fifteen different fungal organisms (21). Causal agents of fruit rot in cranberry are listed in Table 7.

Cranberry fruit-rotting organisms appear to be indigenous to cranberry beds, overwintering each year in older woody plant tissues or as latent infections in living leaves, depending on the organism. Infected fruit is believed to be an insignificant source of inoculum because the great majority of fruit is removed from the beds prior to the formation of any fungal fruiting structure development. Also, tests have shown little transmission of rot from infected to healthy fruit while in storage. Fruit rot fungi appear to infect the fruit during late bloom and early fruit set, as evidenced by fungicide application timing tests conducted in New Jersey and Massachusetts (21).

According to Oudemans et al. (21), loss of registered fungicides without replacement could lead to nearly complete crop losses in as little as five years in Massachusetts. Aside from fungicides, University of Massachusetts researchers recommend several cultural practices to reduce fruit rot incidence (24). These practices include use of sanding, late

water, removal of trash at harvest (cranberry leaves, stems, and fruit left behind after harvest) using post-harvest floods, and planting resistant varieties. Late water reduces fruit rot by disrupting the life cycles of rot-inducing fungi. Trash removal reduces sources of fungal inoculum. Fruit-rot resistant varieties have been identified, however crop yield and yield consistency research is still needed before solid recommendations can be made. Conversely, lush vines (from over-fertilization) will compound fruit rot troubles.

Upright dieback, caused by *Phomopsis vaccinii*, is common in Massachusetts (4). The disease develops during summer when vines are stressed by hot weather, drought, or too much moisture and may be minimized by proper irrigation management in July and August (24). Infection occurs at bud break but symptoms do not appear until plants are stressed. Infected uprights appear scattered among healthy vines and take on a yellowish cast. They eventually turn orange, bronze, or brown and die (4).

Phytophthora root rot affects plants in poorly drained low areas where water accumulates (5). A number of different *Phytophthora* species are pathogenic in cranberry including *P. cinnamomi, P. dreschleri*, and *P. megasperma* (19). *Phytophthora cinnamomi* is considered to be the principal economically significant species. Phytophthora root rot typically causes a reduction in root mass, stunting, and eventual death of the cranberry plant. The symptoms of root rot appear as plants in various stages of general decline. Chronic root rot infections can lead to symptoms of nutrient deficiencies and reduced drought tolerance that will result in decreased productivity (19).

Root rot may be controlled with a combination of drainage improvements, sanding low areas where water tends to accumulate, fertilizing plants on the edge of affected areas to promote root growth, or through fumigation and subsequent replanting (24). Mefenoxam will also control selected Phytophthora species.

A disease of unknown identity causes **fairy ring**, although it is thought to be a Basidiomycete (20). Its infection cycle and rate of spread is poorly understood at this time. According to Oudemans (20) fairy ring is an increasing problem in Massachusetts, although still somewhat sporadic in occurrence and severity (24). Fairy ring can be spread from one bed to another through transport of vines uprooted and carried on equipment during harvest (24). Damage appears to be most severe during periods of water stress.

Registered fungicides, target pests, and use in Massachusetts (1, 24)

Table 8. Fungicide use in Massachusetts, 1996 (7).

Fungicide	**% Acres Treated**	**Average pounds active ingredient applied per acre per year in Massachusetts**
Chlorothalonil	77	6.98
Copper hydroxide	22	5.88
Ferbam	12	4.60
EDBC fungicides	45	4.20
Metalaxyl	16	1.54
	Acres Treated	**Total pounds active ingredient applied in 1996 to Massachusetts cranberry acreage**

Chlorothalonil	10,930	76,290
Coppy hydroxide	3,123	18,360
Ferbam	1,703	7,835
EDBC fungicides	6,388	26,830
Metalaxyl	2,271	3,500

Most of the fungicides available for use on cranberry are protectants that are effective only on the plant surface, although a few have limited systemic activity.

Chlorothalonil is a widely used broad-spectrum fungicide registered for fruit rot and upright dieback at three to five-and-one-quarter pounds active ingredient per acre. Applications should be made at early (ten to twenty percent) bloom and repeated at ten to fourteen day intervals for fruit rot control. In Massachusetts there is a Section 24(c) registration for application at budbreak (April 25 through May 15) for control of upright dieback. Chlorothalonil cannot be applied more than three times per season, nor within 50 days of harvest. It may be applied through sprinkler irrigation equipment, but not to flooded beds, and irrigation water must not be released from beds for at least three days following application. Chlorothalonil was applied to 77 percent of Massachusetts cranberry acreage in 1996 (see Table 8). Seventy-six percent of acreage was treated in 1998.

Copper compounds, including copper hydroxide (e.g., Kocide®, Champ®, and Champion®), metallic copper (Copper-Count-N®), and copper sulfate (Top-Cop®), are registered for control of fruit rot and upright dieback disease in Massachusetts. Copper fungicides are tolerance exempt and there is a zero day pre-harvest interval. Champ® is labeled for the control of upright dieback as a pre-bloom application at the rate of three pounds active ingredient per acre. Copper hydroxide products and copper sulfate are recommended for control of fruit rot beginning at mid-bloom followed by one or two applications at ten to fourteen day intervals. Copper hydroxide products are recommended at the rate of three to five pounds active ingredient per acre per application, depending on product. Top-Cop® is recommended at the rate of one-quarter pound active ingredient per acre per application. Continued use of copper sprays may cause some plant injury. Copper-based fungicides were applied to 22 percent of the cranberry crop in Massachusetts in 1996.

Ferbam is a protective fungicide registered for control of fruit rots and fairy ring (24). For fruit rot, applications of 4.5 pounds active ingredient per acre should be made early bloom and repeated at fourteen-day intervals, with a maximum of five applications per year. According to the label, ferbam should not be applied "…within 28 days from mid-bloom". This confusing label statement has been interpreted by University of Massachusetts researchers as a pre-harvest interval of "28 days after mid-bloom" or a PHI of 50 days. UCB has applied to EPA to change the PHI to 50 days and expect the new PHI to become effective towards the end of the 2000 growing season. For fairy ring control, ferbam is applied at the rate of 0.07 pound active ingredient per *square foot* of infected bed. Ferbam applications should be made immediately after harvest. However, there is a Section 24(c) registration in Massachusetts for an application in June or July for control of fairy ring. Twelve percent of the cranberry acres in Massachusetts were treated with ferbam in 1996. Twenty-eight percent of acreage was treated in 1998.

Mancozeb (a coordination product of zinc ion and manganese ethylene-bisdithiocarbamate) and **maneb** (manganese ethylene-bisdithiocarbamate) are broad-spectrum **e**thylene-**b**is**d**ithio**c**arbamate (EBDC) protective fungicides registered to control fruit rots on cranberry. Mancozeb is applied at 2.25 to 4.8 pounds active ingredient per acre per

application, depending on product and rate selected. Mancozeb applications should begin at mid-bloom and be repeated at seven to ten day intervals, with a maximum of 14.2 to 14.4 pounds active ingredient per acre per season, again depending on product selected. Maneb is applied at 2.4 to 4.8 pounds active ingredient per acre in a similar fashion with a maximum of 14.4 pounds active ingredient per acre per season. If more than one EDBC product is used in the same season the total poundage of active ingredient per acre may not exceed any one of the specified individual maximum allowable active ingredient seasonal limits. There is a 30-day pre-harvest interval. Forty-five percent of the Massachusetts cranberry crop was treated with EDBC fungicides in 1996. Twenty-eight percent of acreage was treated in 1998.

Metalaxyl (Ridomil®) and **mefenoxam** (Ridomil Gold®) are registered for control of soil-borne diseases caused by *Phytophthora*. However, metalaxyl is no longer marketed to the cranberry market by the registrant Novartis. Mefenoxam will eventually replace metalaxyl use in Massachusetts as stocks of metalaxyl are depleted. Metalaxyl is applied at the rate of one to 1.75 pound active ingredient per acre per application with a maximum of three applications per season. The first application is recommended in the fall after harvest, the second in the following spring, and the third 45 days before harvest. No more than 5.25 pounds active ingredient per acre may be applied in a single season. Sixteen percent of the acreage in Massachusetts was treated with metalaxyl in 1996.

Mefenoxam is recommended at the rate of 0.48 to 0.85 pound active ingredient per acre per application. Like metalaxyl, the first application is recommended in the fall after harvest, the second in the following spring, and the third 45 days before harvest. No more than 2.55 pounds active ingredient per acre may be applied in a single season.

Outlook for new registrations

The Cranberry Institute works closely with both the Office of IR-4 and EPA to develop new registrations for cranberry in the United States. The Institute cooperates with the Pest Management Regulatory Agency of Health Canada and IR-4 to develop new registrations for cranberry in Canada.

Residue data from five trials are required for inclusion in the petition for the establishment of a food tolerance in the U.S. – two trial locations in IR-4 Zone 1 (trials are typically located in Maine, Massachusetts, or New Jersey), two locations in IR-4 Zone 5 (trials are typically located in Wisconsin), and one trial in IR-4 Zone 12 (trials are typically located in Oregon or Washington). Pesticide tolerances for cranberry are listed in Appendix B.

Health Canada requires three residue trials to establish a food tolerance; two from Zone 12 (WA, OR, or BC), and one from Zone 5 (Québec or Wisconsin). Health Canada has a history of accepting residue data developed in the U.S. and the cranberry commodity is working diligently to enable simultaneous registrations of new materials (e.g., spinosad and azoxystrobin).

The Cranberry Institute has also provided considerable monetary support for the development of new pesticide registrations, particularly reduced-risk pesticides. Since 1996, the Institute has granted $275,000 to industry and Land Grant university researchers in the major cranberry-producing states for new pesticide screening. Of this sum, $154,000 was for insecticide screening specifically aimed at reducing OP reliance, $63,000 was spent on fungicide screening (predominantly for fruit rot), and $58,000 was allocated towards herbicide screening. Other funding agencies have also contributed generously towards new pesticide testing and registration. They include Ocean Spray Cranberries, Inc., the Wisconsin Cranberry Board, the New Jersey Blueberry and Cranberry Research Council, the Cape Cod Cranberry Growers' Association, the [MA] Cranberry Research Foundation, the Washington State Pesticide Registration Commission,

the Washington Cranberry Commission, the University of Wisconsin Pesticide Use Risk Reduction Program, and the Oregon Cranberry Growers' Association (12). Several University of Massachusetts researchers have received funding for pesticide screening from the Cranberry Institute, including Dr. Anne Averill, Dr. Frank Caruso, Dr. Tom Bewick, and Ms. Hilary Sandler.

In addition, the Cranberry Institute has spearheaded a very successful national fungicide screening campaign with support ($39,000, 1997-9) solicited from registrants (Rohm & Haas, Zeneca, and Novartis). Fenbuconazole, cyprodinil, fludioxinil, trifloxystrobin, kresoxim-methyl, azoxystrobin, and BAS500 are among the fungicides tested in this five-location, multiple-year project. Dr. Frank Caruso, University of Massachusetts, has been an active cooperator.

A quick glimpse of insecticides undergoing registration and evaluation is given in Section 11 of this document. To further expand on these and other pesticides, a short detail of selected pesticides undergoing registration follows.

Spinosad is an EPA reduced-risk insecticide and is the first active ingredient in a new class of biological-based insect control products. Spinosad is a fermentation product of an actinomycete. It has low human and environmental risk, excellent efficacy against target pests (Sparganothis fruitworm, gypsy moth, spanworms, cranberry fruitworm, and possibly cranberry tipworm), and fits well into IPM systems. Spinosad has been shown to be safe to bees during bloom if used with caution.

Azoxystrobin is a novel EPA reduced-risk strobilurin fungicide whose chemistry is based on naturally-occurring fungicides derived from certain wood-decaying mushrooms. It has an excellent environmental profile; it is not persistent, does not leach, and has low ecological risk to birds, mammals, and fish. It has provided consistently good control of fruit rot in New Jersey and Massachusetts trials (1997-9).

Thiamethoxam (Novartis) is a second-generation neonicotinoid insecticide that controls a wide spectrum of sucking and chewing pests at very low use rates. It was very effective against cranberry weevil in 1999 Massachusetts tests (Dr. Don Weber, Ocean Spray Cranberries, Inc.). It also has performed well against cranberry flea beetle. It is a strong candidate for EPA reduced-risk status (3). IR-4 has scheduled thiamethoxam project initiation for 2000.

Methoxyfenozide (Rohm & Haas) is an insect growth regulator, which, like tebufenozide, interferes with insect molting. It is a reduced-risk pesticide. In field trials methoxyfenozide was more effective than tebufenozide on key cranberry pests, including Sparganothis and cranberry fruitworm.

In addition to pesticides, the cranberry industry is evaluating and researching many other pest management approaches including biological and cultural controls. Biological or cultural alternatives being investigated include indigenous entomopathogenic nematodes, *Trichogramma* parasitic wasps, and mycoinsecticides (e.g. *Metarhizium* and *Beauveria*) to control black vine weevil and cranberry girdler. Mycoherbicides, such as *Alternaria* for the control of dodder, and water-management options (e.g., post-harvest flood, later winter floods) are also being investigated.

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Appendix A

New pesticide registration status (March 2000)

INSECTICIDES			
Product	**Target Pest**	**Registrant**	**Comments**
Imidacloprid *Admire*	Soil grubs, cranberry rootworm	Bayer	Petition submission to Agency in 2000.
Spinosad *SpinTor or Success*	Fruitworms, spanworms, Sparganothis, other leps	Dow Agrosciences	Study initiated in 1998. Registration hoped for 2001.
Methoxyfenozide *Intrepid*	Fireworms, Sparganothis other leps	Rohm & Haas	Study initiated in 1999 in MA, NJ, WI (2 locations), and OR.

FUNGICIDES			
Product	**Target Pest**	**Registrant**	**Comments**
Fosetyl-Aluminum *Aliette*	Phytophthora	Rhone-Poulenc	Petition submission to EPA promised by early 2000. EPA review scheduled for April-June 2000.

Fenbuconazole *Indar*	Fruit rots, cottonball	Rohm & Haas	Petition to be submitted to Agency in first half of 2000. EPA to review July-September 2000.
Azoxystrobin *Abound or Quadris*	Fruit rots, cottonball	Zeneca	1999 field studies.

HERBICIDES			
Product	**Target Pest**	**Registrant**	**Comments**
Pronamide [Propyzamide] *Kerb*	Dodder	Rohm & Haas	The petition will be submitted to EPA by December 1999. EPA has cancelled their review previously scheduled for September 2000. It may be reviewed in 2001.
Clopyralid *Stinger*	Wild bean, asters, beggar-ticks, white clover	Dow Agrosciences	IR-4 hopes to submit petition from 1999 study to EPA in 2000. EPA may schedule review in 2001.
Clethodim *Select*	Annual and some perennial grasses	Valent	Petition submitted to EPA December 1999. EPA review scheduled for June 2000.
RH-123652 Thiazopyr *Visor*	Sedges, dodder, and some grasses	Rohm & Haas	Petition may be ready for Agency submission in 2000. However, cranberry label dependent on alfalfa registration (due to production and distribution economics). Alfalfa registration not expected for several years.

PETITIONS SUBMITTED TO EPA – AWAITING A DECISION			
Product	**Target Pest**	**Registrant**	**Comments**
Pyridaben *Pyramite*	Southern red mite	BASF	Submitted to EPA May 6, 1999. EPA scheduled to review petition March 2000.
Propiconazole *Orbit*	Cottonball	Novartis	Petition submitted to EPA June 25, 1997. There is a *chance* that the Agency may take this up spring 2000. Propiconazole is labeled in Canada as Topas.

Appendix B

Pesticide tolerances for cranberry (March 2000)

Common name	Trade name(s)	Registration status	Tolerance (ppm)	Tolerance status
2,4-D	Weedar	Active	0.5	Active
Acephate	Orthene	Active	0.5	Active
Anilazine	Dyrene	Cancelled 1990	10.0	Tolerance revoked 1/25/99
Azinphos-methyl	Guthion	Active	0.5	Active (tolerance reassessment from 2.0 ppm effective 1/1/00
Captafol	Difolatan	Cancelled 1988	8.0	Tolerance to be revoked 10/19/99
Captan	Captan	Cancelled 1989	25.0	Tolerance revoked 8/92
Carbaryl	Sevin	Active	10.0	Active
Carbofuran	Furadan	Cancelled 1999	0.5	Active
Chlorothalonil	Bravo, Terranil	Active	5.0	Active
Chlorpropham	ChloroIPC, Furloe	Cancelled 1990	0.3	Tolerance revoked 1/25/99
Chlorpyrifos	Lorsban	Active	1.0	Active
Clopyralid	Stinger	Section 18 label in MA, OR, WA, WI, and NJ in 1999	2.0	Time-limited tolerance expires 7/31/01
Cryolite	Cryolite	Section 3 registration, but only registered for use in the states of OR, WA, and MA	7.0	Active
Dalapon	Dowpon	Cancelled 1990	5.0	Tolerance revoked 5/1/99
Diazinon	Diazinon	Active	0.5	Active
Dichlobenil	Casoron	Active	0.10	Active
Ethephon	Ethrel	Cancelled, but undergoing reregistration through IR-4	5.0	
Ethyl parathion	Parathion	Cancelled 1991	1.0	Import tolerance
Ferbam	Carbamate	Active	7.0	Active
Folpet	Folpet	Cancelled 1990	25.0	Import tolerance
Glyphosate	Roundup, Rodeo	Active	0.2	Active
Imidacloprid	Admire	NJ Section 18, 1999	0.5	Time-limited tolerance expires 6/1/01

Malathion	Malathion	Cancelled 1992	8.0	Active
Maleic Hydrazide	Royal MH	Cancelled 1990	15.0	Tolerance revoked 6/24/96
Mancozeb	Dithane	Active	7.0	Active
Maneb	Maneb	Active	7.0	Active
Mefenoxam	Ridomil Gold	Active	4.0	Active
Methoxychlor	Methoxychlor	Cancelled 1996	14.0	Active
Napropamide	Devrinol	Active	0.1	Active
Naptalam	Alanap	Cancelled 1990	0.1	Tolerance revoked 1/25/99
Norflurazon	Evital	Active	0.1	Active
Phosmet	Imidan	Active	1.0	Active
Propargite	Omite	Cancelled 1996	10.0	Tolerance 10/19/99
Propiconazole	Orbit	WI and WA Section 18, 1999	1.0	Time-limited tolerance expires 7/31/00
Propyzamide	Kerb	MA and NJ Section 18, 1999	0.05	Time-limited tolerance expires 12/31/01
Pyridaben	Pyramite	Section 3 registration pending	0.75	Time-limited tolerance expired 12/31/99
Sethoxydim	Poast	Active	2.0	Active
Simazine	Princep	Active	0.25	Active
Spinosad	SpinTor, Success	MA Section 18, 1999	0.02	Time-limited tolerance expires 6/1/01
Tebufenozide	Confirm	Active	1.0	Active
Triforine	Funginex	No longer produced. WI 24c label expired 7/25/99	0.1	Active
Zineb	Zineb	Cancelled 1990	7.0	Tolerance revoked 12/31/92
Ziram	Ziram	Cancelled 1990	7.0	Tolerance revoked

Appendix C

Regional percent of acreage treated with major cranberry pesticides in 1998. Source: Cranberry Institute (unpublished).

Percent of acreage treated with major cranberry pesticides by state											
State	**Total cranberry acreage found in region**	**Diazinon**	**Chlorpyrifos**	**Azinphos-methyl**	**Acephate**	**Carbaryl**	**Chlorthalonil**	**Diclobenil**	**Mancozeb**	**Ferbam**	**Napropamide**
		Percent of acreage treated									

WI	14,211	70.0	57.2	66.4	24.9	36.8	7.7	60.6	11.3	0.0	32.2
MA	**13,370**	**77.4**	**86.8**	**17.7**	**14.9**	**51.0**	**76.2**	**64.5**	**27.7**	**28.4**	**29.7**
NJ	3,795	1.3	71.2	17.4	2.2	5.9	95.0	0.0	95.0	75.0	13.1
OR	2,121	60.6	29.3	3.1	11.7	7.7	83.8	58.5	26.9	16.3	28.1
WA	1,617	73.8	33.1	15.0	66.9	5.6	56.2	67.4	77.6	12.3	23.5
US	35,114	65.1	67.2	36.5	19.8	35.7	50.1	44.3	30.6	20.5	28.6