Crop Profile for Blueberries (Wild) in Maine

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General Production Information

- The State of Maine produces 98% of the wild blueberries in the United States harvested from 30,000 acres and has 30,000 additional acres of land non-bearing each year.
- The five year average production in Maine is 64.5 million pounds.
- Most (99%) of the crop is processed by freezing by nine processors in Maine, so value is added to the product within the State of $70 million annually.
- During the harvest approximately 8,000 people are employed, providing needed income to economically challenged areas in Maine.

Production Regions

Maine is the largest producer of wild blueberries in the world (Yarborough, 1997b). Wild blueberries are grown on 60,000 acres in Maine (Yarborough, 1996c). There are approximately 1,000 acres of wild blueberries in New Hampshire and 500 acres in Massachusetts. Maine produces approximately 25 percent of all blueberries (wild and cultivated) in North America. Twenty five percent of the North American crop, as wild blueberries, are produced in the Canadian provinces of Nova Scotia, Québec, New Brunswick, Prince Edward Island and Newfoundland. The remaining 50 percent of the crop are cultivated blueberries produced in Michigan, New Jersey, North Carolina British Columbia, Washington, Oregon, Georgia, Arkansas and other states.

Cultural Practices

Wild blueberries are grown on fields that have been developed from native plants that occur naturally in

the under story of the forest. Because of the pruning practices employed, only half of the acres are available to be harvested every year.

Pruning
Until recently, most commercial blueberry fields have been pruned by fire with straw or oil burners. Repeatedly burning fields for a number of years has resulted in a decline in production associated with the destruction of the organic pad and exposure of the rhizomes. Mechanical mowing will produce equivalent yields without depleting the organic pad. Mowing is less costly than using oil or straw and has been widely adopted by blueberry growers. Burning does reduce certain insects and diseases that reside in the leaf litter. Favorable weather conditions could lead to periodic outbreaks of these pests in mowed fields, which would require periodic burning to reduce populations.

Pollination
Blueberries require insect pollination, and the use of honeybees will increase the fruit set and seed number resulting in higher yields. Current recommendations are for two to four hives per acre depending on the field size and location. More than 50,000 hives are imported into Maine for blueberry pollination (Jadczak, 1998).

Fertilization
Fertilization recommendations used to be based on noting stem height and leaf spotting and applying nitrogen from urea. Growers now use leaf tissue samples to determine if fertilizer is needed since standards of satisfactory levels of nutrients in leaf tissue have been developed (Smagula and Yarborough, 1999). Blueberries have responded well to fertilization, resulting in more rapid establishment, greater plant growth and higher yields (Yarborough and Smagula, 1993).

Soil Acidity
The optimum acidity level, or pH, for wild blueberry soils is 4.5. The acidity of these soils should be kept near this optimal level. Soil testing will identify if treatment with sulfur (to lower pH level and increase soil acidity), or lime (to increase the pH level and lower soil acidity) is needed (Smagula and Yarborough, 1999).

Irrigation
Irrigation will result in an increase in the number and weight of berries, if moisture is limiting. Irrigation provided in the non-bearing year increases bud formation, which could increase yield in the crop year. Currently, irrigation is used commercially by a few growers during the crop year, but irrigating non-bearing fields is being further evaluated.

Propagation
Plants for establishing new blueberry fields have been produced from softwood cuttings of select clones and from seed obtained by pollinating flowers of an outstanding clone with pollen from an equally good clone. Micro propagation techniques have been developed for the wild blueberry. Plants are now commercially available (Yarborough, 1996e). Tissue culture propagated plants exhibit the spreading

growth habit of seedlings along with the uniform productivity characteristics of rooted cuttings (Frett and Smagula, 1983). Mulching has been extremely beneficial for increasing survival of planted wild blueberries and encouraging their lateral spread through rhizome growth (Degomez and Smagula, 1990). Using high yielding clones to fill in existing fields will make the current management practices more efficient and result in higher yields at a lower cost per pound.

Botanical Classification

All blueberries and cranberries are in the Ericaceae plant family or Heath family. There are several species of wild blueberries found in Maine. Blueberries and cranberries are in the genus *Vaccinium*. The most abundant wild blueberry in Maine is known as the low sweet blueberry and has the species name *angustifolium*. It has smooth stems that vary in color from tan to red, and plants vary in height from four to 15 inches. Leaves of *angustifolium* are dark green, smooth and sometimes have slightly toothed edges. Blossoms are bell-shaped and usually white or pinkish-white. The fruit is usually dark blue, but it is colored with a waxy coating or bloom that gives the fruit a light, powder blue appearance.

The next common variety is the sour top blue-berry, *Vaccinium myrtilloides*. This species tends to be more prevalent in mountains or hilly areas. Stems and leaves are covered with tiny hairs and are more branched than are those of the low sweet. Sour top stems grow six to 24 inches tall. Leaves are light green, hairy on the underside and tend to curl down on the edges, earning its other name, velvet leaf blueberry. Berries are usually smaller and less sweet than the low sweet. They are bright blue and covered with a waxy coating

Insect Pests

Blueberry Maggot (*Rhagoletis mendax* Curran) or blueberry fruit fly, is the major insect pest of blueberries in Maine (Dill, 1987) and has been the subject of considerable research since the 1920's (Lathrop and Nickels, 1931, 1932; Patch and Woods, 1922) The first flies begin to emerge from the soil in late June or early July. Flies continue to emerge until early August. After emerging, the flies, which live for about 30 days, spend 1 to 2 weeks resting and feeding on dew, insect honeydew, and secretions on foliage. During this resting and nourishment period, the adult females become sexually mature and mates. Once mated, the females seek ripening blueberries in which to lay eggs. Each female fly may lay up to 100 eggs in a period of 15 to 25 days.

Blueberry Flea Beetle *(Atica sylvia* Malloch) is a major pest on the wild blueberry (Collins et al. 1995a). The immature flea beetle is a black larva, 3/8-inch long when fully grown. The adult beetle is oval-shaped, shiny, coppery bronze, and less than 1/4-inch long. A common characteristic of flea beetle adults is their ability to jump suddenly when disturbed. The blueberry flea beetle spends the winter as an egg in the litter near the base of the blueberry plants. Soon after the blueberry plants begin to develop in the spring (about mid-May), the eggs hatch and larvae start feeding on the foliage. The last larvae finish feeding in late June, and fully grown larvae move into the soil, where they remain as pupae. Adults begin to emerge in about two weeks and continue feeding on blueberry plants through late summer. Eggs are laid in July and August. Infestations of blueberry flea beetle may be confined to isolated areas or damage may be widespread. Large numbers of flea beetles may completely defoliate large areas in both crop and pruned fields.

Blueberry Spanworm *(Itame argillacearia* Packard) is a major pest of the wild blueberry (Collins et al. 1995c; Forsythe and Flanders, 1982) . Young, caterpillar larvae are about 1/8-inch long and dark gray to black with a series of white bands encircling the body. Fully grown larvae are about 3/4-inch long and are yellowish-orange with rows of black spots that may look like continuous black strips running the length of the body. Spanworm larvae often appear on plants in large numbers at night. During the day, many larvae find shelter in the litter at the base of the plants.

An easily recognizable characteristic of this larva is its "looping" walk. Pupae, which are rarely seen, are found in the litter and are dark brown or black.

Adult spanworms are delicate, light gray moths. They have a wingspan of about one-inch. They are especially common in weedy areas or wind breaks and will fly readily when disturbed.

The blueberry spanworm spends the winter as an egg in the litter near the base of blueberry plants. Eggs may begin to hatch and larvae start feeding on developing buds as early as April and continue to feed on blueberry leaves, buds, and blossoms until late June or early July. Fully grown larvae move into the litter, where they remain as pupae. At this stage and time, they do not feed. Moths begin to emerge in about two weeks.

Adults can first be seen in the field in early to mid-June. Some moths may still be present until late July. Eggs laid by the moths do not hatch until the following spring. The first sign of a severe infestation in a pruned field is an area devoid of or with slower developing plants; look for signs of feeding on developing shoots at ground level or below the soil surface.

Infestations of blueberry spanworm may be confined to isolated areas or damage may be widespread. Large numbers of spanworm larvae may completely defoliate areas in both crop and pruned fields. Early in the season, the larvae damage the berry crop by eating flower buds and blossoms. Later larvae chew out notches on developing leaves. Crop fields may be dotted with areas that appear burned.

Blueberry Thrips *(Frankliniella vaccinii* Morgan and *Catinathrips kainos* O'Neill) are present in many fields and can develop into a significant problem if left untreated (Collins et al. 1995d; Lathrop, 1942). Thrips are very small (1/4-inch long) and difficult to see. Uncurling the rolled up leaves of infested plants may reveal small, slender, yellowish to white thrips. This problem is more readily identified by the presence of very tightly rolled together leaves and twisted stems on blueberry plants beginning early in the season (late May or early June). Also, infested leaves often turn bright red and are quite conspicuous. Blueberry thrips winter in the soil as adult females. They begin to emerge and feed on tender new plant material in May or early June. Eggs are laid in developing leaf tissue and young, immature insects can be found within the curled leaves until late July or early August. Eventually, the thrips mature into adults, leave the plant, and move back into the soil. Although thrips damaged plants can be found in crop fields, most economically important damage occurs in pruned fields. Leaves infested with feeding thrips usually do not unfold properly. The infested leaves remain tightly curled around the stem of the plant and fruit buds do not develop normally.

Damage is usually confined to small isolated patches that are heavily infested, while individual thrips injured plants may be found scattered throughout the rest of the field.

Red-striped Fireworm *(Aroga trialbama-culella* Cham) has been increasing in wild blueberry fields (Collins et al, 1994b; Wood, 1972). Young caterpillar-like larvae have a greenish body with darker heads. As they grow, faint reddish lines running the length of the body appear on the back and sides. The red color becomes more pronounced as they mature. Fully grown larvae are about 3/8 inch long and very active when disturbed. They are found feeding between leaves which they have tied together with strands of silk. Pupae are found in the litter and are small and reddish brown. Adult moths are small (about 2 inch long), slender, dark brown or black with a white face and white spots on their forewings and legs. Adults are agile fliers and difficult to detect.

The red-striped fireworm spends the winter as fully grown larvae in old, dead, curled blueberry leaves in the ground litter. At this stage and time they do not feed but trans-form to pupae in late April and early May, after which, the new adults begin to emerge in one to two weeks. Adults can first be seen in the field in mid-May and are present until early August; peak numbers usually occur in July. Eggs are laid on blueberry plants, and larvae hatch and begin webbing together leaves and feeding in early to mid-July. Initially, only one or two leaves may be webbed together with strands of silk; however, as the larvae increase in size, more leaves are webbed together on the stems to provide shelter and food. In heavily infested fields, over 50 percent of the blueberry stems may be webbed together. In September, larvae move into the ground litter where they spend the winter.

Although it has been reported that red-striped fireworm larvae reduce numbers of fruit-buds, this has not

yet been verified in Maine. Currently, the major concern of larval fireworm infestations is their appearance on field machinery and processing lines during harvest. Larvae are apparently jarred from the protective leaf areas during raking and collected mechanically. Larvae are also dislodged or blown with debris from winnowing machines and reinfest blueberry stems immediately adjacent to the equipment; this provides an important center of re-infestation the following year. Larvae are present in the field from July through September. The later in the season leaf-tying activity occurs, the less likely larvae are to be a problem.

Strawberry Rootworm (*Paria fragariae* Wilcox) is an infrequent pest on wild blueberries (Collins et al.1995f).The adult strawberry rootworm is a shiny, oval beetle 1/8-inch long. Its color may vary from brown with four darker blotches on the back to solid black. The adults feed on the plants chiefly at night and are not commonly seen during the day. The larvae are white and are found in the soil.

The adults spend the winter in ground litter or in other protected places and begin to become active in early May. The largest numbers of beetles occur between late May and early June. Eggs are laid during this period and developing larvae burrow into the ground, where they feed on the roots of strawberries and other related plants. They become pupae in the soil, and new adults emerge from mid-July through August and feed on foliage the rest of the season.

This beetle is more commonly a pest of strawberries, but can also damage wild blueberry plants in Maine. Infestations are usually confined to isolated areas. The most severe damage is caused by the adult beetles, which eat holes in the leaves. When adults are abundant, leaves are riddled with holes giving the plants a ragged appearance.

Blueberry Leaf Beetle(*Pyrrhalta vaccinii* Fall) is a pest infrequently seen in Maine (Collins et al. 1995b; Fall, 1924). The blueberry leaf beetle adults range in color from brownish-yellow to reddish-brown. The larvae are light greenish-gray and are about 1/8-inch long when fully grown. The yellowish pupae are found at least one inch deep in the soil.

Blueberry leaf beetles pass the winter as adults hidden in the debris at the base of blueberry plants. They leave their winter quarters in late April to begin to feed on expanding leaf buds and to mate. The largest numbers of beetles occur on the foliage between May and early June. Eggs are deposited in crevices at the base of plant stems from late May to late July. When the eggs hatch, the larvae eat the foliage of blueberry plants. The larvae pupate in the soil, and a new generation of adults becomes common in late July. They feed on the foliage well into the fall before seeking overwintering sites.

Adults and larvae of the blueberry leaf beetle damage blueberry plants by eating the lower surface of the leaf, leaving a lacy network of fine veins; this is called "skeletonizing." The upper surface later turns

brown. Infestations are usually confined to isolated areas and abandoned or poorly managed fields. However, when the beetles are very abundant for two or three successive seasons, they may kill blueberry plants over large areas.

Grasshoppers (*Melanoplus spp.* and *Camnula sp)* are present in most wild blueberry fields (Collins et al. 1995e; Morse, 1921). The species of grasshoppers that attack blueberries are all similar in body shape and structure. They are generally elongate insects with narrow, leathery fore wings; large, membranous flying wings; and chewing mouthparts. The hind legs are large and adapted for jumping. They vary in color from greenish-yellow to gray to brown to brownish-black. All vary in size up to 1 1/4-inches long when fully grown. Immature grasshoppers are smaller and closely resemble adults but do not have wings.

Most grasshoppers spend the winter in the egg stage in the soil. The time for egg-laying varies with the species of grasshopper, but normally it begins after the middle of July and may continue through September for some species. Eggs are placed well below the surface of the ground, preferably in firm, unbroken soil along roadsides, edges of fields, or in open areas of managed fields. Eggs begin to hatch in early to late May and the young grasshoppers, called nymphs, push to the surface of the ground and begin feeding on the nearest vegetation. The grasshoppers begin to become adults in early to late June and continue to feed on foliage and berries.

Several species of grasshoppers have been observed feeding on blueberries in Maine. The extent of damage varies from year to year depending on the species of grasshopper, numbers present, and weather. Both young grasshoppers and adults feed by chewing foliage and by biting and chewing on berries. Feeding damage is often detected later as a calloused scar on the fruit.

Blueberry Sawfly *(Neopareophora litura* Klug) are found in most wild blueberry fields (Collins et al. 1994a; Neilson, 1955, 1958). Adults are 1/4 inch long, black, and generally wasp-like in appearance but do not have the narrow waist usually associated with a wasp. They have membranous wings which they hold flat over their body. The slow-moving, caterpillar-like larvae are usually the color of blueberry foliage (grass green) which makes them difficult to detect directly on the foliage. Fully grown, larvae are about 4/10 inch long. When feeding, they usually coil their body over the edge of the leaf and chew around the edge. Pupae are enclosed in a camouflaged cocoon in the litter.

Blueberry sawfly adults lay eggs in early to late May inside newly developing, still folded, leaf whorls of wild blueberries. The eggs hatch and larvae emerge within one to two weeks. Larvae feed on leaf tissue inside the developing whorl, killing the new leaves and filling the interior of the whorl with their excrement, a flaky brown material. Young larvae, which are rarely seen, are white or flesh-colored with black heads and black legs. Older, green larvae begin to appear on the blueberry foliage in late May or early June when leaves are well-developed. The larvae continue to feed on late June. After reaching

maturity, the larvae move to the ground and spin cocoons in the litter where they spend the winter.

Although not usually an economic concern to growers, in large numbers larvae may cause damage by defoliating the plants. Blueberry sawfly larvae feed on blueberry leaves from late May to late June. The damaged leaves have a scalloped appearance around the edges. Infestations are usually confined to isolated areas within a field.

Other Insects

Other insects such as the black army cutworm (*Agrostis fennica* Tausch.) and chain dotted measuring worm (*Cingilia catenaria*) have been a problem in the past (Phipps, 1930; Woods 1915) and could reappear if pest management practices were drastically changed.

Insecticides:

Research on the ecology of the major pest species, the blueberry maggot was conducted as early as 1925. The history of insect pest management is well documented since 1949. Before the 1940's, large areas of blueberry were harvested in Maine (about 200,000 acres) and insects were generally accepted as part of the many sources of yield loss with low input agriculture. Insecticides, such as calcium arsenate, were used occasionally to control the major pest, the blueberry maggot.

By 1949, pest management recommendations had been formulated which linked crop phenology with timing of control tactics. Also by 1940, the first synthetic organic insecticides were being used in Maine. DDT was recommended for control of cutworms, black armyworms, flea beetles, leaf beetles, and gypsy moth. Calcium arsenate was now commonly recommended for blueberry maggot control. On the one hand caution was recommended in regards to killing bees by applying insecticides during bloom, but on the other hand indiscriminate use of insecticides were recommended by suggesting that one should apply "insurance" applications of DDT whether or not insect pests are present.

In 1959, the arsenical compounds were no longer recommended for insect control, two organochlorine insecticides, Dieldrin and DDT were used for insect control on thrips, cutworms, and blueberry maggot which were the major pests of concern at this time. This time in the history of wild blueberry production marked an era when wild blueberry production was becoming a more conventional agriculture, utilizing capital and technological inputs. The major advance in blueberry production by 1959 that greatly affected insect pest management was the recommendation of farm record keeping (bee colonies rented, weeds, acres bearing, fertilizer, insecticides, and fungicides used). Laws enforced by the USDA reflect the recommendations to blueberry growers in 1969, suggesting the great care be taken in disposal of insecticide containers, and when applications could be made relative to harvest so that residues would

not contaminate fruit. By 1969 seven insecticides were registered for use in wild blueberry (2 carbamates, 3 organo-phosphates, and 2 organochlorines), but the insect pests of concern still only numbered three: thrips, cutworms, and blueberry maggot.

The first recommendation specific to aerial spraying was made in 1969. In 1976 aerial spraying was conducted on about 4,000 acres out of a total 24,949 bearing acres (16%). Recommendations in 1979 strongly urged following insecticide label directions and rates. Five insecticides were recommended for only two insect pest species, thrips and blueberry maggot.

By 1980, about 50,000 acres of wild blueberry were managed and an integrated pest management program was established on 2,000 acres in Washington and Hancock counties. This program used traps for monitoring blueberry maggot and the decision to spray an insecticide was based upon an action threshold (Dill, 1987), so that insecticide applications were timed to the emergence of the fruit fly and applications were made only when sufficient numbers of flies were present to cause rejection of the fruit because of USDA standards (Grange, 1966).

Research on pest insect life cycles and biology was conducted by the University of Maine in the 1980's. Action thresholds for several other insects, based on the use of sweep nets, were established (Yarborough et al. 1993). In addition, the use of Bt (*Bacillus thuringiensis*) was researched and registered for blueberry spanworm control (Yarborough and Collins, 1999).

- **Azinphos-methyl** as a 2L or 2E is registered for control of the blueberry maggot, our primary insect pest, and is applied at 1pt/a with 1pt/water for a cost-effective low volume aerial application. Growers may apply from 0 to three applications per season depending on insect pressure as indicated by threshold levels on fly-traps. There is a 7 day pre-harvest interval. It accounted for 39% of the insecticide applications in 1997 (Dill et al., 1998).

- **Phosmet** as a 70WP and 2.5EC is used to control blueberry maggot at 1.3 lb/a or 1.5 to 3 pt/ product a in a ULV 6-9 pt/a on a 24-C label. There is a 6 pt/a season limit and a 7 day preharvest interval. Phosmet is also registered on flea beetle, spanworm and sawfly and is the second most used insecticide and accounted for 23% of the insecticide applications in 1997 (Dill et al., 1998).

- **Bacillus thuringiensis** is the insecticide of choice to control the blueberry spanworm, and is very effective 94% when applied to small instars up to 0.6 cm and will control 87% up to 1.25 cm (Drummond, 1998). Several formulations with different percentage active ingredient are registered.It accounted for 7% of the insecticide applications in 1997 (Dill et al., 1998).

- **Carbaryl** is registered as Sevin 4 XLR plus at 2qt/a on blueberry maggot, flea beetle adults, and sawfly. It is toxic to bees and is not frequently used. It has a 7 day to harvest interval. No use was reported in 1997 (Dill et al., 1998).

- **Methoxychlor**is registered as a 50WP at 4-5 lb/a for use on the blueberry maggot, spanworm,

flea beetle, and sawfly. It has been used infrequently when bees are present in the fields. It has pre harvest interval of 14 days. It accounted for 5% of the insecticide applications in 1997 (Dill et al., 1998).

- **Malathion** is registered as a 5 or 57EC and applied at 1pt/a for use on blueberry maggot, flea beetles, sawfly and thrips. It has a 12 hour preharvest interval, and so has little residual activity. It accounted for 21% of the insecticide applications in 1997 (Dill et al., 1998).

- **Diazinon** is registered as a 50WP for thrips control and applied at 1-2 lb/a just after plant emergence in the spring of the non-bearing year. It is the most effective chemical control measure for thrips.It accounted for 3% of the insecticide applications in 1997 (Dill et al., 1998).

Diseases

Mummy Berry *(Monilinia vaccinii-corymbosi* Reade) Honey is the most economically important disease of wild blueberries (Hildebrand and Braun, 1991; Hildebrand et al. 1995; Lambert and Degomez, 1987). The principal damage is the blighting of leaves, flowers and even entire stems by the primary ascosporic infection of the vegetative tissue. The secondary conidial infection of the blossoms results in a dry fruit rot that mummifies fruit. Crop losses can be extremely severe, depending on the inoculum level, environmental conditions and the proportion of susceptible clones in any given field. The mummified berries or pseudosclerotia germinate to produce an apothecia which produces the ascospores that may discharge for over 30 days. Wild blueberry plants are predisposed to infection for 4 days following a frost. Free water is required for infection, and higher temperatures reduce the time needed for infection. The occurance of frost, moisture duration, and temperature are used to estimate the severity of infection and is used to determine the timing of fungicide applications to prevent the primary infection (Delbridge et al., Hildebrand and Yarborough, 1998). Blight symptoms develop about 2 weeks after infection. High humidity favors the production of conidiospores on blighted tissue which is decimated by wind, rain and bees to produce a secondary infection of the blossom. This infection will develop into the pseudosclerotia which drops to the soil before harvest and may remain viable for several years. The fungicide triforene controlled this disease for may years, but with its cancellation propiconazole, used under an emergency Section 18 in 1998, is the only effective fungicide available.

Botyrtis blight *(Botrytis cinerea)* (Lambert, 1995c; Lambert and Degomez, 1987). Although Botrytis blossom blight and fruit rot are among the most widely distributed disease on many crops throughout the world, it is of secondary importance on the wild blueberry. Six to nine days of high humidity are necessary for infection of dormant buds, but only three to four days are needed for blossom infection, so this disease is more prevalent in coastal fields. The fungus attacks tender green twigs, blossoms, leaves and fruit and can cause severe damage, especially when rainy weather persists through bloom. Weak or

injured tissue is particularly susceptible, and mature or frost-damaged blossoms are most affected. One week after infection, blossoms turn light brown and develop a greyish-brown mold which is easy to see under low magnification. Botyris blight may be distinguished from frost damage by the presence of the mold growth on the blossoms and the lack of frost damage on other plants in the area. Since the Botyris blight fungi are able to over-winter and grow on dead or dying material of may plant species, spores produced in adjacent fields or woods may reinfect the blueberry clones when conditions are favorable for infection. Benomyl at 0.5 lb/a ai is used for Botyris blight control.

Powdery Mildew *(Microsphaera vaccinii)* (Lambert, 1995d) is universally present in wild blueberry fields and contributes to leaf reddening and early abscission. Because the onset of infection is usually late in the season, it is not considered an important disease. Mildew is evident in July on susceptible clones and will be more severe if the plants are deficient in phosphorus. Powdery mildew may be controlled by 0.5 lb/a ai of benomyl, but is seldom used since the expense is not justified.

Red leaf *(Exobasidium* spp) (Lambert and Degomez, 1987; Nickerson, 1995). Plants with red leaf disease occur singly, in scattered clumps, or in patches. They are recognizable by their bright red color, which may occur in irregular blotches on partially affected leaves. Later in the season, the underside of diseased leaves turn white. Few or no fruit develop; some twigs may be killed. The disease overwinters in stems and rhizomes. No fungicides adequately control this disease, but it does not seem to be increasing in importance. The only control recommendation is roguing of infected plants by directed spraying with an herbicide.

Witches-Broom (*Pucciniastrum goepperatianum)* (Lambert and Caruso, 1995) is a rust fungus that is a relatively minor disease of wild blueberries because of the low incidence of infection. Infected plants produce no fruit and there is no fungicide treatment to control infection. The alternate host fir (*Abies*) is ubiquitous, so aeciospores produced on the balsam fir needles are carried by wind to infect the leaf or stem of the wild blueberry plant in the summer. There is an incubation period of one year, so the symptoms develop in the following spring through autumn as swollen stems of the brooms. Because the plants are pruned that fall or the following spring, there is limited production of the basidiospores to infect the fir. The pathogen is perennial and systemic in the wild blueberry rhizome, so burning does not eliminate the disease.

Leaf Spot Diseases: Anthracnose *(Glomerlla cingulata)***, Brown leaf spot** *(Septoria sp.)***, Gloeosporium** *(Gloeosporium minus)* **stem and leaf spot** (Lambert, 1995a, 1995c; Caruso, 1995). cause blossom blight symptoms, leaf spots, red lesions and fruit rot in wild blueberries.

Losses are not consistent but appear to be related to stress on the plants. These diseases have been increasing in incidence over the last few years and are causing premature defoliation and crop loss. Currently benomyl and captan are used if substantial infection has occurred and research efforts are being devoted to develop better treatment options.

Fungicides:

In the 1940's, monohydrated copper sulfate and hydrated lime were used with limited effectiveness. In the 1950's and 1960's the fungicides Ziram and Ferbam were used, again with limited effectiveness. In the 1970's, Benomyl was recommended but again only had limited effectiveness with mummy berry disease. With the increase in production and the change from burning to mowing fields for pruning in the 1980's, mummy berry disease increased in incidence. The protectorant fungicide triforine provided good control of mummy berry disease but since the label was canceled in 1997, the only effective control is propiconazole applied under an emergency Section 18 (Yarborough and Lambert, 1999).

Triforine 1.6EC at 24 oz/a represented 79% of the fungicide applications in 1997 (Dill et al. 1998), but since nearly all of the existing stocks have been depleted, it is expected that **propiconazole** 3.6 E at 6 oz/a applied one to three times, will be the fungicide used the most frequently. **Benomyl** 50WP at 1 lb/a represented 11% of the applications (Dill et al. 1998). Other fungicides infrequently used include, **captan**, **chlorothanil**, and **iprodine**.

Weeds

A wide variety of woody and herbaceous species native to Maine naturally occur in Maine's wild blueberry fields. Any plant occurring in a field other than a wild blueberry is considered a weed (Yarborough, 1996b). The wild blueberry competes with weed species for space, water and nutrients. This competition usually results in a reduction in crop yields and prevents the blueberry from spreading. Weeds may also contribute distasteful fruit such as bunchberries and choke-berries, which reduce the quality of the processed pack. Weeds hinder harvest and reduce the quality of the fruit. When harvested by rakes, crushing and cutting of the fruit occurs. Weeds may also harbor pests or act as alternate hosts for diseases. However, weeds can give shelter to beneficial insects and help to reduce erosion on slopes. Yet, when weeds are controlled, blueberry yields increase. This increase may be attributed to reduced competition, which enables blueberries to increase plant stand, flower bud set, and fruit size.

Weeds have always been a major yield limiting factor in wild blueberry production (Chandler and Mason, 1946). Research in the 1940's was limited to cultural management of cutting woody weeds. In the 1950's the first synthetic herbicide, 2,4-D was used. Development of weed wiper devices provided a non-selective means of controlling woody broadleaf weed species in wild blueberry fields. It was not until the 1970's that the preemergence herbicide Terbacil was available to control grasses and herbaceous weeds. Glyphosate was registered to provide non-selective, woody and herbaceous broadleaf weed control, and the selective grass herbicides, Clethodim Fluazifop-P butyl, and Sethoxydim were registered for use in wild blueberries. In the 1980's, the registration of Hexazinone provided a greater

spectrum of weed control and enabled growers to increase the blueberry crop threefold in 10 years. The detection of hexazinone in groundwater in Maine has resulted in Best Management Practices (Yarborough et al. 1996) being established and adopted by growers to minimize the leaching of this herbicide.

Annual Grasses have increased in importance over the past five years with the reduction rate of hexazinone use. Common species include witchgrass (*Panicum capillare)* or fall panicum (*P. dichotomiflorum)* and a bent grass or fools-hay (*Agrostis capillaris*).

Perennial Grasses often occur in patches, with spread from roots, rhizomes, or stolons. Species such as quack grass (*Agropyron repens*) and little bluestem (*Andropogon scoparius*) do not occur frequently, but if established are difficult to control.

Herbaceous Flowering Plants Wild blueberry plants have been developed from cut-over forest, abandoned hay-fields and woodlots a great diversity of species are present in fields if herbicides are not used (Hall, 1959; Sampson et al. 1990, Yarborough, 1991). With the use of selective herbicides species such as asters (*Aster* spp.), goldenrods (*Solidago* spp.) Cinquefoil (*Potentilla simplex*) have decreased while others including bunchberry (*Cornus canadensis*), dogbane (*Apocynum androsaemifilium*) and St. Johns- Wort (*Hypericum perforatum*) have increased (Yarborough and Bhowmik, 1989).

Woody Perennial Plants aggressively establish themselves in wild blueberry fields and require additional measures for control.

Species such as black chokeberry (*Pyrus melanocarpa*), sheep laurel (*Kalmia latifolia*), meadowsweet (*Spirea latifolia*), blackberry (*Rubus* spp.), rose (*Rosa carolina*) and cherry (*Prunus pensylvanica*) may be controlled with preemergence herbicides but will reestablish if herbicide rates are lowered, or applications discontinued. Other species such as maple (*Acer rubrum*) birch (*Betula populifolia*) and oak (*Quercus rubra*) require post-emergence treatments for successful control (Yarborough, 1996b; Yarborough and Bhowmik, 1989).

Sedges, Rushes, Ferns Although wild blueberries tend to grow in well drained sites, there are wet inclusions in fields which allow the establishment of these species. The most aggressive is Bracken fern (*Pterdium aquilinum*) which shades out the lower growing blueberries and reduces yield (Yarborough and Marra, 1997) . Three square sedge (*Scirpus americanus*) and rushes such as (*Juncus effusus, J. tenius*) are also common in wet portions of the field.

Herbicides:

Commercial herbicides are used for most weed control in wild blueberries today (Dill et al., 1998; Yarborough, 1999). Cultural management techniques such as cutting and reducing soil pH are also integrated into a weed management programs (Yarborough, 1996b).

- **Hexazinone** comprised 67% herbicide used on wild blueberry fields in 1997 (Dill et al., 1998). It may be applied as preemergence broadcast spray as a L or DF formulation, or postemergence as a 10G or fertilizer impregnated granule (Yarborough, 1995). Use rates vary from 0.5 to 2 lb ai/a, depending on weed pressure. This herbicide provides selective control for many grasses, broadleaf herbaceous and woody weeds. All applications have been made in the non-bearing year, but a 24-C label granted in 1998 will allow for crop-year treatments up to 45 days before harvest. Hexazinone is the primary contributing factor in increasing the wild blueberry crop three-fold over the past 15 years (Yarborough, 1997b). It is also highly soluble and prone to leaching, so use rates have decreased to an average of 1 lb ai/a in response to groundwater concerns (Yarborough, 1997a). Other preemergence herbicides used include **terbacil** 80WP and **diuron** 80DF at 2 to 3 lb/a. These herbicides do not have as an extensive spectrum of control as hexazinone, and are used on a limited basis, less than 1% in 1997 (Dill et al., 1998), as a rotational herbicide to hexazinone.

- **Glyphosate** is a non-selective herbicide used to control perennial herbaceous and woody weeds in wild blueberry fields (Yarborough, 1996d). Applications are made in a hand-held wiper or rope-wick wiper at 10 to 20% v/v solutions to weeds taller than wild blueberry plants. Directed sprays of a 1 to 2% solution may also be used on weeds growing among the wild blueberry clones.

This treatment provides control of weeds not suppressed by the lower rates of the preemergence herbicides. Most treatments are applied in the non-bearing year, but applications may be made up to 30 days before harvest. Eighteen percent of the herbicide use was with glyphosate in 1997 (Dill et al., 1998).

The selective grass control herbicides, **Sethoxidim** at 0.28 to 0.47 lb/ai a, **Fluazifop-P butyl** at 0.5 to 1.0 lb/ai a**,** and **Clethodim** at 0.09 to 0.13 lb/ai a are used as a postemergence broadcast spray or spot treatment (Yarborough, 1998) to control annual or perennial grasses. Most applications are made in the non-bearing year. Sethoxydim may be used up to 30 days before harvest, but fluazifop-P butyl and clethodim are applied only in the non-bearing year. Selective grass herbicides comprised 11% of the herbicide use in 1997 (Dill et al., 1998).

Alternative Pest Control Strategies

Burning wild blueberry fields has been the standard practice for pruning up until the last 15 years.

Burning does provide cultural control of insects which reside in the litter, destroy some of the mummy berry propagules and weed seed, but is not sufficient by itself as a practice to control insects, weeds and diseases. Because of the expense, air pollution and danger of fire destroying adjacent property, most of the fields which are suitable to mow are now mowed instead of burned, which has increased pest pressure and resulted in increased reliance of chemical controls. Pruning every other year does disrupt insect and disease cycles because in the non-bearing year there are no blossoms or fruit to infect, so this practice reduces pest pressure on the crop.

Cultural control techniques are an important component of wild blueberry management (Yarborough, 1999; Yarborough and Collins, 1999; Yarborough and Lambert, 1999). Clean harvesting techniques that reduce fruit loss can minimize the number of fruit with blueberry maggots and mummy berries which are left in the field. Burning or removing and composting winnow debris piles will reduce blueberry maggot, fireworm, and mummy berry. Spot burning stems infested with thrips is also a cultural practice used if the infestation is not too extensive.

Cultural controls used in weed management include cutting herbaceous weeds before they go to seed, cutting woody weeds several times, reducing soil pH, testing for leaf nutrient contents to limit excess fertilizer, and use of mulch and interplanting of blueberry plants improve cover and reduce weed competition.

Critical Pest Control Issues

Although many cultural pest controls practices are routinely used in wild blueberry production, synthetic chemical pesticides are a critical component in the pest control strategy. The wild blueberry industry continues to fund research to develop both chemical and cultural means of pest suppression to incorporate into the existing pest management strategies.

Insecticides are extremely important to prevent damage to the plant and reduce yields and to prevent infestation of the fruit with the blueberry maggot, which would make the fruit unsaleable under USDA standards. With the exception of Bt, which is only effective against the spanworm, all of the insecticides registered for insect pests in wild blueberries are organophospates or carbamates, so cancellation of these products would leave no alternatives and could result in up to 100% crop loss from blueberry maggot (Drummond, 1999).

Mummy berry disease can cause significant crop losses, unless a protectorant fungicide is applied. Since the cancellation of triforine, no effective fungicides are registered for the control of this disease. Although a section three label has been pending since 1995, growers have relied on an emergency section 18 label to allow the use of propiconazole to control mummy berry. Research is continuing to find other effective alternatives such as fenbuconazole.

Substantial gains in blueberry production have been made by the use of the preemergence herbicide hexazinone (Yarborough, 1997b). The loss of this herbicide because of groundwater detections would result in a reduction in crop by two-thirds, approximately 40 million pounds, since effective alternatives are not available. Research efforts have been concentrating on alternatives for this herbicide.

Outlook for New Registrations

Because wild blueberries are a minor crop, less than 62,000 acres, and grown in a restricted area; Maine, New Hampshire and Massachusetts, the IR-4 program has been essential in obtaining minor use labels for wild blueberries. The IR-4 program has been responsive to the needs of the wild blueberry industry and funded residue and efficacy trials for alterantive and reduced risk pesticides.

Research in insect pest management at the University of Maine is currently being conducted in the following five areas: 1) Biological control of blueberry flea beetle, blueberry spanworm, and blueberry thrips using the insect pathogenic fungus *Beauveria bassiana* and insect pathogenic nematodes and viruses; 2) Refinement of economic thresholds for the blueberry flea beetle, blueberry spanworm, and blueberry maggot; 3) Development of strategies for conservation of pollinators and natural enemies by improving timing of insecticides before and after bloom or parasitoid emergence (parasitoids of blueberry maggot and blueberry spanworm) and by discovery of insecticides or control measures with low toxicity to these beneficial insects; 4) Development of less toxic alternative insecticides such as red food dye and neem oil (plant derived natural product) for blueberry maggot control and improved control tactics for blueberry maggot and blueberry spanworm based upon detection of within field population variation resulting in spot treatments; 5) Improved monitoring methods for blueberry maggot (trapping and phenology modeling) and blueberry thrips (trapping methods).

Time will be required to develop and test new alternatives, and evaluate their effect on the current management strategy.

Evaluation of the timing and efficacy of alternative fungicides such as fenbuconazole and azoxystrobin on mummy berry disease need to be developed to determine if the recommendations on the use of moisture and temperature made for triforine will be the same, and how effective these fungicides will be on Septoria leaf spot.

Development of effective, selective herbicides which will not leach are needed. Research efforts on dinitroaniline and sulfonylurea herbicides and are being evaluated as alternatives and will be integrated with cultural controls to provide a weed management strategy. It is expected that 24C labels will be obtained for alternative herbicides in the next five years.

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