Crop Timeline for Blueberries in Michigan and Indiana

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Introduction

This timeline provides specific information on crop production of blueberries both fresh and for processing in Michigan and Indiana. It also reviews key pests and usual worker activities in blueberry production. The timeline provides information to help assess worker risk and identifies benefits of pesticide applications where relevant. Because blueberry production for the fresh market and for processing is treated alike, there are no differences in cultural activities and in pesticide usage associated with the final marketing of the product. Methods of application of pesticides are provided to illustrate common practices, which, however, may vary somewhat between the two production regions because of differences in geography and weather.

Crop Production Facts

The Highbush Blueberry Plant

The highbush blueberry, *Vaccinium corimbosum* L., is a highly specialized crop with exacting soil and climatic needs (1). It is a perennial plant and consists of a shallow root system and woody canes originating from the crown of the plant. The root system is very fibrous but is devoid of root hairs that make the blueberry plant very sensitive to changing soil water conditions. A mature cultivated blueberry plant, five to eight years old, usually has 15 to 18 canes. Growth habit varies among cultivars. Some bushes grow upright; others have a spreading growth pattern. Blueberries generally tolerate temperatures of -20°F during the dormant stage. Most highbush blueberry varieties require some chilling in order to terminate the winter rest. Although there is some cultivar variation, most varieties require 750 hours of chilling below 45°F. This requirement is usually met between mid-January and early February. After the chilling requirement is met, the plant loses its dormancy and also its cold hardiness with each warm period. Susceptibility to cold injury increases as the season progresses. In early spring, during the bud break stage, temperatures below 18°F will cause severe damage to both vegetative and fruiting organs

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The best soils for blueberries are well-drained sandy silt loam or silt loam, with a pH of 4.5 to 5.2, organic matter of 4 to 7%, and adequate phosphorus and potassium. In major commercial blueberry areas, blueberries are produced on sandy soils with high water tables. Most midwestern soils (except some Michigan soils) require amendments and irrigation for maximum growth and yield (2).

Annual Growth Cycle.--In early spring, buds begin to grow using sugars stored in the buds. Terminal buds begin growth and development first, and the lateral buds follow. Buds further down the shoot begin growth later than those closer to the tip. Flower buds in blueberries usually contain 6 to 12 flowers in a cluster. The flowers at the tip of the bud emerge and open first and have the potential of developing the largest fruit. Fruit from the lower buds will always be smaller. After bloom, the fruit begins to grow, and by the time the fruit starts its final swell for harvest, most of the shoot and leaf growth for the season has stopped.

After harvest, the plant begins to prepare for next year's growth. Sugar is stored as starch in the bark and wood of the shoots and in the roots, and root growth increases. The roots will grow if the soil is moist. If the soil is dry and drought stress continues, then food reserves for next season's growth will be reduced, and the root system will be small and weak. Next year's flower buds are formed during the fall. If another spurt of shoot growth does not begin, the terminal bud becomes fat and plump as it changes from a leaf bud to a flower bud. Under favorable conditions, other leaf buds below the terminal bud will also change to fruit buds.

Highbush blueberry growth stages are classified as follows: (1) *Dormant*: no swelling of the fruit buds; (2) *Bud swell*: fruit buds become swollen; (3) *Leaf bud break*: leaf buds begin to swell and leaves emerge from the tip; (4) *Early green tip*: green leaf tissue is visible as leaves begin to emerge from the leaf buds; (5) *Bud burst*: the fruit buds pop open and the individual flowers can be seen between the bud scales; (6) 0.25" *green*: a ¼-inch of leave tissue is visible, at about the same time as bud burst; the flower bud stage is often called tight cluster; (7) *Early pink bud*: the partly formed flowers are readily visible and the flowers have separated; (8) *Late pink bud*: most of the flowers on the bush are nearly fully developed, overlapping into first bloom; (9) *25% bloom*: 25 % of the flowers are open; (10) *Full bloom*: most of the flowers on the bush have opened; (11) *Petal fall*: the corolla tubes or petals fall off the flowers, revealing small green fruit; (12) *Early green fruit*: early in fruit growth when the fruit are growing by cell division; (13) *Late green fruit*: late in fruit growth when the fruit are growing by cell expansion; (14) *Fruit coloring*: the fruit changes color from green to blue; (15) *First harvest*: the first fruit are ripe and ready to be harvested from the cluster; (16) *Harvest*: blueberries are picked several times as the fruit ripens; (17) *Postharvest*: the blueberry stores reserves for next year's growth (2a).

Midwest Varieties (Michigan and Indiana)

Blueberry varieties exploited in the North Central states are selected by their cold hardiness and marketable characteristics, such as color, berry size, flavor, and firmness of the fruit. The common varieties in this region are as follows (3,4,5).

Bluecrop.—This variety ripens early midseason, just after Blueray. The fruit is large with a small scar, has excellent color, firmness, and good flavor. Its foliage is somewhat sparse, but production is good. This berry is suitable for mechanical harvest. It is the most popular variety in New Jersey and the second most popular in Michigan.

Bluejay.--This midseason berry was released by a Michigan Agricultural Experiment Station. The fruit is medium in size with long stems that aid in mechanical harvesting. The bush is vigorous and upright.

Blueray.—This variety is an early midseason berry. It ripens a few days ahead of Bluecrop. The fruit is very large and firm, has a fair scar, and produces an aromatic flavor. The clusters are large and very tight. The bush is vigorous and productive. This berry is popular for the pick-your-own trade but does not machine-harvest well.

Jersey.--A late midseason berry, Jersey fruit is medium sized, has a medium scar, fair color, fair flavor, and is firm. The bush is very vigorous and productive. The clusters are long and loose. It is suitable for mechanical harvesting.

Elliott.--This late season berry ripens two weeks after Jersey. The fruit is medium in size, firm, light blue, and has good flavor. The bush is vigorous, upright, winter-hardy, and productive. It is suitable for mechanical harvesting.

Nelson.--USDA released the Nelson in 1989. It ripens midseason. The fruit is large, firm, light blue, has good flavor, and has a scar. The bush is vigorous, upright, and is suitable for commercial and pick-your-own harvest.

Patriot.--This early season berry ripens ahead of Blueray. The fruit is large, small scarred, with good color, and has very good flavor. The bush is vigorous, upright, and relatively open. Tests have proved it to be very winter-hardy. It is recommended for trial in commercial production. It is tolerant or resistant to some strains of *Phytophthora cinnamomi*, a soil fungus that causes root rot.

Spartan.--Spartan is an early season berry that ripens just ahead of Patriot. It has large, firm fruit, light blue in color, and has excellent flavor. The bush is vigorous, upright and open, and productive. It is suitable for machine harvest. Because it ripens early and has large fruit, this variety is very desirable for the pick-your-own trade.

Northcountry.—The Northcountry berry ripens early. The berries are very light blue, sweet and mild, typical of the lowbush clones. The blueberry bush is vigorous, heavily branched, growing 36 to 40 inches tall.

Northsky.--The Northsky variety ripens early. The berries are medium in size and sky blue in color. The bush has short stature, about 10 to 18 inches tall. The plants are dense and have glossy dark green summer foliage that turns dark red in the fall.

*Duke***.—**Duke is a variety that ripens early. The color of the berries is medium blue. The berries are medium to large size with a good flavor. This variety is well adapted for mechanical harvest.

*Rubel***.--**This is a midseason variety. The color of the berries is medium blue, and the size of the fruit is medium to small with fair flavor. This variety is suitable for mechanical harvesting.

Small-fruited varieties, such as Jersey and Rubel are the most desirable for processing. Varieties best suited for fresh packing and shipping include Bluecrop, Bluejay, Duke, Elliott, and Nelson (5).

Production Regions

According to the North American Blueberry Council, Michigan ranks first among the highbush blueberry producing states, as shown in the following tabulation (6,7,8,9).

	Michigan	Indiana
Production, million pounds	635	1.5
Acreage	18,000	795
Average yield, pounds per acre	3,710	3,500
Crop value, million dollars	55.4	2.46
Average price per pound, dollars	0.88	0.98

In 2001, Michigan's production was 30% of the total U.S. production. Indiana's production was less than 1% of the national total. Blueberries produced in Michigan and Indiana are suitable for both fresh and processing market. However, 70% of Michigan blueberries are for processing whereas Indiana sends only 30% of its production for processing.

In Michigan, blueberry production occurs mainly in the west central part of the state. The counties of Van Buren (southwest Michigan), Ottawa (west central Michigan) and Allegan (southwest Michigan) together account for 83% of the acreage, 37%, 31%, and 15%, respectively. Muskegon and Berrien counties have 6% each, and the rest of the state has 5% (10). In Indiana, blueberries are produced mainly in the northern portion of the state, in La Porte, Jasper, St. Joseph, Starke, and Pulaski counties. However, 60% of the blueberry production occurs in La Porte and Jasper counties (8).

Table 1 gives the crop stages calendar for blueberry production in Michigan and Indiana.

Table 1.—Crop stages calendar for blueberry production in Michigan and Indiana.

Crop Stage	Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Dormancy																				
Bud break																				
Early green tip																				
0.25” green																				
Early pink bud																				
Late pink bud																				
25% bloom																				
Full bloom																				
Petal fall																				
Early green fruit																				
Late green fruit																				
Fruit coloring																				
1st harvest																				
2nd harvest																				
3rd harvest																				
Postharvest																				

Worker Activities

The seasonal occurrence of workers activities in blueberry production in Michigan and Indiana is given in Table 2.

Table 2. Seasonal occurrence of workers activities in blueberry production in Michigan and Indiana.

Workers activity	Mar		Apr		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Pruning																		
Dormant spray																		
Frost protection																		
IPM scouting																		
Disease control																		
Insect control																		
Cultivation																		
Weed control																		
Fertilization																		
Irrigation																		
Harvest																		

Labor requirements for cultural practices are estimates developed through small group discussions with blueberry growers from Michigan and New York in 1988, 1989, and 1993. A hypothetical farm of 80 acres of blueberries is assumed together with equipment and cultural practices generally used by a typical grower. However, in some instances, figures are presented for 10 acres to make it easy to visualize the resource input (12, 13).

Planting

The initial cost of establishing a planting is high, and the first full crops occur 5 to 7 years after planting. No crop is harvested the first 2 years. In the third year, 400 to 800 lb per acre are produced, and in the fourth year, there are 1,400 to 2,000 lb per acre. Full crops of 2 to 3 tons per acre (4 to 6 pints per bush) can occur as early as the fifth year and should be expected by the eighth year. Highly vigorous, spreading cultivars, such as Jersey and Bluejay should be spaced 4 to 5 ft in 10-ft rows (871 to 1,089 plants/acre). Less vigorous, more upright cultivars, such as Duke, Earliblue, Patriot, Spartan, Blueray, Bluecrop, and Elliott should be planted 3 to 4 ft apart (in 10-ft rows yielding 1,089 to 1,452 plants/acre). For mechanically harvested fields, there is a trend toward within-row spacing of 3 ft in addition to annual pruning to keep the base of the row relatively narrow, and 10 ft row spacing for machine harvesters. For fields that will be hand harvested, row spacing of 8 to 9 ft makes optimum use of the land, although 10 ft may still be preferred to simplify cultural practices (11, 12). Plants for transplanting are 2-year old cuttings that have been maintained in a greenhouse with no insecticide or fungicide treatment.

The costs of establishing and maintaining a blueberry planting are high, but returns from well-managed plantings on suitable sites can be substantial. The common row and plant spacing requires between 1,000 and 1,200 plants per acre. Two-year-old blueberry plants cost $1-2; it will cost $1,000-2,400 per acre just for the plants (13). Planting involves labor. However, the number of workers required per acre depends on the type of planting. Most growers use partly mechanized systems that require 5 to 7 people to plant 8 to 10 acres in an 8-hr work period (13).

Irrigation

Irrigation is necessary for blueberry cultivation because its root system is shallow and lacks root hairs. In the north central region, most blueberry growers use overhead sprinklers with movable or permanent lines. Sprinkler irrigation is also utilized for spring frost control. Spring frosts are a major factor in determining the total production of blueberries for a region in any given year. In a year with numerous or widespread frosts, blueberry yields in early varieties are adversely affected (unpublished). Drip irrigation provides good water management but is unsatisfactory for frost protection. Irrigation requires a minimum amount of labor, except with a movable irrigation system. Two to three people are required to operate this system.

Fertilization

Blueberries are fertilized two to three times during the growing season with soil-applied fertilizers. Commonly, fields are fertilized after petal fall and again before harvest. Some growers apply fertilizer a third time right after harvest. Soils are fertilized with machinery, and a tractor operator and one or two other people are required to assist. At least 3 hr are needed to fertilize 10 acres (13). Fertilizer formulations are prepared and delivered by fertilizer distributors. Granular products are delivered in spreaders, and liquid formulations arrive in tanks ready to use with minimal exposure to farm workers. Foliar fertilization is a common practice in many blueberry fields. However, foliar fertilization is limited to minor elements and is applied together with pesticides.

Cultivation and Mowing

Because the blueberry root system is shallow, cultivation is limited to the center of the rows. Disking followed by rotivation occurs once or twice before harvest. However, most growers prefer to maintain a permanent ground cover to facilitate the movement of mechanical equipment during the growing season. Mechanical weed mowing, on the other hand, is a common practice and occurs at least twice. Labor requirements are minimal because it takes only 7 hr to mow a 10-acre field (13).

Pruning

Blueberries need annual pruning. The removal of small, spindly growth near the base of the plant promotes a more upright bush and keeps the fruit away from the ground. Pruning also removes dead and injured branches, fruiting branches close to the ground, spindly and bushy twigs on mature branches, and old stems or parts low in vigor. When blueberry bushes are pruned moderately each year, larger berries are produced and the fruit tends to ripen faster. Pruning is carried out during dormancy, after the leaves have dropped in the fall, and during winter before the buds swell in the spring (12).

Scouting for Disease and Insect Pests

Scouting for plant pests is conducted weekly from bud break to harvest. About 25 pest consultants provide scouting services to the blueberry industry in Michigan and Indiana. Pest control consultants can be both independent and self-employed, work for a chemical supplier or a private pest control business, or work in-house for a grower/packer/shipper who provides scouting services. Independent pest consultants tend to specialize in several fruit crops and frequently contract for services with several blueberry growers. They may have seasonal workers, often agricultural students, to help them in scouting fields. However, as many as 80% of the blueberry growers conduct their own scouting and do not require additional seasonal scouts (personal observation).

Lepidopteran pests are monitored using pheromone-baited traps. Leafrollers, fruit worms, and beetles are monitored by inspecting a minimum of 20 bushes, 3 min each, for

every 40-50 acres of blueberries. This inspection also includes monitoring of diseases (personal observation).

Harvest: Fresh Market versus Processing Blueberries

There is no difference in blueberry production practices in the final marketing of the product. The only difference occurs during harvest. Fresh market blueberries are mostly hand harvested to ensure freshness and quality. Careful hand pickers generally cause the least damage to the bushes and the fruit. Hand harvesting, followed by careful sorting and packaging, does not remove the white "bloom" or surface wax that consumers have come to expect on fresh blueberries. Hand-harvested fruit also is generally not bruised, thus reducing postharvest decay. In Michigan and Indiana, both migrant farm workers and local laborers hand pick blueberries. Five to ten people per acre are needed through the harvest season. As blueberries do not ripen uniformly within clusters on the plants, multiple harvests are required. Most of the common cultivars can be picked clean in two to three harvests spaced 7 to 10 days apart. With larger acreage, growers find they must utilize pickers every third day to keep up with ripening. Recent improvements in mechanical harvesters have made it possible, however, to consider their use in partially meeting the needs of the fresh market producer (11, 12).

Fruit destined for processing (preserves, bulk frozen, individual quick frozen) is either hand harvested if the field is small or inaccessible to machinery or mechanically harvested by over-the-row harvesters which shake the fruit off the bushes. Mechanical harvesting of blueberries has increased as a result of more stringent labor regulation, changes in immigration law, and overall improvements of over-the-row mechanical harvesting technology. Over-the-row self-propelled harvesters with collecting pans and conveyer belts are capable of picking one-half acre per hour, thus replacing about 160 hand pickers (12). As a general rule, a minimum of 10 acres of blueberry production is required to justify the expense of purchasing a self-propelled machine. Usually, harvester operation requires five people, one driver and four helpers to load and unload the bins at the collection site.

Postharvest

Fresh packing of blueberries requires strict worker supervision. If any leaves or stems are placed in the boxes, the fruit will have to be re-sorted prior to packing. Inspection and grading of the fruit takes place in a packing shed. Here the fruit can be passed through an air separation unit to remove twigs and leaves. Then the fruit is carried on a slowly moving conveyor so that overmature, underripe, or decayed fruit can be removed manually or by computers sorting by color (7).

Pest Control

Compared with other fruit crops, blueberries are attacked by few insect pests. However, diseases are a major concern. Fruit rots left uncontrolled can cause extensive fruit losses both before harvest and postharvest. Also, bacterial diseases that attack the

bush during the growing season cause losses of plants and of fruiting wood (shoots and branches in which the fruit will be produced). Early season pests include those that attack buds, such as the oblique banded leafroller, *Choristoneura rosaceana* (Harris), that attacks young shoots, leaves, and flower clusters. The cranberry fruitworm (*Acrobasis vaccinii* Rileyi) and the cherry fruitworm (*Grapholita packardi Zeller*) attack the young fruit during and after bloom. The blueberry maggot (*Rhagoletis mendax* Curran) and the Japanese beetle (*Popillia japonica* Newman) attack the fruit in midsummer before harvest. Aphids, *Illinoia pepperi* McGillivray, can be a problem as a virus vector (14).

The most common fungal diseases in Michigan and Indiana blueberry fields are mummy berry caused by *Monilinia vacinii-corymbosi;* fusicoccum or gordonia canker caused by *Fusicoccum putrefaciens* (=*Godronia cassandrae);* and phomopsis canker caused by *Phomopsis vaccinii*. These diseases affect the vegetative structure of the blueberry bush and the infective stages appear early in the season.

Fruit rots are important diseases both during fruit growth and postharvest. Anthracnose, caused by *Colletotrichum gloeosporioides,* is considered a postharvest fruit rot, but infection may occur much earlier than harvest. Crop losses may run as high as 10 to 20%. Alternaria fruit rot is caused by *Alternaria tenuissima*. The major effect is a leaky, watery fruit rot near harvest. In some seasons, 20 to 30% crop loss can occur (15).

Blueberry root systems are shallow and lack root hairs, a disadvantage when competing for water nutrients. Therefore, good weed control is essential for optimum growth and yield. Mowing, plowing, or rototilling destroy weeds and their seeds and incorporate nutrients into the soil. Herbicide applications are necessary when persistent or perennial weeds need to be controlled. Most common weed problems are wild brambles, invasive *Rubus* spp. (wild blackberries), quack grass, *Agropyron repens* (L.) Beauv., Canada thistle, *Cirsium arvense* (L.) Scop., field bindweed, *Convolvulus arvensis* L., common milkweed, *Asclepias syriaca* L., wild garlic, *Allium vineale* L., wild onion, *Allium canadense* L., and others.

Chemical Pest Control

Chemical agents to control insects and diseases are applied mostly by airblast sprayers. The usual capacity of these sprayers is 500 gal, enough to spray 7-8 acres per tank load. Because of the nature of vegetative growth of the blueberry bush, terrestrial application is made only before fruit coloring. After that, most terrestrial applications are border applications. Aerial applications are preferred nearer harvest time because bushes and berry crop are not damaged. On average, seven applications of insecticides and fungicides are required during the growing season. However, the labor supply is limited and, in most cases, a total of 14 hours are required to spray 10 acres of blueberries (13.)

Tractor-mounted, pull-type, pickup-mounted, and self-propelled sprayers are employed by blueberry growers for weed control. Herbicide sprays are applied at pressures ranging from near 0 to more than 300 pounds per square inch, and application rates varies from less than 1 to more than 100 gallons per acre. Blueberry growers use

various methods for applying herbicides. Overall broadcast spraying is done with a boom sprayer for treating large infestations of perennial weeds during the fall after the pruning operation. Spot sprays are usually applied with either backpack sprayers or by operating a handgun from a line connected to a tractor-mounted sprayer. Spot spraying applies herbicide to the foliage of weed species, avoiding contact with the blueberry foliage. Applications are often made in the summer of the sprout year. On average, chemical weed control in a 10-acre blueberry field requires 3 hr of labor whereas spot weed control require 8 hr (12, 13).

Pesticides

The most common pesticides applied to both fresh and processing blueberries during the year 2000 are listed in Tables 3-5. Not all materials were necessarily used on a single field.

Insecticides

Blueberry production requires the regular use of insecticides to control insect pests (Table 3).

Table 3.—Insecticides, formulations, and dosages applied in blueberry production in the North Central Region, 2002 (17, 18).

Insecticide	Formulation[a]	Rate/acre
Azadirachtin	3 EC	10 fl.oz
	4.5 EC	1 pt
	Aza-direct® EC	32 fl.oz
Azinphos-methyl	50 WP	2 lb
Bacillus thuringiensis kurstaki	DiPel® 150 D	1.5 lb
Carbaryl	80 WSP	1.25-2.25 lb
	50 WP	3-4 lb
	4 EC	1.5-2 qt
Diazinon	50 WP	2 lb
Endosulfan	3 EC	2 qt
Esfenvalerate	0.66 EC	4.8-9.6 fl.oz
Malathion	LVC	10 fl.oz
	8 EC	1.5-2.25 pt
Methomyl	90 SP	1 lb
	2.4 EC	3 pt
Phosmet	70 WP	1.33 lb
Pyrethrins + piperonyl butoxide	Pyronyl® EC	12 fl.oz
Pyrethrins + rotenone	Pyrellin® EC	1-2 pt
Spinosad	2 SC	4-6 fl.oz
Tebufenozide	2 FC	16 fl.oz

[a] D = dust; EC = emulsifiable concentrate; FC = flowable concentrate; LVC = low volatility concentrate; SC = suspension concentrate; SP = soluble powder; WP = wettable powder; WSP = water-soluble packet.

The percentage of blueberry acreage treated with insecticides in the four major blueberry-growing states (Georgia, Michigan, New Jersey, and Oregon) ranged from 58 in Oregon to 98 in Michigan (16). The spray program in Michigan and Indiana included both fungicides and insecticides. Thirteen applications were made in Michigan and 10 in Indiana (17, 18). Most growers make six applications with insecticides. In a typical season, the first insecticide spray occurs at the pink bud stage directed against leafrollers. The second insecticide application takes place at the early petal fall stage. This application is made to control leafrollers, cranberry and cherry fruit worms. A third application at 100% petal fall is for the control of leafrollers, plum curculio, fruitworms, and thrips. Three more insecticide applications are required to control the blueberry maggot and the Japanese beetle, one before the first harvest, and two between the two subsequent harvests.

Early in the season, when the foliage is not full developed, insecticides are applied with ground equipment, and the whole field is treated. Near the first harvest, insecticides are applied using either aircraft or ground equipment. However, because tractors driven in the field would cause damage to the bushes and crops, ground applications are restricted to border sprays. Fixed wing aircraft with closed cockpits are used for most aerial applications; a few growers prefer to use helicopters. Typically, air applications are made with 5-10 gal per acre. The usual capacity of ground airblast sprayers is 500 gal, enough to spray 7-8 acres per tank load (12).

Fungicides

The use of fungicides is an important part of the production of blueberries (Table 4). In the four major blueberry-growing states (Georgia, Michigan, New Jersey, Oregon), 87% of the blueberry acreage was treated with fungicides during the field season of 2001 (16). The percentage of area treated with fungicides in Michigan and Oregon was 74 and 90%, respectively. The number of fungicide applications in Michigan in a typical season is 11, but some of these applications are combined with an insecticide. The first two fungicide applications occur early in the season during the green tip stage, mainly against phomopsis twig blight, fusicoccum canker, and mummy berry. The next three applications are made at pink bud, 25% bloom, and full bloom against the same diseases. However, these applications are also directed against anthracnose and alternaria fruit rots. After petal fall, five more applications are made. One application during postharvest is made to manage the next year's outbreak of phomopsis and fusicoccum cankers (17, 18). Most applications are foliar sprays with airblast sprayers early in the season, but fixed wing aircraft is used preharvest and throughout the harvest.

Table 4.—Fungicides, formulations, and dosages applied in blueberry production in the North Central Region, 2002 (17, 18).

Fungicide	Formulation[a]	Rate/acre
Azoxystrobin	FL	6.2-15.4 fl.oz
Calcium polysulfide	S	5-6 gal
Captan	4 LF	2.24 qt
	50 WP	5 lb
Chlorothalonil	6 EC	3-4 pt
Fenbuconazole	75 WSP	2 oz
Fosetyl-aluminum	WDG	5 lb
Mefenoxam	EC	0.25 pt
Ziram	76 DF	3-4 pt
	76 WDG	3 lb

[a] DF = dry flowable; EC = emulsifiable concentrate; FL = flowable; LF =liquid flowable; S = solution; WDG = water-dispersible granules; WP = wettable powder; WSP = water-soluble packet.

Herbicides

In the four major blueberry-growing states (Georgia, Michigan, New Jersey, Oregon), 65% of the bearing acreage was treated with herbicides (16, Table 5). In Michigan, herbicides were used for weed control in 71% of the blueberry fields. Typically, a preemergence herbicide application for grasses and annual weeds occurs in the fall or early in the spring during the first year after planting and on established blueberries. A postemergence application occurs 30-45 days preharvest for emerged weeds or actively growing grasses (17, 18).

Table 5.—Herbicides, formulations, and dosages applied in blueberry production in the North Central Region, 2002 (17, 18).

Herbicide	Formulation[a]	Rate per acre
Dichlobenil	4 G	100-150 lb
Diuron	80 DF	2-4 lb
Fluazipop-P-butyl	2 E	1-2 pt
Glyphosate	4 L	1-2 qt
Hexazinone	2 L	2-4 qt
Isoxaben	75 DF	0.66-1.33 lb
Isoxaben + trifluralin	2.5 TG	100-200 lb
Napropamide	50 DF	8 lb
Norflurazon	80 W	2.5-5 lb
Oryzalin	4 AS	2-4 qt
Paraquat	3 L	1.7-2.7 pt
Pronamide	50 W	2-4 lb
Sethoxydim	1.5 E	1-2 pt
Simazine	90 WG	2.2-4.4 lb
Sulfosate	4 L	1-2 qt
Terbacil	80 W	1-2 qt

[a] AS = aqueous suspention; DF = dry flowable; E = emulsifiable concentrate; G, TG = granular; L = liquid; W = wettable powder; WG = water-dispersible granules.

Insect Pests

In Michigan and Indiana the blueberry insect pest complex can be divided into those insects that affect the foliage and those that damage the fruit. There are several species for which there is a zero tolerance in blueberries for the fresh or processing markets, namely, cherry and cranberry fruitworms, blueberry maggot, and Japanese beetle. The seasons of expected occurrence of insect and mite pests for blueberry production in Michigan and Indiana are given in Table 6.

Table 6—Time of expected occurrence of insect and mite pests in Michigan and Indiana blueberry fields.

Insect or Mite	Apr		May		Jun		Jul		Aug		Sep		Oct	
Cherry fruitworm														
Cranberry fruitworm														
Plum curculio														
Oblique banded leafroller														
Blueberry aphid														
Blueberry maggot														
Japanese beetle														
Blueberry bud mite														

Early Season Insect Pests

Oblique banded leafroller.--The oblique banded leafroller (OBLR) is a major pest of blueberries. It has many wild hosts and also infests apple, pear, cherry, plum, peach, rose, raspberry, gooseberry, currant, strawberry, and many weeds.

Leafrollers are the larvae or caterpillars of some species of small moths. The name leafroller is derived from their habit of rolling leaves for shelter. Early in the growing season, these brown or green worms feed on floral buds, blossoms, and leaves. When full grown (3/4 to 1 in. long), the larvae seal up the leaf shelter, form a cocoon (a glossy brown case), and undergo metamorphosis. One to two weeks later, they emerge from their shelter. The adults vary in color from brown to yellow, and are about ¾-1 in. long. Most leafrollers have at least two cycles, or generations, per year. Larvae of the summer generation feed on leaves, green berries, and ripe berries. Feeding injury to berries is common. This damage predisposes the tissue to attack by fungal pathogens. Leafrollers are often a problem because they may contaminate harvested fruit. Most processors and consumers alike have a zero tolerance policy for this pest (14, 19).

Chemical Controls.--Pheromone-based monitoring systems have been developed to improve application timing. Insecticides to control OBLR are applied at pink bud, full bloom, 100% petal fall, and preharvest cover spray. Azinphos-methyl, methomyl, carbaryl, and phosmet are effective against the larvae of various leafroller species. Early season applications, before bloom, are based on field scouting. Late season application timing is based on a degree-day model used in conjunction with pheromone trap monitoring and scouting (17, 18).

Biological Control.-- *Bacillus thuringiensis berlinerensis* (B.t.) can be used to control OBLR. Used at egg hatch, B.t. effectively controls first instar larvae. However, its efficacy declines as larval size increases.

Cherry fruitworm.--The damage by the cherry fruitworm (CFW) occurs during ripening of the berries. Infested berries are easily observed because the worm usually joins pairs of berries with silk. Sawdustlike frass is within the berries and is not visible outside the berries. The larva is an orange-pink caterpillar with a brown head. When fully grown, it is about 1/3 inch long. The adult is a mottled gray-black moth with forewings about 3/16 inch long and a wingspan of about 3/8 inch. The cherry fruitworm has one generation per year. It overwinters as mature larvae in hibernacula on the bush. The larvae pupate in the spring and remain in the pupal stage for about 29 days. The appearance of the first adults will vary with seasonal conditions. Moth flight starts 2-4 weeks after petal fall and lasts for 2-3 weeks. The moths are most active during dusk and late evening. The adult moths mate immediately after emergence after which the female is ready to lay eggs. The eggs are laid on the unripe fruit at the time that blossoms drop. After an incubation period of about 10 days, hatching larvae bore into the calyx cup (blossom end) of the berry, feed until about half grown, and then move to a second fruit. Feeding within the berries reduces the size of the crop and spoils the marketability of the berries because there is a zero tolerance for this damage in fresh or processing blueberries (14, 19).

Chemical Controls.--Adult activity is monitored by means of pheromone-baited traps. Traps are placed at the edges of the field 1 or 2 weeks before petal fall. The first application against CFW takes place at full bloom, a second application is recommended 10 days later during 100% petal fall. In cases of severe infestation, a third application is recommended 7-10 days after petal fall. Benzoic acid, phosmet, azinphos-methyl, esfenvalerate, malathion, carbaryl, and methomyl are effective against larvae of CFW (17, 18).

Biological Control.-- *Bacillus thuringiensis berliner* (B.t.) can be used to control CFW. Applied at egg hatch, B.t.s are effect to control first instar larvae. However, timing is very important because once the larva bores into the fruit, B.t. loses its efficacy.

Cranberry Fruitworm.--The cranberry fruitworm (CBFW) is a serious pest of blueberries in the eastern U.S. Some fields have suffered 50-75% losses of fruit; earlier varieties usually are the most infested. Infested berries may be harvested without detection, but later inspectors or consumers find larvae in packaged berries. Wild blueberries and cranberries are often heavily infested with CBFW. Any nearby commercial fields will likely have problems with this pest. Weedy, unattended plantings are also likely to have high populations of this insect. As with the cherry fruitworm, CBFW develops in ripening berries. However, in contrast to the cherry fruitworm, the larva of the CBFW completes its development in more than one berry that is consumed entirely. A single larva may feed within as many as eight berries to complete its development. They move from one berry to another within a cluster and usually web the berries together with silk. In the larval stage, the CBFW is a smooth caterpillar that is mostly green with some brownish-red coloration on its top surface. Larvae are about ½ inch long when fully grown. The adults are brownish-gray moths with a wingspan of about 5/8 inch (14, 18, 19).

The CBFW overwinters in the soil as a full-grown larva within a cocoon made of silk and soil particles. The larvae pupate in the spring and complete development. Adult moths emerge, mate, and lay eggs during the period from bloom through late green fruit. Adults are small night flying moths. The eggs are deposited on the berries, almost always on or inside the calyx cup (blossom end) of unripe fruit. Eggs hatch in about five days. The eggs are very small and difficult to see without a hand lens. Young larvae move to the stem end of the fruit, enter, and feed on the flesh. The larvae attain a length of about 3/8 inch and are usually greenish, sometimes light brown along the back. The frass of the larvae fills the tunnels in the berries and clings to the silk webbing. Very messy feeding sites are produced, which easily distinguish cranberry fruitworm damage from cherry fruitworm damage. Full-grown larvae drop to the ground and spin a hibernation chamber in which they overwinter. There is only one generation per year (2, 12, 18).

Chemical Controls.-- Synthetic sex pheromones for the cranberry fruitworm have been available for several years. Monitoring the flight of adults with sex pheromone-baited traps greatly improves the timing of pesticide treatments for this pest. Experienced scouts can also monitor the calyx ends for eggs to determine the amount of egg laying and the beginning of egg hatching. The CBFW control period is often 7-8 weeks long and begins prior to complete petal fall. Applications 10 and 20 days after blossom drop are important for CBFW control. Benzoic acid, diazinon, azinphos-methyl, phosmet, methomyl, carbaryl, spinosad, malathion, and esfenvalerate provide excellent control. Carbaryl is preferred where cranberry fruitworm and cherry fruitworm are both present (2, 12).

Biological Control.--*Bacillus thuringiensis berliner* (B.t.) can be used to control CBFW. It may be used effectively at egg hatch to control first instar larvae. Growers with severe infestation of cranberry fruitworm during bloom use B.t. However, timing is very important because once the larva bores into the fruit B.t. loses its efficacy. It is moderately effective if weather conditions are favorable following application.

Cultural Control**.--**Elimination of weeds and trash around plants helps to control CBFW by reducing overwintering protection for fruitworm cocoons.

Mechanical Control.--Cranberry fruitworm was effectively controlled in the past by hand-picking infested berries. These are easily detected because of the webbing and their early ripening. This method is still practical in small plantings with light infestations (2, 12, 17, 18).

Plum curculio**,** *Conotrachelus nenuphar* (Herbst).—The plum curculio (PC) is one of the most important insects attacking tree fruits. This beetle overwinters in the adult stage in wooded areas near fields. Adults PC become active in the spring about the time that the earliest varieties begin to bloom. They are found on developing flower buds and later on developing berries. Plum curculio is particularly destructive, and the problem is intensified where stone fruits and apples are interplanted. The female makes distinctive, crescent-shaped wounds on the skin of the fruit when laying eggs. The larva bores into

the fruit and eats its contents over a two-week period. Larvae drop to the ground and pupate in the soil for about four weeks (19).

Chemical Control.—Monitoring of PC begins during petal fall and the first cover period. The foliage or small limbs are tapped early in the morning and the adults are caught on a beating tray. In addition, developing fruits are inspected for feeding and oviposition injury, especially after rain. The activity of this pest is closely related to temperature: 75°F is highly favorable, and activity is reduced at lower temperatures. Below 60°F, activity is negligible. If temperatures reach 70-75°F for two days before the petals fall, the beetles have an opportunity to feed and mate (19).

Petal fall sprays and the first and second cover sprays are directed at the adult and the egg-laying period. Once the fruit is exposed, the females can lay many eggs in a short period of time and cause considerable damage. If the weather is cool at bloom time and petal fall, the beetles may not leave hibernation quarters and move into the fruit trees until first cover. Under these conditions, a first cover application and possibly another application at second cover will be needed. Plum curculio is considered a difficult pest to control and requires a full dosage of an effective pesticide. Diazinon, azinphos-methyl, phosmet, malathion, and carbaryl are excellent products to control PC. However, in the case of azinphos-methyl, no more than three applications should be made during the season (2, 12, 17, 18).

Midseason Insect Pests

Blueberry aphid.—This pest is the primary blueberry aphid found in the north central United States. It feeds on the undersides of the youngest leaves and on tender shoots. Aphids reproduce very rapidly by parthenogenesis (no males are required for reproduction) and can literally cover stems and leaves. The sap loss is a concern only when the plants are very young, during the first 3 years. In Michigan and Indiana, the blueberry aphids overwinter as eggs laid by wingless females very late in the season. Eggs are laid on small sucker shoots and bud scales near the base of the bush and hatch in the spring.

The blueberry aphid is responsible for the transmission of the shoestring virus. The disease is spread from infested plants to healthy plants by the blueberry aphid. Very few of these aphids are winged, therefore, they usually move from one plant to another by crawling along the touching branches. Because of this, the disease spreads down the row, affecting several plants in one row, while the neighboring rows are disease-free. It takes four years from the time a plant is infected until it begins to show symptoms (14, 15).

Chemical Control.—There is no economic threshold that drives the control of blueberry aphids. However, pest control actions are required when the aphid population exceeds more than five aphids per leaf in more than 50% of the bushes sampled after the petal fall stage (unpublished). Diazinon, methomyl, esfenvalerate, and malathion are

recommended for aphid control. The first treatment is applied right after petal fall, with the first cover. If required, a second treatment is applied with the fourth cover (17, 18).

Biological Control.—In most blueberry fields, ladybird beetles and other natural enemies control aphids. However, because aphids usually reproduce more rapidly than their natural enemies, aphids become a greater problem when an insecticide kills their natural enemies.

Blueberry maggot.—This most important blueberry pest in the Midwest will cause processors to reject a load of blueberries containing one maggot. This zero tolerance makes it essential for growers to be certain that their fruit is free of maggots. The blueberry maggot feeds inside ripening fruit and may remain there for some time after harvest. Infested berries cannot be separated from sound berries during harvest and packing, and maggots may emerge from the berries at the point of sale. The blueberry maggot feeds on all varieties of blueberries. Continuous migration from the wild makes it difficult to keep cultivated blueberries free of maggots if they are grown near areas containing stands of wild plants. This insect overwinters in a brown, puparium, about 1/8 inch long, buried in the soil 1-2 inches deep. Adult flies emerge over a prolonged period from late June to early August. The female flies do not begin laying eggs until about 10 days after emergence. Flies alight on fruit to lay one egg per berry under the fruit skin just as the fruit begins to turn blue. The egg hatches in about one week. Maggots feed for about three weeks inside ripening and harvested fruits. There is one generation per growing season (14, 19)

Chemical Control**.—**The determination of the onset of adult fly activity is essential to the control of the blueberry maggot. Protective sprays must be applied before the 7- to 10-day preoviposition period ends. Regular monitoring of blueberry maggot emergence is done with yellow baited sticky traps. This procedure serves three purposes: detection of blueberry maggot populations before they reach damaging levels, optimization of timing of insecticide sprays, reduction of the amount of insecticide used by spraying only those areas actually infested. Adult blueberry maggot flies are controlled during fourth, fifth, and sixth cover with diazinon, azinphos-methyl, phosmet, malathion, carbaryl, esfenvalerate, methomyl, spinosad, and azadirachtin. It is not possible to control the egg or larva chemically because the egg is laid and hatches inside the fruit (17, 18).

Biological Control**.--**Parasitism and predation do not affect maggot infestation. Therefore, pesticides are needed to produce clean fruit. (12, 14, 18).

Japanese beetle, *Popillia japonica* Newman.—This beetle is becoming one of the most important insect pests of blueberries in Michigan and Indiana. Adults cause significant direct and indirect yield loss by causing injury from feeding on the berries and causing concomitant decay from fruit-rotting pathogens. However, the greatest problem occurs during harvest: There is a zero tolerance for Japanese beetles when blueberries are processed and beetles end up as contaminants together with mechanically harvested berries. As contaminants, adult beetles are hard to remove because they are

similar in weight and size to blueberries. There is one generation of Japanese beetle per year. Larvae, or grubs, develop in pastures, lawns, and other types of turf where they live in the soil and feed on roots of grasses. Adults begin to emerge in late June. They feed on the upper surface of blueberry foliage. Adults also feed on sassafras, raspberries, grapes, and peaches. The adult beetle is about ½ inch long and copper-colored, with metallic green markings and tufts of white hairs on the abdomen. Adult beetles will quickly reinfest sprayed fields (14).

Chemical Control.--There are several compounds that provide good control of adult Japanese beetles. However, only those with relatively short preharvest intervals may be used because of the frequency of harvest. Azinphos-methyl, phosmet, methomyl, malathion, carbaryl, esfenvaerate, azadirachtin, pyrethrum + rotenone, and pyrethrins + piperonyl butoxide are recommended for the control of adult beetles. However, only azadirachtin, pyrethrum + rotenone, pyrethrins + piperonyl butoxide may be applied 24 hours before harvest (17, 18).

Cultural Control Practices.--Clean harvesting prevents an accumulation of overripe fruit and helps to prevent beetles from being attracted to plantings. Plowing or cultivation can destroy pupae in the soil. Field rotivation has shown considerable reduction of Japanese beetle larvae in comparison with fields with permanent sod (18, 19, 20).

Biological Control.--Japanese beetle populations may be affected by a number of biological control agents. The important parasitoids include two wasp species that parasitize the larvae, *Tiphia vernalis (*Rohwer*)* and *T. popilliavora* Rohwer, and a tachinid fly that attacks the adults, *Istocheta (=Hyperecteina) aldrichi (*Mesnil). Predation by moles, shrews, skunks, and birds can also account for considerable mortality among immature beetles. But the most important natural enemy is probably *Bacillus popillae*, the etiological agent of milky spore disease. However, parasitoids and bacterial agents have not been successfully developed into a commercially viable management strategy.

Mites Pests

Blueberry bud mite, *Acalitus vaccinii (*Keifer)

This mite has been identified as the cause of poor growth and low yield in blueberry fields. This mite is found at low populations levels in most of the major blueberry production regions in the north central states. The mite is microscopic and feeds inside buds in the winter when it causes damage to developing tissues. This injury results in symptoms that include blistered red bud scales, misshapen flowers, and small leaves and fruit. Whereas these symptoms suggest infestation, shoot samples should be examined under high magnification to confirm the presence of bud mites. Some of the symptoms of mite infestation are quite similar to the catchall category of winter damage (12).

Chemical Control.—The bud mite is challenging to control because of its small size and the difficulty of miticide residues penetrating into the tiny cracks and crevices it inhabits. However, immediately after harvest is the recommended timing for targeting this pest because it is relatively exposed at this time before the buds have formed. Effective control is extremely difficult once the mites are protected under bud scales; therefore, prompt action is needed if control of bud mites is required. A registered miticide for this pest is limited to endosulfan. Bud mites require one application immediately after harvest and again a week later (R. Isaacs, Michigan State University, personal communication).

Cultural Control.--Pruning infested shoots from bushes is an added measure that should be done to reduce infestation. Many growers leave pruning residues in the row middles and chop them in the row. However, in fields infested with bud mites, the removed wood should be taken out of the field and burned or buried. Chopping this wood in the row middles may release the mites back onto the bushes.

Blueberry Diseases

The blueberry disease complex in the north central states includes those caused by pathogenic fungi, viruses, and phytoplasmas. However, the diseases are not all equally important economically. The following blueberry diseases require some type of control on a yearly basis. The time of expected occurrence of blueberry diseases is given in Table 7.

Table 7.–Time of expected occurrence of diseases in blueberry production in Michigan and Indiana.

Blueberry disease	Apr		May		Jun		Jul		Aug		Sep	
Mummy berry		■	■									
Phomopsis canker	■	■	■	■	■	■	■	■	■	■	■	
Fusicoccum canker	■	■	■	■	■	■	■	■	■	■	■	
Botrytis blight		■	■	■								
Anthracnose		■	■	■	■	■	■	■	■	■		
Alternaria fruit rot				■	■	■	■	■	■	■		

Mummy Berry.

Mummy berry is probably the most common disease of blueberries. The fungus overwinters in the shriveled fruit mummies on the ground. In early spring, fungal fruiting cups called apothecia are produced in overwintering mummified berries on or near the soil surface. Ascospores from fruiting cups infect leaves shortly after buds open. A

second type of fungus spore (conidia) is produced in about 3 weeks on blighted flowers and shoots. These conidia are spread to healthy flowers by wind, rain, and insects. Infected flowers turn brown and wither. Leaf and shoot growth expanding from newly opened leaf buds are blackened in the center and eventually wilt and die. The death of the infected shoots is called shoot blight or primary infection. Infected berries look like healthy ones in early developmental stages, but as they near maturity they turn reddish buff or tan. Mature mummy berries are gray, shriveled, and hard. Usually the diseased berries fall before healthy ones are harvested. The resident fungus population in the field becomes highly adapted to the cultivar in the field. The fruiting bodies of the fungus often emerge the same day the buds begin to show green tissue susceptible to infection. Native stands of blueberries can be an important source of windblown spores (2, 12, 15).

*Chemical Control.--F*ungicide applications for mummy berry control are applied at early and late green tip, pink bud, 25% bloom, and full bloom. Fenbuconazole provides excellent control. Azoxystrobin plus captan applications do not control primary infections. Chlorothalonil gives only fair to moderate control. Bloom sprays are targeted for mummy berry and bloom infections of fruit rots. Midseason sprays are targeted for the control of stem cankers and twig blights. Preharvest sprays are targeted for controlling fruit rots (17, 18).

*Cultural Control***.--**In very small plantings, mummies can be raked up and burned. In larger plantings, mummies are buried by cultivating and disking between rows or by covering them with a new layer of mulch at least 2 inches thick. This should be accomplished prior to bud break.

Phomopsis Canker

This disease occurs in the southern Lower Peninsula of Michigan, Indiana, and Illinois. The disease can be devastating to bushes planted in low areas where winter injury and spring frosts are a problem.

Injuries from mechanical harvesting or pruning may also serve as portals for infection. Phomopsis canker appears as an elongated, flattened canker. The conidiospores are spread by splashing rain during the growing season from bud break through September. After the stems have been infected for a season, they will wilt during the summer months. This one-year lag between infection and stem collapse makes control difficult (2, 12, 15).

Chemical Control.--Phomopsis canker can be controlled with azoxystrobin plus captan, chlorothalonil, fosetyl-aluminum, or mefenoxam. All of these products provide good control. Fosetyl-aluminum is used to control phomopsis during green tip and to control phomopsis canker, anthracnose, and alternaria during pink bud through fourth cover and again at preharvest. A calcium polysulfide solution can be applied just before bud break (17, 18).

*Cultural Control***.--**Mechanical damage and cold stress are necessary for phomopsis infection. Therefore, careless pruning, cultivating, and fertilization late in the summer should be avoided. Keeping the plants well watered through prolonged periods of dry weather in the summer and avoiding stress also will help prevent this disease.

Fusicoccum or Godronia Canker

This is a serious disease in the northern Lower and the Upper Peninsula of Michigan. If an east-west line is drawn through Grand Haven, MI, the area north of this line will be where fusicoccum canker is a problem. The area south of this line is where phomopsis canker is a problem. Fusicoccum is caused by the fungus *Fusicoccum putrefaciens (=Godronia cassandrae)*. Fusicoccum is a fungus that infects blueberry stems causing dieback and plant decline. Infected stems (current season, 1-, and 2-year-old) develop elliptical, brownish-purple lesions 1-6 inches long. Losses from this disease can be serious. The fungus overwinters in cankers on stems and crowns of infected plants. Conidia account for nearly all infections and disease spread. Conidia are released during wet weather and dispersed by splashing rain. Infection occurs from bud swell (early spring) through early leaf drop in the autumn. Natural openings in the bark may also serve as infection sites. Infections appear on the current year's stems at bud sites or wounded areas as small reddish-brown areas in early spring. Cankers enlarge each year and eventually may girdle stems, causing them to wilt and die. Cankered branches should be pruned out and destroyed (2, 12, 15).

Chemical Control.--Fusicoccum canker is a season-long disease. Four applications of protective fungicides are required from green tip to petal fall. Another four applications are required from the first cover to preharvest and one more in postharvest to manage this disease. Azoxystrobin plus captan are the main fungicides used to control this canker. Chlorothalonil is also used at 25% bloom (17, 18).

Cultural Control.--Sanitation is essential. Cankered branches should be pruned and destroyed. Varieties differ in their resistance to this disease. The cultivars Jersey and Bluecrop (75% of the Michigan acreage) are highly susceptible.

Botrytis Blight

Botrytis blight is a sporadic disease caused by the fungus, *Botrytis cinerea*. When conditions are favorable, the disease can cause considerable crop loss. Botrytis primarily affects ripening fruit, although under certain circumstances the fungus can cause stem blight as well. Infection occurs primarily on flowers during bloom. The first symptom is a blossom cluster blight or blast. This symptom is similar to the shoot blight caused by mummy berry disease, except that the blossom and cluster blight/blast caused by *Botrytis cinerea* does not have the cream-colored sporulation present. A week or two later, some leaves will show symptoms of death or necrosis. Usually the disease does not progress any further. The fungus survives the winter on dead twigs and in soil organic matter. It is present every year but only causes severe damage during cool, wet periods of several days duration. The disease is more severe when excessive nitrogen has been used, where

air circulation is poor, or when frost has injured blossoms. Rotted berries typically have a gray cast due to the presence of mycelia and spore-bearing structures. Stem symptoms are difficult to distinguish from those caused by *Phomopsis* sp. Cultivars possessing tight fruit clusters, e.g., Weymouth, Blueray, and Rancocas, are particularly susceptible to this disease (2, 12, 15).

Chemical Control.--When weather or history indicates that *Botrytis* sp. will be a problem, fungicides should be applied starting at midbloom with additional sprays at 7- to 10-day intervals through petal fall. Captan or captan plus azoxystrobin are excellent fungicides to control botrytis infections (17, 18).

Anthracnose

Anthracnose is usually a postharvest fruit rot, but infection can occur as early as bloom. The fruit are symptomless until they begin to ripen. A shoot blight is the earliest symptom of the presence of anthracnose, usually causing a few blossom clusters to turn brown or black. Spores are not formed on these blossom clusters. When fruit is ripening and turning blue, there are vast numbers of spores on each fruit that spread to other fruit on the bush by rain or after harvest, when one fruit touches another. The fungus overwinters in and on twigs. The spores can cause blossom cluster blight. The ripening fruit is the most susceptible tissue. Cultivars in which the ripe fruit hangs for a long time on the bush prior to picking are especially susceptible. These include Berkeley, Coville, Bluecrop, Blueray, and Jersey. No cultivars are completely resistant when the weather conditions are favorable for the disease (2, 12, 15).

Chemical Control.--A fungicide spray program beginning at bloom and continuing at 7- to 10-day intervals until harvest is usually effective. Azoxystrobin plus captan tank mix, chlorothalonil, fosetyl-aluminum, or ziram can be used to control anthracnose with excellent results (17, 18).

Cultural Control.--*T*here are several measures that can be taken: harvest frequently to prevent overripe fruit; cool berries rapidly after harvest; and, thoroughly prune bushes to remove dead twig tips and wood to reduce the inoculum.

Alternaria Fruit Rot

This fruit rot is characterized by a green fuzzy growth on infected fruit. The fruit rot's major effect is a leaky, watery fruit rot near harvest. The earliest symptom is the presence of a black, dark green sporulation on the blossom end of the fruit. This appears a week or two before harvest. The causal fungus overwinters in and on the twigs and in debris on the ground. Spores are wind-dispersed and are not usually abundant until early to mid-June. Infections occur mainly after the fruit begins to ripen (2, 12, 15).

*Chemical Control***.--**A fungicide spray program beginning at bloom and continuing at two-week intervals until harvest is usually effective against alternaria.

Azoxystrobin plus captan tank mix, chlorothalonil, or fosetyl-aluminum can be used to control alternaria fruit rot (17, 18).

*Cultural Control.--T*here are three cultural control measures that can be taken: harvest frequently to prevent overripe fruit, cool berries rapidly after harvest, and avoid wounding or bruising fruit during harvest.

Weeds Pests

Perennial weeds are an important problem in blueberry plantations (Table 8). Blueberry root systems are shallow and lack root hairs: this puts them at a disadvantage when competing for water nutrients. Thus, good weed control is essential to optimize growth and yield. Uncontrolled weed growth competes with the crop for water and nutrients. They also exacerbate disease problems by minimizing air movement throughout the plantation, thereby maintaining higher moisture levels on foliage, stems, and fruits. In addition, weeds are hosts for insect pest such as aphids, Japanese beetles, and lepidopterans that feed on blueberries (21).

Table 8.—Seasonal occurrence of weed pests of blueberry production in Michigan and Indiana.

Weed	Apr		May		Jun		Jul		Aug		Sep		Oct	
Quack grass		■	■	■	■	■	■	■	■	■	■	■	■	■
Wild brambles		■	■	■	■	■	■	■	■	■	■	■	■	
Horsenettle					■	■	■	■	■	■	■	■		
Bindweed			■	■	■	■	■	■						
Canada thistle						■	■	■	■	■	■	■		
Poison ivy					■	■	■	■	■					
Swamp smartweed					■	■	■	■	■	■				
Milkweed			■	■	■	■	■	■	■	■	■	■		
Wild garlic & onion				■	■	■	■	■	■	■				
Common dandelion			■	■	■	■	■							
Smooth pigweed			■	■	■	■	■	■	■	■				

Wild Brambles

Invasive wild blackberries have the capacity to rapidly invade blueberry plantations and effectively reduce the growth and survival of newly planted fields. Wild brambles also serve as a source of inoculum for diseases and must be completely eliminated from the field (21). Brambles are a favorite host for Japanese beetles, and fields with extensive invasion of wild brambles require repeated applications of insecticides to eliminate the beetles before harvest (unpublished).

Quack Grass

Quack grass is considered a primary noxious weed in most states. It reproduces by seed and underground rhizomes. Rhizomes vary from 2 to 8 inches (5 to 20 cm) in depth, depending on soil type and soil treatment. Individual rhizomes live only two summers and one winter, but new ones develop from buds in the axils of reduced leaves. Roots arise only at nodes. Quack grass is found in open waste places, pastures, and most cropped areas. It requires special control methods because of its weedy habits (22).

Canada Thistle

Canada thistle reproduces by seeds and horizontal roots that extend several feet deep and some distance horizontally. Stems are 2-5 feet (0.6-1.5 m) tall, grooved, branching only at the top, slightly hairy when young, and increasingly hairy as they mature. The leaves usually have crinkled edges and spiny margins, somewhat lobed and smooth. Flower heads are numerous, compact, about ¾ inch (1.9 cm) or less in diameter, consisting of lavender disk flowers only and surrounded by bracts without spiny tips. Canada thistles are found in all blueberry fields and are a persistent and troublesome weed (22).

Poison Ivy

Rhus radicans L., poison ivy, is a woody perennial reproducing by seed and rootstocks. The plant may be either a low shrub or a vine climbing high into blueberry bushes. When climbing, it is supported by aerial roots along the stem. Leaves consist of three large shiny leaflets each 2-4 inches (5-10 cm) long, pointed at the tip. Leaflet edges are either smooth or irregularly toothed. Poison ivy is found in open woods, hedgerows, thickets, orchards, and wasteland. Because all parts of this plant contain a poisonous material that may cause blistering of the skin, poison ivy is a serious problem during harvest time when blueberry pickers are in the field. Control of poison ivy is very difficult because the plant grows close to the blueberry bush and the potential for damage to the bush is high when herbicides are used (22).

Swamp Smartweed

Polygonum coccineum Muhl., swamp smartweed, also commonly known as tanweed and devil's shoestring, is a perennial reproducing by long, creeping, tough, woody, horizontal rhizomes and by seed. Stems are erect 1-3 feet (0.3-0.9 m) long, enlarged at the nodes, and usually unbranched. They may produce roots at the nodes. Leaves are alternate, oblong, 2½-8 inches (6.3-20 cm) long, pointed at the tip, and rounded at the base with prominent veins. A sheath at the base of each leaf surrounds the stem. Flowers are rose in color and are produced in a compact erect spike 1-3 inches (2.5-7.5 cm) long. Swamp smartweed is found usually in low, wet places in fields,

gardens, or roadsides but may be present elsewhere. The extensive root system makes it a strong competitor with other plants, and it is difficult to kill (22).

Field Bindweed

Field bindweed, also known as creeping jenny, is a perennial, reproducing by seeds and rootstocks and having an extensive root system that may go down 20-30 feet (6-9 m). Stems are smooth, slender, 2-7 feet (0.6-2 m) long, twining or spreading over the surface of the ground. Field bindweed is found in all noncultivated areas and under most cropping systems where it is able to persist and spread. Field bindweed is one of the most troublesome weeds in the region (22).

Common Milkweed

Common milkweed is a perennial reproducing by seed and from rootstocks. The stems are stout and erect, 2-5 feet (0.6-1.5 m) tall, and covered with short, downy hairs, and when severed, exude milky juice. The leaves are opposite, oblong, rounded, 4-8 inches (10-20 cm) long with prominent veins with the upper surfaces smooth and the lower surfaces covered with short white hairs. Milkweed is found in cultivated fields, pastures, open woods, and roadsides (22).

Wild Garlic

Wild garlic is another perennial commonly found in blueberry fields in the north central states. This weed and wild onion are serious pests in some fields where they have shown resistance to most herbicides (unpublished). Wild garlic is a perennial reproducing from seed, aerial, and underground bulblets. The stems are 1-3 feet (30-90 cm) tall, smooth, and waxy. The leaves are slender, hollow, nearly round, and are attached to the lower half of stem. Aerial bulblets form in a cluster at the top of stem and are oval and smooth with a shiny covering.

Wild Onion

Wild onion is similar to wild garlic but does not produce by underground bulblets. The leaves are flat, not hollow, and arise from the base of the plant only. The old bulb coat of wild onion is fibrous-matted whereas it is thin and membranous in wild garlic. It is found in the same places as wild garlic (22).

Other perennial weeds commonly found in blueberries are horsenettle, *Solanum carolinense* L., and common dandelion, *Taraxacum officinale* Weber. The smooth pigweed, *Amaranthus hybridus* L., is an annual weed also found commonly in blueberry plantations. Weed management of these species in blueberries is summarized in Tables 9 and 10.

Table 9.—Herbicides recommended for use on blueberries; the transplanting year (2).

Weed	Timing of treatment	Herbicide	Formulation	Dose/acre
Preemergent				
Grasses	At transplanting	Norflurazon	Dry flowable	2.5 lb
		Napropamide	50% wettable powder	4 lb
Annual broadleafs, broadleaf weeds	Early spring or fall	Simazine	80% wettable powder	2.5 lb
Some perennials, grasses, broadleaved weeds	Fall after transplanting	Dichlobenil	4% granular	100-150 lb
Postemergent				
Grasses	When grasses are 2-8" tall prior to seed head	Sethoxydim	Emulsifiable concentrate	2 pt + 2 pt oil
		Fluazipop-P-butyl[a]	2000	32-48 oz
Emerged weeds	Fall (mid-September)	Glyphosate	Water soluble liquid	1-3 qt
	When new weeds are present	Paraquat	Liquid	2-3 pt

[a] Discontinued by manufacturer.

Table 10.—Herbicides recommended for use on established blueberry plantings (2).

Weed	Timing of treatment	Herbicide	Formulation	Dose/acre
Preemergent				
Annual broadleafs, Grasses	Fall to early spring	Simazine	80% wettable powder	2.5-5 lb
Annual grasses, some broadleafs	Late fall to early spring; before weed seeds germinate	Napromamide	50% wettable powder	4-6 lb
Some pereninials, annual grasses, some broadleafs	Late fall or early spring, soil temperature must be below 50°F	Dichlobenil	4% granular	100-150 lb
Annual broadleafs, grasses, weeds	Fall to early spring	Diuron	80% wettable powder	2-3 lb
Broadleafs, some perennials	Early spring or in fall After harvest; preemergence or early stages of growth	Terbacil	Wettable powder	2-3 lb
Grasses, some broadleafs	Early spring; over weed-free surface	Oryzalin	Aqueous suspention	2-6 qt
Grasses	Fall-early spring	Norflurazon	Dry flowable	2.5-5 lb
Grasses, chickweed	Fall-early winter	Pronamide	Wettable powder	2-4 lb
Postemergent				
Grasses	When grasses are 2-8 in. tall prior to seed head	Sethoxydim	Emulsifiable concentrate	2 pt + 2 pt oil
	When new weeds are present	Paraquat	Liquid	2-3 pt
Emerged weeds	Fall (mid-September)	Glyphosphate	Water soluble liquid	1-3 qt

Vertebrate Pests

Birds

Birds are a major pest problem in highbush blueberries from late June until early August. If left unchecked, they can destroy enough of the crop to ruin the profitability of a planting. In some years, up to 30% of the crop is lost to birds. In the north central states, damage is most frequently caused by robins (*Tordus migratorius* L.), common grackles [(*Quiscalus quiscula* (L.)], and starlings [*Sturnus vulgaris* (L.)]. The unavailability of chemical deterrents has made bird control a more difficult task in recent times, but effective means are still available. Among them, blueberry growers rely on the following tools (12).

Auditory frightening devices.--Sounds repel vertebrates due to pain, fear, communication jamming, disorientation, or audiogenic seizures. However, after some time most animals adapt quickly and ignore the sounds. Control methods for birds rely on bangers, crackers, poppers, bombers, sirens, etc., but birds quickly habituate to the sound. However, a combination of noise and visuals may be effective. Some grower operations have hired people to regularly drive motorcycles and/or all-terrain vehicles

through the planting when the fruit is ripe. This seems to keep birds away quite well (2, 7, 12).

Visual scare devices.—Visual scare devices are variably effective with birds. Scarecrows, balloons, kites, or stuffed owls may work on certain bird species in certain areas, but none seems to have widespread dependability. Scarecrows, scare-eye balloons, stuffed owls, or snakes are devices that may be placed in the planting only when the fruit begins to ripen and then moved at least once per day. Scare-eye balloons should be removed from the field after harvest. This action will reduce the chance of birds becoming accustomed to the devices and will increase the duration of their effectiveness. Kites and helium-filled balloons positioned high above the planting with a silhouette of a hawk hanging from them have provided good results in some areas (2, 7, 12).

Voles

Voles can be a serious problem in blueberry plantings. They feed on the bark of stems or on the roots, depending on which species of vole is present. In the Midwest, two species are found:, the meadow vole [*Microtus pennsylvanicus* (Ord)] and the pine vole [*Microtus pinetorum* (Leconte)]. Both may be present in a blueberry planting. It is important to determine which species is present in order to make management decisions. Size and appearance of the two species differ, although it is somewhat rare to actually see them. The meadow vole has a long body (6-8 inches, 150-195 cm) and a relatively long tail, prominent eyes and ears, coarse fur, and is dull gray to chestnut in color with a gray belly. The pine vole has a short body (4-5 inches, 110-135 cm) and short tail, sunken eyes and ears, fine velvety fur and is bright chestnut in color with a slate gray belly.

Meadow voles are active on the surface of the ground, feeding on the bark of the bushes and making shallow trails in the grass or mulch around the plants. Food caches and droppings can be found in these surface trails. Pine voles are active below ground, feeding on roots. Subsurface trails can be found by digging around the bushes. These trails come to the surface where mounds of dirt can be seen. Holes leading into these trails are about 1 inch in diameter (2, 7, 12).

Management.--In some cases, the removal of mulch material around the bushes may help to reduce the meadow vole population. However, this is risky for bushes susceptible to drought stress. In such cases, a mulch material that does not support tunneling is desirable, that is, a mulch that caves in easily. In some states, rodenticides or avicides are restricted and would require a U.S. Fish and Wildlife Service permit applied only by a state-certified pesticide applicator (24). For example, the use of zinc phosphide pellets is prohibited in some counties of Texas, Utah, and Puerto Rico. However, some toxicants are allowed under certain situations with proper permits (2, 7, 12.).

Toxicants.--Used in conjunction with habitat modification, rodenticides are an important component of most control programs because they provide the quickest and most practical means of bringing large populations of voles under control. In Indiana, rodenticides containing zinc phosphide, chlorphacinone, or diphacinone + sodium

saccharin are currently registered for use in orchards (25). In Michigan, zinc phosphide concentrate is approved for use in blueberries. Most rodenticides may be used only during the dormant season when bushes are not bearing fruit (26).

Postharvest Considerations

There are two considerations that give growers and shippers concern from the production side of the blueberry industry. First, there is a zero tolerance for insect parts in blueberries destined for processing. However, the presence of the Japanese beetle in blueberry fields of Michigan and Indiana has increased the number of complaints from buyers in relation to the frequency of finding insects in blueberries for processing. This situation has been exacerbated by the restriction on the use of broad-spectrum insecticides traditionally used to clean the crop before harvest. New chemistries available are narrow-spectrum and less effective against the Japanese beetle. As a result, multiple applications of these compounds are required to meet the standards imposed by the industry. The second concern is the presence of natural microorganisms present in harvested blueberries. The food industry demands more clean products from blueberry growers, that is, fewer naturally occurring microorganisms, such as yeast, molds, etc. This constraint is forcing the blueberry industry to buy expensive equipment to sanitize the berries before being shipped (D. Trinka, Michigan Blueberry Growers Assoc., personal communication).

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