COOPERATIVE EXTENSION SERVICE
UNIVERSITY OF KENTUCKY COLLEGE OF AGRICULTURE, FOOD AND ENVIRONMENT, LEXINGTON, KY, 40546

ID-210

Midwest Blueberry Production Guide

Agriculture and Natural Resources • Family and Consumer Sciences • 4-H Youth Development • Community and Economic Development

Contents

Edited by

Nicole Ward Gauthier and Cheryl Kaiser, Department of Plant Pathology, University of Kentucky

Contributors

University of Kentucky—Tom Barnes, Department of Forestry; Chris Smigell, John Strang, Dwight Wolfe, and Shawn Wright, Department of Horticulture; Nicole Ward Gauthier, Department of Plant Pathology

University of Missouri—Patrick Byers, Extension Service

Pennsylvania State University—Kathy Demchak, Department of Horticulture

The Ohio State University—Michael Ellis, Department of Plant Pathology; Gary Gao, South Centers and Department of Extension

Michigan State University—Eric Hanson, Department of Horticulture; Rufus Isaacs, Department of Entomology

University of Arkansas—Donn Johnson, Department of Entomology

Mississippi State University—Eric Stafne, Department of Plant and Soil Sciences

The Midwest Fruit Workers would also like to thank the authors of the following publications for contributions to this guide: Mid-Atlantic Berry Guide, Michigan State University Blueberry Facts, and Northwest Berry and Grape Information Network.

Cover photo: Mark Ehlenfeldt, USDA-ARS

Chapter 1

Introduction

Blueberries are one of the few fruit crops native to North America. Wild blueberries were utilized by Native Americans for making medicines, dyes, and flavorings, as well as for direct consumption. Once a small-scale crop produced within limited regions, blueberries are now grown throughout the United States and the rest of the world. Although highbush blueberries (*Vaccinium corymbosum*) are the primary type of blueberry grown commercially, others such as southern highbush (*Vaccinium* spp.), rabbiteye (*V. virgatum;* syn. *V. ashei*), and lowbush (*V. angustifolium*) are commonly grown in regions that suit their horticultural requirements.

Before improved varieties were available for commercial production, wild blueberries were used to supply the market demand. Highbush blueberry cultivation and breeding programs, which began in the early 1900s, paved the way for the modern blueberry industry. Early blueberry production was limited to the eastern United States and Upper Midwest, but with the new cultivars available, growers and researchers alike began to look outside of this region. By the 1930s and 1940s, blueberries were being grown in North Carolina and the West Coast, with further expansion occurring in subsequent decades. Desirable traits were intensified, and the highbush blueberry industry continued to grow worldwide. Today, nearly 90 percent of the world's blueberries are grown in North America.

The main blueberry production regions in the United States are the Northeast (Maine, New Jersey, New York), Southeast (Alabama, Florida, Georgia, Mississippi, North Carolina), Northwest and West (California, Oregon, Washington), and Midwest (Arkansas, Indiana, Michigan). The production-use in the United States is divided between fresh and processed, with a slight majority (about 55 percent) sold for fresh consumption. The United States not only exports blueberries, but it also imports fruit from other countries, such as Canada and Chile, between harvest seasons.

Commercial production of blueberries is a relatively new phenomenon when compared to other fruit crops (such as apples, peaches, and grapes). Cultivated blueberry acreage, which was essentially nonexistent during the last century, is more than 70,000 acres in the United States alone. Markets are varied, with berries sold in both retail and wholesale markets. Small scale, local production has also grown substantially in recent years, including farmers markets, roadside stands, and pick-your-own.

Blueberries, when compared to other fruits, are desirable because they have small seeds, thin skins, vibrant flavor, attractive color, good storage capability, can be mechanically harvested, and are adaptable for value-added products. In addition to flavor, blueberries have a number of health benefits, such as low levels of calories, sodium, and cholesterol, along with high vitamin C and fiber. Blueberries also contain one of the highest levels of antioxidants, including flavonoids and phenolic compounds, of any other fruit or vegetable. Researchers have linked blueberries to the reduction of "bad" cholesterol and slowing of age-related memory loss. Increased recognition of these and other health benefits contributed to the 160 percent increase in U.S. blueberry consumption between 1994 and 2003 and has also sparked an increased use of blueberries in jams, jellies, and pastries.

Additional Resources

Bushway, L. 2005. Eat your blueberries. Cornell University. http://www.fruit.cornell.edu/berry/.

Coville, F.V. 1937. Improving the wild blueberry, pp. 559-574 in United States Department of Agriculture Yearbook of Agriculture 1937. Washington, D.C.

Eck, P., R.E. Gough, I.V. Hall, and J.M. Spiers. 1990. Blueberry management, pp. 273-333 in Small Fruit Crop Management. G. Galletta and D. Himelrick, eds. Prentice Hall, Englewood Cliffs, NJ.

Economic Research Service. 2012. USDA http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID = 1765.

Pritts, M. and J. Hancock. 1992. Highbush blueberry production guide. Northeast Regional Agricultural Engineering Service, NRAES-55.

Blueberry Growth and Development

Figure 2-1. Blueberry bush with ripe berries.

Blueberry plants (Figure 2-1) are perennial woody shrubs that mature in 5 to 7 years. Canes emerge from a central crown, and each plant typically produces 15 to 18 upright canes by maturity. Growth habit is usually upright, although some cultivars have a spreading form. Blueberry plants are deciduous, reaching full dormancy during the winter months. Most highbush blueberry cultivars require over 600 hours below 45°F to satisfy their chilling requirement.

Plants break dormancy in spring after chilling requirements are met and temperatures begin to warm. Often, chilling period requirements are reached during mid-winter, and then cold temperatures maintain dormancy. Warm spring temperatures break dormancy, but once dormancy is broken, sap begins flowing, making plants more susceptible to freeze damage. As flower buds begin to swell, leaf emergence and shoot growth occurs. This shoot growth continues through flowering. The first growth flush is the most vigorous, but at least two additional, less vigorous growth flushes occur later during the season. Emerging young, tender green shoots eventually mature to produce woody canes.

As day length shortens and temperatures cool in autumn, growth ceases and plants begin to acclimate for dormancy. This acclimation is a major contributor to cold tolerance. Until hardened off, plants can be damaged at temperatures as low as 28°F. In order for plants to acclimate to cold temperatures, they require proper hardening conditions: progressively cooler temperatures through autumn, followed by several mild freezing events. Maximum cold hardiness is reached after several days of sub-freezing temperatures.

Once chilling hours are met, warm temperatures can coax blueberry plants out of dormancy, leading to greater freeze sensitivity. Fluctuations between above-freezing and below-freezing temperatures result in loss of hardiness, especially during the spring months. Typically, the more southern latitudes in the U.S. have greater temperature fluctuations in spring. While upper plant parts acclimate to winter temperatures, roots do not acclimate because they are protected from extreme temperatures by soil. In areas where extreme cold temperatures are prevalent during winter, mulch serves as an effective insulator (see Chapter 6: *Irrigation and Water Management*).

Cold tolerance and acclimation (hardening-off) are also dependent upon plant health and vigor. Stressed blueberry plants often do not properly acclimate or reach maximum cold tolerance levels. Plants build up food reserves during the acclimation period, and reduced photosynthesis can reduce food production. Pest damage or stress due to poor cultural practices reduces acclimation and maximum cold hardiness. Proper pruning methods and timing (see Chapter 9: *Pruning and Growth Management*) reduce stress. Avoid drought stresses and winter desiccation by providing sufficient water during the acclimation period, as well as throughout the year, as necessary. Hot weather above 95° to 100°F can lead to high water loss, so supplemental water availability is critical in order to avoid plant stress.

Flowers

Blueberry flower buds form in autumn, with 5 to 8 flower buds on each shoot (highbush). Each bud has 5 to 10 potential flowers. Flowering can last 1 to 2 weeks, although early flowering cultivars usually bloom for a longer period due in part to genetics and to cooler temperatures. Buds on shoot tips open first, and then flowering occurs sequentially down shoots. Buds on thin canes open before those on thick, woody canes.

Blueberries have urn-shaped, inverted flowers (Figure 2-2) that shield them from wind and rain. As a result, self-pollination often cannot occur and pollination by insects is required (see Chapter 7: *Pollination*). Flower sweetness readily attracts insects such as bees; bees vibrate/sonicate and loosen pollen, thereby spreading pollen from flower to flower or self-pollinating flowers. Stigmas are only receptive to pollen for 3 to 6 days after bloom. Pollinated flowers turn red colored, while unpollinated flowers remain white. Each of several ovaries per flower requires pollination; the more that

Figure 2-2. Blueberry flowers in the early stage of bloom.

Figure 2-3. Ripe blueberry fruit ready to harvest.

are pollinated, the larger the fruit will develop. Some cultivars are self-unfruitful, so cross-pollination increases fruit set for these cultivars, also resulting in earlier fruit production and larger berries.

Overall, open flowers with exposed stigmas are susceptible to a number of potential problems. They are the least cold hardy flower stage and can be easily damaged during extreme cold weather. Early blooming cultivars also risk poor pollination as cool spring weather limits bee activity.

Fruit

Blueberry fruit develop approximately 2 to 3 months after bloom, dependent upon cultivar, weather conditions, and plant vigor. Overall, thicker canes produce larger berries. Fruit is initially tart, but as fruit-acids are broken down during ripening, tartness is lost. Sugar is manufactured by leaves and transported to berries. Sugar levels increase for several days after fruit turns blue. For the highest quality fruit, berries should be allowed to ripen on plants (Figure 2-3); fruit flavor and sugar content will not improve after harvest. Green fruit contain approximately 7 percent sugar while mature fruit contain approximately 15 percent sugar. Additionally, fruit size increases up to 35 percent after fruit turns blue, culminating in about 85 percent water. Consequently, drought reduces fruit size, lowers starch content, and ultimately results in lower sugar content. The riper the fruit, the shorter the postharvest shelf life, but storage at 32°F and 90 percent relative humidity can extend storage life by up to 12-fold.

Roots

Root growth begins in spring when soil temperatures reach 43°F, usually the time buds begin to swell. Root growth stops when fruit reach maturity and resumes again after harvest. In fact, during late summer and autumn, after harvest and when soil temperatures drop below 60°F again, blueberry roots make most of their growth. Blueberries have extremely fibrous root systems, which require porous sandy or sandy loam soil; their roots cannot extend through compacted soil. Moreover, blueberry root systems are shallow, remaining in the top 8 to 12 inches of soil. Roots are contained primarily (90 percent) within the dripline. Because they lack root hairs, blueberry roots are sensitive to drought and changes to soil-water conditions. This sensitivity to temperature extremes and moisture fluctuations makes mulch a critical practice in blueberry cultivation (see Chapter 6: *Irrigation and Water Management*). In addition to intolerance for drought conditions, blueberry plants are also sensitive to standing water and root rotting pathogens; never plant blueberry in flooding or heavy soil (see Chapter 11: *Blueberry Diseases*). Finally, blueberry plants are not aggressive competitors and do not compete well with weeds, especially when shrubs are young. Therefore, weed control is of paramount importance when establishing a blueberry planting (see Chapter 14: *Weed Management*).

Resources

Reproductive Growth and Development of Blueberry (University of Florida), http://edis.ifas.ufl.edu/pdffiles/HS/HS22000.pdf.

Growth Stages

Dormant or tight bud

Plant part: Flower bud.
Description: No visible swelling of fruit buds. Bud scales tightly closed. No visible signs of growth.

Bud swell

Plant part: Flower bud.
Description: First sign of growth in spring. Visible swelling of the flower buds; outer bud scales begin to separate at the tip revealing paler interior bud scales.

Bud break or bud burst

Plant part: Flower bud.
Description: Flower buds open and individual flowers can be seen between bud scales.

Tight cluster

Plant part: Flower.
Description: Individual flowers are distinguishable in flower clusters.

Early pink bud

Plant part: Flower.
Description: Expanding flowers are readily visible and have separated. Pink corolla tubes (petals) are short and closed.

Late pink bud

Plant part: Flower.
Description: Individual flowers fully developed. Expanded corollas are now white but still closed.

Full bloom

Plant part: Flower.
Description: Most flowers on the bush have opened.

Petal fall

Plant part: Flower.
Description: Corolla tubes are falling off flowers, revealing small green fruit. This is the most vulnerable stage to freeze injury.

Early green fruit

Plant part: Flower.
Description: Small green berries are expanding. Fruit in clusters vary from large to small pea-sized. Early fruit growth is by cell division.

Fruit coloring

Plant part: Fruit.
Description: Oldest, largest fruit in clusters begin to change color from green to pink to blue. Fruit begins to soften. Cell division has stopped and fruit growth is by cell expansion.

Fruit bud set

Plant part: Shoot.
Description: After harvest the blueberry bush stores reserves for next year's growth. Shoot growth may begin again. Flower buds for next year's crop form in September and October. These flower buds form first at shoot tips. These large, clearly visible buds can be used to estimate next year's crop potential.

Fall color

Plant part: Shoot.
Description: At the end of the growing season, leaves change color as nutrients are mobilized back into shoots for growth next spring.

Chapter 3

Types of Blueberries and Cultivar Selection

Taxonomically, there are a number of species of blueberries, but all belong to the genus *Vaccinium*. Further, there are many interspecific hybrids that are produced under artificially-controlled conditions. These hybrid selections include diploid, tetraploid, hexaploid, and heteroploid crosses. For practical purposes, however, this publication will consider the four types (or species) of blueberries that are primarily used commercially.

Northern Highbush (*Vaccinium corymbosum*). The most common type of blueberry and the primary commercial blueberry in the Midwest is the northern highbush (Figure 3-1). This species is native to the eastern United States, ranging from southern Nova Scotia to Wisconsin and down the Atlantic coast to eastern Texas. Plants, which prefer highly acidic, organic soils, can reach 6 to 10 feet in height at full maturity. Chilling requirements vary from 650 to 900 hours, and flowers survive temperatures as low as -22° to -31°F. Fruit ripens 60 to 100 days after petal fall during a 2- to 5-week harvest season. Fruit can reach up to 1 inch diameter. Production varies from 4,000 to 10,000 pounds per acre, with reports of up to 25,000 pounds per acre.

Rabbiteye (*Vaccinium virgatum;* syn. *V. ashei*). Native to the Southeastern U.S., rabbiteye blueberries grow from North Carolina to northeastern Florida and west to Mississippi and Louisiana. Plants may reach a height of 15 feet at maturity (Figure 3-2). Chilling requirements, which are lower than highbush types, vary from 350 to 650 hours. Bloom occurs from 1 to 1½ weeks earlier than highbush types, and flower buds can survive temperatures of -12 to -15°F. Bushes can grow to 30 feet in height and produce from 8,000 to 9,000 pounds per acre.

Southern Highbush (*Vaccinium darrowi x V. virgatum*). Southern highbush are hybrids with northern highbush and native southern varieties in their ancestry. Southern highbush varieties have greater heat tolerance and a lower winter chilling requirement than northern highbush blueberries. Plants average 3 to 6 feet tall when mature. Flower buds can survive mid-winter temperatures from 10°F to -10°F, depending upon cultivar. Growers in the southernmost ranges of the Midwest have been successful with southern highbush; however, new growers should contact local Extension agents or specialists for guidance.

Lowbush (*V. angustifolium, V. myrtilloides*). Native to the northeastern United States and parts of Canada, lowbush blueberry (Figure 3-3) is the most important commercially-grown blueberry in the northernmost regions of the U.S. The small deciduous shrub has a spreading form; plants grow together in a 6- to 24-inch high thicket that is harvested with hand rakes. Most of the fruit is used for processing, as opposed to fruit from highbush plants, which are primarily sold on the fresh market.

Figure 3-2. Rabbiteye blueberry planting.

Figure 3-3. Lowbush blueberries.

Figure 3-1. (a) Northern highbush blueberry planting, (b) Bluecrop variety, and (c) Bluetta variety.

Table 3-1. Northern Highbush Blueberry Varieties.

Variety	Season	Growing Zones	Habit	Fruit Size	Picking Scar	Uses	Comments
Aurora	very late	4-7	upright, vigorous	M-VL	S	F P U	New; moderate yields; latest ripening variety, can overbear; fruit firm, excellent flavor, tart if not fully ripe, good shelf-life
Berkeley	mid to late	3-7	upright	L	L	U	Moderate yields; fruit firm, fair flavor, good shelf-life; powdery mildew resistant, susceptible to Phomopsis stem canker
Bluecrop	early to mid	4-7	upright, open	L-VL	S	F P U	High, consistent yields; can overbear; adapts to variety of sites; long harvest period; drought resistant; fruit firm, high quality, resistant to cracking, limited shelf-life; very resistant to shoestring virus and moderately resistant to red ringspot virus, mummy berry, and powdery mildew, very susceptible to anthracnose
Bluegold	mid to late	4-7	upright, vigorous, small	M-L	S	F P U	Moderate yields; easy to pick, concentrated harvest period, suitable for mechanical harvest; fruit flavor varies with site, firm, stem can stay on berry; very susceptible to shoot phase of mummy berry but some resistance to fruit phase, moderate anthracnose resistance
Bluejay	early to mid	4-7	upright, vigorous	M	S	F P U	High yields; fast growth, easy to establish; suitable for mechanical harvest; fruit mild flavor, very firm, ships well, holds up well on bush; resistant to shoestring virus, moderate resistance to anthracnose, resistant to both phases of mummy berry
Blueray	early to mid	3-8	upright, open	L-VL	M	F U	High yields; does well in hot summers, very cold winters; can overbear; fruit dark, firm, out-standing flavor; susceptible to mummy berry, anthracnose, red ringspot virus
Bluetta	early	4-7	upright, small	M	L	F P U	Moderate yields; late bloom; fruit tangy, dark color, fair flavor, short shelf-life; susceptible to Phomopsis stem canker in the south
Brigitta	mid to late	4-8	upright, spreading	M-L	S		Moderate yields; fruit tart, very firm, good shelf-life
Cara's Choice	mid	5-7	small, spreading	M	S	F U	New; moderate yields; fruit hangs long on bush, outstanding flavor, dry scar, very firm; moderate resistance to mummy berry shoot phase but susceptible to fruit phase, moderately susceptible to anthracnose
Chandler	mid to late	4-7	slightly spreading	VL	S	U	Large yields, production variable; long harvest period; fruit very large, fair flavor
Collins	early to mid	4-7	upright, spreading	M	S	F	Low yields; fruit with fair to good flavor, hangs long on bush; susceptible to mummy berry
Croatan	early	3-7	vigorous, spreading	M-L	L	F U	High yields; fruit medium firm, moderate flavor, ripens fast when hot; moderately susceptible to Botryosphaeria stem blight (dieback), resistant to bud mite
Darrow	late	5-7	upright, vigorous	L-VL	M	F	High yields but inconsistent; fruit excellent flavor, firm; resistant to mummy berry and shoestring virus
Draper	early to mid	5-7	upright, vigorous, stocky	L	S	F P U	New; high yields; concentrated harvest period; fruit excellent flavor, very firm; good shelf-life, easy to pick; some susceptibility to mummy berry
Duke	early	4-7	upright, stocky	L	S	F P U	Consistently large yields; concentrated harvest, suitable for mechanical harvest; blooms late; needs very good growing site; fruit firm, mild, sweet, holds up well on bush; moderately resistant to twig blight, susceptible to Botryosphaeria stem blight (dieback), moderately susceptible to mummy berry fruit phase
Earliblue	very early	5-7	upright	L	M	F P U	Moderate yields, the first to ripen; plant where well suited; erratic fruit set; fruit fair flavor, firm, hangs long on plant, resists cracking, ships well; moderate powdery mildew resistance, susceptible to Phomopsis stem canker
Elliot	very late	4-7	upright	S-M	S	F U P	High yields; blooms late, can overbear, suitable for mechanical harvest, pick fully ripe; fruit small, tangy, resists cracking, stores well; resistant to powdery mildew and shoot phase of mummy berry, susceptible to fruit phase of mummy berry, resistant to anthracnose
Hannah's Choice	early	5-7	upright, vigorous	M-L	S	F	New; moderate yields; fruit mild, excellent flavor, firm, sweet, size decreases as harvest progresses; some resistance to both phases of mummy berry, moderate anthracnose resistance
Hardyblue	mid	4-7	upright, vigorous	M		P	Moderate to large yields; adapts to heavier soils, suitable for mechanical harvest; fruit dark, very sweet, outstanding quality
Herbert	late	4-7	small, spreading	VL	M	U	Moderate yields; hangs long on plant; fruit dark, soft, thin skin, wet scar; some susceptibility to mummy berry shoot phase, moderately resistant to fruit phase
Jersey	late	4-7	upright, vigorous	S-L	M	F P U	High yields; occasionally small fruit due to poor pollination, easy to establish, tolerates variety of soils; suitable for mechanical harvest; fruit firm, dark, good shelf-life; moderate anthracnose and red ringspot virus resistance, some resistance to both phases of mummy berry

continued

Table 3-1. Northern Highbush Blueberry Varieties (continued).

Variety	Season	Growing Zones	Habit	Fruit Size	Picking Scar	Uses	Comments
Liberty	late	4-7	upright, vigorous	M-L		F P U	New; moderate yields; adaptable to variety of conditions; concentrated harvest, suitable for mechanical harvest; fruit distinctly flavored, easy to pick, very firm
Nelson	mid to late	4-7	upright, spreading	M-L	S	F P U	Moderate yields; fruit firm, very good flavor
Patriot	early	3-7	short, spreading	L	S	U F	Consistently high yields; blooms early; adapts to many soils, may do better in wetter soils; fruit firm, slightly tangy, dark, very good flavor; moderate Phytophthora root rot resistance, moderate resistance to both phases of mummy berry
Reka	early	4-8	upright, vigorous	M-L		P U	Large yields; adapts to variety of soils, adapted to northern climates; suitable for mechanical harvest; fruit outstanding flavor, dark; moderately resistant to both phases of mummy berry, some resistance to anthracnose
Rubel	mid to late	4-8	upright	S	M	P	Consistently large yields; suitable for mechanical harvest; fruit very sweet, outstanding flavor; moderately resistant to Phomopsis stem canker, susceptible to mummy berry, and moderately susceptible to anthracnose
Sierra	early to mid	4-7	upright, spreading	L	S	F P U	Moderate to large yields; does well on some sites; suitable for mechanical harvest; fruit firm, good flavor; moderately anthracnose resistant, some susceptibility to both phases of mummy berry
Spartan	early	5-7	upright, vigorous	VL	M	U	Moderate to large yields; sensitive to high pH, requires light soils with high organic matter; blooms late; suitable for mechanical harvest; fruit firm, easy to pick, outstanding flavor; moderate resistance to both phases of mummy berry, susceptible to anthracnose
Toro	early to mid	4-7	spreading, stocky	M-VL	S	F U	Moderate to large yields, concentrated harvest; slow growing; fruit outstanding quality, easy to pick; some resistance to both phases of mummy berry, moderately resistant to anthracnose

Abbreviations: Fruit Size: S = small, M = medium, L = large, VL = very large
Picking Scar: S = small, M = medium, L = large
Uses: F = sold fresh, P = for processing, U = u-pick

Table 3-2. Southern Highbush Blueberry Varieties.

Variety	Season	Growing Zones	Habit	Fruit Size	Picking Scar	Uses	Comments
Arlen	late	6-10	upright	M-L	S	F	Moderate yields; suitable for mechanical harvest; fruit good flavor and shelf-life; Botryosphaeria stem blight (dieback) and mummy berry resistant
Bladen	early	6-10	upright, vigorous	M	S	F	Suitable for mechanical harvest; fruit firm, resists cracking
Carteret	early to mid	6-9	upright, vigorous	S-M	S	F	New; high yields; adapts to variety of soils, suitable for mechanical harvest; fruit very good quality, good shelf-life
Legacy	mid to late	5-10	upright, vigorous, spreading	M-L	S	F P U	Consistently large yields; blooms early, long harvest period, suitable for mechanical harvest; fruit holds up well on bush, outstanding flavor; resistant to anthracnose, some resistance to both phases of mummy berry
Lenoir	mid	6-10	vigorous, spreading	M	S	F P	New; moderate yields; needs well-drained soil, suitable for mechanical harvest; fruit firm, very good flavor, good shelf-life; excellent disease resistance
Misty	early	5-10	upright, vigorous, spreading	M-VL	S	F	Consistently high yields; can overbear, long harvest period, suitable for mechanical harvest; fruit very firm; susceptible to Botryosphaeria stem blight (dieback)
O'Neal	very early	5-10	upright, spreading	L	S	F U	Moderate yields; sensitive to high pH, early long bloom makes it a good pollinizer; fruit very firm, outstanding flavor
Ozarkblue	mid to late	4-9	upright, vigorous spreading	M-L	S	F P	Moderate yields; tolerates hot weather, drought resistant, late bloom, long harvest period; fruit firm, fair to excellent flavor; resistant to powdery mildew, some susceptibility to Botryosphaeria stem blight (dieback)
Pamlico	early tomid	6-10	vigorous, spreading	S	S		New; high yields; into production quickly, suitable for mechanical harvest; fruit good shelf-life, good flavor; Botryosphaeria stem blight (dieback) resistant

continued

Table 3-2. Southern Highbush Blueberry Varieties (continued).

Variety	Season	Growing Zones	Habit	Fruit Size	Picking Scar	Uses	Comments
Reveille	very early	5-10	upright, narrow	M-L	S	F U	Consistently moderate yields; early bloom, adapts to variety of soils, suitable for mechanical harvest; fruit firm, crunchy, may crack in rain; moderately Botryosphaeria stem blight (dieback) and anthracnose resistant
Star	early	6-10	upright, spreading	L		F	New; moderate yields; early bloom, low chill, concentrated harvest, suitable for mechanical harvest; fruit firm, dry scar, good flavor, excellent quality, may split in rain; susceptible to Septoria, resistant to Phytophthora root rot and to Botryosphaeria stem blight (dieback)
Summit	mid to late	6-10	spreading	L	S		New; high yields; blooms late; fruit excellent flavor, good shelf life, resists cracking

Abbreviations: Fruit Size: S = small, M = medium, L = large, VL = very large
Picking Scar: S = small, M = medium, L = large
Uses: F = sold fresh, P = for processing, U = u-pick

Table 3-3. Northern Half-high Varieties. Although these can grow in a range of hardiness zones, they were developed for northern production areas. Half-high varieties reach a maximum of height of 3 feet or less.

Variety	Season	Growing Zones	Habit	Fruit Size	Picking Scar	Uses	Comments
Chippewa	mid	3-7	small	M-L	S	F	Moderate yields; fruit firm, very sweet; excellent disease resistance
Northblue	early to mid	3-7	upright, small	M-L	M	F	Low yields; good quality fruit, wild flavor; resistant to mummy berry
North-country	early to mid	3-7	very small	M	M	U F	Low yields; adapts to variety of soils, bears in 2 years
Northland	early to mid	3-7	upright, small, spreading	S-M	M	P	High yields; most hardy northern highbush, adapts to variety of soils and sites; fruit firm, soft, dark, very sweet, wild flavor; resistant to shoestring virus
Northsky	early to mid	3-7	very small	S-M	M	F U	Low yields, good shelf-life; resistant to mummy berry
Polaris	mid	3-8	upright, small	M	S	F P	Moderate yields; requires sandy, acid soil; fruit sweet, tart; excellent disease resistant
St. Cloud	early to mid	3-5	small	M	S		Moderate yields; fruit good flavor, good shelf-life

Abbreviations: Fruit Size: S = small, M = medium, L = large, VL = very large
Picking Scar: S = small, M = medium, L = large
Uses: F = sold fresh, P = for processing, U = u-pick

Cultivar Selection

There are numerous high quality highbush blueberry cultivars available in the commercial trade due to strong breeding efforts in the United States. Blueberry growers are encouraged to check with local Extension professionals and other growers in their state or region for local performance of various blueberry cultivars. Keep in mind that vigorous or high-producing cultivars in one state may not be productive in other states, as climate and soil conditions vary throughout the region.

This section discusses some of the factors that growers should consider when selecting blueberry cultivars. Highbush blueberry cultivars are the focus of this production guide, since they are the predominant blueberry type in the Midwest. If specific microclimates allow for other blueberry types, growers should contact local Extension offices or state specialists for more information.

Desirable Qualities. Desirable fruit characteristics are large size, light blue color, firm fruit, crack resistance, high storage quality, and pleasant aroma and flavor. Additional desirable characteristics include the tendency for fruit to remain attached to plants rather than drop at ripening and presence of a small, dry fruit scar that lessens decay after harvest.

Maturity. Blueberry cultivars also differ in time of ripening. As a rule, berries ripen 60 to 100 days after bloom. Berries on each blueberry bush do not ripen all at once, resulting in each bush supplying fresh fruit for a 2- to 3-week period. Selection of cultivars that differ in ripening dates can result in a continuous supply of fresh berries throughout the fruiting season.

Some blueberry plants are self-compatible and can set economical crops without cross-pollination with another cultivar. However, planting fields with two cross-compatible cultivars can result in larger berries and higher yield. Before planting, carefully research compatible cultivars to plant together and consider the logistics of having multiple cultivars in a field. If it is economically beneficial to plant more than one cultivar in the same field, select those that bloom at the same time. Growers should group cultivars by ripening dates so that harvest will progress in an orderly fashion. For example, Duke and Spartan are popular early-season cultivars; Bluecrop, Draper, and

Toro are common mid-season cultivars; and Nelson, Darrow, and Elliott are often suitable late-season cultivars. Various other combinations are possible and new cultivars are released regularly. Consider bloom and ripening time, compatibility, and productivity of the cultivar options for your region.

Frost Hardiness. Spring frost hardiness is based upon developmental stages of flowers, which varies per cultivar. Earlier maturing cultivars bloom earlier than late-maturing cultivars, and therefore, early maturing cultivars are consequently more prone to frost injury. One exception is Patriot, which ripens later than Duke, but blooms earlier. Blossoms of highbush cultivars withstand temperatures of approximately 28°F when plants are in full bloom.

Harvest Method. Many blueberry growers in the Midwest sell fresh berries though a pick-your-own operation. However, most large-scale blueberry growers also harvest blueberries by machine. If berries are to be machine-harvested, growers should choose suitable cultivars with an upright growth habit. Those cultivars that ripen fruit over a relatively long period or have berries that drop as soon as they ripen are not suitable for mechanical harvest. For best results, berries should hang on bushes for a longer period of time, but drop off once the mechanical harvester shakes the bush.

Chapter 4

Site Selection

The best blueberry planting sites are those with full sunlight, low late-frost risk, and good soil drainage. Selection of a site with desirable climatological characteristics helps reduce cultural problems and assures success of the planting.

Climate

General climatic conditions in many regions of the Midwest are favorable for growing blueberries. Cultivars should be selected according to climatic constraints such as minimum temperatures and length of growing season. Additionally, climate may influence disease, insect, and other pest problems, which will vary due to the differing climatic conditions within the Midwestern region.

Topography

Monitoring or mapping site conditions before planting is recommended. Any prior knowledge of an area's elevation effects and other conditions may help producers locate plantings above frost pockets and avoid damaging seasonal frosts. Advice from those who have grown fruit in a given area can help potential producers avoid frost pockets.

The most frost-free sites are those with higher elevations than surrounding areas, since cold air drains from higher to lower areas. Avoid planting in low areas because cold injury is often greater, resulting in reduced yields in these sites.

Generally, sites with steep slopes (10 percent or more) should be avoided in commercial plantings because of soil erosion and difficulty in operating equipment. Slopes of 3 percent to 5 percent are often ideal, as they promote water and air drainage and reduce risk of frost injury.

Cool temperatures on northern slopes often delay plant growth enough in spring to reduce spring frost damage. However, these slopes may be subject to more harsh winter conditions. The opposite effect may occur on a southern slope, resulting in earlier spring growth and increased risk of frost injury from late frost. A western slope may have the disadvantage of exposure to prevailing winds that, in some areas, may be strong enough to damage plants.

If cold sweeping winds are common during winter, windbreaks may be needed. Sheltering plants from wind not only protects them in the winter, but also leads to reduced desiccation and water loss during summer. Furthermore, since bees are negatively influenced by excessive wind, reducing wind flow favors bee flight in the planting. Windbreaks should be porous, so that winds are slowed by approximately 50 percent. This still permits good air circulation in the planting, as this air movement helps dry dew and rain from the foliage, thereby reducing disease problems.

Table 4-1. Critical Cold Temperatures for Blueberries.

Growth Stage	Critical Cold Temperature
Bud swell	10° to 15°F (-12° to -9°C)
Tight cluster	20° to 23°F (-7° to -5°C)
Early pink bud	23° to 25°F (-5° to -4°C)
Late pink bud	24° to 27°F (-4.4° to -2.8°C)
Full bloom	28°F (-2.2°C)
Petal fall	32°F (0°C)

Frost and Freeze Damage

Low temperatures during mid-winter often are not fatal to blueberry; however, fluctuating early spring temperatures can be detrimental to plantings and reduce yield (Figures 4-1 and 4-2). As plants break dormancy and flower buds begin to open, they are more sensitive to cold temperatures (Table 4-1). Thus, sites with good air drainage and proper cultivar selection are critical.

Figure 4-1. Blueberry flowers with frost-damaged pistils.

Figure 4-2. Young blueberry fruit damaged by frost.

Air Drainage

Air drainage refers to the movement of air from tops to bottoms of hills. A slight slope is ideal for good air movement. Trees and brush should be cleared from the slope to allow cold air to drain away. Air movement helps reduce spring frost injury, especially at lower elevations. Cold air should not be allowed to stagnate.

Air movement also assists in the drying of fruit and foliage. Various diseases, such as gray mold and anthracnose fruit rot, are favored by high humidity and wet plant tissue (see Chapter 11: *Blueberry Diseases*).

Soils and Water Drainage

A location with a permeable soil texture that has good internal and surface drainage is required for vigorous plantings. Water drainage means removal of surface water, as well as percolation or internal movement of water. With good management, blueberry plantings can produce satisfactorily on soils ranging from gravelly loams to silt clay loams.

The USDA Natural Resources Conservation Service (NRCS) has mapped most of the soils in the Midwest. Before producers establish plantings, they should contact the local NRCS office to obtain county soil survey maps and examine soil conditions in the proposed site. Soil maps are helpful in determining soil-drainage characteristics and in evaluating potential sites. However, maps are not substitutes for taking soil samples of the site and making visual evaluations of the subsoil.

Growers should avoid soils that are consistently wet. These soils may have impervious subsoils or other drainage problems. Roots may remain shallow in poorly drained soil, whereas they should penetrate 12 to 18 inches in a deep, well-drained soil. Soils with only moderate drainage characteristics require more intensive soil management (e.g., tiling), and yields may not be satisfactory. In addition, just as cold air should not be allowed to stagnate on a planting site, neither should water be allowed to accumulate (Figure 4-3). Avoid planting bushes in areas where water ponds or puddles for extended periods following a rain. Phytophthora root rot can be a severe problem in wet sites (see Chapter 11: *Blueberry Diseases*).

Figure 4-3. Low areas, such as bottoms of slopes, are susceptible to water accumulation and root rotting diseases. The lower portion of this field is infected with Phytophthora root rot, caused by water accumulation during rainy seasons.

Subsoil characteristics are important when choosing a site because they often indicate the nature of internal drainage. For example, bright, uniformly yellowish-brown subsoil often indicates good internal drainage. Subsoils showing slight mottling of yellow, gray, and orange indicate only moderate drainage. Poorly drained subsoils are characterized by greater mottling or, in some cases, a uniform dark-gray color. Soils should contain at least 3 percent organic matter. In addition to contribution of nutrients, organic matter improves soil texture and improves internal drainage.

To assess internal drainage capacity, examine sites during winter after a heavy rain. Ideally, no standing water should remain after 24 hours. Drain tiles or perforated, corrugated pipe may be used below soil surfaces, but they should be installed prior to planting. If the general topography (elevation, slope, etc.) is favorable, but internal drainage is imperfect, a drainage system should be considered. Tile drainage or perforated pipe drainage improves most sites for the production of the majority of fruit crops. Producers should carefully examine these conditions before blueberries are planted.

Most university Extension specialists recommend that blueberries be planted on raised beds or mounds for improved drainage. Planting on raised beds is just as effective or often more effective as drainage systems and considerably less expensive. Mounds or beds should be 8 to 18 inches high and built with loamy soil amended with organic matter.

Planting and Establishment

Preparation of a proposed blueberry site should begin at least 1 year before planting. Site preparation at this time should include land leveling, drain tile installation (when needed), application of organic matter, and fertility adjustments based on a soil tests. The soil test should provide information on soil pH status as well as sulfur and fertilizer requirements (see Chapter 10: *Soils, Fertilization, and Nutritional Disorders*).


Figure 5-1. Incorporation of peat moss into raised beds.


Figure 5-2. Incorporation of peat moss into raised beds.


Figure 5-3. Peat moss is available in large, compressed bales.


Figure 5-4. Plants are available as container-grown stock plants (shown) or as bare root liners (not shown).


Figure 5-5. Plants should be watered immediately upon delivery and kept moist until installation.

Site Preparation

Adjusting Soil pH. If soil pH is high, apply elemental sulfur to lower pH to a more desirable level (4.5 to 5.0). The application should be made at least several months before planting. Additionally, calcium levels will affect soil pH. If soil tests indicate that calcium levels are greater than 2,500 pounds per acre, it will be difficult to maintain a low pH in the desirable range. Thus, it may be a good idea to consider a crop other than blueberry.

Adding Organic Matter. Organic matter content should be above 3 percent. Peat moss, composted pine bark or composted sawdust should be incorporated (Figures 5-1 to 5-3), and then used as a mulch to improve organic content. As sawdust or other wood products decompose, soil nitrogen is often temporarily unavailable. Addition of supplementary nitrogen and monitoring of soil nutrients is essential, so amendments should be made before planting. Use only composted sawdust, as fresh sawdust could lead to severe nitrogen deficiencies and possible plant death.

A preplant cover crop is recommended the year before orchard planting. In addition to improvement of organic matter content, cover crops suppress weeds and improve soil structure. Animal manures, when available, may be applied in autumn before spring planting. They provide both nutrients and organic matter, but they may raise the soil pH. A suitable application is 10 to 12 tons of horse or cow manure per acre or 50 to 75 pounds per 100 square feet.

Weed Management. Prior to planting, growers must manage persistent weed pests, such as thistle, Johnsongrass, quackgrass, dock, and woody species,

Figure 5-6. A new blueberry planting with recently-installed bushes (background) and prepared beds that are ready for planting (foreground).

Figure 5-7. Proper spacing allows plants room to grow.

such as poison ivy and brambles (see Chapter 14: *Weed Management*). Several safe and effective herbicides are available to control such troublesome weeds during site preparation, but they cannot be used after bushes are planted. If possible, avoid sites that are severely infested with such weeds until they have been eradicated. Once raised beds are developed, grass middles may be planted using a mix of fescue or creeping red fescue and ryegrass in August or September prior to autumn or spring planting. Final weed removal may also be necessary just before planting.

Planting

Planting Material. Proper handling of plant material once received from the nursery is important. Typically, blueberry plants are 2- to 3-years old and are available in either in containers (pots, Figure 5-4) or bare root. Container-grown plants have the advantage of higher transplant success rate, but they are more expensive. Plants in containers can be kept outdoors until planting, as long as they are watered and protected from extreme environmental conditions (heat, cold, hail, etc.) (Figure 5-5). Container plants, if actively growing, can be set in the field after the threat of frost and freeze have passed. Bare root plants are shipped in a dormant state and should be kept under refrigeration until planting. They are sensitive to desiccation and should not be allowed to dry out. Bare root plants can be set in the field once received, generally in the late winter or early spring.

Timing. For best results, blueberry bushes should be planted in autumn into well-prepared beds (Figure 5-6). Spring installation is also acceptable, as long as spring rains do not delay planting into the warmer months. Spring preparation should not be performed until the soil is dry enough to work properly. If soil is worked while wet, soil structure may be damaged. Effects of compaction and a puddled soil, particularly one with high clay content, may result in poor plant growth for a number of years.

Planting Layout. Blueberry plantings should be designed to achieve the following goals:

- Prevent soil erosion.
- Use land area efficiently.
- Optimize plant performance.
- Facilitate management and equipment operation.

Row spacing is typically 10 to 12 feet between rows and 3 to 5 feet between plants within a row (Figure 5-7). About 1,450 plants per acre are installed at a spacing of 10 feet by 3 feet. Plant and row spacings may be adjusted for larger or smaller cultivars.

Irrigation and Water Management

Blueberries have fine roots that are extremely shallow-rooted, thus, plants are highly susceptible to drought stress (Figure 6-1). Root systems of established plants are within 18 inches of the soil surface, while roots of young plants are within the top 12 inches of soil. Soils with hard pans result in even more shallow root systems, and thus, plants become more sensitive to drought conditions. Supplemental watering (1 to 1.5 inches water per week), especially from fruit expansion through harvest, is often required.

Drought conditions can result in the following types of damage to plants and fruit:

- **Root damage and plant decline:** Recovery may be difficult for less vigorous plants.
- **Fruit cracking:** During periods of drought, skins of expanding fruit become dry. Following rain or irrigation, fruit swell faster than skins can accommodate and then split.
- **Reduced bud set:** Flower initiation for the following year begins during midsummer. Water stress reduces bud set the subsequent year.

Different soil textures have different water-holding capacities. Water loss from soil and through plants can be up to 0.25 to 0.60 inches per day, depending upon temperatures, plant size, and soil texture. Some sandy soils may hold less than 1 inch of available water; loamy soils can hold about 2 inches. Thus, available water may be depleted from soils in as little as 2 days during hot, dry conditions. Irrigation schedules must take water losses into account to prevent plant damage. Blueberries have thick leaves and wilting is not always apparent, but wilted foliage and/or shriveled berries indicate that plants are already stressed. Supplemental irrigation should always be applied before wilting occurs.

Figure 6-1. Symptoms of drought stress on blueberry foliage.

Types of Irrigation

Either sprinkler or drip irrigation systems may be used to irrigate blueberry plantings.

Drip Irrigation. Producers that have small plantings with a limited amount of water availability or low water pressure may choose drip systems. Overall, drip irrigation systems are more efficient than sprinkler systems; there is less water loss and soil remains evenly moist. When combined with mulch, this method is most beneficial to plants. Fertilizers and some soil drench pesticides may be applied through drip irrigation.

Some negative aspects of drip irrigation include: dust cannot be washed off fruit using irrigation water, plants cannot be cooled by irrigation on hot summer days, frost protection is not possible, cover crops cannot be irrigated, and maintenance to prevent emitters from clogging is time-consuming and difficult to monitor.

Initially, one emitter per plant is sufficient, but addition of a second emitter is often required as the plants mature (Figure 6-2). One emitter on each side of individual bushes is required because blueberry plants cannot laterally translocate (move within the plant) water or most nutrients. Therefore, if only half the root system receives water or fertilizer, only half of the top portion benefits. It is important for drip-irrigated fields to have a uniform water supply.

Do not place emitters near centers of crowns as water may puddle in this area, producing conditions favorable for Phytophthora root rot (see Chapter 11: *Blueberry Diseases*). Also, in fields newly planted with container stock, emitters should be placed near edges of media so that lighter soil of the potting medium wets before water moves into heavier surrounding soil. Once emitter systems have been installed, they should not be disturbed, as roots will grow predominantly in wetted zones.

Figure 6-2. Drip tape should include at least two emitters per plant in order to provide even watering.

Sprinkler Systems. Overhead sprinklers (Figure 6-3) offer a number of advantages in addition to irrigation. These include: cooling plants during hot weather and providing frost/freeze protection (Figure 6-4) when temperatures drop below freezing during bloom. Overhead irrigation can provide cold protection to plants when temperatures drop as low as 24°F. Overhead irrigation can also be used to maintain soil moisture in cover crops planted between rows. Sprinkler systems are not prone to clogging and require little maintenance. Consider, however, that risers of sprinklers may interfere with machines on fields that are machine harvested.

When considering sprinkler system design, calculate amounts of water emitted by individual sprinkler nozzles to determine spacing. Nozzle size and water pressure are used to determine spacing. Consider that 20 percent to 30 percent of water from overhead sprinkler systems may be lost to evaporation, and operating times should be adjusted accordingly. Additionally, sprinkler systems usually have only 70 percent uniformity, so in order to sufficiently cover all areas of a planting, 30 percent more water than calculated should be applied.

Figure 6-3. Overhead irrigation consists of nozzles mounted onto risers.

Figure 6-4. Overhead irrigation can provide frost protection during early spring.

Mulch

Benefits of Mulch. Blueberries often grow better in mineral soil when mulched, although many successful plantings have no mulch. Mulching to a depth of 5 to 6 inches on soil surfaces of mature plantings keeps soil cool, helps conserve soil moisture, adds organic matter to soil, improves soil structure, and aids in preventing annual weeds from becoming established. Mulch is less effective against perennial weeds.

Blueberry roots tend to grow in mulch, as well as in soil. Thus, as mulch decomposes, roots may become exposed. Mulch should, therefore, be maintained by adding 2 to 3 inches every 2 to 3 years in a 3 to 4 foot band underneath plants.

Types of Mulch. Sawdust is commonly used as mulch for blueberries (Figure 6-5), although it is often discouraged. Sawdust mulch can provide winter habitat for rodents, which can create tunnels

Figure 6-5. Sawdust is commonly used for mulch, but it can have negative effects if not managed properly.

Figure 6-6. Sawdust should be composted for at least 1 year before use as mulch.

Figure 6-7. Woven propylene fabric can be used as mulching material.

under root systems and eat bark from young canes. If applied in thick layers, sawdust can hold excessive amounts of water, or it can crust over and reduce water penetration. Growers who use sawdust as mulch should prepare to reapply often, as it decomposes quickly. Despite the challenges of using sawdust as mulch, strict field management can overcome possible problems. However, non-composted sawdust should never be used. If not well composted, sawdust can tie up nitrogen (N) and cause severe nutrient deficiencies that can lead to plant death. Stockpile sawdust at least 1 year prior to spreading, if possible, for sufficient breakdown (Figure 6-6). Pine sawdust (composted, not fresh) usually has little effect on soil pH. On the other hand, hardwood sawdust increases pH by releasing calcium as it breaks down. Soil pH should be monitored on a yearly basis if hardwood sawdust is used. An additional 50 percent to 100 percent N may be necessary for the first few years to compensate for increased microbial activity and nitrogen consumption. Thus, soil tests are critical to a balanced nutritional program (see Chapter 10: *Soils, Fertilization, and Nutritional Disorders*).

Other organic materials (e.g. tree trimming chips and pine needles) work well as mulch substrates. However, straw and deciduous leaves are not recommended, as they tend to pack, thus preventing adequate water penetration. Straw decomposes quickly and must be replenished more often than most mulch types.

Black plastic has been used effectively as mulch in some areas. If plastic mulch is considered, drip irrigation tubes must be placed underneath plastic. Fertilizer application can be more difficult when plastic mulch is used. Plastic usually deteriorates after 2 to 3 years. Disposal of plastic can be problematic, especially from an environmental standpoint.

Weed matting, consisting of a woven polypropylene fabric (Figure 6-7), is also used successfully as a mulching material in some regions (e.g. Michigan). Water easily passes through mats. Edges must be covered with soil to keep the weed mat in place. On wet sites, weed matting can hold excess moisture and can lead to losses from soil-borne diseases such as Phytophthora root rot (see Chapter 11: *Blueberry Diseases*).

Additional Resources

Northwest Berry and Grape Information Network, USDA-ARS, Oregon State University, University of Idaho, and Washington State University, http://berrygrape.org.

Strik, B., C. Brun, M. Ahmedullah, A. Antonelli, L. Askam, D. Barney, P. Bristow, G. Fisher, J. Hart, D. Havens, R. Ingham, D. Haufman, R. Penhallegon, J. Psheidt, B. Scheer, C. Shanks, and R. Williams. 1993. Highbush blueberry production. Oregon State University Pacific Northwest Extension Publication 215.

Chapter 7

Pollination

Blueberries are capable of setting fruit on 100 percent of flowers, although 80 percent set is considered a full crop. Because blueberry pollen is sticky and heavy, it is not easily transported by wind; therefore insects, especially bees, are needed to visit flowers so high fruit set and berry size can be achieved.

Figure 7-1. Bumblebees are efficient pollinators.

Figure 7-2. Honeybees do not pollinate as efficiently as bumblebees, but hives can provide large numbers of pollinators during flowering.

Pollination and Pollinators

Blueberry pollen is shed from pores in anthers onto bodies of bees as they feed on nectar inside flowers. Bumblebees (Figure 7-1) and other specialized wild solitary bees are capable of "sonicating" or vibrating pollen from anthers, loosening pollen for easier dissemination.

Honeybees (Figure 7-2) are not as efficient as bumblebees in pollinating blueberry flowers. They forage less when the temperatures are cool, the day is overcast, or the wind speed is high. Compared to wild bees and bumblebees, honeybees begin flying later in the morning and return to their hives earlier in the evening. Honeybees do not sonicate blueberry flowers and rarely collect much blueberry pollen.

Carpenter bees can be problematic during pollination, as they pierce holes in flowers during nectar collection, and no pollination occurs. Moreover, other bees often feed through these holes and, thus, carry out no pollen in the process. This is especially problematic in flowers with long corollas (petals).

Flowers with short corollas are more easily pollinated than those with longer corollas. Some attribute the consistent fruit set of Bluecrop to its shorter corolla, and poor set of Earliblue to its longer corolla. Cultivars also vary in their ability to attract pollinators. Earliblue, Stanley, and Coville are relatively unattractive to bees, whereas Rubel and Rancocas are more attractive. Evidence suggests that attractive cultivars produce more nectar than those that are less attractive to bees.

Maintaining dense native plantings along perimeters of blueberry plantings encourages nesting by wild bees, which aid with pollination. However, wild bees cannot always be depended upon for pollination because of inadequate or fluctuating population numbers. One rule of thumb is that four to eight bees should be foraging on each blueberry plant at any one time during the warmest part of the day during bloom. When wild pollinators are not abundant, honeybee hives should be introduced into the area.

Hive Placement

Hives should be in place when about 5 percent of flowers have opened, but no later than 25 percent of full bloom. They should remain in plantings until petals begin to drop. Hives should be placed in wind-sheltered, sunny locations with their entrances facing east. Bees become active sooner if facing morning sun. Distribute hives evenly throughout plantings to maximize probability of flower visitations. Bees fly further along rows than across them. Place hives 300 feet apart along every tenth row. Competing flowers should be eliminated (e.g. mow the dandelions).

One strong hive (minimum of 45,000 bees) is sufficient for 2 acres of Rancocas and Rubel; one hive per acre for Weymouth, Bluetta, Blueray, Pemberton, and Darrow; three hives for every 2 acres of Bluecrop; two hives per acre of Stanley, Berkeley, Coville, and Elliott; and five hives per 2 acres of Jersey and Earliblue. These recommendations were developed in the 1980s, and growers with high-yielding fields are using additional hives to help ensure maximum yields.

Protecting Pollinators

Growers should be aware of the importance of pollination in blueberry culture and make every effort to protect honeybees and native bee populations. Never use bee-toxic insecticides during bloom. Bee colonies should have a pesticide-free source of water nearby. Arrangements should be made with beekeepers in advance to remove hives before bee-toxic insecticides are applied after bloom.

Poor Fruit Set

If fruit set is poor, gibberellic acid sprays can be applied to increase set. This hormone induces parthenocarpic fruit set (seedless berries), but results in smaller, later maturing fruit.

Reprinted from Strik, B., C. Brun, M. Ahmedullah, A. Antonelli, L. Askam, D. Barney, P. Bristow, G. Fisher, J. Hart, D. Havens, R. Ingham, D. Haufman, R. Penhallegon, J. Psheidt, B. Scheer, C. Shanks, and R. Williams. 1993. Highbush blueberry production. Oregon State Univ. Pacific Northwest Ext. Pub. 215. Adapted for the Midwest.

Propagation

Most blueberry plantings are established with nursery-propagated plants, saving growers the time and investment involved in propagation. However, if growers are able to delay planting for an additional season or prefer to produce their own plants, the following basic knowledge of blueberry propagation should be helpful.

Commercial blueberry bushes are typically propagated asexually, usually by hardwood cuttings. Plants may also be asexually propagated by softwood cuttings, but hardwood cuttings are less perishable and easier to handle. However, some cultivars are difficult to root by hardwood cuttings and may root more easily by softwood cuttings (e.g. Bluecrop, Darrow, Herbert, Ivanhoe, and Stanley).

Plants may also be sexually propagated by seed; however, resulting plants will not be true-to-type. Breeders use sexual propagation to develop new cultivars.

Figure 8-1. Blueberry cuttings set in a propagation bed; some have started to leaf-out.

Figure 8-2. Blueberry cuttings set in a propagation bed showing overhead mist system.

Hardwood Cuttings

Collecting and Storing Cuttings. The first step for propagation of blueberries by hardwood cuttings is collection of 12-inch to 30-inch shoots or "whips" from healthy, true-to-type mother plants. Shoots should be from the previous season's growth and collected while plants are dormant in late winter or early spring. Avoid highly branched shoots, shoots with flower buds, and shoots that developed late during the previous growing season. Growers should take precautions to confirm cultivar labeling before taking cuttings; many off-types appear in plantings due to improper identification. Cut shoots into 5- to 6-inch lengths; each cutting should be about ¼ inch in diameter and have 4 to 6 buds. About fifty cuttings may be placed in a plastic bag with moist (not wet) paper towels or moist sphagnum peat moss. Bags may be stored for several weeks in a refrigerator or area where the temperature is maintained between 35° and 40°F.

Figure 8-3. Blueberry cuttings in propagation boxes on the floor of a greenhouse with a mist system.

Figure 8-4. Blueberry cuttings in propagation containers on benches in a greenhouse with a mist system.

Figure 8-5. Potted blueberry plants that have been transferred from a propagation bed.

Propagation Mixes. Root cuttings in a potting mixture that is well drained yet retains moisture. Examples of suitable potting mixes include sand and sphagnum peat moss (1:1), peat and vermiculite or perlite (1:1), or perlite, sand, and vermiculite (1:1:1). Sphagnum peat moss must be thoroughly wetted prior to mixing with the other parts of the media.

Propagation Beds/Containers. Propagation mixtures are usually placed into propagation beds (Figures 8-1 and 8-2) or boxes (Figures 8-3 and 8-4) that are 4 to 10 inches in height with ⅛ to ¼ inch mesh either on or (as in the case of wood boxes with hardware cloth) attached to the bottom. Width and length of propagation beds or boxes vary depending upon numbers of cuttings to be rooted.

Rooting Cuttings. In spring, after threats of freezing weather have passed, insert cuttings vertically 2 to 3 inches apart with one or two buds sticking above media (Figure 8-1). Distal or basal ends of each cutting should point downward without touching the bottom of the box. Difficult-to-root cultivars can be dipped into rooting hormone prior to planting. Keep cuttings moist by placing them under an intermittent mist system (Figures 8-1 to 8-4). Cuttings should be misted every 3 to 5 minutes for 6 to 8 seconds for about 6 hours per day until rooting occurs.

Cuttings may be rooted outdoors, in high tunnels, or in greenhouses. High tunnels and greenhouses offer greater control over temperature and humidity than outdoor settings, while also providing protection from adverse environmental conditions.

After root development, cuttings may be overhead sprinkle-irrigated until they are ready to be transferred into individual pots (Figure 8-5) or set out into the nursery. Rooted cuttings with new leaves should be fertilized with a complete form of slow-release fertilizer and supplemented with an ammonium form of nitrogen (N) to maintain active growth. Ammonium sulfate applied at 1 ounce per gallon of water is typically preferred, but urea and other formulations may also be used.

Softwood Cuttings

Softwood cuttings are taken before flower buds form during the growing season. The procedures used for hardwood cuttings also apply to softwood cutting; however, the latter require more care. Softwood cuttings should be adequately shaded from sun and properly ventilated to prevent moisture from condensing on cuttings. Also, an intermittent mist system is more critical for keeping softwood cuttings moist than it is for hardwood cuttings.

Tissue Culture

Blueberry plants may also be propagated by using tissue culture techniques, often referred to as micro-propagation. Half-inch long sections of stems, each containing a bud or growing tip, are sterilized and then transferred using sterile techniques into an agar-based medium. After a few weeks, newly formed plantlets are transferred onto rooting media and grown under high-humidity conditions in greenhouses in transplant trays. Tissue-cultured plants are extremely tender and should be slowly acclimated to outdoor conditions before they can be transplanted into fields. Due to the expensive laboratory equipment required, growers often purchase micropropagated plants from producers who specialize in this method of propagation.

Disease Issues

Virus diseases can be spread via any one of these propagation methods. Because viruses are systemic (distributed throughout entire vascular systems), apparently non-symptomatic plant parts of infected plants also contain virus particles (see Chapter 11: *Blueberry Diseases*). Thus, it is critical that propagators use clean, disease-free parent stock for blueberry cultivation.

Chapter 9

Pruning and Growth Management

Blueberry bushes require annual pruning to help plants become established and to develop vigorous plants that will consistently produce crops of large, early maturing berries.

Pruning of established plants is also necessary to manage canes for increased productivity. Canes that are larger than 1-inch diameter at ground level should be removed. These canes use their energy to produce leaves at the expense of fruit production. Large leafy canes also shade inner canopies, resulting in reduced flowering. On the contrary, younger vigorous canes are more efficient at fruit production, and should be preserved. Growers may also selectively prune canes in order to position fruit for ease of harvest.

Pruning is also necessary to remove dead and diseased canes which, if left in the field, can serve as sources for fungal inoculum (see Chapter 11: *Blueberry Diseases*). Many disease-causing pathogens overwinter in dead and diseased canes and should be removed from planting sites and destroyed. Other pathogens, such as the causal agent of stem blight, may be transmitted by tools. Thus, sanitation is an important consideration. When pruning diseased wood, disinfest pruners between cuts or from one plant to the next with a commercial sanitizer or with 10 percent solution of Lysol.

When to Prune

Prune plants during dormancy, generally in spring between February and prior to bud break. Avoid pruning after bud break because many buds and flowers may be rubbed off. Pruning during bloom will also retard vegetative growth. If possible, prune during dry periods to reduce the possibility of disease spread.

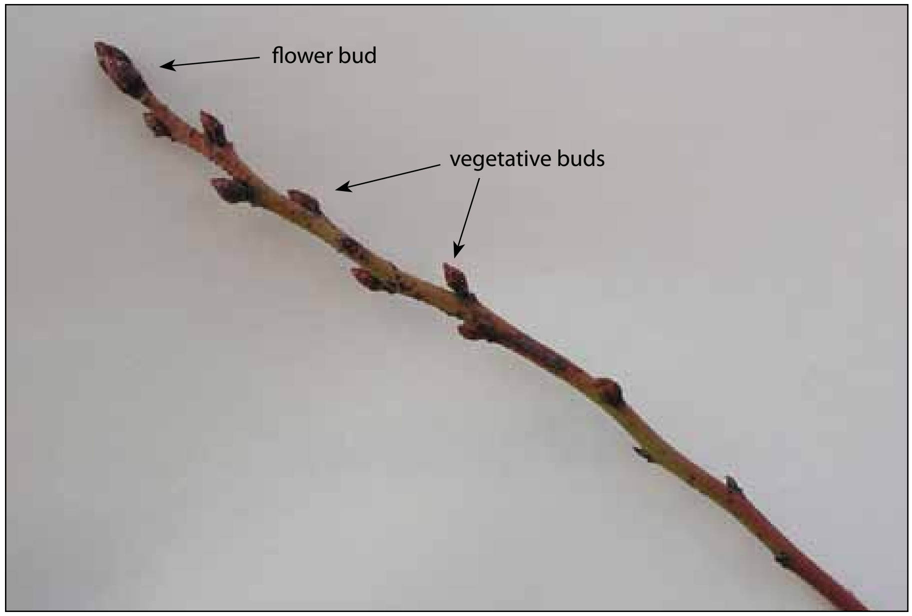

Figure 9-1. Flower buds are plump and located near the terminal end of shoots. Vegetative buds are smaller and pointed.

Figure 9-2. (a) Flower buds on first year shoots are large and fruitful. (b) Flower buds on a third year shoot. Note that the shoot has branched; these flower buds will be fruitful. (c) Shoots that are 5 years and older produce many flower buds on short branched growth at the end of shoots. These flower buds produce smaller fruit.

Flowering and Fruiting

To prune highbush blueberry plants correctly, it is important to understand their flowering and fruiting characteristics. It is also important to differentiate between fruiting and vegetative buds (Figure 9-1). Flower buds are formed during late summer and early fall in leaf axils on top portions of current season's growth. These buds bloom and produce fruit the following summer. Each flower bud has five to eight flowers, and approximately six of these flowers will produce fruit. Since 150 to 300 fruit equal one pound, 25 to 50 flower buds are needed to produce 1 pound of fruit. The highest quality and largest berries are borne on the most vigorous canes (less than 1 inch in diameter at their base) (Figure 9-2).

How to Prune

At planting, remove from one-third to one-half of the top growth to help balance foliar and root mass. This often improves plant survival. During the first 3 years, leave thicker shoots and remove all spindly wood. The only additional pruning required during this time is removal of diseased or damaged canes. Blossoms should be rubbed off during the first 2 years to promote vegetative and root growth. Blossoms are easily removed by moving a gloved hand quickly along limbs during bloom. If blossoms are left on bushes during these early years, plants will produce little growth or become dwarfed, resulting in reduced future yields.

After the third growing season, prune bushes into an open-vase shape, removing inward-facing branches. Excess shoots should be cut at ground level. Leave the most vigorous, largest diameter canes intact.

Mature bushes (more than 3 years old) have a different set of pruning requirements. The first cuts should remove any diseased or injured wood. If two canes are rubbing against each other, remove one of the canes. Next, remove some (usually about two) of the oldest, least vigorous canes so that all canes are less than 5 or 6 years old. When canes are removed, cut them as close to the ground as possible (Figure 9-3). This will eliminate stubs that decay and become an entry point for disease. Weak, brushy or twiggy wood, low limbs, and limbs extending into the open, vase-shaped canopy should also be removed (Figure 9-4). Remove short-branched canes that are shaded, as these produce fruit that ripens late. Flower buds on thick shoots (more than 1 inch diameter) tend to open later in spring than those on twiggy wood and are less prone to frost injury.

Figure 9-3. Removing an old cane from a mature blueberry bush.

Figure 9-4. Removing week, twiggy growth from a mature blueberry bush.

Cultivars with spreading habits often require pruning of low drooping branches (Figure 9-5). Examples of these cultivars include:

Berkeley	Chandler	Summit
Blueray	Coville	Toro
	Patriot	

Those with erect growth habits often require thinning in plant centers (Figure 9-6). These include:

Bluecrop	Elliot	Nelson
Collins	Lateblue	Reka
Duke	Legacy	

Once blueberry bushes are established, the following pruning method may be adopted each year: remove two of the oldest canes and allow two of the newest canes to develop. Altogether, a mature bush should have about 20 productive canes. If a particular cultivar has small berries, berry size may be increased by cutting off tips of fruiting wood (tipping). Most growers do not allow plants to grow taller than 6 feet for ease of har-

Figure. 9-5. Spreading growth habit of Summit blueberry.

Figure. 9-6. Upright growth habit of Reka blueberry.

vest. If mechanical harvesters are used, growers should maintain a more upright growth habit and a narrower crown that fits the particular harvester.

Up to 20 percent of the wood in blueberry bushes may be removed without decreasing yields. Numbers of berries will be decreased, while individual berry size will increase (Figure 9-7). Conversely, if too many blossoms and fruit are left, a large crop of small berries that ripen over a long period of time will result; in fact, many of these small berries may not ripen at all. An ideal blueberry plant has two to three canes of each age up to 6 years old. Overgrown or weak plants may be renewed or rejuvenated by cutting the entire plant to the ground and regrowing a new bush.

Sanitation

After pruning, all cuttings should be destroyed in order to remove fungal inoculum from the planting area. A flail mower may be used to chop cuttings into small pieces so that the prunings break down more quickly. However, if diseases such as Phomopsis canker or Botryosphaeria stem blight were problematic during the season, growers should remove all cuttings from the planting site and either burn or bury them as soon as possible (see Chapter 11: *Blueberry Diseases*).

Figure 9-7. Excess flower buds on older shoots may produce fruit that is small and does not ripen properly.

Figure 9-8. A well-pruned blueberry bush, with canes of varying ages. Older canes have a gray peeling bark, 2- to 4-year canes have a reddish bark with ridges, and young canes have a smooth reddish bark.

Soils, Fertilization, and Nutritional Disorders

Figure 10-1. Ideal soils for blueberry production are sandy, naturally acidic, and have high organic matter content.

Figure 10-2. Raised beds can be an effective method to improve soil drainage for successful blueberry production in the Midwest.

Blueberry plants have specific soil requirements for optimum growth and production. 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 percent to 7 percent (Figure 10-1), and adequate phosphorus and potassium (see Chapter 5: *Planting and Establishment*). Some areas in the Eastern United States contain sandy soils with naturally low pH and high organic content. These areas are southwest Michigan, northern Indiana, southern New Jersey, and costal Carolina plains. Blueberries naturally thrive in sandy soils with high organic content and high water tables. Thus, these regions are major commercial blueberry production areas.

Most Midwestern soils require both soil amendments and irrigation for optimum growth and yield. Soil amendments often include pH adjustments and addition of organic matter. Soil drainage may also be required; poorly drained sites may require installation of internal drainage systems or surface ditches (see Chapter 6: *Irrigation and Water Management*). In most Midwestern soils that contain 10 percent or more clay, raised beds are preferred for improvement of drainage (Figure 10-2). Properly prepared raised beds have been shown to be an effective way to grow blueberries in mineral soils (a mixture of clay and loam). Preferred beds are 8 to 10 inches higher than the original height or soil grade, and 4 feet wide. Over time, beds compact and settle 2 to 4 inches, so addition of hardwood or other suitable mulch will be necessary to maintain bed height (see Chapter 5: *Planting and Establishment*).

Most soils also require adjustment of pH. First, soil should be tested to determine current pH and to determine amounts of sulfur required to lower soil pH to optimum levels (4.5 to 5.2 pH). Refer to the soil testing section of this chapter for more information.

Soil acidification is a relatively slow process and can take 6 to 8 months. It is important to adjust soil pH at least 1 to 2 years before planting, since higher amounts of soil acidifying agents may be applied to bare soil without risk of plant injuries. A high pH results in reduced availability of certain nutrients such as copper, iron, or manganese. Insufficient uptake of these mineral nutrients leads to yellowing between veins (chlorosis), and reduced plant growth and yields. Refer to the Table 10-1 for information on soil acidification or pH adjustment.

Table 10-1. Amount of Elemental Sulfur Required To Lower Soil pH for Blueberries (lb/100 sq ft[a]).

Present pH of Soil	Target pH of Soil					
	4.5			5.0		
	Sand	Loam	Clay	Sand	Loam	Clay
4.5	0.0	0.0	0.0	0.0	0.0	0.0
5.0	0.4	1.2	1.4	0.0	0.0	0.0
5.5	0.8	2.4	2.6	0.4	1.2	1.4
6.0	1.2	3.5	3.7	0.8	2.4	2.6
6.5	1.5	4.6	4.8	1.2	3.5	3.7
7.0	1.9	5.8	6.0	1.5	4.6	4.8
7.5	2.3	6.9	7.1	1.9	5.8	6.0

[a] To convert to lb/acre, multiply by 435.

Source: Pennsylvania State University, Small Fruit Production and Pest Management Guide. Used with permission.

In locations where top and subsurface soils have a naturally high pH (6.0 to 8.0) and there is a high buffering capacity, soil amendments may be unable to sufficiently lower pH, and blueberries should not be planted.

Sulfur may be used to decrease soil pH to proper levels if pH is not too high. According to the Highbush Blueberry Production Guide, "as a general rule, modification of soil with 20 percent or more of its exchangeable capacity saturated with calcium or with 2,000 pounds of calcium per acre is impractical. Modifying such soils is expensive and does not last; the underlying soil tends to buffer the treatment and return the pH to its previous level."

Incorporate sulfur, phosphorus, and organic matter into the raised beds (upper 6 to 12 inches) 3 to 6 months prior to planting. This allows time for chemical reactions to occur and reduces potential root damage. Retest soil 3 to 6 months after application and make further adjustments. Apply all nutrients according to soil test results. Phosphorus will not move through soil and is ineffective after plant establishment.

In rare cases, soils may be too low in pH. In this event, manganese or aluminum can be available at toxic levels. If soil pH needs to be raised, apply lime.

Soil Testing

It is important to have soil tested a year or two before planting. If soil pH is too high, soil pH-reducing agents, such as elemental sulfur or iron sulfate, should be applied to reduce soil pH. Soil tests reveal buffer pH (also called lime index), nutrient levels, and base saturation. A fertilizer recommendation will also be provided with test results.

Soil samples should be collected with a soil tube or probe (Figure 10-3), whenever possible, to ensure that all samples are taken at the same depth. Though not as accurate, a shovel or garden trowel may be used. Sampling depth for blueberries is 8 inches. Remove sod, mulch, or organic debris first. Take 12 to 15 soil cores or samplings randomly from an entire area. Soil cores should be air dried, crumbled, and mixed together to form a composite sample. A composite soil sample should represent a field of 5 acres or less. Separate soil samples should be taken for different cultivars (or types) or fields containing different soil types, topography, or fruit yield. A "standard" test should be requested. In addition, organic matter content test and a particle size analysis should also be performed for a greater evaluation of the soil condition.

There are many university and private soil and tissue testing labs available. Consult local Extension offices for soil testing labs. Some universities, such as University of Kentucky, Michigan State University and Pennsylvania State University, still operate soil testing labs. Other universities, such as Purdue University and The Ohio State University, no longer have such labs and direct growers to private sources.

Instructions on soil or tissue sampling techniques are also available from individual soil or tissue testing labs. Growers are encouraged to check the website(s) of soil and tissue testing labs for proper sampling techniques. Good samples are the first critical step in ensuing accurate results.

Selection of a reputable testing lab is also important. It is beneficial to utilize the same lab year after year for consistency, since extraction methods and recommendations can very significantly from one lab to the next. Growers can have the soil tests performed through soil testing labs affiliated with local Extension offices or universities, or they may work directly with a commercial soil and tissue testing lab.

Figure 10-3. Soil testing should be done using a soil probe or a shovel a year or two before blueberry bushes are planted.

Table 10-2. Interpretive Nutrient Levels For Tissue Analysis of Blueberries

% Dry Weight	Low	Normal	High	Excessive
Nitrogen	1.65	1.70	2.10	2.50
Phosphorus	0.06	0.07	0.18	0.22
Potassium	0.35	0.40	0.65	0.80
Calcium	0.25	0.30	0.80	1.00
Magnesium	0.18	0.20	0.30	0.40
Sulfur	0.06	0.12	0.20	0.80
ppm Dry Weight				
Manganese	45	50	500	650
Iron	65	70	300	400
Copper	4	5	15	20
Boron	29	30	50	65
Zinc	9	15	30	40

Source: Penn State University Agricultural Analytical Services Lab

Tissue Testing

Tissue samples are the best way to monitor the nutrient status of blueberry plants. Soil sampling is only an estimate of nutrients available in soils, but tissue sampling measures the nutrient concentrations in plants. One tissue sample can represent up to 5 to 10 acres of blueberries. However, multiple samples provide greater accuracy.

Because the suggested sampling time recommendations may differ from one lab to another, consult with local Extension agents for more information. For example, Michigan State University recommends tissue sampling in between July 15 to August 15, while Penn State University recommends the first week of fruit harvest. Check with the testing lab you work with for optimum timing and sampling techniques.

Tissue samples should consist of leaves taken from middles of current year's growth. Collect 100 fully expanded leaves per sample. Avoid leaves that are damaged, as well as those that are near fruit clusters or on vigorous first-year shoots. Sample leaves from as many different bushes as possible to get a representative sampling of the entire planting.

Wash leaves to remove dust and spray residue, blot them dry with a clean paper towel, and allow them to air dry in a well-ventilated location 1 to 2 days. Ship dried leaves in paper bags. Tissue sample forms should be downloaded from the testing lab's website, filled out, and included with the tissue sample.

Typical values used to interpret tissue nutrient levels are provided in Table 10-2. Each tissue test report should indicate mineral nutrient presence, ranging from low to excessive. Different labs employ different ways to report data, but each should provide recommendations to correct nutrient disorders.

Fertilization

Fertilize blueberry bushes according to soil and tissue test reports. Soil tests reveal nutrients available in soils, while tissue tests reveal amounts of nutrients taken up by plants. It is important to utilize both tests to determine amounts of nutrients needed by blueberry bushes, especially for established plantings. Blueberry plants, like all plants, require 17 essential elements. Three of these are essential non-mineral elements that are taken up from atmospheric carbon dioxide and water: carbon (C), hydrogen (H), and oxygen (O).

The other fourteen elements are essential minerals: nitrogen (N), phosphorus (P), potassium K), calcium (Ca), magnesium (Mg), sulfur (S), boron (B), copper (Cu), iron (Fe), chloride (Cl), manganese (Mn), molybdenum (Mo), zinc (Zn), and nickel (Ni). The elements N, P K, Ca, Mg, and S are considered macronutrients and are needed in large quantities. B, Cu, Fe, Cl, Mn, Mo, Zn, and Ni are considered micronutrients and are needed in smaller quantities. Since some mineral elements are present in sufficient quantities in soils, they may not need to be applied through fertilization.

Figure 10-4. A fertilizer injector can be used to inject water soluble fertilizer through drip irrigation.

Figure 10-5. Nitrogen deficiency in blueberry is usually characterized by a light green to yellow color on older leaves, along with poor growth.

Blueberry plants are sensitive to readily soluble fertilizers and excessive amounts can cause plant injury or death. Therefore, it is critical to apply fertilizer at recommended rates. Broadcast elements evenly; do not concentrate fertilizer in a small area, such as in centers of plants or against canes.

Nitrogen Application. Annual applications of nitrogen (N) are necessary for vigorous growth and development. Blueberry plants prefer the ammonium form of N rather than nitrate. Do not apply nitrate formulations to blueberries; it is too readily soluble and can injure blueberry plants. Ammonium sulfate is recommended when soil pH is above 5.0, and urea is best for soils below 5.0. Apply urea during cool, rainy weather or irrigate after application. Ammonium sulfate or urea may be injected through drip (aka. trickle or micro-irrigation) systems (Figure 10-4). Use one half of recommended ground application rates when applying N with irrigation or in banded application.

Nitrogen rates differ depending upon plant age. For newly planted blueberries, broadcast two applications each of 10 pounds of actual N per acre—once at

Figure 10-6. Magnesium deficiency usually shows up as a green "Christmas tree" in the center of a chlorotic leaf.

Figure 10-7. (a) Iron deficiency occurs on younger leaves and (b) is characterized by yellowing between veins.

bloom and again 3 weeks later. Young plants require approximately 10 pounds of actual N per acre at each broadcast application in mid-April, mid-May, and mid-June during years two to four. In mature plantings, 50 to 70 pounds of actual N is often needed, but growers should respond to tissue sample results and maintain leaf nitrogen levels between 1.7 percent and 2.1 percent, and potassium levels between 0.35 percent and 0.40 percent. Refer to Table 10-2 for nutrient levels of mineral nutrients.

When injecting nitrogen fertilizer with drip (trickle) irrigation, broadcast the mid-April application as recommended and then apply one-half of the remaining broadcast amount from mid-May to mid-June through drip irrigation. (Example: 60 pounds annually = 30 pounds mid-April, broadcast; 30 pounds irrigated mid-May to mid-June). Monitor leaf nutrient levels to make sure that blueberry plants receive adequate supplies of minerals for optimum growth and production.

Continue to irrigate with water only after mid-June, as needed. In most Midwestern areas, soil may lose 0.25 to 0.30 inches of water per day. Use a tensiometer to monitor soil moisture, if possible, maintaining 20 to 25 centibars in the upper 12 inches of soil.

Mineral Nutrient Disorders

Nutrient disorders are the symptoms that plants exhibit when too little of an essential nutrient (deficiency) or too much of an essential nutrient (toxicity) is absorbed by growing plants. It is beyond the scope of this bulletin to discuss all of the possible mineral deficiencies and toxicities. Growers are encouraged to refer to additional literature on plant nutrition, mineral nutrient deficiencies, and toxicities, or to contact local Extension agents or specialists for assistance. Common nutrient deficiencies in blueberries are discussed below.

Nitrogen Deficiency. Nitrogen is essential for the synthesis of protein and chlorophyll. Nitrogen deficiencies are common in blueberries. Typical symptoms are characterized by light green leaves with color that is uniform across leaves and with no particular pattern (Figure 10-5). Both leaf veins and tissue between veins are light yellow. Light green color appears on older leaves first because nitrogen is mobile in plants. Nitrogen deficient blueberry bushes are often smaller in size than healthy plants. They also have shorter stems, fewer new canes, and lower yield. Sometimes, small brown or red spots may appear on light green-colored leaves.

Phosphorus Deficiency. Phosphorus is an important element for root growth and energy transfer within plants. Phosphorus deficiency is not common in blueberries. However, when it occurs, phosphorus deficient leaves show purple coloration in older leaves. This is because phosphorus is involved in the translocation of sugar or carbohydrates. Insufficient phosphorus results in sugar accumulation, and excessive sugar accumulation leads to red pigment production. Phosphorus deficient blueberry bushes are also smaller in size.

Potassium Deficiency. Potassium contributes to photosynthesis and water regulation. Potassium deficiency is also rare in blueberries in the Midwest. Typical symptoms are browning of leaf margins or marginal scorching of older leaves.

Calcium Deficiency. Blueberries have a low requirement for calcium and seldom, if ever, are deficient.

Magnesium Deficiency. Magnesium is involved in chlorophyll production. Magnesium deficiency is not common in blueberries. On highbush blueberries, magnesium deficiency is characterized by a green area in the shape of a Christmas tree in centers of chlorotic leaves (Figure 10-6). Since magnesium is mobile in plants, deficiency symptoms usually occur on older leaves.

Iron Deficiency. Iron is involved in chlorophyll production. Iron deficiency usually occurs on younger leaves first (Figure 10-7a) since iron is not mobile in plants. Iron deficiency, also referred to as iron chlorosis, is characterized by yellowing between veins (Figure 10-7b).

Blueberry bushes deficient in iron may show adequate levels of iron in soils, but this iron may be in an unavailable form. Soil pH above 5.3 causes low iron availability. In addition, high calcium or phosphorus can induce iron chlorosis. During dry summer months, blueberry bushes may exhibit temporary iron deficiency, especially if they are irrigated with alkaline water from deep wells in lime rock.

To correct iron chlorosis, soil pH should be reduced with applications of elemental sulfur or iron sulfate to the root zone. Iron chelate can be applied as a foliar spray, although results are temporary. Follow directions on product labels, as there are many forms of iron chelates. A surfactant should also be used to help move iron chelate into waxy blueberry leaves.

Manganese and Copper Deficiencies. The deficiencies of manganese and copper can be common. Symptoms mimic those of iron deficiency. Only tissue tests can reveal levels of manganese and copper. Do not apply a combination of copper, iron, and manganese to plants because they may have antagonistic effects on each other. Foliar spray of copper or manganese should be applied separately to determine which is responsible for deficiency symptoms.

Additional Resources

Ellis, M., M. Brown, B. Bordelon, D. Doohan, R. Funt, R. Williams, and C. Welty. 2004. Ohio State University Extension Bulletin No. 861, Midwest Small Fruit Pest Management Handbook, The Ohio State University, Columbus, Ohio.

Hart, J., B. Strik, L. White, and W. Yang. 2006. Nutrient Management for Blueberries in Oregon. EM-8918. Oregon State University, Corvallis, OR.

Ohio State University Extension Fact Sheet. HYG No. 1132-09. Soil Testing Is an Excellent Investment for Garden, Lawn, and Landscape Plants, and Commercial Crops http://ohioline.osu.edu/hyg-fact/1000/pdf/1132.pdf.

Pritts, Marvin, P. and J.F. Hancock (editors). 1992. Highbush Blueberry Production Guide, NRAES-55. Northeast Regional Agricultural Engineering Service, 152 Riley-Robb Hall, Cooperative Extension, Ithaca, NY 14853. Phone: (607) 255-7654.

Chapter 11

Blueberry Diseases

Blueberry is considered one of the most disease-free fruit crops in the Midwest. Many of the diseases that do affect blueberry result in minor damage; however, a few can impact plant health and yields. The keys to avoiding most blueberry disease problems are proper site selection and following good crop management practices. Development and use of an integrated disease management program (similar to an IPM program) is essential to the successful production of blueberries.

Integrated Management of Blueberry Diseases

The objective of an integrated disease-management program is to provide a commercially acceptable level of disease control on a consistent (year-to-year) basis. This is accomplished by development of a program that integrates all available control methods into one program. An effective disease-management program for blueberries must emphasize the integrated use of specific cultural practices, knowledge of pathogen and disease biology, disease-resistant cultivars, and timely applications of approved fungicides or biological control agents, when needed. In order to reduce the use of fungicides to an absolute minimum, use of disease-resistant cultivars and various cultural practices must be strongly emphasized.

Blueberry cultivars with high levels of resistance to most of the major diseases are not currently available; however, several cultivars are known to be resistant to multiple diseases. Table 11-1 provides information on disease resistance in several of the most common blueberry cultivars grown in the Midwest.

Table 11-1. Disease Resistance in Blueberry Cultivars Commonly Grown in the Midwest.

Cultivar	Mummy Berry	Phomopsis Twig Blight and Canker	Powdery Mildew	Anthracnose Fruit Rot	Red Ringspot Virus	Shoestring Virus	Botryosphaeria dothidea
Arlen							R
Berkeley	S	VS	R	-	VS	-	
Bluecrop	MR	-	MR	VS	MR	VR	
Bluegold	S	-	-	MR	-	-	
Bluehaven	S	S	-	-	-	-	
Bluejay	R	-	-	MR	-	R	
Blueray	S	-	-	VS	S	-	
Bluetta	S	R	-	VS	-	-	
Bounty				VS			
Brigitta Blue				R			
Burlington	R	-	-	-	-	S	
Cape Fear							R
Chanticleer				VS			
Collins	S	-	-	-	-	-	
Coville	MR	-	MR	VS	-	-	
Darrow	R	-	-	-	-	R	
Duke	MR	-	-	-	-		S
Earliblue	S	S	MR	-	-	S	
Elliott	MR	R	R	R	-	S	
Hannah's Choice	MR			MR			
Harrison		S		VS			
Jersey	MR	VS	S	VS/MR	MR	S	
Lateblue	R	-	-	-	-	-	
Legacy	MR			R			
Little Giant	-	-	-	R	-	-	
Morrow				R			
Murphy		S		R			R
Northblue	R	-	-	-	-	-	
Northland	S	-	-	-	-	R	
Northsky	R	-	-	-	-	-	
O'Neal							R
Ozark Blue				R			
Pamlico							R
Patriot	MR	-	-	-	-	-	
Polaris	-	-	-	-	-	-	
Rancocas	MS	-	R	-	-	MS	
Reka	MR			MR			
Reveille				R			MR
Rubel	S	MR	-	MS	-	S	
Sierra	S	-	-	MR	-	-	
Spartan	MR	-	-	VS	-	S	
Star							R
Toro	MR	-	-	MR	-	-	
Weymouth	S	-	-	-	-	S	

VR = very resistant, R = resistant, MR = moderately resistant, MS = moderately susceptible, S = susceptible, VS = very susceptible; - = resistance is not known.
Table based on information provided by J. Hancock, E. Hanson, D. Trinka, and A.M.C. Schilder, Michigan State University.

Cultural Practices for Disease Control in Blueberry

The use of any practice that provides an environment within the planting that is less conducive to disease development and spread should be used. The practices listed here should be carefully considered and implemented in disease management programs.

Use Disease-Free Planting Stock. Always establish plantings with healthy, virus-indexed plants obtained from a reputable nursery. Remember that disease-free plants are not necessarily disease resistant—cultivar selection determines disease resistance.

Select Sites Carefully. Selecting a planting site with good water drainage is extremely important; avoid low, poorly drained wet areas. When there is standing water in the field, plants are subject to infection. Any site in which water tends to remain standing after rains is, at best, only marginally suited for blueberry production and should be avoided.

Effective water drainage (both surface and internal drainage) is especially important for control of Phytophthora root rot. This water-mold pathogen requires free water (saturated soil) in order to infect plants and establish in root zones. If there are low areas in fields that have tendencies to remain wet, Phytophthora root rot will often develop.

Any practice (such as tiling, ditching, or planting on ridges or raised beds) that aids in removing excessive water from root zones is beneficial to the disease management program.

Site Exposure. A site with good air circulation that is fully exposed to direct sunlight should be selected. Avoid shaded areas. Good air movement and sunlight exposure are important to aid in drying fruit and foliage after rain, irrigation, morning dew, or fog. Any practice that promotes faster drying of fruit or foliage will aid in the control of many different diseases.

Control Weeds. Weed control is essential to successful blueberry production. From the disease control standpoint, weeds in plantings prevent air circulation and result in fruit and foliage staying wet for longer periods. Several diseases can be more severe in plantings with poor weed control compared to plantings with good weed control.

Some weeds can serve as hosts for plant pathogens such as fungi, viruses, and nematodes. Removal of weeds reduces inoculum.

In addition, weeds will reduce production through direct competition with blueberry plants for light, nutrients, and moisture. Weeds will make the planting less attractive to pick-your-own customers, especially if there are thistles!

Practice Good Sanitation. Any practice that removes and destroys infected twigs, branches, and other plant debris present in plantings is beneficial in reducing the amount of fungal inoculum. For example, removal of fruit mummies is critical for mummy berry control, while the removal of infected twigs and branches is important for controlling Phomopsis twig blight and other canker-causing diseases.

Avoid Excessive Fertilization. Fertility should be based on soil and foliar analysis. Excess fertilizer, especially nitrogen, should be avoided. Sufficient fertility is essential for producing a crop, but excessive nitrogen can result in dense foliage that increases drying time in the plant canopy (i.e., remains wet).

Maintain Proper Soil Conditions. Vigorous plants are not as susceptible to infection by pathogens. If infection does occur, disease often does not reach epidemic proportions.

Protect from Winter Injury. Winter injury predisposes blueberry plants to many diseases. In colder regions of the Midwest, snow can be piled around bushes to insulate from fluctuating temperatures. Protect crowns (base of plant at soil line) with wood-chip or straw mulch. Injury sites are often ideal infection or entry sites for pathogens.

Harvesting Procedures

- Pick fruit frequently and early in the day before the heat of the afternoon (preferably as soon as plants are dry).
- Overripe berries are most susceptible to fruit rot pathogens, and can develop symptoms during and after harvest.
- Handle berries with care during harvest to avoid bruising. Bruised and damaged berries are extremely susceptible to many rot diseases.
- Train pickers to recognize and avoid berries that have disease symptoms such as mummy berry or anthracnose. If possible, have pickers put these berries in a separate container and remove them from the field.

Post-Harvest Handling

- Always handle fruit with care during movement from field to market to avoid any form of damage.
- Get the berries out of the sun as soon as possible.
- Refrigerate berries immediately to 32°F to 35°F in order to slow the development of fruit rots.
- Market berries as quickly as possible. Encourage customers to handle, refrigerate, and consume or process fruit immediately. Remember that even under ideal conditions, blueberries are quite perishable.

Use of Fungicides

Although fungicides are an important component of the integrated disease management program in the larger blueberry production regions, such as Michigan, fungicides are not extensively used in most Midwestern blueberry plantings. This is one of the reasons that blueberries are considered to be one of the most disease-free fruit crops in the Midwest. However, if certain diseases become established, fungicides may be required to help manage disease. A good approach to blueberry disease control is use disease resistant (or at least, less susceptible) cultivars combined with good cultural practices. Therefore fungicides will be used only in plantings where potentially damaging disease develops.

For the most current information on fungicides registered and recommended for control of blueberry diseases, obtain a copy of the “Midwest Small Fruit and Grape Spray Guide” through your local cooperative Extension agent or educator. This publication is also available on the Internet.

Major Root and Stem Diseases

It is important for growers to be able to recognize the major blueberry diseases. Proper disease identification is critical to making the correct disease management decisions. In addition, growers should develop a basic understanding of pathogen biology and disease cycles for the major blueberry diseases. The more growers know about diseases, the better equipped they can be to make sound and effective management decisions.

The following is a description of symptoms, causal organisms, and management options for the most common blueberry diseases in the Midwest. For additional sources of information, consult the resources at the end of this chapter or contact local Extension agents or specialists.

Phytophthora root rot, caused by the water mold (oomycete) *Phytophthora cinnamomi*, causes root decay in warm, wet soils. Highbush blueberries, which are intolerant of poorly drained soils, are extremely susceptible. The soil-borne pathogen attacks small feeder roots, spreads to main roots, and eventually invades crowns. Above-ground symptoms begin with leaves yellowing or reddening (Figure 11-1). Lack of water and nutrient uptake (caused by root loss) eventually leads to stunting, lack of new growth, and plant death.

This fungus-like pathogen is commonly present in soil; however, under optimal conditions, it can infect and destroy blueberry plantings. Water molds such as *Phytophthora* spp. require free water to survive and reproduce. Spores have long whip-like structures (flagella) that assist in their "swimming" movement. Wet soils provide a medium for pathogens to move into root zones. Once established, these pathogens produce overwintering structures (chlamydospores) that can survive in a variety of climate extremes. When environmental conditions reach optimal levels (68° to 90°F), accompanied by saturated soils, the pathogen breaks out of dormancy and infects susceptible plants.

Botryosphaeria stem canker, caused by the fungus *Botryosphaeria corticus*, is an important disease of highbush blueberry in the Southeast and may become an important disease in the more southern regions of the Midwest. The first symptoms appear as small red lesions on succulent stems (Figure 11-2a), which often resemble winter injury on new wood. These lesions develop into cankers (Figure 11-2b). The fungus can only infect the current season's growth; however, the disease can progress into older tissues.

Optimal conditions for spore production and infection are temperatures between 77° and 82°F and wet conditions. Upon infection, the pathogen grows slowly and does not seriously affect plants the first year. Without proper disease management, disease becomes increasingly more severe each year.

Figure 11-1. Premature foliar discoloration due to Phytophthora root rot.

Phytophthora root rot
Disease Management
Site selection is critical. Avoid poorly or marginally drained soils.
Improve drainage by planting on raised beds or install drainage systems prior to planting.
Avoid excess irrigation.
Fungicides such as mefenoxam and phosphorus acid are effective in controlling diseases caused by *Phytophthora* spp. and other water molds.

Figure 11-2. (a) Small, red lesions due to *Botryosphaeria* (b) develop into cankers.

Botryosphaeria stem canker
Disease Management
Use clean, disease-free planting stock.
Remove and destroy infected stems, cutting at least 6 inches below each lesion.
Fungicides are ineffective once infection occurs. Preventative fungicides may be used in high-risk plantings.

Figure 11-3. (a) Botryosphaeria dieback symptoms. (b) Brown discoloration under the bark of cane infected with Botryosphaeria stem blight.

Botryosphaeria stem blight (or dieback), is caused by the fungus *Botryosphaeria dothidea*. Symptoms include yellowing, reddening, or drying of leaves on one or more branches (Figure 11-3a). As symptoms progress in infected stems, leaves turn brown and remain attached for a period of time. Brown or tan lesions develop on stems. Upon cross-sectioning infected stems, internal wood appears brown on the diseased side of the stem (Figure 11-3b). Blighted young plants can die within 2 years. Symptoms often resemble winter injury. Young plants are more susceptible than older, well-established plants.

Botryosphaeria stem blight
Disease Management
Avoid wounding plants.
Retain vigorous plants by promoting optimum health.
Avoid fertilizing late in the growing season (August or later). Plants fertilized late in the season do not harden off properly (winterize) and are more susceptible to winter injury. Winter-injured tissues are most susceptible to infection.
If stems become infected, remove infected tissue at least 6 inches below each lesion.
Fungicides are ineffective against Botryosphaeria stem blight.
Resistant cultivars include: Murphy, Cape Fear, O'Neal
The disease has been observed primarily on the cultivar Duke.

Infections occur in spring (May-June) when temperatures reach 82° to 88°F. The pathogen enters host tissue primarily through wounds, such as mechanical damage or *Phomopsis* infections. Infected stems may provide overwintering sites for the fungus. Disease susceptibility decreases as plants age.

Phomopsis twig blight or **stem canker,** caused by *Phomopsis vaccinii*, is the most common canker disease in blueberry and is one of the first diseases to develop in spring. Symptoms include dead or blighted 1-year-old twigs that eventually cause loss of flower buds (Figure 11-4a). Early symptoms occur shortly after green-tip, at which time buds begin to turn brown and die. Necrotic, reddish-brown lesions often develop around these blighted buds and then spread downward. Eventually stems die, and sudden wilting and flagging of stems occur as warm summer weather progresses. Leaves on infected twigs often turn reddish and remain attached to stems. Girdling cankers can kill entire twigs (Figure 11-4b), while leaf spots may occur on foliage of surviving twigs. Late-season symptoms can also include premature ripening of fruit or fruit rot.

Infection by this fungus occurs through opening buds. In flower buds, pathogens move through blossoms and into vascular tissue of stems, killing multiple unopened flower buds. The fungus can also penetrate fruit directly. During the second year, twigs become blighted and bud loss is more severe. The fungus overwinters in dead or infected twigs. During spring, spores ooze from stem lesions at precisely the same time as bloom. Rain splashes spores onto flowers. These spores can also infect through wounds on young woody stems, causing cankers. Infection through stems is most common on those damaged or wounded by freeze.

Crown gall, caused by the bacterium *Agrobacterium tumefaciens*, is usually not a severe problem in blueberry. It most often occurs in propagation beds and new plantings, but not mature plantings. Symptoms include stunting of plants and development of galls at bases of canes (Figure 11-5). Galls eventually turn dark brown and rough, and harden with age.

Figure 11-4. Phomopsis twig blight causing (a) loss of flower buds and (b) death of branches.

Phomopsis twig blight or stem canker
Disease Management
Remove infected twigs during dormancy and blighted twigs that develop during the growing season by cutting at least 6" below infected tissue.
Avoid overhead irrigation to reduce amounts of splashing spores.
Avoid planting sites that are prone to spring frosts and use fertilizer, irrigation, and weed control practices that discourage late season growth and that promote early hardening off in winter.
A protectant fungicide such as captan, azoxystrobin, fenbuconazole, or propiconazole may be applied at bud-break and at regular intervals through full bloom in plantings with high risk for infection.
A dormant application of lime sulfur during bud break is recommended in plantings where disease is established.
Avoid stem wounding to reduce amounts of infection through canes.
Avoid overripe fruit.
Resistant cultivars include: Bluetta, Elliott
Susceptible cultivars include: Murphy, Harrison

Figure 11-5. Crown gall.

Crown gall
Disease Management
Use clean stock that is free from the pathogen.
If infection occurs, remove and destroy diseased plants.
Rotate away from susceptible plants for 3 years if soil becomes infested.

This disease is caused by a soil-borne bacterium that enters plant tissue through natural and mechanical wounds on stems and roots. It is more prevalent in neutral to alkaline soils.

Foliar Diseases

Powdery mildew, caused by *Microsphaera vaccinii*, is commonly associated with lowbush blueberry, but is rarely a problem on highbush blueberry. Damage from the pathogen is usually not serious, but can sometimes become severe. Disease symptoms begin as light green or yellow areas on leaves in midsummer. Infected leaf tissue develops spots with red halos and then becomes entirely red or reddish-brown and somewhat puckered (Figure 11-6). White powdery fungal growth may develop on upper leaf surfaces during humid weather and occasionally on lower leaf surfaces on some cultivars. Plants may defoliate during severe infections. For the most part, powdery mildew is a superficial disease; the fungus only penetrates leaf surfaces (epidermis). This is a summer disease that is more severe in warm, dry climates.

The powdery mildew fungus overwinters in fallen leaves or on dormant buds as fruiting bodies (cleistothecia). Spores (ascospores) within these fruiting structures are released and initiate infections during warm, humid weather. Free water, such as rainfall, impedes (stops) sporulation and infection. Once primary infections occur, airborne spores (conidia) are produced which continue the infection cycle. During autumn, the overwintering structures appear as dark specks on infected leaves.

Fungal leaf spots are generally considered minor diseases of highbush blueberries in the Midwest. They may be caused by a variety of fungi: double spot by *Dothichiza caroliniana*, Gloeosporium leaf spot and dieback by *Gloeosporium minus* (Figure 11-7), Gloeocercospora leaf spot by *Gloecercospora inconspicua*, Phomopsis leaf spot by *Phomopsis vaccinii* (Figure 11-8), and Phyllosticta leaf spot (Figure 11-16) by *Phyllosticta vaccinii* and *P. elongate*.

Symptoms range from small brown leaf spots with reddish or purplish margins to larger irregular lesions. Fungal fruiting bodies may appear as dark specks in spots. Spots may develop during mid- to late-summer, a few weeks after periods of frequent rainfall. In severe cases, defoliation may occur. Fungi that cause leaf spots may also infect and kill succulent stems, causing severe dieback.

Leaf spot fungi overwinter in infected tissue that falls to field floors. Rain disperses spores as temperatures warm. Infection occurs during mid-season, but symptoms are not visible until mid- to late- season, or 1 month after infection.

Leaf rust, caused by *Nachidemyces vaccinii*, formerly referred to as *Pucciniastrum vaccinii*, is a minor disease of highbush blueberry, but it sporadically causes epidemics on lowbush blueberry in the eastern United States. Symptoms begin as yellow leaf spots during early summer, developing into reddish leaf lesions in mid-season (Figure 11-9a). Orange sporulating pustules develop on undersides of leaves (Figure 11-9b). Infected leaves, which rapidly turn yellow and then brown, fall prematurely from bushes.

Infection occurs during late spring when spores (aeciospores) are blown from hemlock. Hemlock is the alternate host and is required for the disease to complete its cycle. Infected blueberry produces a "repeating" spore type (urediniospores) in midsummer, which can reinfect and continue to spread disease on blueberry. A different spore type (teliospore) is produced on blueberry during late-fall. Teliospores overwinter on blueberry leaves and initiate infection (basidiospores) on hemlock in spring. The cycle continues as the fungus sporulates during late spring and infects blueberry again. If hemlock is not in the area, primary spring infections are not likely.

Figure 11-6. Powdery mildew.

Powdery mildew

Disease Management
Fungicides are usually not required.
Space and prune plants for maximum air circulation and reduced humidity.

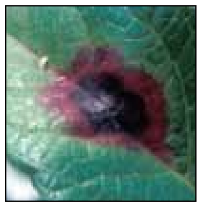

Figure 11-7. Gloeosporium leaf spot.

Figure 11-8. Phomopsis leaf spot.

Fungal leaf spots

Disease Management
When possible, avoid planting susceptible cultivars, such as: Jersey *(Gloeosporium, Phyllosticta),* Murphy *(Phyllosticta),* Harrison *(Phyllosticta)*
Limit overhead irrigation.
Space and prune bushes to reduce humidity and promote rapid leaf drying.
Fungicides may be applied after harvest and through leaf drop to control subsequent infections.
Maintain a clean planting floor; rake or cultivate (bury) fallen diseased leaves.

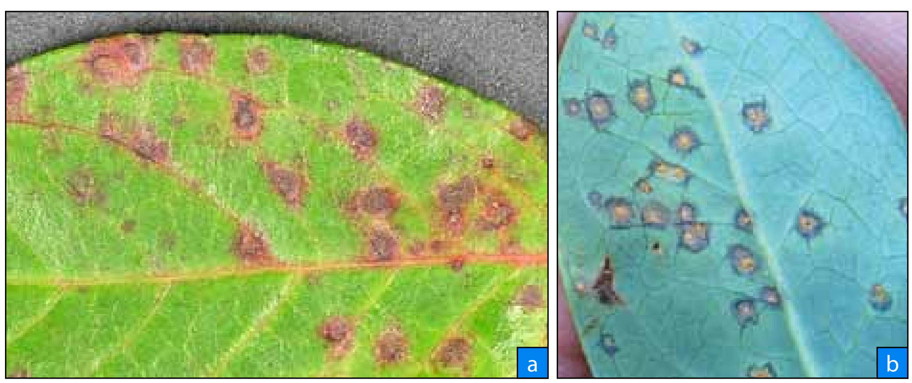

Figure 11-9. (a) Symptoms of leaf rust on upper leaf surface, and (b) pustules on the leaf underside.

Leaf rust

Disease Management
Remove hemlock within one-third of a mile of orchards.
Avoid planting susceptible cultivars, such as: Corville, Pemberton, Washington, Atlantic
No fungicides are registered for this disease.

Septoria leaf spot and **stem canker,** caused by *Septoria albopunctata*, is a fungal disease of highbush and rabbiteye blueberries. Symptoms include tan spots with reddish-purple halos that develop during spring (Figure 11-10). Often, dark spore-producing structures (pycnidia) develop in centers of leaf spots on upper leaf surfaces. If stems become infected, lesions appear purple with centers which eventually become tan or lighter in color. Pycnidial structures develop in centers of stem cankers, as well. This disease is most severe in cuttings and young plants. Septoria leaf spot symptoms are similar to Botryosphaeria and Phomopsis leaf spots.

The fungus overwinters in infected leaves that have fallen to the ground or remain attached to stems through winter and in stem lesions. Sporulation begins during rainy periods as weather warms (75° to 80°F). Symptom development increases progressively through summer.

Red leaf, caused by the fungus *Exobasidium vaccinii*, is a disease of blueberries in the northwestern United States. It is most commonly found on lowbush varieties, but it may occasionally occur on highbush. Symptoms include reddening, thickening, and puckering of terminal leaves in mid-summer (Figure 11-11). During late summer, a white layer of fungal spores develops underneath infected leaves; these leaves then become necrotic. Infected plants do not flower. Symptoms do not appear the same year as infection, and second-year symptoms are minimal. In fact, it may be several years before symptoms are noticeable. Once the fungus becomes established, symptoms appear on new growth every year. During the advanced stages of disease, new leaves are red upon emergence. Plants die after several years.

Infection by this fungus is systemic (inside plant tissue, dispersed throughout) and cannot be cured. Fungal spores develop on leaf lesions in spring and summer and are blown by wind. Optimal fungal conditions are cool, moist environments and excessive nitrogen.

Figure 11-10. Septoria leaf spot.

Septoria leaf spot and stem canker

Disease Management
Rake or cultivate (bury) fallen diseased leaves.
Apply 4 applications of fungicides such as captan and thiophanate-methyl beginning after harvest and continue until leaf drop.
Susceptible cultivars include: Murphy, Bounty

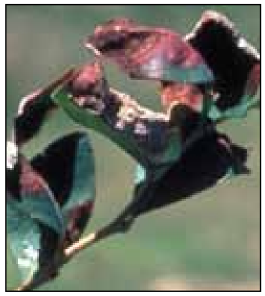

Figure 11-11. Red leaf.

Red leaf

Disease Management
Remove and destroy infected plants; plants will not recover from this disease.
Healthy bushes that are near infected plants may be treated with a protectant fungicide when white fungal growth (hymenium) develops on leaves of nearby infected plants. Maintain a regular protectant spray schedule as long as the fungus produces spores (basidiospores) on leaves.
Avoid excessive nitrogen fertilization.

Fruit and Flower Diseases

Overall, management for fruit and flower diseases includes some basic cultural practices, below. Additional recommendations are listed with each specific disease.

- Plant resistant cultivars.
- Reduce nitrogen in spring to limit succulent growth. Do not apply nitrogen late in the growing season (August or later).
- Reduce humidity with spacing and pruning.
- Follow spray recommendations if plantings have a history of disease.
- Remove infected tissue.
- Harvest berries often to avoid overripe fruit.
- Promptly cool harvested berries.

Alternaria fruit rot, caused by *Alternaria tenuissima*, is the most common fruit rot of highbush blueberry. Symptoms begin as sunken lesions at the calyx end of fruit. Lesions later turn gray-green with fungal masses (mycelia) and dark green spores (conidia) (Figure 11-12). Infected fruit become leaky. Fruit may not develop symptoms until after harvest; this disease is most severe as a post-harvest rot. Leaf infections, which appear as small, round, necrotic spots with red halos, can occur as temperatures warm above 70°F.

The fungus is a common saprophyte and overwinters in dried-up berries (mummies) and leaf debris, or on dead peduncles as mycelia and spores. During cool wet weather, usually between late bloom and fruit maturity, spore produc-

Figure 11-12. Alternaria fruit rot.

Alternaria fruit rot

Disease Management
Cultivars with dry stem scars, such as Bluehaven, are less prone to infection.
If disease is a problem, a regular spray program from early bloom until harvest may be beneficial.
Pick fruit frequently as it ripens. Do not allow fruit to become overripe.
Fruit should be rapidly cooled after harvest to inhibit symptom development.

tion occurs. Rain and wind disperse spores. Leaf spots can occur early in the growing season and fungal sporulation can occur throughout the season. Infection from these late-produced spores can infect stem scars, resulting in post-harvest rot. This fungus grows most profusely at temperatures from 65° to 70°F and high humidity.

Botrytis fruit rot and **blossom blight,** caused by *Botrytis cinerea*, is usually a minor disease of highbush blueberry, but it can be a major problem on lowbush blueberry. Fast-growing, gray/tan, fluffy fungal masses (mycelia) and spores (conidia) develop on infected fruit (Figure 11-13). This disease may appear similar to Alternaria fruit rot; however the fungal growth of *Botrytis* is not dense or as green as that of *Alternaria*. Tender growth such as blossoms, fruit, and young leaves are most susceptible to infection. Infection of blossoms causes the most severe damage, as infected blooms do not develop fruit. Occasionally, green twigs may become infected; damage may resemble winter injury. Mature hardened plant parts are rarely affected. Botrytis fruit rot occurs after harvest.

The fungus overwinters as either viable masses of fungal tissue (mycelia) or hardened survival structures (sclerotia) in plant debris, fruit, stems, and leaves. Sporulation occurs in spring as temperatures range between 59° and 68°F with 6 to 9 days of humid or wet weather. Sporulation can occur any time of year during periods of a few hours of ideal temperatures and free water. Spores are spread by wind and rain.

Mummy berry, caused by the fungus *Monilinia vaccinii-corymbosi*, is one of the most serious and most economically important diseases of blueberry fruit. All blueberry varieties are susceptible, especially highbush types. Early symptoms include rapid blighting of twigs (Figure 11-14a) and shoots, followed by production of fungal spores within a 24-hour period. These spores (conidia) form dense, tan-gray tufts. Infected young leaves and shoots often wilt; leaves frequently develop brown areas along midribs (Figure 11-14b), veins of leaves, and at bases of flowers. Young vegetative shoots generally die and fall to the ground within 72 hours. Symptoms may disappear until berries begin to ripen. At this stage, berries that develop from infected flowers begin to rot. They soon turn pink or gray (Figure 11-14c) and shrivel and harden into mummies (Figure 11-14d).

The fungus overwinters in hard, dry berries or mummies (pseudosclerotia) that fall to the ground. These structures may survive for several years. In spring, when conditions are rainy and as temperatures reach 50° to 60°F, the fungus forms fruiting bodies (apothecia) (Figure 11-14e) that produce spores. These spores (ascospores) are carried by wind and rain

Figure 11-13. Fluffy fungal masses develop on *Botrytis*-infected fruit.

Botrytis fruit rot and blossom blight

Disease Management

- Cultivars with loose clusters pose less risk for disease outbreaks.
- Space plants, and prune for increased circulation and rapid drying of tissue.
- Avoid excess nitrogen, which can stimulate growth and produce susceptible, tender tissue.
- Pick fruit frequently as it ripens. Do not allow fruit to become overripe.
- Fruit should be rapidly cooled after harvest to inhibit symptom development.

Figure 11-14. (a) Mummy berry twig blight. (b) Foliar symptom. (c) Infected berries on branches. (d) Mummies look like tiny black pumpkins. (e) Mummy berry apothecia.

Mummy berry

Disease Management

- Practice strict sanitation; cultivate or remove mummies from orchards to eliminate the primary source of inoculum (ascospores) in spring.
- Prune wounded canes and plant parts damaged by frost, as they are most susceptible to infection.
- Fungicides such as captan, azoxystrobin, fenbuconazole, propiconazole, and others applied at leaf emergence are recommended; repeat according to label instructions.
- Resistant cultivars include: Duke, Elliot, Late Blue, Northsky

to infect newly emerging green tissue. A different type of spore (conidia) is produced on resulting dead tissue in the early spring as flowering begins. Infected blossoms smell like fermented tea and attract insects. Conidia can be carried to flowers by insects and wind.

Anthracnose fruit rot/ripe rot, caused by the fungi *Colletotrichum acutatum* or *C. gloeosporioides*, results in both pre- and post-harvest fruit rots. Rabbiteye varieties are less susceptible than highbush blueberries. Early symptoms include blighted blossoms; leaf spots or twig lesions may develop later in the season. Infected twigs develop dark brown lesions that are surrounded by spore-producing structures (acervuli). While this disease is primarily a fruit rot, leaf infections resulting in reddish-brown spots can also occur. Ripening berries decay rapidly, (Figure 11-15a) and orange spores usually ooze from infected berries (Figure 11-15b).

The fungus overwinters in blighted twigs and old infected fruit on the ground. Spores are released during rainy periods throughout the season. Infection can occur anytime. Green berry infections remain latent (dormant) until fruit begins to ripen, when temperatures range between 68° and 80°C, and leaf wetness exceeds 12 hours.

Phyllosticta fruit rot and **leaf spot,** caused by *Phyllosticta vaccinii* or *P. elongate*, is a disease of highbush and rabbiteye blueberries. Foliar symptoms are described under "leaf spots," above (Figure 11-16). Fruit symptoms may develop in late spring, but most often develop during storage. Infected fruit contain numerous speckles or small circular spots with purple margins. Lesions become hard, gray, and slightly depressed. Fungal fruiting bodies (pycnidia) may develop in centers of lesions.

Fungi overwinter in infected tissue that falls to orchard floors. Rain disperses spores (conidia). Infection occurs during mid-season, but visible symptoms do not occur until fruit ripening.

Figure 11-15. (a) Anthracnose fruit rot causes ripening berries to decay rapidly. (b) Masses of spores appear as an orange ooze on infected berries.

Anthracnose fruit rot/ripe rot
Disease Management
If disease becomes a problem, fungicides should be applied at regular intervals beginning at full bloom. Suggested fungicides include captan, azoxystrobin, and pyraclostrobin.
Pick fruit frequently as it ripens. Do not allow fruit to become overripe.
Rapid postharvest cooling is critical for inhibition of postharvest rot.
Resistant cultivars include: Brigitta Blue, Elliot, Hannah's Choice, Legacy, Little Giant, Morrow, Murphy, Reveille
Highly susceptible cultivars include: Berkeley, Bluecrop, Bluetta, Blueray, Bounty, Chanticleer, Coville, Harrison, Jersey, Spartan

Figure 11-16. Phyllosticta leaf spot.

Phyllosticta leaf spot and fruit rot
Disease Management
Maintain a clean field floor; rake or cultivate fallen diseased leaves.
Avoid susceptible cultivars, such as: Jersey, Murphy, Harrison
Limit overhead irrigation.
Space and prune bushes to reduce humidity and to promote rapid drying of tissue.
If disease becomes a problem, fungicides may be applied after harvest until leaf drop in order to control subsequent infections.

Viruses and Phytoplasmas

Shoestring virus is a widespread virus that is especially prominent in the eastern United States. Symptoms of shoestring virus appear approximately 4 years after infection. Leaves appear red or purplish along midribs (Figure 11-17a) and at bases of leaves. Red or purplish, elongated, strap-like leaves are also characteristic of this disease (Figure 11-17b). Green stems may develop red, elongated streaks, especially stems exposed to sun. Infected plants contain reddish flowers (Figure 11-17c) and purple fruit.

The virus is vectored by the blueberry aphid *Illinoia pepperi*, which acquires the virus upon emergence in spring and transmits it through the growing season.

Tomato ringspot virus can cause a serious disease on the West Coast. It is rare in the Midwest, but has occurred in Pennsylvania. Symptoms include cupped and malformed leaves with numerous small, necrotic spots. Young leaves may be strap-like and mottled (Figure 11-18). However, symptoms vary from plant to plant and within the same plant. Infected plants defoliate by mid-harvest and die after severe winters.

The virus is spread by dagger nematodes (*Xiphinema* spp.) that are often present in soil. The virus has a wide host range, so disease may be transmitted from many different plant species from one plant to another. Disease spread within a field is often slow. Infection may also be seed-borne.

Leaf mottle virus is not common in the Midwest, but is has been reported in Michigan. Symptoms include mottling patterns and puckered leaf spots (Figure 11-19), which usually are not observed until 3 to 4 years after infection. Symptoms differ with cultivar: infected Rubel plants usually have dead stems, while Jersey and Blueray become stunted upon infection and small rosette terminal leaves develop. The virus is spread by pollen, which is carried by bees.

Red ringspot is a viral disease that is most commonly found in the eastern United States. Symptoms include red spots or circular blotches on stems and reddish-brown circular spots on upper sides of mature leaves (Figure 11-20) in mid- to late-summer. Similar circular blotches may develop on infected fruit.

Figure 11-17. (a) Oakleaf pattern symptom of shoestring virus. (b) Reddish elongated streaks on branches infected with shoestring virus. (c) Pink to red discoloration of blossoms due to shoestring virus.

Shoestring virus

Disease Management
Plant virus-indexed (virus-free) plants from a reputable nursery.
Apply insecticides when aphids emerge.
Inspect plantings frequently and remove and destroy infected plants. Diseased bushes cannot be cured. They must be removed from the field as soon as they are diagnosed.
Resistant cultivars include: Bluecrop

Figure 11-18. Strap-like, mottled leaves resulting from tomato ringspot virus.

Tomato ringspot virus

Disease Management
Plant virus-indexed (virus-free) plants from a reputable nursery.
Inspect plantings frequently and remove and destroy infected plants.
Control weeds to reduce inoculum.
Diseased bushes cannot be cured. They must be removed from the field as soon as they are diagnosed.

Figure 11-19. Pale, puckered terminal leaves due to leaf mottle virus.

Leaf mottle virus

Disease Management
Plant virus-indexed (virus-free) plants from a reputable nursery.
Inspect plantings frequently and remove and destroy infected plants.
Diseased bushes cannot be cured. They must be removed from the field as soon as they are diagnosed.
Monitor sources of beehives to limit introductions of the virus to orchards.

Figure 11-20. Foliar symptoms of red ringspot.

Red ringspot

Disease Management
Plant virus-indexed (virus-free) plants from a reputable nursery.
Inspect plantings frequently and remove and destroy infected plants.
Diseased bushes cannot be cured. They must be removed from the field as soon as they are diagnosed.
Use insecticides to control insects.

The virus is vectored by mealy bugs.

Blueberry mosaic virus is commonly found in both the eastern and western United States. Symptoms include mosaic patterns of red, yellow, green, and pink (Figure 11-21). Symptoms may not be produced every year, as they seem to be temperature-dependent. On infected plants, fruit ripens late and is of poor quality.

The virus is spread through cuttings, but not through mechanical means such as tools. No known vector has been reported. Little else is known about this virus.

Blueberry stunt was originally thought to be caused by a virus but is now known to be caused by a phytoplasma. The only known carrier is the sharpnosed leafhopper (see Chapter 12: *Insect and Mite Pest Management*), though other vectors may exist.

Symptoms vary with stage of growth, time of year, age of infection, and the cultivar. Symptoms are most noticeable during mid-June and late-September. Affected plants become dwarfed, developing shortened internodes, excessive branching, and low vigor (Figure 11-22a). Small, downward-cupped leaves turn yellow along margins and between lateral veins (Figure 11-22b), giving a green and yellow mottled appearance. These mottled areas turn brilliant red prematurely in late summer, although the midrib remains dark bluish-green. Fruit on affected bushes are small, hard, lack flavor, ripen late (if at all), and remain attached to plants much longer than on healthy plants.

Figure 11-21. Foliar symptoms of blueberry mosaic virus.

Blueberry mosaic virus

Disease Management
Diseased bushes cannot be cured. They must be removed from the field as soon as they are diagnosed.

Figure 11-22. (a) Short bushy growth at the base of a bush infected with blueberry stunt. (b) Downward cupping of leaves with marginal chlorosis typical of blueberry stunt.

Blueberry stunt

Disease Management
Plant virus-indexed (virus-free) plants from a reputable nursery.
Diseased bushes cannot be cured. They must be removed from fields as soon as they are diagnosed.
Removal of bushes may facilitate the further spread of the disease in the field. Agitation of the bush during removal will dislodge leafhoppers, causing them to move to a neighboring healthy bush. Therefore, infected bushes should be sprayed with an appropriate insecticide prior to removal.
Susceptible cultivars include: Bluetta, Jersey, Weymouth
Resistant cultivars include: Rancocas

Additional Resources

Compendium of Blueberry and Cranberry Diseases. American Phytopathological Society, 3340 Pilot Knob Road, St. Paul, Minnesota 55121. Phone: (612) 454-7250 or (800) 328-7560. *This is the most comprehensive book on blueberry diseases available. All commercial growers should have a copy.*

Highbush Blueberry Production Guide. Northeast Regional Agricultural Engineering Service, 152 Riley-Robb Hall, Cooperative Extension, Ithaca, NY 14853. Phone: (607) 255-7654. *This is a comprehensive book covering most phases of blueberry production.*

Midwest Commercial Small Fruit and Grape Spray Guide, ID-94. http://www.ca.uky.edu/agcollege/plantpathology/ext_files/PPFShtml/ID-94.pdf.

Midwest Small Fruit Pest Management Handbook, B-861. http://www.ca.uky.edu/agcollege/plantpathology/ext_files/PPFShtml/MwSmFruitPM-Handbook.pdf.

Insect and Mite Pest Management

Table 12-1. Blueberry Insect Pest Monitoring and Control Relative to Crop Phenology.

	Dormant	Bud swell	Bud break/Green tip	Tight cluster/shot expansion	Early pink bud	Late pink bud	Early bloom	Full bloom	Petal fall	Green fruit	Fruit coloring	25% blue	75% blue	Postharvest
Blueberry bud mite	+ (green)	+ (green)	+	+	+	+	+	+	+	+	+	+	+	+ (blue)
Cutworm		+ (blue)	+ (blue)	+ (green)										
Blossom weevil		+	+ (green)	+ (blue)	+ (blue)	+ (green)	+ (green)							
Oblique-banded leafroller			+ (green)	+ (blue)	+ (blue)	+ (green)	+			+ (green)	+ (green)	+ (green)	+ (green)	
Eastern tent caterpillar						+ (green)	+ (green)	+ (green)	+ (green)					
Cherry fruitworm							+ (green)	+ (blue)	+ (blue)	+ (blue)	+ (green)	+ (green)		
Cranberry fruitworm								+ (green)	+ (blue)	+ (blue)	+ (blue)	+ (green)		
Blueberry aphid								+	+	+ (blue)	+ (blue)	+	+	
Plum curculio*								+	+ (blue)	+ (blue)	+		+ (blue)	
Sharp-nosed leafhopper									+ (green)	+ (green)	+ (green)	+	+ (green)	+ (blue)
Oriental beetle										+ (blue)	+ (blue)	+ (green)		
Flat-headed apple tree borer										+ (green)	+ (green)	+ (green)		
Azalea stem borer											+ (green)	+ (green)	+ (green)	
Blueberry maggot											+ (blue)	+ (blue)	+ (blue)	+ (green)
Japanese beetle											+ (blue)	+ (blue)	+ (blue)	+ (green)
Spotted wing drosophila											+ (blue)	+ (blue)	+ (blue)	
Bagworm												+ (green)	+ (green)	+ (green)
Green June beetle													+ (blue)	+ (blue)
Yellow-necked caterpillar														+ (green)
Fall webworm														+ (green)

■ (blue) Usual time for monitoring and control
■ (green) Less risk, monitoring or control may be required
+ Potential pest activity
* In the southern region of the Midwest, only summer generation plum curculio larvae have been found in ripening berries from mid-June to the end of harvest.

General Management Principles

Introduction to Scouting. Regular scouting for pests is an essential element of Integrated Pest Management in blueberries. The pest scouting calendar (Table 12-1) can be used to begin and end scouting for a particular pest. This can consist of visual inspection of the crop and monitoring insect traps. By checking the planting in this way, trends in pest populations can be identified and the efficacy of pest management activities can be assessed. Monitoring traps are efficient tools for checking pests; traps are available for fruitworms, blueberry maggot, spotted wing Drosophila, and other key pests. Maintaining a weekly record of insect captures in these traps will provide early warning of pest activity and the need for management.

Weekly checks of 100 growing shoots and 100 fruit clusters spread through the field are also a good basis for making decisions on whether some other pests are present, and at what level. Pest pressure is often greater towards the edge of a planting, so selecting some samples at the field edge and others in the field interior will provide a perspective on whether pests show greater abundance in one area.

Record scouting information in a notebook for comparison from season to season. After a few years this will provide information on annual trends and give the grower a clearer view of when and where certain pests develop on the farm.

Non-chemical Approaches

Blueberries have a relatively small pest complex compared with some other crops, but there are some key insect pests that can defoliate bushes or infest fruit making it unsellable. Pests like eastern tent caterpillars, bagworms, fall webworms, and yellownecked caterpillars can all be easily **removed by hand.** Pest pressure can be minimized by **regular pruning** to remove older canes (typically the larger 4-year-old wood) and also by effective **weed control.** This helps remove sites in which pests hide from natural enemies and improves the effectiveness of other management techniques (see below).

Resistant cultivars are also an effective strategy for avoiding pest problems. For example, some popular varieties, such as Bluecrop, are resistant to shoestring virus and selection of these varieties can avoid the need for aggressive aphid control to prevent infection. Local blueberry recommendations can assist growers in selecting cultivars that are resistant to local pest complexes.

Biological control can contribute to the suppression of many pest populations, and so the use of tactics to support natural enemies is encouraged. Providing areas designated for flowering plants during the summer months can increase parasitic wasps and other beneficials, More information is available at http://www.nativeplants.msu.edu. Natural enemies such as lacewings and lady beetles can also be purchased, but there is relatively little information on their survival and effectiveness.

While non-chemical approaches are encouraged, production of fresh blueberries can be challenging when invasive species such as Japanese beetle and spotted wing Drosophila, or the native pest blueberry maggot, are present. For these direct pests, it may be necessary to take a more intensive approach to their management to ensure the high-quality fruit that customers expect.

Spray Techniques. There are various registered insecticide options for use in blueberry, and these range from highly selective and biological insecticides to broad-spectrum insecticides that require applicator certification. Local Extension agents can assist with product recommendations suitable for local pest complexes.

In order for pesticide applications to control the target insect pest(s), it is essential that the spray reaches the target. This may sound simple, but factors such as bush architecture, weed density, pest behavior, and insecticide type can all influence the effectiveness of spray coverage.

Well-pruned canopies allow for good air movement and lower disease pressure, but they also allow for improved spray penetration. This, coupled with good weed control, can greatly aid in the success of spray programs by allowing greater opportunity for contact between the pesticide and the insect pest.

In general, insecticide applications need to have sufficient water as the carrier, along with sufficient air speed to transport the pesticide to its target. Some pests, such as blueberry maggot fly, can be well-controlled by a spray that covers leaves and fruit. In this case perfect coverage is not essential because the insect walks over the bush surface during the week from emergence to the start of egg laying. In contrast, the cranberry fruitworm moth lays its egg inside the calyx cup of the berry, and the larva crawls around the berry to enter at the stem end. There is consequently a short period of time and a very specific area that must be covered for this insect to be controlled.

A range of sprayer designs can be effective at providing good coverage of blueberry bushes. Whether using airblast sprayers, tower sprayers, or cannons, calibration of the sprayer should be done before each season. Adjustments should also be made to ensure that the spray is focused in the appropriate part of the bush. For example, Japanese beetle and blueberry maggot are most active on the top of the bushes, whereas spotted wing Drosophila can attack fruit anywhere on the bush, but they particularly prefer the shady interior of the canopy.

Insects and Mites of Blueberries

The primary insect pests of blueberries in the Midwest Region are cranberry fruitworm, Japanese beetle, blueberry maggot, and spotted wing Drosophila. Additional insect pests include plum curculio, blueberry tip borer, whitemarked tussock moth, blueberry aphid, Putnam scale, and gypsy moth.

Insects That Attack Blueberry Buds

Climbing cutworms (Order: Lepidoptera; Family: Noctuidae) are nocturnal insects that feed on swollen blueberry buds during the evening hours. They hide under vegetation or stones, or burrow into the ground during daylight. The extent of damage varies from year to year and site to site.

Mature cutworm caterpillars are 1¼ inches long, with a smooth, light brown body, a dark brown head, and five pairs of fleshy prolegs on the abdomen (Figure 12-1a). Typically, cutworms will curl up tightly when disturbed (Figure 12-1b).

Figure 12-1. (a) Several climbing cutworm species. (b) Cutworms curl up tightly when disturbed.

Climbing cutworms

Monitoring and Management
Scout daily at bud swell for hollowed out, damaged buds.
Apply insecticide if more than 2 percent of the buds are damaged.

Blueberry bud mite (*Acalitus vaccinii*) causes blistering on outsides of bud scales, poor flower set, poor plant growth, and reduced fruit set, particularly in the tops of plants.

Sample the current season's growth after harvest and dissect floral buds nearest to shoot tips; a microscope will be needed to see the tiny white mites. Females reproduce rapidly, laying clear, spherical eggs, and producing multiple generations each year. The mites live on the inner bud scales from fall to spring; feeding injury becomes evident when populations build to high levels.

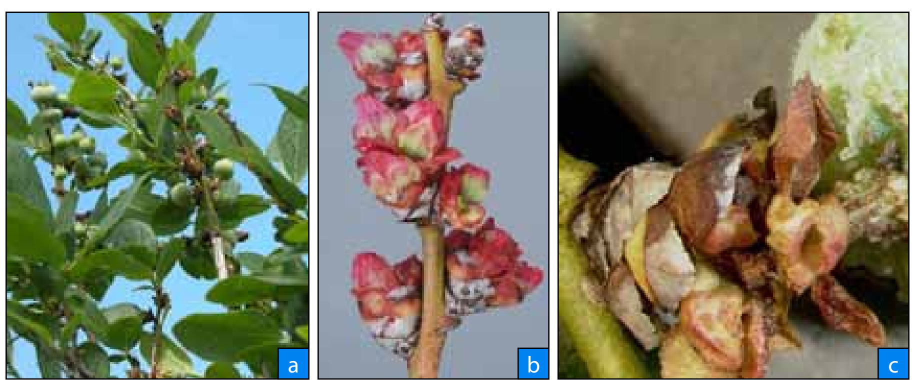

Figure 12-2. (a) Rossetted and (b) desiccated bud and (c) blueberry fruit growing from bud infested with blueberry bud mites.

Blueberry bud mite

Monitoring and Management
From February through April the presence of bud mites is relatively easy to detect by looking for the distinctive red blisters on bud scales.
Selectively prune out old canes to help reduce bud mite populations in established plantings.
When infestations are severe, 2 applications of an approved miticide (1 month apart immediately following harvest) should give adequate control.
Apply sprays before mites penetrate too deeply into the buds and destroy the tissues that produce the next year's fruit.

Insects That Attack Blueberry Flower Clusters and/or Berries

Eastern tent caterpillar (*Malacosoma americanum*) nearly-mature larvae disperse from infested trees adjacent to fruit plantings. Development is completed by feeding on and defoliating blueberry plants, often during bloom.

Larvae have a white line down the center of the back, plus a series of light blue and black dots, and are 2 to 2½ inches long when fully grown (Figure 12-3b). They produce silk nests (tents) in crotches of fruit trees (Figure 12-3c); this group of larvae can defoliate trees. Once the host is defoliated, the nearly mature larvae disperse to adjacent plants like blueberries where they feed on buds, flowers, and leaves, defoliating these plants as well. Mature larvae disperse to protected areas to pupate. In midsummer, adults emerge, mate, lay egg masses on pencil-sized terminals on fruit trees (Figure 12-3a), and overwinter.

Cranberry fruitworm (*Acrobasis vaccinii*) male moths are brown and elongate with white triangular patterns on the wings (Figure 12-4a). The females lay white oval eggs (Figure 12-4b) in the calyx cup starting at early petal fall. Larvae are green with a brown head and covered with fine hairs.

The insect overwinters in leaf litter under the bush and is also present on wild blueberry in the woods. Moths emerge during early bloom and lay eggs. Egg hatch typically starts while blueberries are still in bloom. Larvae infest fruit in the early part of the season (Figure 12-4c). There is one generation per year.

Cherry fruitworm (*Grapholita packardi*) larvae feed inside individual berries after making a tiny entry hole in the berry wall. However, since little visible damage occurs to the fruit exterior, infestations may be difficult to detect. Infested berries often turn blue prematurely.

The moth is 6 mm (¼ inch) long, dark brown-gray, with a mottled silver pattern. Eggs are round, flat, and shiny. The larva resembles cranberry fruitworm, but cherry fruitworm has a dark head capsule and a reddish body, reaching 9 mm (about ⅓ inch) in length.

Moths typically begin egg laying at first petal fall. Eggs are laid in the calyx. Larvae often enter berries in the calyx or on the berry side.

Figure 12-3. (a) Eastern tent caterpillar egg mass on pencil-sized terminal, (b) larva, and (c) larvae on silk nest in branch crotch.

Eastern tent caterpillar

Monitoring and Management
Remove and destroy egg masses during winter pruning
Scout wild cherry trees as they begin to leaf out.
Remove silk nests and larvae from tree crotches and bushes.
Insecticides are usually not warranted.

Figure 12-4. (a) Male cranberry fruitworm moth, (b) cranberry fruitworm egg (arrow), and (c) a cranberry fruitworm larva and damage.

Cranberry fruitworm

Monitoring and Management
Control weeds and remove wild hosts
Deploy monitoring traps at wooded borders prior to bloom and check weekly. Egg hatch begins at about 100 growing degree days (GDD) base 50°F from the first sustained catch of moths.
The most important spray is at petal-fall. In high-pressure sites, an additional, earlier application at the predicted start of egg hatch will improve control.

Cherry fruitworm

Monitoring and Management
Infested berries often drop prematurely before harvest, thus they are not a high risk as a harvest contaminant.
Insecticides used for management of cranberry fruitworm typically control this pest, though early activity may require a specific spray.

Blueberry maggot (*Rhagoletis mendax*) activity is first determined by monitoring traps. The first symptom of blueberry maggot infestation is typically seen as soft fruit with white maggots (Figure 12-5b).

Blueberry maggot adults (5 mm long) have distinctive 'W' or 'M' wing pattern (Figure 12-5a). The legless maggot is white with black mouthparts and grows to 7 mm (a little more than ¼ inch) in length.

The blueberry maggot overwinters as pupa below the soil surface. Most pupae emerge 1 year after going into the soil. Adult emergence typically begins in mid- to late June, especially after rain, with adult flight continuing through August. Female flies lay eggs 7 to 10 days after emergence, placing them under skins of ripening blueberries with a single egg deposited per fruit.

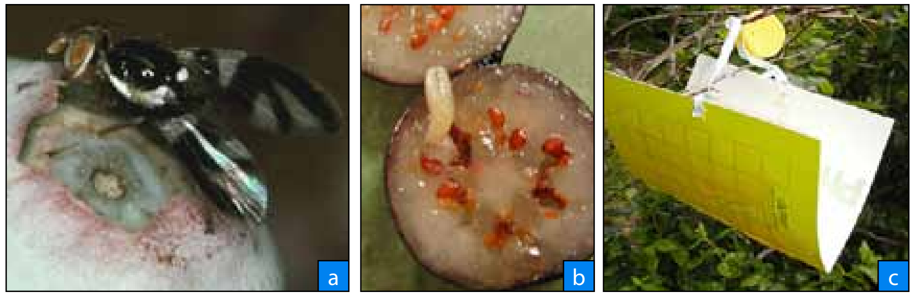

Figure 12-5. (a) Blueberry maggot fly with distinctive wing pattern, (b) legless blueberry maggot larva and (c) baited monitoring trap placed in a blueberry bush.

Blueberry maggot

Monitoring and Management
Use baited yellow sticky traps baited with ammonium acetate (or ammonium carbonate) as a food attractant (Figure 12-5c). Deploy traps before the first anticipated flight in late June.
Place traps on a stake or hang on an upper branch of a blueberry bush in a perimeter row (south facing side of bushes). Hang traps with the colored side down in a V-orientation (Figure 12-5c).
Check traps weekly starting at 700 GDD base 50°F until the first fly is caught, triggering fruit protection activities.
Use recommended insecticides, which kill the adult fly on contact, preventing it from laying eggs into the fruit.
A boil test can be used with ripe fruit to sample for maggot infestation.

Spotted wing Drosophila (*Drosophila suzukii*) adult male flies have a spot on each wing (Figure 12-6a). Females lack wing spots but have serrated ovipositors (egg-laying device) used to cut a slit into the skin of intact fruit in order to lay eggs. Flies are 1.6 to 3 mm (1/16 to ⅛ inch) long, and look similar to the small vinegar flies that typically infest fruits and some vegetables in late summer. Infested berries soften, become leaky, and contain small legless, cylindrical, white maggots (Figure 12-6b) with black mouthparts that are approximately 3 mm (⅛ inch) long at maturity.

Mature female flies overwinter and become active before fruit ripening. Multiple generations occur each year, with populations building in late summer. As fruit start ripening, females begin laying eggs into fruit. Fly abundance increases throughout the blueberry harvest season, with greater pest pressure for later-ripening varieties.

Figure 12-6. (a) Male spotted wing drosophila fly and (b) a spotted wing drosophila larva on a blueberry (bottom) in comparison to a larger blueberry maggot larva (top).

Spotted wing Drosophila

Monitoring and Management
Trap flies with a simple monitoring trap. • Use a plastic 32-oz cup with ten 3/16 inch holes around the upper side of the cup; leave a 3- to 4-inch section without holes to facilitate pouring out the liquid bait. The small holes allow access to vinegar flies, but keep out larger flies, moths, bees, etc. • A small yellow sticky trap can be hung on a paper clip inside traps to trap flies. • Bait the traps using a mix comprised of 1 tablespoon of active dry yeast and 4 tablespoons of sugar per 12 oz of water. • Hang traps in a shaded area in the fruit zone. • Check traps and change the bait weekly. • Identification of flies can be aided by information available at http://www.ipm.msu.edu/SWD.htm.
Fruit can also be sampled for spotted wing Drosophila using a boil test (also used to test for blueberry maggot) or by placing crushed berries in a strong salt solution (¼ cup of salt in 1 quart of water). Wait 10 to 20 minutes and look for white larvae.
Pick berries before over-ripening and softening and keep fruit cool after harvest to slow insect development.
Complete insecticide coverage of the canopy and timely response to fly activity are important for effective control.

Plum curculio (*Conotrachelus nenuphar*) does not just attack plums; hosts also include blueberries, peaches, apples, pears, and an array of wild and cultivated fruits.

Adult plum curculios are small brownish-black snout beetles, about 4 to 6 mm (⅛ to ¼ inch) long, mottled with lighter gray or brown markings (Figure 12-7a). The mouthparts are at the end of a moderately curved snout that is about one-fourth the length of the body. Larvae are slightly curved, yellowish-white, legless, brown-headed grubs, about 6 to 9 mm long (¼ to ⅜ inch).

Adults overwinter by finding protection under debris on the ground. They emerge from hibernation in early spring when daytime temperatures reach a consecutive high temperature for 3 to 4 days. Adults feed on all new growth tissues in spring. As soon as new fruit are formed, egg laying begins and will last for 3 or 4 weeks. The female will create a small pocket for the egg on the outside of the fruit. Females can lay 50 to 160 eggs which hatch within a week. Larvae emerge within 10 to 16 days. Larva will then burrow into the soil and in approximately 5 weeks, they emerge as adults. The summer brood, which emerges in late July and August, feeds on fruit but does not lay eggs.

Cranberry weevil (*Anthonomus musculus*) is also known as the blueberry blossom weevil. Adult female weevil activity is evident by holes in flower buds. Grub feeding within the bud prevents flowering and causes injured buds to drop to the ground.

The cranberry weevil is 1.6 to 3 mm (1/16 to 1/8 inch) long with white flecks on wing covers and a snout nose (Figure 12-8). The grub is small, legless, and yellow-white with a brown head.

The weevil adult overwinters in wooded areas and moves to blueberry bushes as early as bud swell. The adult chews a hole in a blossom bud and lays a single egg. Injured buds fall, larva feed inside and later pupate in the buds. Adults emerge in late spring to feed on leaves. There is typically one generation per year.

Green June beetle (*Cotinis nitida*) are attracted to and feed as a group on the ripening berries.

Adults are about 19 to 25 mm (¾ to 1 inch) long and have green forewings with light brown margins (Figure 12-9b). The larva is a legged, C-shaped grub (Figure 12-10c) that crawls on the ground on its back (Figure 12-9a).

In late June and July, after rain has moistened and loosened the soil, adults emerge. Females lay eggs in soil beneath the grass surface where compost or green manure has been applied. Eggs hatch in mid-summer and larvae feed until the following May on decomposed manure and vegetable matter in the soil. Adults feed for about a month on ripening fruit.

Green June beetle

Monitoring and Management
In July, scout weekly to detect dispersal into blueberry plantings and identify first adult feeding damage.
Manually remove or apply insecticides after first damage is detected.

Figure 12-7. (a) Plum curculio adult, (b) feeding scar on blueberry and (c) legless, white larva with brown head capsule inside a blueberry.

Plum curculio

Monitoring and Management
Keep planting floors closely mowed after harvest to eliminate protective cover for overwintering.
Destroy nearby plum thickets, abandoned fruit blocks, and other alternate hosts to reduce dispersal from outside sources.
Monitor insects with a baited, gray pyramid Tedders trap, set out before bloom. Place it along perimeters of plantings, adjacent to woodlots. Check traps weekly.
Once adults are detected, begin checking berries for the presence of feeding scars.
Use insecticides to protect berries if feeding damage is detected.

Figure 12-8. Adult cranberry blossom weevil.

Cranberry weevil

Monitoring and Management
Cultural controls, such as clean cultivation may be used for low infestations.
When there is a history of weevil damage, check for damaged blossom buds or weevil presence as the first blossom buds develop. To detect weevils, use a sweep net or shake them onto a white ground cloth.
Once weevil damage or weevils are detected, apply a recommended insecticide.

Figure 12-9. (a) Green June beetle larva moving on back, (b) adult, and (c) feeding aggregation on ripe grapes.

Insects That Attack Blueberry Foliage

Japanese beetles (*Popillia japonica*) remove skin of fruit and skeletonize leaves (Figure 12-10a).

Adults are about 13 mm (½ inch) long, with shiny metallic brown wings, a green prothorax and head, and a series of white spots on the edge of the abdomen (Figure 12-10b). Grubs are C-shaped and have a distinctive pattern of hair on the hind end of the abdomen (rastral pattern) of 14 hairs in a V-shape on the abdominal tip. The rastral pattern distinguishes it from other grubs species found in soil under turf (Figure 12-10c).

During fruit ripening and through the harvest season, beetles emerge from the soil. Eggs are laid in the soil under turf, and larvae feed on roots of grasses and other plants, but not on blueberry.

Bagworms (*Thyridopteryx ephemeraeformisz*) defoliate blueberry plants (Figure 12-11a), leaving behind brown spindle-shaped bags attached to leaves (Figure 12-11b) and limbs (Figure 12-11c). Bags are made from the cemented leaf parts of the host plant and each contains a single caterpillar. As caterpillars grow, bags can increase to 2 inches in length.

Bags are most noticeable during winter after leaf fall. Overwintering bags contain eggs that hatch in June or July. In late summer, caterpillars pupate inside bags and later develop into adult moths. Female moths are wingless, remain in bags, and attract winged males. Mated females lay 500 or more eggs inside bags and then die.

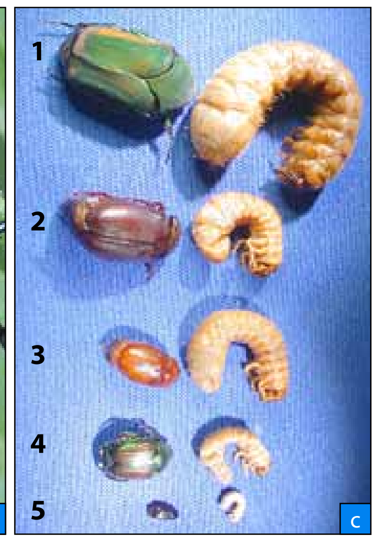

Figure 12-10. (a) Leaf and fruit damage, (b) adult Japanese beetle, and (c) comparison of scarab beetle adults (left) and "C"-shaped grubs (right) in turf: 1) green June beetle, 2) May beetle (Phyllophaga), 3) masked chafer, 4) Japanese beetle, and 5) black turfgrass Ataenius.

Japanese beetles

Monitoring and Management
Do not use commercial Japanese beetle traps near plantings because traps attract additional beetles.
Scout blueberries in June or July.
Remove beetles by hand or apply recommended foliar insecticides.
Remove wild hosts such as wild grape, raspberry, and blackberry.
Maintain cleanly cultivated fields to reduce suitability for beetle development.
Soil insecticide may be necessary in grassy fields to reduce populations.
There is a low tolerance for beetle contamination in picked fruit, so thresholds are essentially zero.

Figure 12-11. (a) Bagworm defoliated blueberry plant, (b) bagworms on underside of blueberry leaf and (c) a bag hanging from a branch.

Bagworms

Monitoring and Management
Begin scouting plantings for bagworm bags during winter pruning.
Mechanically remove and destroy overwintering bagworms.
Scout plants again in mid-June after larvae have dispersed into planting and then remove and destroy bags.

Fall webworm (*Hyphantria cunea*) skeletonizes leaves within a protective web. Though the webs are very unsightly, damage to most plants is considered to be insignificant if webs are removed soon after development.

Fall webworm is most often discovered when the light gray, silken webs (Figure 12-12c) appear in the planting in June and July (1st brood) and August through September (2nd brood). Webworms enclose leaves (Figure 12-12a) and small branches (Figure 12-12b) in their silk nests. This distinguishes them from tent caterpillars, which make a smaller nest in the crotch of trees (Figure 12-3c). Webworm caterpillars, which are covered with long to yellowish tan hairs, remain inside webs; if food runs out, new foliage is encased.

Yellownecked caterpillar (*Datana ministra*) occasionally results in outbreaks that may completely defoliate one or more plants.

Full-grown larvae are about 2 inches long with a black body and black head. A bright orange-yellow spot characterizes the "neck" area behind the head. The remainder of the body is marked with four longitudinal yellow stripes interspersed with black, and the entire body is clothed with long, soft, white hairs (Figure 12-13b). Larvae feed in large colonies on leaves near the tips of twigs and branches (Figure 12-13a).

Pupae overwinter in soil. Adults emerge in mid-summer, laying masses of 50 to 100 eggs each. Emerging caterpillars feed as a group, resulting in plant defoliation as caterpillars mature. There is one generation per year.

Leafrollers, such as the obliquebanded leafroller (*Choristoneura rosaceana*) and redbanded leafroller (*Argyrotaenia velutinana*) can be found on blueberries.

Obliquebanded leafroller larvae are green with dark heads and are about 25 mm (1 inch) long when fully grown. Moths are about 18 mm long with wings that are banded with tan to brown scales. Redbanded leafroller larvae are small (up to 16 mm long) and green or pale yellow. Moths (6.3 to 9.5 mm long) are reddish-brown with faint tints of grey and orange; wings have a distinct reddish-brown band.

Figure 12-12. (a) Newly hatched group of fall webworm caterpillars on birch leaf, (b) caterpillars defoliating leaves inside silk nest, and (c) damage to blueberry plant.

Figure 12-13. (a) Feeding aggregation of yellownecked caterpillars and (b) U-shaped defensive posture.

Fall webworm

Monitoring and Management
Scout plants from late-June through September for webs.
Prune or pick off the nests and larvae while they are still small.
Do not burn or torch the nests while on bushes as this may do additional damage to the plants.

Yellownecked caterpillar

Monitoring and Management
Scout every 2 weeks beginning in June or July.
It may be faster to remove larvae by hand than to spray.
If an insecticide is used, spray entire plants, not just colonies.

Leafrollers

Monitoring and Management
Leafrollers are usually controlled by natural enemies or by sprays applied for other pests. Insect growth regulator insecticides can be highly effective.
Pheromone traps can be used to determine adult emergence.
Trap information can be combined with growing degree-days to predict egg hatch, larval development, and optimal timing for control.
Timing of treatment depends on the type of insecticide.

The obliquebanded leafroller is one of the most damaging leafroller species and can feed directly on fruit during the summer. First-generation larvae are active before and during bloom, and sprays for fruitworm typically control first generation leafrollers. Focus scouting on flower buds and look for webbed flowers and leaves. The summer generation larvae are active during fruit ripening, feeding on fruit and foliage. They also feed on flower clusters, leaves, and green fruit. Larvae feed inside the webbing and may be hard to find. Redbanded leafroller larvae may be present as soon as green foliage appears, and this first generation can injure leaves and young clusters. The later generation rarely causes injury.

Whitemarked tussock moth (*Orgyia leucostigma*) does not cause significant feeding damage to mature bushes, but it can defoliate young blueberry plants. Larvae have irritating hairs, and the second generation can cause problems for pickers or contamination of harvested fruit.

Female moths are white and flightless; they create a large egg mass wrapped inside a dried leaf that is typically stuck to a blueberry branch. Male moths are brown with feathery antennae. The 1½-inch larvae are very distinctive with yellow stripes, yellow and red tufts, and many fine white hairs on the black body (Figure 12-14).

Figure 12-14. The distinctive larva of the whitemarked tussock moth.

Whitemarked tussock moth
Monitoring and Management
Prune out egg masses during winter.
Control weeds in fields.
The first generation of this pest is typically controlled by insecticide sprays for cranberry and cherry fruitworm. Effective control early in the season usually avoids late-season problems with the larvae.

Insects That Attack the Blueberry Roots, Canes and Terminals

Azalea Stem Borer (*Oberea myops*) chews two rows of holes (Figure 12-15b) into terminals, causing girdled canes to wilt (Figure 12-15c) and often die. Larval tunneling can be detected by the accumulation of sawdust at the cane (Figure 12-15d).

Adult beetles are about 13 mm (½ inch long), with long black antennae, tan wings with darkened margins, and two black spots on their orange pronotum (upper surface of the prothorax) behind the head. Larvae are creamy-yellow with a brown, round head capsule.

Adult borers (9 to 18 mm long) emerge from mid-May through June and feed on the underside of the leaves along the mid-vein. Callus tissue forms around the injured vein and the leaf may curl abnormally. In late-May to June, adult females lay eggs in new shoots several inches below a bud. Eggs are inserted under the bark between two rows of holes (Figure 12-15b), causing the first 3 to 4 inches of the current season's growth to wilt and die in June (Figure 12-15c). Larvae (Figure 12-15a) then bore down into roots where they overwinter.

Figure 12-15. (a) Azalea stem borer larva. (b) Two rows of chewed holes on terminal where egg is laid causes (c) tip to wilt, and (d) sawdust appears at base of cane as evidence of larval tunneling.

Azalea Stem Borer
Monitoring and Management
In midsummer, look for infested twigs that are wilting, are breaking off at the base, have coarse sawdust-like frass at the base of the plant, or are dying.
Remove and destroy wilting branches, pruning low enough to remove larvae.
A history of azalea stem borers may require insecticide applications during the egg laying period (applied in mid-May and again in early June).

Blueberry tip borer (*Hendecaneura shawiana*) infests the current year's shoot growth, feeding inside the stem (Figure 12-16b). The larva's point of entry is usually visible as a small (1 mm diameter) brown pinhole on the side of the stem. Foliage above the feeding site turns brown from the leaf tip (Figure 12-16a). Borer damage can also reduce fruit set for the following year.

The moth is about 9 to 14 mm (about ½ inch) long with mostly brown wings. Each front wing has orange marks near the tip and a silver spot along the hind margin. Larvae are slender, light pink caterpillars.

Larvae enter shoots soon after hatching from an individual clear egg laid on young stems. Larvae feed and tunnel inside stems. Larvae are visible with a hand lens if an infested stem is broken open. Insects pupate in stems and emerge the following year. Moth flight occurs during mid- to late-June around the time of fruitworm activity. There is only one generation per year.

Scale (Terrapin scale, European fruit Lecanium, Putnam scale) can infest fruit or stems, resulting in blemished fruit and sooty mold on berries. Scales suck sap from plants and can reduce bush vigor.

Scales are small 2 to 3 mm round or oval dots with waxy protective coverings (Figures 12-17a and b) that shelter the small yellow insects.

Different scales have varying life cycles, but all overwinter on plants. Egg-laying stage in the spring or summer is followed by a period when crawlers emerge from the scales seeking places to settle and feed. Crawlers are susceptible to insecticides. Monitor emergence of crawlers using double-sided sticky tape placed around branches.

Insects That Feed on Blueberry Sap (disease vectors)

Blueberry aphid (*Illinoia pepperi*) causes deformed and wilted leaves on new growth that can indicate an aphid infestation. Severe infestations can reduce the formation of fruiting buds for the subsequent year's harvest. Aphids constantly produce honeydew, which can lead to sooty mold outbreaks on fruit and foliage. They are also vectors of

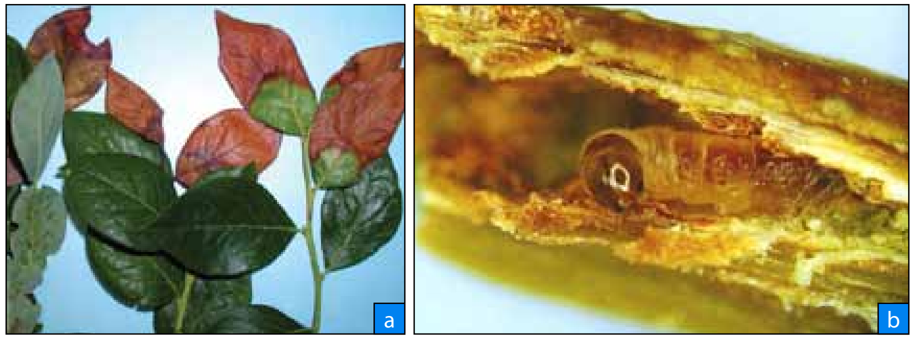

Figure 12-16. (a) Symptomatic terminal leaves as (b) blueberry tip borer larva tunnels in the stem.

Blueberry tip borer

Monitoring and Management
There is no effective trapping system.
Scout weekly to detect early symptoms.
Remove and destroy infested shoots to reduce risk for infection the following year. Larvae inside pruned shoots will dry out and die as the shoots desiccate.
Fields with high levels of infestation should be treated with insecticides during predicted time of egg laying. This period overlaps with cranberry fruitworm activity.

Figure 12-17. (a) Scales can infest berries and (b) stems.

Scale

Monitoring and Management
Remove infested canes during winter pruning.
Apply a delayed-dormant application of oil if populations are high.
Specialized, scale-specific growth regulators are also available.

Figure 12-18. A blueberry aphid feeding on a blueberry leaf.

Blueberry aphid

Monitoring and Management
Protect natural enemies such as lacewings and ladybeetles.
If chemical control is required, the newer systemic insecticides are highly effective.
Reduce weeds, which can reduce effective insecticide coverage.
If shoestring virus symptoms are present (see Chapter 11), more active aphid management is needed to prevent movement of the virus between bushes.

blueberry shoestring virus (see Chapter 11: *Blueberry Diseases*) that can cause decline of susceptible blueberry cultivars.

Aphids colonize undersides of leaves on lower new shoot growth. They are 2 to 4 mm long and green with long legs and antennae (Figure 12-18).

Aphids hatch from overwintering eggs during early bloom and colonies slowly increase. Aphids grow fastest on new young growth, especially on heavily fertilized bushes. Warm weather also promotes faster growth, and populations can grow quickly through May and June.

Blueberry sharpnosed leafhopper (*Scaphytopius magdalensis*) transmits a mycoplasma (virus-like pathogen) that causes blueberry stunt disease (Figures 12-19a and b). Refer to Chapter 11 for information on disease symptoms and management. This disease appears to be more detrimental in the northernmost regions of the Midwest.

Adults (Figure 12-19b) are active from mid-May to mid-November with peaks in mid-June, mid-August, and mid-October.

Figure 12-19. (a) Blueberry stunt infected plant and (b) sharpnosed leafhopper.

Blueberry sharpnosed leafhopper

Monitoring and Management
Monitor weekly using yellow sticky boards between blueberry plants beginning May 1.
Fruitworm sprays usually control the first generation of leafhopper feeding.
In late summer, scout for symptoms of blueberry stunt disease and rogue out the diseased plants.
Remove wild blueberry.
Select resistant cultivars if leafhoppers are problematic: *V. vergatum* Reade, *V. crassifolium* subsp. *crassifolium* Andrews, *V. elliottii* Chapman, *V. staminium* L., and *V. arboretum* Marshall.

References

Brandhorst-Hubbard, J.L., K.L. Flanders, and A.G. Appel. 2001. Oviposition site and food preference of the green June beetle (Coleoptera: Scarabaeidae). J. Econ. Entomol. 94: 628-633.

Jenkins, P., A. Schilder, R. Isaacs, E. Hanson, G. Bird, B. Bordelon, and L. Jess. 2008. Pest management strategic plan for the North central region blueberry industry. Sponsored by The North Central Regional IPM Grants Program.

Johnson, D.T., B.A. Lewis, R.J. Bryant, R. Liyanage, J.O. Lay, and M.A. Pszczolkowski. 2009. Attractants for the green June beetle, *Cotinis nitida* (Coleoptera: Scarabaeidae). J. Econ. Entomol. 102: 2224-2232.

Meyer, J.R., and J.R. Ballington. 1990. Resistance of *Vaccinium* spp, to the leafhopper *Scaphytopius magdalensis* (Homoptera: Cicadellidae). Ann. Entomol. Soc. Am. 83: 515-520.

Other Resources

Michigan Blueberry Facts http://www.blueberries.msu.edu.

Michigan State University IPM Scouting Guide http://blueberries.msu.edu/publications.

Managing Wildlife Problems in Blueberries

Wildlife provides many positive values to humans, but when it comes into conflict with agricultural production, wildlife has the potential to cause economic losses to producers. A 1998 USDA APHIS survey conducted in six major fruit-producing states found that blueberry producers lost about 4 percent of their crop to wildlife at an estimated cost of $443,000 dollars. Much of this loss can be attributed to physical damage by deer and feeding by birds (Figure 13-1), particularly blackbirds, starlings, robins, crows, and ravens. The survey also revealed that producers use pyrotechnics (fireworks), frightening devices, fences, repellents, and flagging as the most common methods to alleviate wildlife damage. This chapter discusses the most effective management options for deer and bird problems. While other animals, such as voles, can cause damage, they will not be discussed; however, this information can be obtained from local county Extension agents or fruit production specialists.

General Principles Relating to Control of Wildlife Pests

One of the most important concepts to understand when managing wildlife pests is that these problems are substantially easier to solve before wildlife become habituated to feeding on fruit or plants. Once a feeding pattern has been developed, it is difficult to solve without large expenditures of time and money. For example, growers located near deer habitats are most likely going to experience damage at some point. It is more effective to develop a plan for dealing with feeding behavior before deer begin to repeatedly enter production fields and, thereby, cause economic damage.

Figure 13-1. Bird damage on ripe fruit.

Figure 13-2. A double-strand high tensile electric fence is effective for keeping out deer.

The second concept to understand is that growers cannot simply kill the offending animals, since most are protected by state and federal laws. Furthermore, it takes substantial time to obtain appropriate permits and, as is often the case, damage is done and crop is harvested before hunting permits arrive.

Finally, it is important to think about the economics of short-term control efforts (such as repellents) versus long-term solutions (such as fencing or netting). It is usually cheaper and more effective (in the long term) to keep the animals away from production fields, rather than testing various solutions after problems begin. For example, methyl anthranilate, a bird repellent, costs about $25 per acre and lasts for 10 to 14 days. However, the repellent needs to be reapplied after each rain or heavy dew. Even then, as some research has shown, it does not completely repel birds. Furthermore, some producers have noticed off-flavored berries caused by repellant residues. On the other hand, the cost of a high quality netting system can cost $2,300 per acre, with additional labor costs of approximately $500 to $600 per acre per year to hang and later remove netting. Producers should critically evaluate each situation and construct a cost-benefit analysis for each technique.

Deer

White-tailed deer typically do not kill blueberry plants, but instead browse on buds and shoots, thereby reducing yields. Much of this damage occurs during the dormant season, although it can occur any time populations are high and deer are nutritionally stressed. The most effective long-term solution for deer feeding is allowance of a judicious legal harvest of female animals (depredation permit) and then put up temporary or permanent electric fencing.

Electric Fencing. Much research has shown that a single or double strand of high-tensile electric fence (Figure 13-2) can be very effective at keeping deer out of production fields (Figure 13-2). The key to success in using this system is to ensure that chargers produce enough electricity to give sufficient shocks to intruding animals. Fences should be kept clear of all weedy growth to ensure that vegetation does not ground the system. Electric fencing is the most cost-effective fencing solution available. If smaller animals, such as rabbits, raccoons, or opossums are a problem, this fence can be adapted to a two-wire system where one wire is about 2 inches from the ground and the second wire is 8 inches to 10 inches above the ground. The two-wire system prevents smaller animals from entering under, through, or over the fence.

Producers can also erect more permanent electric fencing using pressure-treated posts that have life-expectancies of 35 to 40 years. They are powered by high voltage, low impedance chargers (New Zealand style) capable of charging 5,000 feet of fence per unit. An additional benefit is that they have a reduced susceptibility to grounding by vegetation. These fences use high-tensile, smooth wire (200,000 psi, 12½ gauge). Special accessories help maintain a 150 to 250-pound

Figure 13-3. Deer can be deterred with a 6-wire high tensile electric fence.

Figure 13-4. Dryer sheets are often not effective for repelling wildlife.

Figure 13-5. Noise makers are only partially effective, as birds quickly become accustomed to the noise.

tension, so fences can absorb the impact of running deer and spring back to their original positions. The six-wire vertical high-tensile electric fence design is a modification of the Penn State five-wire design (Figure 13-3). The lowest wire should be 8 inches above the ground and remaining wires are spaced at 10-inch intervals. The bottom wire is "hot" and remaining wires alternate between ground and hot. Rigid corner assemblies must be installed. Fiberglass battens are placed at 30-foot intervals along fences to maintain wire spacing. Eight-foot line posts are placed every 60 feet for structural support.

Repellents, whether chemical, visual, or auditory, are not designed to eliminate damage, rather reduce it to tolerable levels. The best chemical repellents can reduce damage by up to 50 percent; damage is reduced more during the dormant season compared to the growing season. There are few commercially available, EPA-registered repellents available for use on fruit crops. In general, commercially available repellents have better efficacy than do home remedies, such as human hair, soap, dryer sheets (Figure 13-4), animal droppings, or urine, etc. Furthermore, most repellents last from 1 to 6 days and must be reapplied. They are often not effective once the animals become familiar with them, which can occur rather quickly. The best way to use these products is to treat plants before animals become used to feeding on them. Some producers use well-trained border collies or blue-heeler dogs to chase animals away from production fields. However, these dogs must not be pets, require special training, and are often expensive to purchase and keep. Loud sounds, lights, or other deterrents are not effective for more than a few days, as animals become accustomed to the noise or lights.

Birds

Of all the wildlife problems that blueberry producers combat, birds appear to be the most serious and persistent. Birds are highly mobile, can concentrate into large flocks, and their flocking behavior assists them in quickly locating new food sources. It is impossible to completely prevent birds from causing damage, only reduce amounts of damage that occurs.

Many of the bird species that damage blueberries are federally protected, including the American robin, house finch, and northern mockingbird. Others, such as brown-headed cowbird, common grackle, red-winged blackbird, and European starling, can be destroyed with appropriate permits from the U.S. Fish and Wildlife Service. Receiving a permit has become more difficult, as rusty blackbirds, a species that is seriously declining and protected, can often be found intermingling with grackles, cowbirds, and starlings. While many of these birds are protected by various federal laws, growers are allowed to frighten or harass them as long as none are killed or physically harmed.

Chemical Repellents. Methyl anthranilate is an EPA-registered bird repellent that can be used on blueberries, but the volatility of this compound makes it difficult to retain repellency for long periods of time. For best results, apply methyl anthranilate as large droplets, rather than as a fine mist. There are no poisons labeled for avian use in blueberry fields.

Sugar sprays have been reported to be temporarily effective. Many fruit-eating birds cannot digest table sugar, so these birds often avoid sugar-treated berries. This will not affect berry quality, and humans cannot distinguish between the monosaccharide sugars found in blueberries and disaccharide table sugar. Applications of a concentrated solution of table sugar should be made just as fruit begin to ripen to prevent birds from establishing feeding routines. Reapplication is required after rain or heavy dew.

Figure 13-6. Bird scaring device are only effective until birds become accustomed to the noise.

Figure 13-7. Scary-eye balloon devices should be used in combination with other deterrent methods.

Figure 13-8. Bird netting that covers entire plantings can be costly yet effective.

Figure 13-9. Small growers may hang bird netting down single rows because it is easier to maneuver.

Noise Repellents. The use of hazing or loud noises such as fireworks, exploding shells, gas-fired cannons (Figure 13-5), and distress calls (Figure 13-6) are generally not effective when used alone because birds quickly grow accustomed to them. However, when used in combination with one another and with the use of stationary objects (such as the scary-eye man or balloon, Figure 13-7) these techniques can help reduce damage for a few days until crops can be harvested. Because the effective range of decoys such as a scary-eye balloon is about 12 feet, a large number of these products are required for efficacy. Use of bird bangers now requires an ATF federal explosive permit that costs $100, renewable every 3 years for $50. The use of siren screamers does not require this permit, but they are generally not as effective as bird bangers.

The key to successful use of loud noises is to move sources of sound frequently during the day to prevent birds from adapting to them. Ideally, growers should use multiple cannons in combination with multiple firing screamers, distress tape calls, and visual deterrents, simultaneously. While this is often not physically possible, it is usually more cost effective than purchase of netting.

Netting. Recent restrictions on toxicants (poisons), pyrotechnics (bird bangers), and repellents, leave netting as the only practical alternative to management of bird problems in blueberry fields. Unfortunately, netting is expensive, time-consuming, and difficult to work around during harvest.

One-quarter-inch plastic nets are commonly used for small fields. Wire or cables are suspended from poles at the ends of each row and often within rows. Nets are then rolled out along these wires either over entire plantings (Figure 13-8) or individual rows (Figure 13-9). Netting is secured to the ground so that birds, such as wild turkeys, cannot enter underneath. During the remainder of the year, nets should be re-rolled and stored (Figure 13-10). Draping netting over plants without supports is not effective (Figure 13-11). Overall, if the netting can be kept from touching plants, it provides better control of bird pests (Figure 13-11). However, if birds learn to peck holes through netting, heavier and stiffer bird netting can be stitched in around these locations. Netting may not be practical for large fields and may interfere with machine harvesting.

Figure 13-10. Bird netting should be stowed after harvest to prevent tears and to ease operations.

Figure 13-11. Draping netting over plants will not prevent birds from feeding.

Figure 13-12. If bird netting comes in direct contact with plants, birds can feed on any berries that are on within reach.

Chapter 14

Weed Management

The main objective of a weed management program should be to encourage a healthy planting that will lead to productive, profitable, and sustainable plantings for many years. Weeds should be managed in blueberry plantings in order to decrease competition for water and nutrients (Figure 14-1), remove alternate hosts for some pests and pathogens, reduce competition for pollinating bees, improve ease-of-harvest, and to promote attractiveness of plantings for pick-your-own customers (Figure 14-2).

The term "weed" has many definitions, but simply, a weed is a plant that enters habitats occupied by mankind and is potentially able to suppress or displace resident plant populations that are deliberately cultivated or are of ecological or aesthetic interest. In blueberry plantings, any plants other than blueberry are considered weeds.

Weeds may have some of the following common characteristics:

- High reproductive output
- More than one means of reproduction
- Ability to withstand environmental extremes such as acidity and drought
- Efficient use of limited resources

Weeds often establish in areas of blueberry plantings where:

- Growth conditions are less favorable
- Edges of fields
- Near blueberry plants

In order to produce the best blueberry crop possible, growers must learn to effectively manage weeds.

Weed Identification

The first step in a successful weed management program is proper identification. In addition, understanding how weeds grow and reproduce, along with understanding different means of management, increase the likelihood of success for blueberry growers. For example, annual weeds require different management strategies than perennials, and grasses are managed differently than broadleaf weeds.

There are several online resources for weed identification through university Extension services, as well as through various weed science society websites. The USDA Plants Database (http://plants.USDA.gov) is also useful for weed identification materials. Print resources can be obtained through booksellers as well. County Extension agents can also assist with weed identification or provide helpful materials.

When soliciting assistance in weed identification, it is helpful to have access to a digital camera. With a good quality photo, Extension agents or specialists often can identify weeds using digital correspondence. A rare weed or very small weed, however, may need to be dug up and replanted so that it can grow large enough for positive identification. Once weeds are correctly identified, growers should focus on understanding the best methods for management.

Annual weeds are those that grow from seed and then flower and set seed within 12 months. Annual weeds are easiest to manage soon after emergence. They should be eliminated before setting seed, which can prevent subsequent infestations. Summer annual weeds germinate early in the year and then mature and die during summer. Winter annuals germinate in autumn and grow until weather turns cold. They then become dormant until the weather warms the following spring, after which they flower and die.

Perennial weeds survive for multiple years. They can grow and become established in new areas from seed (Figure 14-3); however, they often reproduce and spread through overwintering structures such as tubers, stolons, rhizomes, and buds, as well. In order to effectively manage perennial weeds, growers should eliminate or kill underground portions of weeds so that they cannot regrow. Other than newly germinating perennials, most perennial grasses and some broadleaf perennials are best controlled during early spring after regrowth starts. Growers should not attempt to eradicate weeds too early in spring, however. Plants are most vulnerable when reserves in roots have been exhausted. Broadleaf perennials tend to be sensitive to herbicides just before blooming, and both perennial

Figure 14-1. Competition from weeds can reduce water and nutrients available to young plants.

Figure 14-2. Unsightly, weedy plantings can discourage pick-your-own customers.

Figure 14-3. Perennial weeds are more difficult to control than annual weeds.

Figure 14-4. Organic producers often rely on cultural practices as the primary component of their weed management programs.]

grasses and perennial broadleaf weeds may also be controlled in autumn when plant sugars are being sent to the root system for storage.

Biennial weeds have a two-year life cycle. They often do not mature because effective management measures targeted toward annuals often manages biennials, as well. These weeds produce foliage the first year, enter a dormant period, and then flower and die the second year.

Integrated Weed Management Strategies

Prevention is one of the first steps to a successful weed management program, especially for new blueberry plantings. The easiest weeds to manage are those that never become established. If growers eliminate perennial weeds prior to establishment of plantings, fewer weeds are likely to become problematic. Blueberries are perennial crops, so established weeds in blueberry plantings are often present for many years. Thus some useful weed management options, such as some herbicides and summer fallow, cannot be employed as weed management tools. Therefore, managing weeds during the site establishment phase is critical.

Prevention includes elimination of overwintering structures such as stolons, tubers, and rhizomes. Effective weed management prevents spread of weeds throughout blueberry plantings. Maintaining clean fence rows and ditch lines, cleaning equipment to remove weed seeds, and obtaining clean planting stock are also beneficial and reduce the likelihood of future weed epidemics. Avoid planting in areas that are known to be infested or areas in which weeds establish due to spread by wind patterns, irrigation water, or flooding.

Scouting. Detection is another major component of a weed management plan. While harvesting or other routine maintenance, growers should take notes on weed presence and emergence. A pocket-sized notebook is useful. Remember: it is easier to manage young weeds than older, established weeds, particularly perennial types. Record any instances of herbicide failure. There has been a recent increase in frequency of herbicide-resistant weeds. Thus, by noting where previously successful herbicide treatments have failed, it is possible to identify early signs of herbicide resistance.

Suppression is a component of weed management that many growers turn to first. This component includes cultural, mechanical, and chemical means of managing weed growth.

Cultural methods include site selection, crop-weed competition, and suppression using mulch. Crop rotation is used as a cultural means of weed control in many annual crops, but it is not practical for blueberry plantings. Blueberries require an acid soil which limits opportunities for site selection, as many soils throughout the Midwest may not be suitable for blueberry production. Crop-weed competition is a strategy that suppresses weeds by promoting vigorous, healthy blueberry plant growth though appropriate fertilization, watering, and pest and disease management (Figure 14-4).

One of the most effective cultural means of weed control is through suppression of weeds using mulch. Blueberry plants benefit from the annual addition of decomposed, organic mulches such as wood chips. An annual layer of 1 to 2 inches of mulch can be effective in smothering new weeds or preventing weed seed germination. Woven plastic mulches that allow water penetration can also successfully suppress weeds. Hand hoeing and manual removal can be effective, particularly when coupled with the use of organic mulches; weeds growing through mulch tend to be shallow-rooted and fairly easily removed. Mechanical cultivation can be difficult because blueberry roots are shallow and often grow into the same root zone as weeds.

Herbicides are an important part of weed management programs in most plantings. However, only specific herbicides are labeled for use in blueberry. Herbicide labels are legal documents that provide the information needed for managing target weeds without harming plants. Read and understand herbicide labels before use; they indicate targeted weeds, as well as the appropriate rate and timing. Plant age restrictions are often included on the label, as well.

Pre-emergent herbicides (PRE) successfully suppress weed emergence when applied to soils before seeds germinate. They tend to be somewhat selective and are more effective on some weeds than others. However, blueberry plants can be sensitive to pre-emergent herbicides. Some pre-emergent herbicides are safe to use on new plants, whereas others should only be applied to blueberries that have been established for 2 to 3 years. Check labels for specific instructions.

Pre-emergent herbicides are usually applied in bands under blueberry rows. Treatments times vary from autumn to spring, and these treatment times are indicated on labels. Weed seedlings die as they grow through herbicide barriers established in soils. Therefore, growers should not disturb soil barriers (such as through cultivation) after application of pre-emergent herbicides. In addition, frequent irrigation or heavy rain may move herbicides through soils, below levels where weed seeds reside. Moreover, pre-emergent herbicides vary in levels of persistence in soil, and control periods range from a few weeks to several months.

Post-emergent (POST) herbicides are effective against weeds that overcome pre-emergent herbicide barriers. These products can often be applied as spot sprays. Post-emergent herbicides are applied to the foliage of weeds. Some of these products are contact herbicides that only affect plant parts that were directly contacted. Systemic herbicides, on the other hand, are absorbed through leaves and stems and move to other plant parts (e.g. from foliage to roots). They are effective against established perennial weeds. Finally, some post-emergent herbicides are selective and may be effective only on grasses, or only on broadleaf weeds. Others are non-selective and are effective against a broad spectrum of weeds.

Herbicide rates listed on labels are recommended for broadcast applications across entire fields. Reduce amounts applying products in bands or concentrated patterns (e.g. only blueberry beds and not row centers). This is often referred to as the "treated acre" and can result in significant decreases in total herbicide applications and costs. For best results, follow manufacturers' application instructions regarding rates, additives, soil type, soil moisture conditions, weed growth stage, environmental conditions, and product limitations.

Every weed management program should consider herbicide resistance. There are a number of different classes (i.e. chemistries or HRAC groups) of herbicides that are labeled for blueberries. Rotation from one class to another is important for reducing risk of herbicide-resistance. Herbicide classes are indicated by a number on fronts of labels.

Photo credits

Chapter 1: Erik Draper, The Ohio State University

Chapter 2: Gary Gao, The Ohio State University

Chapter 3: Gary Gao, The Ohio State University: 1abc, 2, growth stages 10-12; Mark Longstroth, Michigan State University: 3, growth stages 1-9

Chapter 4: Gary Gao, The Ohio State University: 1, 2; Nicole Ward, University of Kentucky: 3

Chapter 5: Gary Gao, The Ohio State University

Chapter 6: Gary Gao, The Ohio State University: 1-3, 5-7; Jim Chatfield, The Ohio State University: 4

Chapter 7: Gary Gao, The Ohio State University

Chapter 8: John Strang, University of Kentucky: 1, 2, 5; Gary Gao, The Ohio State University: 3, 4

Chapter 9: Patrick Byers, University of Missouri: 1, 2abc, 5-8; Dwight Wolfe, University of Kentucky: 3, 4

Chapter 10: Gary Gao, The Ohio State University: 1-5, 7ab; Eric Hanson, Michigan State University: 6

Chapter 11: Michigan State University: 1, 3ab, 7, 9b, 10, 11, 17c, 18-20, 22ab; Gerald Holmes, Valent USA Corp, Bugwood.org: 2a; Gary Gao, The Ohio State University: 2b; W. Cline, North Carolina State University: 4a; Annemiek Schilder, Michigan State University: 4b, 8, 12, 13, 14d, 15ab; Mary Ann Hansen, VPI, Bugwood.org: 5; John Strang, University of Kentucky: 6, 16; Bruce Watt, University of Maine: 9a; University of Georgia Plant Pathology Archives, Bugwood.org: 14abc; North Carolina State Extension: 14e; Mark Longstroth, Michigan State University: 17ab; Nicole Ward, University of Kentucky: 21

Chapter 12: Donn Johnson, University Of Arkansas: 1a, 9abc, 10c, 11abc, 12abc, 17b; Roger Schmidt, University of Wisconsin, Madison, Bugwood.org: 1b; University of Florida Institute of Food and Agricultural Sciences: 2abc; Robert Anderson, USDA FS, Bugwood.org: 3a; Ric Bessin, University of Kentucky: 3b; Rufus Isaacs, Michigan State University: 4ac, 5bc, 6b, 7b, 10b, 14, 16ab, 17a, 18; Soo-Hoon Kim, University Of Arkansas: 3c, 7c; Jerry Payne, USDA ARS, Bugwood.org: 4b, 5a, 19b; Gevork Arakelian, Los Angeles County Department of Agricultural Commissioner/Weights and Measures: 6a; E. Levine, The Ohio State University, Bugwood.org: 7a; WonGun Kim, BugGuide: 8; David Cappaert, Michigan State University, Bugwood.org: 10a; Clinton Trammel, University Of Arkansas: 13ab; Alan Eaton, University of New Hampshire: 15abcd; Michigan State University: 19a

Chapter 13: Gary Gao, The Ohio State University: 1, 3-12; John Strang, University of Kentucky: 2

Chapter 14: Gary Gao, The Ohio State University

Issued 7-2013