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Growing Blueberries in Missouri

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Introduction

The highbush blueberry (*Vaccinium corymbosum* L.) has become a popular fruit with both consumers and growers in Missouri. The cultivated highbush blueberry is a perennial woody, deciduous shrub that attains a height of five to ten feet. The large, flavorful, blue-colored berries are delicious as fresh fruit and can be processed into pies, muffins, jams, sauces, or other tasty treats. The lustrous green (summer) and red (fall) colored foliage, plus the compact size, make the highbush blueberry plant an attractive landscape plant.

Blueberries can be a challenging, yet rewarding fruit crop for both the backyard gardener and commercial producer. While the cultural requirements for highbush blueberries are rather specific and differ greatly from other small fruits, blueberries can be grown in most parts of Missouri. For the homeowner/gardener, the highbush blueberry is a relatively easy plant to grow and manage. For the commercial producer, blueberries offer one of the highest potential returns of any fruit crop grown in Missouri. Most commercial plantings in Missouri have been established since 1975 and generally range from one to 15 acres in size. In 2005, there were about 125 acres in commercial production.

Site Selection

Selection of a proper location and good soil preparation are important first steps in establishing a successful blueberry planting. Highbush blueberries are shallow-rooted plants with a fibrous root system and require rather exact soil and cultural conditions for best growth. Blueberries are best adapted to well-drained, sandy-type soils that have a low pH and high organic matter content.

Since only a few soils in Missouri have these characteristics, modifications are usually necessary to grow blueberries. Highbush blueberries planted on an unfavorable site usually perform poorly, regardless of other cultural or management practices.

In choosing a site for blueberry planting, air flow, water drainage, exposure to sunlight, soil pH, and access to water for irrigation are the major factors to consider. The kind or type of marketing system (i.e., U-pick, roadside market, farmers' market, etc.) must also be carefully evaluated when selecting a location for growing blueberries.

Sunlight. Highbush blueberries should be planted in areas with full sunlight. A north-south orientation for rows in a planting is ideal for most efficient use of sunlight. Other considerations, however, such as reducing the erosion risk on sloping sites, can affect row orientation.

Airflow. Blueberries should be planted in areas with good air circulation. In general, elevated sites are more suited for blueberry production than low-lying sites. Low spots where cold air can collect or areas surrounded by buildings, fences, trees, or other obstacles that shade the planting or curtail air movement should be avoided. Blueberries can withstand temperatures of –20°F during midwinter. Blueberry flower buds are hardy to at least 25°F, but open flowers may be injured or killed by late spring frosts.

Water Drainage. Although roots of blueberry plants require a readily available supply of water, they will not tolerate excessively wet soil conditions. Plants growing in wet soils for even a short time during any season may be killed due to lack of air around the roots. Extremely shallow, poorly-drained, or flood prone areas should be avoided as planting sites. Other sites that are seasonally wet (primarily early spring or late fall) may require some modification to reduce excessive soil wetness. Setting blueberry plants on raised beds or berms (ridges) or installing a tile-drainage system under the plant row will improve soil drainage. Incorporating large quantities of organic matter into the soil surface and mixing peat moss with soil in the root area of each plant will also improve the water-air relationships in many of these soils.

Irrigation Considerations. Blueberries in Missouri need supplemental water most every year and should not be planted unless water for irrigation is available. Planting close to a source of good quality water will help reduce the overall cost of the irrigation system. Consult with an agricultural engineer or irrigation specialist early in the planning process for assistance in evaluating a water supply and designing an irrigation installation.

Soil Considerations. A recent soil test that properly represents the prospective site will provide valuable information on the suitability for blueberry production. For example, blueberry plants require an acid soil and often fail to grow properly when planted in soils of higher or excessively low pH. When interpreting soil pH levels from soil test reports, it is important to recognize that the Missouri Soil and Plant Testing Laboratory reports the soil pH both as pHs (measured with a dilute salt solution) and pH (measured in distilled water). The pHs will be slightly (0.1-0.5 units) lower than the pH of the same soil measured in water. Blueberries are adapted to a target pH of 4.7-5.2 (pHs of 4.5-5.0). Soils with higher pH levels may be modified (see below) by adding acid-forming compounds. However, soils with a high cation exchange capacity (CEC), high levels of calcium, or a native pH above 6.0, tend to resist any permanent changes in soil pH, which can reduce the overall effectiveness of the acid-forming compounds and the long term viability of a blueberry planting. The soil test will also provide information on soil nutrient levels. Recommended preplant soil ranges for blueberries are 25-30 pounds for phosphorus (P) and 100-125 pounds for potassium (K).

Marketing Considerations. A good location for on-farm marketing of blueberries (U-pick or prepicked) has sufficient resident population or the potential to attract non-resident customers, convenient access, and an attractive setting. A good location for off-farm marketing is located within convenient driving distance of the market (farmers' market, grocery store, restaurant, food circle customers, etc.).

Site Preparation

Many of the soils in Missouri have a pH higher than the recommended range for maximum blueberry growth and will require acidification to lower the pH. While several acid-forming compounds can be used to lower the soil pH, powdered or granular sulfur are the most frequently used acidifying materials. The quantity of sulfur to apply depends on the initial soil pH and soil type (sandy, silty, or clayey) and can best be determined from soil test results. As a general guide, sandy soils in Missouri require $^{1}/_{2}$ to $^{3}/_{4}$ pounds of sulfur per 100 square feet to lower the pH by one unit (e.g., pH 6.0 to 5.0). Medium-textured soils (example silt loams) need 1 to $1^{1}/_{2}$ pounds of sulfur per 100 square feet, while clay-type soils may require $1^{1}/_{2}$ to 2 pounds of sulfur per 100 square feet to lower the pH by one unit. Precautions should be taken to avoid over-acidifying the soil. A soil with too low a pH can be just as detrimental to plant growth as one with too high a pH. Sulfur amendments should be incorporated into the soil at least six months prior to planting to allow adequate time for the pH to be adjusted. Applying sulfur to only the plant row (3-4 feet strip), rather than the entire planting area, will reduce the amount and cost of sulfur needed.

The recommended in-row spacing between highbush blueberry plants is 3-4 feet, with the rows spaced 10 to 12 feet apart.

Since the majority of the blueberry roots will be located in a rather small area around each plant, the preparation of the 3- to 4-foot strip in which the plant will be growing will eliminate the need to till the entire area. The space between plant rows can be left in sod or seeded to a lawn-type grass to provide a suitable area for walking and operating equipment. These 3- to 4-foot planting strips should be plowed, disked, or rototilled to form a good planting bed. Incorporation of organic matter, application of fertilizers, eradication of noxious perennial weeds, formation of raised beds or berms (8-10 inches high), and other tillage operations needed to prepare the soil should be completed at least six weeks prior to setting the blueberry plants.

Fig. 1. A bermed blueberry planting.

Cultivar Selection

Selecting the proper cultivar (variety) is important from a horticultural and marketing perspective. Only cultivars that are adapted to the area's climatic conditions and have the potential for high yields of quality berries should be selected. Since cultivars differ greatly in fruit and plant growth characteristics, the following factors should be carefully evaluated when selecting the correct cultivar(s) to be grown: ripening date, type of market to be used, availability of labor for harvest, intended use of fruit, potential for mechanical harvesting, yields and flavor of fruit, berry size, and duration of harvest.

Most cultivars of highbush blueberries produce ripe fruit for four to five weeks, with the highest yields occurring in weeks two and three. Berry size normally is largest during the first two or three weeks and then sharply declines with subsequent harvests. Approximate dates of berry ripening in Missouri are early season cultivars– early to mid-June, midseason cultivars– mid- to late June, late season cultivars– early to mid-July.

Highbush blueberries are self-fertile, but do benefit from cross pollination, so growing at least two cultivars is recommended. Bloom time of the early and midseason or mid- and late season cultivars overlap enough in most years to pollinate each other. Overlap of bloom between early- and late season cultivars may not be sufficient for good pollination. Abnormally cool or wet weather can alter the blossom periods, affect pollen tube growth, and reduce the activity of pollinators (bees), thus resulting in poor pollination. Early season cultivars appear to be affected more by adverse spring weather conditions than midseason or late season cultivars.

Characteristics of several highbush blueberry cultivars currently grown for commercial or home production in Missouri are listed below. Cultivar ratings, recommended(**) or recommended with reservation(*), are based on cultivar performance in research and commercial plantings located in Missouri. The "recommended with reservation" designation means that the cultivar may have characteristics that could reduce productivity (cold tenderness, pathogen susceptibility, lower vigor, etc.), or that the cultivar has not been tested for a long enough period of time to evaluate its performance in Missouri.

Berry size ratings are small (1-1.5 g), medium (1.5-2 g), large (2-2.5 g), and very large (greater than 2.5 g). Ratings of yield are moderate (6-9 lbs/plant), high (9-12 lbs/plant), and very high (greater than 12 lbs/plant). Berry size and yield ratings are based on results of cultivar evaluation trials at Mountain Grove and Springfield, Missouri. Flavor is a subjective measure. What is good flavor to one individual may be less so to another. Good flavor implies that the taste is balanced between tart and sweet characters, i.e., a typical blueberry taste. Fair flavor implies a blueberry taste that is either more or less tart or sweet with less balance, and can sometimes be partly attributed to the degree of fruit ripeness. Fair flavor in blueberry is still very acceptable.

Berkeley** – 1949 USDA and New Jersey release. Midseason ripening. Fruit large, very light blue, firm with large stem scar and fair flavor. Loose fruit clusters. Very high yields. Upright, spreading bush.

Bluecrop** – 1952 USDA and New Jersey release. Midseason ripening. Fruit medium, very light blue, very firm with small stem scar and fair flavor. Loose fruit clusters. High yields and consistent producer. Upright, spreading, open bush. Standard midseason cultivar.

Bluejay** – 1978 Michigan release. Midseason ripening. Fruit medium, light blue, and very firm with small stem scar and good flavor. Moderate yields. Upright, spreading bush.

Blueray** – 1955 USDA and New Jersey release. Midseason ripening. Fruit large, light blue, firm with medium stem scar and good flavor. Small, tight fruit clusters. Moderate yields. Upright, spreading bush.

Bluetta* – 1968 USDA and New Jersey release. Early ripening. Fruit medium, light to medium blue, firm with large stem scar and fair flavor. Moderate yields. Short, compact, spreading bush. Susceptible to Botryosphaeria (stem blight) canker.

Brigitta Blue** – 1977 Australian release. Midseason ripening. Fruit medium to large, medium blue, very firm with small, dry stem scar and good flavor. High yields. Upright, spreading, dense bush.

Chandler** – 1994 USDA release. Late ripening. Fruit large to very large, light blue, firm with small, dry stem scar and good flavor. High yields. Upright, spreading, open bush.

Collins* – 1959 USDA and New Jersey release. Early ripening. Fruit small to medium, light blue, very firm with small stem scar and fair flavor. Loose fruit clusters. Moderate yields. Upright, spreading, open bush. Susceptible to Botryosphaeria (stem blight) canker. Less vigorous at Mountain Grove.

Coville** – 1949 USDA and New Jersey release. Late ripening. Fruit large, very firm with medium stem scar and good flavor but tart until ripe. Loose fruit clusters. Very high yields. Upright, spreading bush.

Darrow** – 1965 USDA and New Jersey release. Late ripening. Fruit medium, light blue, firm with medium stem scar and fair flavor. High yields. Upright, spreading, open bush.

Duke** – 1987 USDA release. Early ripening. Fruit medium, medium blue, firm with small, dry stem scar and fair flavor. Moderate yields. Upright, spreading, open bush. Standard early season cultivar.

Earliblue* – 1952 USDA and New Jersey release. Early ripening. Fruit small, light blue, firm with medium stem scar and fair flavor. Loose fruit clusters. High yields but not consistent. Upright, spreading bush.

Elliot** – 1973 USDA release. Late ripening. Fruit medium, light blue, very firm with small stem scar and fair flavor. Loose fruit clusters. Moderate yields. Upright, spreading bush.

Jersey** – 1928 USDA release. Late ripening. Fruit small, medium blue, firm with medium stem scar and fair flavor. Loose fruit clusters. Moderate yields. Upright, spreading bush.

Lateblue** – 1967 USDA and New Jersey release. Late ripening. Fruit medium, light blue, firm with medium stem scar and good flavor. Loose fruit clusters. High yields. Upright, spreading bush.

Legacy** – 1993 USDA and New Jersey release. Midseason ripening. Fruit medium to large, medium blue, firm with small stem scar and good flavor. High yields. Upright, spreading, open bush. Considered a southern highbush cultivar, so it may be cold tender in northern climates.

Nelson** – 1988 USDA release. Late ripening. Fruit medium to large, light blue, firm, fair flavor. High yields. Upright, spreading, open bush.

Northland* – 1967 Michigan release. Midseason ripening. Fruit small, dark blue, firm with medium stem scar and fair flavor. High yields. Upright, spreading bush.

Nui** – 1989 New Zealand release. Early ripening. Fruit large to very large, medium blue, and fair flavor. Moderate to high yields. Short, spreading bush.

Ozarkblue** – 1996 Arkansas release. Midseason ripening. Fruit medium to large, light blue, firm with small stem scar and fair flavor. Moderate yields. Upright, spreading, open bush. Considered a southern highbush cultivar, so it may be cold tender in northern climates.

Patriot* – 1976 USDA and Maine release. Early ripening. Fruit medium, light blue, firm with small, dry stem scar and good flavor. Moderate yields. Upright, spreading bush.

Reka** – 1989 New Zealand release. Midseason ripening. Fruit small, medium blue, and good flavor. High yields. Upright, spreading, open bush.

Sierra** – 1988 USDA release. Midseason ripening. Fruit medium to large, medium blue, firm with small stem scar and good flavor. Moderate yields. Upright, spreading, open bush.

Summit* – 1998 USDA, Arkansas and North Carolina release. Midseason ripening. Fruit medium to large, light blue, firm with small stem scar and fair flavor. Moderate yields. Upright, spreading, open bush.

Toro* – 1987 USDA release. Midseason ripening. Fruit medium to large, medium blue, firm with small stem scar and fair flavor. Moderate yields. Upright, spreading bush. Less vigorous at Mountain Grove.

Descriptions are from observations of cultivar performance in research and commercial plantings in Missouri and from the Brooks and Olmo Register of Fruit & Nut Varieties, Third Edition (1997, ASHS Press, Alexandria, VA).

Planting

Blueberry plants can be planted in either late fall or early spring. Plants should only be purchased from reputable, state-inspected nurseries to minimize the chances of obtaining diseased plants. Extra precautions must be taken to insure that plant roots are protected from drying out or being damaged after leaving the nursery and before the plants are set into the soil.

Highbush blueberry plants can be purchased as rooted cuttings, bare-rooted plants, or potted plants. Rooted cuttings have a rather limited root system and are usually taken directly from the propagation bed. Two- and three-year-old plants are normally sold as bare-rooted or potted plants. While these older plants cost slightly more than the rooted cuttings, the larger root system usually results in greater plant survival and better early growth. Older potted or balled plants do not appear to perform better than two-year-old plants; therefore, the additional expense of buying, transporting, and handling these plants is normally not justified.

Plants should be set into the soil at the same depth as they were growing in the nursery, making sure that the collar or crown of the plant is at the soil surface. A furrow or hole, 12 to 15 inches deep, filled with a blended mixture of soil and wet peat moss, is needed for each plant. The blueberry plant, with roots spread laterally, is set in the soil-peat moss mixture. For potted plants, cutting the ball of roots with shallow vertical cuts prior to planting will encourage the roots to spread and grow into the surrounding soil.

Other organic materials such as sawdust, hay, or compost should not be substituted for peat moss unless they are well decomposed. Otherwise, early growth can be greatly reduced from the lack of available water and plant nutrients.

Highbush blueberries are very sensitive to wet soil conditions. Raised beds or berms (8-10 inches high and 3-8 feet wide) should be used in soils with potential drainage problems. Beds or berms should be formed well in advance of planting to allow time for the soil to settle. Plants should be watered immediately after planting to settle the soil around roots and remove unwanted air pockets. Careful attention to soil moisture conditions during the following few weeks is critical to insure adequate water for newly-established plants.

Mulching

Mulching the plant row with sawdust, wood chips, pine needles, rotted hay, bark, or similar materials is beneficial in growing blueberries. A 4-6 inch layer of mulch around the plant roots has a moderating effect on soil water and soil temperatures. A large volume of mulch is needed to mulch blueberries, and a local source is recommended. Organic mulches have a higher water holding capacity than most soils and yet maintain a good balance between water and air. Since most roots of highbush blueberries grow in the decayed mulch and upper few inches of soil, much of this water is readily available for plant use. Fresh (green) mulching materials should not be used as they tie up nitrogen and generate heat during decomposition that can injure plants. A mixture of coarse and fine mulch materials will reduce problems of crusting at the mulch surface and improve water penetration. As mulches decompose, organic matter and plant nutrients are added to the soil, thus improving the physical and chemical properties of the surface soil. Mulches should be replenished as needed to maintain a depth of four to six inches around the plants.

Fig. 2. A blueberry planting mulched with a mixture of chips and sawdust.

Mulches act as an insulator of the soil surface in both winter and summer. In the winter, the soil surface remains warmer and the soil temperature does not fluctuate as much as without mulch. The mulch protects plant roots and may prevent root damage from cold temperatures. Heaving (lifting) of plants during freezing and thawing may also be significantly reduced. In the summer, mulches keep the soil cooler, reduce evaporation of water from the soil surface and retain much needed soil moisture.

The seasonal fluctuation in soil water contents is much less under mulches; therefore, plant roots will be subjected to a gradual rather than abrupt change in soil moisture conditions. More uniform soil water levels should result in healthier, faster growing, and higher producing plants.

Irrigation

Moisture conditions in Missouri soils fluctuate a great deal from one season of the year to the next. Sufficient to excessive water is often present during the winter and early spring months, the dormant season for blueberries. During the growing season, one or more periods will usually occur when soil water is insufficient for optimum plant growth. Irrigation at this time is essential for maximum growth and berry production. The amount of additional water required depends on several factors: age of plants, crop load, temperature, relative humidity, wind movement, amount of sunshine, frequency and distribution of rainfall, and the moisture-holding capacity of the soil.

The water status of soils also varies greatly with location. Some soils in Missouri are deep, well-drained, and have good moisture-holding capacities. The major moisture problem in these soils is a deficiency of water, normally occurring during July and August. Irrigation will be needed at this time to maintain an adequate moisture level. Other soils may be shallow, poorly drained, or contain an impermeable layer (such as a fragipan) that restricts water movement. Excess water may accumulate in these soils during rainy periods, reducing air in the plant root zone. These same soils, however, may have water deficiencies during June, July, and August. Problems of excess water and drought often occur during the same year. Since the lack of water can be corrected by irrigation, the removal of the excess water is generally the more difficult problem to solve.

Although deep, well-drained soils are best for growing blueberries, most soils in Missouri can be used, provided that the pH and water contents are controlled. Extremely shallow, poorly drained, or very low-lying areas should be avoided when selecting a planting site.

For soils that are seasonally wet, incorporating organic matter into the soil surface or mixing moist peat moss with the soil at planting will improve the water-air relationship. Setting blueberry plants on raised beds or berms, or installing a drainage system, can also help remove excess water from these soils.

Table 1. Feel and Appearance Guide for Determining Soil Moisture Conditions.*

	Soil texture	
Moisture conditions	**Sands-sandy loams**	**Loams-silt loams**
Ideal	Soil will cling together. Upon squeezing, outline of ball is left on hand.	Wet outline of ball is left on hand when soil is squeezed. Sticks to clean (bright) tools.
Good	Forms a weak ball, breaks easily when squeezed in the hand. Can feel moisture in soil.	Forms a ball, very pliable, sticks readily, clings slightly to tools.
Fair	Tends to form a ball under pressure, but will not hold together when sqeezed in the hand.	Forms a ball, somewhat pliable, will stick slightly with pressure. Doesn't stick to tools.
Too dry	Dry, loose. Can't feel moisture.	Will form a weak ball when squeezed. Won't stick to tools.

*Adapted from *When and How Much to Irrigate*. UMC Guide: Agriculture Engineering 3.

Drip or trickle irrigation systems allow the blueberry grower to closely control the amount of supplemental water added, making it easier to maintain the proper soil moisture level. The drip or trickle system provides a small amount of water at frequent intervals to the plant root zone and uses much less water than the overhead sprinkler or similar systems that wet the entire soil surface. Over-watering is less likely with drip irrigation, and the placement of water near the plant root at a time when the plant needs water reduces the potential of soil erosion. Water is delivered with point emitters or microsprinklers.

The proper design and installation of irrigation systems are of utmost importance for a successful operation. Consultation with an agricultural engineer or an irrigation equipment dealer concerning the proper selection of pumps, filters, emitters, etc., can save time and money by eliminating many problems associated with poorly designed systems. The irrigation system should be installed and ready to operate so plants can be irrigated immediately after planting.

Some method of irrigation scheduling is necessary to determine the appropriate time and amount of water to add. Some individuals monitor soil water by the "feel method" (Table 1), in which a handful of soil is squeezed in the palm of the hand and the need of water determined by the feel or appearance of the soil.

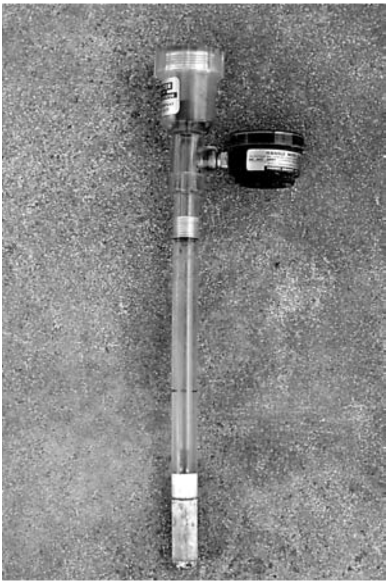

Fig. 3. Tensiometer.

Fig. 4. Tensiometers placed near trickle irrigation line.

Other growers irrigate by using a moisture accounting system in which the water used by plants (estimated from evapotranspiration) is subtracted from the available water held in the soil. When the moisture "balance" is lowered to 50% of the available water-holding capacity, irrigation is applied. In a similar, but less exact method, growers simply irrigate on a regular basis; i.e., every day, every third day, etc., and make adjustments when rainfall occurs. While all three of these methods have merit, each has limitations that frequently lead to inadequate or improper watering of blueberry plants.

A more accurate method of predicting moisture availability in the soil is use of a tensiometer, an instrument that determines the relative moisture status around plant roots. Tensiometers are relatively inexpensive, can be easily installed and maintained in most soils, and can be adapted to automated irrigation systems. Tensiometers have a scale of 0 to 100 centibars (cbar), with 0 corresponding to wet (saturated) soil conditions. As the soil dries, higher tensiometer readings are attained. Irrigation research indicates that highbush blueberry plants make maximum growth when readings are maintained between 30 and 65 cbar on tensiometers installed at a 6-inch depth in the soil. A tensiometer reading of less than 30 cbar indicates excess soil water, while a reading of 65 cbar or more indicates the soil is too dry for optimum growth. Thus, if a tensiometer reading of 65 cbar is recorded, supplemental water should be applied until the tensiometer reading drops to approximately 30 cbar.

Nutrient Management

Seventeen chemical elements (nutrients) are classified as essential for plant growth. Three of the nutrients, carbon (C), hydrogen (H), and oxygen (O), are obtained from the air from CO_2 or from H_2O. The remaining 14 essential elements are assimilated into the plant via the roots. They are divided into two groups: macro (major) nutrients are required in relatively large quantities by plants, and micro (minor) nutrients that are required in trace amounts.
A deficiency of any of the essential nutrients will disrupt either the vegetative or reproductive growth cycles in plants. While nutrient deficiency symptoms in blueberries are usually easy to detect, they can be difficult to identify. Changes in leaf color or shape, poor plant vigor, or other abnormalities of the leaves or canes may indicate a nutrient deficiency or a nutrient imbalance. Recognizing specific foliar symptoms can be helpful in diagnosing nutritional problems in blueberries.

Nitrogen (N). Deficiencies of N are the most frequently encountered problems in growing blueberries in Missouri. Nitrogen deficiencies are common during the first year after planting and are more severe when plants are mulched. In plantings mulched with fresh or non-decomposed materials, much of the soil N will be immobilized by soil microorganisms, thereby lowering the amount of available N for the plants.

Plants lacking in N are usually stunted, slow growing, and exhibit uniform yellow (chlorotic) colored leaves. The symptoms appear first on lower leaves and will eventually encompass the entire plant if not corrected. Nitrogen deficiencies in mature plants can occur at any time during the growing season, so adhering to a rigid schedule of applying supplemental N is critical in maintaining healthy blueberry plants. Nitrogen recommendations of 90 to 120 pounds of N per acre are common for mulched blueberries grown in Missouri.

Excessive amounts of N result in an abundance of vegetative growth in the plant. Foliage is very dark green and appears healthy, but is very succulent and more susceptible to drought stress and winter injury. Excessive N fertilization also can render plants more susceptible to diseases.

Phosphorus (P). Deficiencies of P are more difficult to detect than N deficiences in blueberry plants. The most common symptom is a purplish coloration on the older plant leaves and stems. The purplish color can be caused by other nutrient deficiencies and by cool spring temperatures, so P fertilizers should be applied only when soil test or leaf analyses ratings indicate a low P level. Excessive P also causes adverse effects by interfering with the absorption and metabolism of micronutrients, such as iron, zinc, and manganese.

Potassium (K). Chlorosis of leaf margins on older leaves is the earliest detectable deficiency symptom of K in blueberry leaves.

Necrotic (dead) spots may appear on the leaf margins as the shortage becomes more severe. Excessive K can cause several nutrient imbalances in blueberry leaves, especially with magnesium and calcium. The level of K in the leaf is greatly influenced by crop load; leaf levels are lower when plants are bearing heavily and higher when a light crop is present.

Calcium (Ca). Calcium deficiencies occur on the younger, growing parts of the plants. Browning (scorched-looking) edges of newly-formed leaves is characteristic of a lack of Ca. Calcium deficiencies in blueberry plants in Missouri are unlikely due to the high Ca level in the soils. Excessive Ca in blueberry leaves is usually associated with a high soil pH. Excessive Ca can reduce the absorption of iron by plant roots. High Ca levels can also adversely affect magnesium and K metabolism in the plant.

Magnesium (Mg). Soils in several parts of Missouri have low Mg contents, thus Mg deficiencies in blueberries can occur. Deficiencies of Mg begin as an interveinal chlorosis of older leaves in which the veins remain dark green. Leaves may turn red, yellow, or brown and prematurely drop from the plant as the deficiency becomes more severe.

Sulfur (S). Deficiencies of S are often confused with N deficiencies. Plants lacking in S are stunted and light yellow-green in color, with the chlorosis appearing first on the younger leaves. Deficiencies of S in blueberries in Missouri are unlikely since sulfur, ammonium sulfate, and sulfuric acid are frequently used as fertilizers or soil amendments.

Iron (Fe). The most noticeable micronutrient deficiency in Missouri has been Fe, which appears as yellowing (chlorotic) tissue on young leaves. As the deficiency becomes more severe, leaves turn a brownish color and may drop. Iron deficiencies occur most frequently when the soil pH is above 5.5, but has also been observed in soils that are over-watered, poorly-drained, or have extremely high manganese or P levels.

Manganese (Mn). Deficient blueberry plants exhibit reduced leaf size and interveinal chlorosis of young leaves. While Mn deficiencies in Missouri are rarely found, toxicities are more likely. Toxicity symptoms of Mn appear as an interveinal chlorosis followed by red spots on young leaves. Toxicity problems occur more frequently in poorly-drained or extremely low pH soils. High Mn levels in the soil also adversely affect P and Fe absorption. Both Fe deficiency and Mn toxicity symptoms have been observed in blueberry plants at the same time and both have detrimental effects on plant growth and berry production.

Boron (B). Short internodes, abnormal growth of shoot tips, and cupped leaves with bluish-green colors are symptoms of B deficiencies in blueberries. Boron may also reduce damage to the tips of cane that generally occurs during cold weather.

Problems with other micronutrients, such as zinc (Zn), copper (Cu), molybdenum (Mo), chlorine (Cl), and nickel (Ni) have not been reported in Missouri.

Nutrient Monitoring: Soil Testing

Highbush blueberries are grown on high organic soils in many parts of the United States, but in Missouri they are grown exclusively on mineral soils. Mineral soils have a lower organic matter content and require careful attention to insure the proper amount and balance of plant nutrients. Blueberry plants require the same nutrient elements as other crops for growth and development. Since blueberry roots are primarily located in the mulch and upper few inches of soil, care must be taken to insure adequate, but not excessive, amounts of nutrients. The best way to insure the proper nutritional status of blueberry plants is to test the soil and foliage on a regular basis. Corrections of nutrient deficiencies must be done before deficiency symptoms appear on the plant to avoid reductions in plant growth and yields.

Soils should be tested every year to maintain the optimum pH and to properly adjust fertilizer sources. Soil sub-samples should be taken from beneath the drip-line of several plants to obtain a good, representative soil sample. The sub-samples should be well mixed in a clean plastic container and a composite sample of about one pound removed for analysis. A separate sample should be taken from areas where plants are exhibiting nutritional or other problems. Growers should number and keep good records pertaining to the location of each sample. Soil samples can be sent to the Missouri Soil and Plant Testing Laboratory (coordinated locally by the University Outreach and Extension Service) or to a private testing laboratory for analysis. A standard soil test will usually include measurements of soil acidity (pH), % organic matter, available Ca, Mg, K, and P. Analysis for Fe, Mn, Zn, or other nutrients can be obtained for a nominal fee. The amount and type of fertilizers to apply is governed by soil pH, soil nutrient contents, and nutrient balance in the soil.

The soil pH should determine type of N fertilizer to apply. There are differences in the amount of acidification caused by the different types of N fertilizers. Fertilizer recommendations should be changed as soil pH changes to maintain an optimum soil pH. For example, ammonium sulfate produces a much greater acidic reaction in the soil than urea or ammonium nitrate fertilizers. Therefore, ammonium sulfate should be used when the soil pH is above 5.2 (Missouri pH's above 5.0). When the soil pH is below 5.2 (Missouri pH's less than 5.0), urea should be used instead of ammonium sulfate. Ammonium nitrate can be used if ammonium sulfate or urea is unavailable, although nitrate N is a less preferred form of N for blueberries. Organic forms of N, such as feather meal and blood meal, will not lower the soil pH appreciably. Farm manures have a high pH and should not be used for fertilizing blueberries unless acidified prior to use.

Since the N contents of ammonium sulfate, ammonium nitrate, urea and the organic fertilizers are different, rate adjustments will be needed to provide equivalent amounts of N. For example, 0.6 pounds of ammonium nitrate or 0.5 pounds of urea provides the same amount of N as 1.0 pound of ammonium sulfate. To provide the same amount of N to the plant with feather meal or blood meal, nearly 3 pounds would be required (assuming 50% release of N the first year). Although the soil pH of established plantings will change by altering the type of N fertilizer, a gradual change should not harm the plant root system or overall plant performance as much as a sudden, abrupt pH change. Annual monitoring of soil pH will help in planning the fertilizer schedule for the coming year. Additional applications of supplemental N may be needed with severe N shortages. Ammonium sulfate and ammonium nitrate should not be applied after August 1 to allow proper hardening of the plants before frost. Urea should not be applied later than July 20.

Nutrient Monitoring: Foliar Testing

Changes in leaf color or shape, overall plant growth, or abnormalities in leaf or stem tissue often signal a nutrient deficiency or imbalance in the plant. Some nutrient deficiencies exhibit unique symptoms that make identification rather easy. Other deficiencies may be less obvious or have characteristics too similar to insect, disease or other nutritional problems to be diagnosed visually. Foliar (leaf) analysis provides a more accurate measure of the nutrient levels within the growing plant. Analyses of leaf samples can be made anytime during the growing season; however, tests should be done at the same time each year to compare year-to-year results. Recommendations from other states indicate that sampling should be done during the latter part of the harvest season, or just after the last harvest. Select shoots from the current season's growth for analysis, and collect fully expanded leaves from the fourth through tenth node. Collect three to four leaves from several bushes for a composite sample of 30 to 40 leaves. Leaves should be placed in a paper bag and air-dried before being sent to the laboratory for analysis. Leaves should be rinsed and blotted dry to remove dust or pesticide residue if needed. Foliar nutrient levels deemed sufficient for highbush blueberry plants growing in Missouri are shown in Table 2.

Foliar nutrient contents outside the sufficiency ranges imply a need to adjust fertilizer rates. When the plant leaf contents exceed the sufficiency levels for a particular nutrient, no fertilizer containing the specific nutrient need be applied for the next year. For blueberry leaves testing lower than the sufficiency levels (a more common problem), an increase in the amount of fertilizers to be applied is

Table 2. Foliar Nutrient Levels in Blueberries.

Element	Sufficiency Range
Nitrogen (N)	1.50 - 2.10 %
Phosphorus (P)	0.07 - 0.12 %
Potassium (K)	0.40 - 0.80 %
Calcium (Ca)	0.40 - 0.90 %
Magnesium (Mg)	0.10 - 0.30 %
Sulfur (S)	0.10 - 0.20 %
Iron (Fe)	40 - 70 ppm
Boron (B)	20 - 50 ppm
Manganese (Mn)	40 - 250 ppm

needed. As a general rule, a 10% increase over the previous year's rates should be applied and the leaves retested again after the harvest season. For example, if plants fertilized with 70 pounds of N contained less than 1.50% N after berry harvest, the N rate should be increased to 77 pounds for the upcoming year.

Nutrient Management: Fertilizer Forms

Blueberry plants require annual applications of fertilizers to produce high yields of quality fruit. Fertilizers for blueberry plants should contain the needed plant nutrients (elements), release the nutrients at the time plants need them, be obtained at an acceptable price, be convenient to use, and have no adverse effects on the plant or the environment. These criteria can be met by either organic (natural) or chemical (inorganic or synthetic) materials, but will require different application techniques to insure that each fertilizer provides the proper amount and balance of nutrients for plant growth. Market availability of both organic and chemical fertilizers varies greatly from one part of the state to another. Some organic fertilizers may be waste materials from nearby farms or industries and may be inexpensive. However, specific organic fertilizers, such as fertilizers containing only nitrogen, can be difficult to find or may have to be purchased in large quantities. These same problems can also occur with specific chemical fertilizers.

Organic fertilizers are basically plant or animal residues and therefore vary in total nutrient content. Organic fertilizers contain most, if not all, of the essential plant nutrients. However, the organic fertilizers must be broken down (mineralized) to release these nutrients for plant uptake. The mineralization of organic matter depends on the soil microbes and is greatly influenced by soil temperature, moisture, pH, and texture as well as the type of organic material applied. Organic materials, such as blood meal, soybean meal, feather meal, etc., that contain high quantities of sugars, proteins, and other easily digestible compounds, are mineralized at a much faster rate than coarse, woody, fibrous materials such as leaves, sawdust or wood chips. Organic fertilizers should be applied at least 3 to 6 weeks before the plants actually need the nutrients to allow enough time for the mineralization process. Organic fertilizers, on average, release approximately 50% of their nutrients during the first year after application, with decreasing amounts in subsequent years. Therefore, application rates must be adjusted to insure that adequate quantities of nutrients will be available for proper plant growth and production.

Chemical or inorganic fertilizers are sold in both solid and liquid forms. Inorganic fertilizers contain a precise nutrient content expressed as the fertilizer grade. A “22-3-9” fertilizer contains (by weight) 22% nitrogen (N), 3% phosphate (P_2O_5), and 9% potash (K_2O). Other nutrients, such as Mg or S, can be added to most mixed fertilizers for an additional cost. Compared to the organic fertilizers, inorganic fertilizers dissolve much faster and therefore the nutrients become available at a faster rate. On the other hand, the nutrients from inorganic fertilizers will not remain in the soil for a long period of time and must be replenished on a regular basis. It is recommended that solid inorganic fertilizers be broadcast-applied three times during the growing season. One-third of the N and all of the P and K (if needed) should be applied at first bloom. Additional amounts of N should be split equally and applied at six-week intervals.

Both organic and chemical fertilizers can usually be applied to blueberry plantings without any major problems. Organic and solid chemical fertilizers are normally broadcast on the soil or mulch surface. Liquid and water-soluble solid chemical fertilizers can be sprayed on the soil or mulch surface, injected into irrigation lines (fertigation), or foliar applied. When fertilizers are supplied via fertigation, frequent (weekly) applications are recommended.

Solid chemical fertilizers must be completely water soluble to avoid plugging emitters or irrigation lines. Small amounts of fertilizer can be applied as a foliar spray to alleviate certain nutritional problems. For example, Fe fertilizers sprayed on the plant leaf will temporally correct an Fe deficiency. Care must be taken to avoid burning the leaves when applying some N, K, and S fertilizers.

Pruning

Annual pruning of highbush blueberries is needed to remove unproductive canes and to promote new growth to maintain vigor and high production levels of quality fruit. Pruning helps shape the blueberry plant, manage crop load and berry size, reduce disease problems and rejuvenate older plants. Improperly pruned or unpruned plants often become crowded with thin, twiggy growth, resulting in poorly developed, low-vigor canes, along with small berries.

Fig. 5. Young blueberry shoot with large flower buds.

The best time to prune highbush blueberries is during late winter or early spring just before bud swell. Pruning late in the dormant season reduces the chances of freeze damage at cut surfaces and enables winter-damaged wood to be selectively removed.

At planting, thin, willowy, and damaged canes should be removed, leaving only the stronger shoots to establish a strong plant framework. The extent of pruning during the first three growing seasons consists of removing diseased or broken canes and heading back or thinning out twiggy and low-growing shoots.

Blueberry flowers and fruit arise from buds on one-year-old wood. Flower buds are initiated during late summer and early fall of the previous year and normally occur near the tips of all new growth. Therefore, a certain amount of new growth each year is essential for sustained production. Flower buds should be removed for the first two growing seasons to allow the plant to become established and develop into a more vigorous plant. Production during the third growing season should be based on the size and vigor of the plants. Vigorous three-year-old bushes can be allowed to produce a small crop, while most if not all flower buds from weak third-year plants should be removed. Mature plants that tend to overbear or produce small berries should be tipped (removal of tips of branches) to remove fruit buds and reduce the crop load. An excessive number of fruit buds may delay leaf bud development, cause insufficient early foliage, and result in an overall reduction in fruit size. Under these circumstances, removal of 20-30% of the fruit buds will result in fewer but larger berries.

In pruning older, mature plants, use loppers to remove any damaged, diseased, or weak canes and branches. Since canes become less productive with age, approximately 20% of the older canes should be removed each year after the fourth harvest. All canes in a bush should be less than six years old. If several old canes are

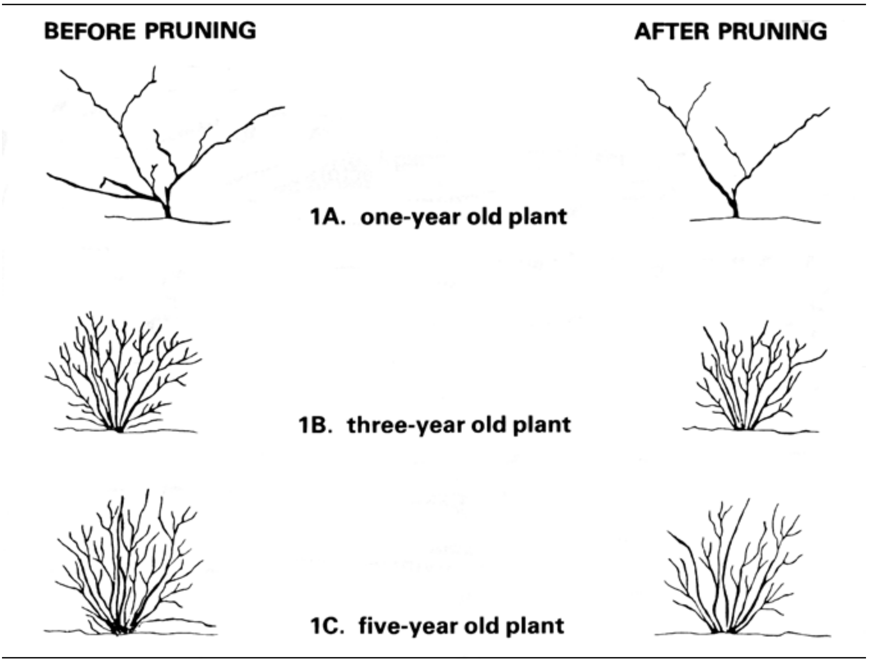

Fig. 6. Pruning one-, three-, and five-year-old blueberry plants.

present, the ones in the middle of the bush should be removed to increase light penetration into the center of the plant. Hand pruners are used to thin clusters of twiggy growth in the bush center and ends of canes, to remove weak growth and thin the center of the bush, and to remove low, drooping branches.

Some blueberry cultivars, such as Coville and Berkeley, tend to have spreading growth habits and should be pruned to encourage more upright growth. Jersey and Bluecrop should be pruned to promote spreading-type growth.

Rather severe pruning will often revitalize old plants and encourage new and more productive growth. Cut the plant entirely to the ground. Retain 6-8 of the strongest shoots that grow the following year. Do not fertilize the rejuvenated bushes during the year after pruning.

Sanitation is an important part of pruning. If diseases such as stem blight are present in the planting, disinfect pruning shears and loppers between each cut (with isopropyl alcohol or a bleach dip) to reduce disease spread. Use particular care in disinfecting pruning equipment before moving to a new bush.

Weed Control

Weed control is one of the more challenging cultural practices in blueberry production. A weed is defined as a "plant out of place." Weeds include annual and perennial grasses and broadleaf weeds, sedges, and other woody herbaceous plants that seem to thrive in the same space as blueberries. Weeds compete with plants for nutrients, water, and light, can serve as intermediate hosts for diseases and insects, and may interfere with harvesting and irrigating operations. While weed species vary from one planting to another, good weed control is essential for maximum production of high quality berries.

There are two distinct areas in blueberry plantings in which weeds need to be controlled: 1) between plant rows and 2) within the plant row. Weeds growing in the area between plant rows can be controlled by cultivation or by maintaining the row middles in a bluegrass, perennial ryegrass, or fescue sod. Keeping the row middles in sod works well in Missouri. The sod provides a firm soil for operating sprayers, mowers and other power equipment, reduces potential problems from soil erosion, and provides a suitable place for pickers to walk. Weeds and grass height can be easily controlled in the sod areas by frequent mowing.

Weed control within the plant row, however, is a more difficult task. One cultural practice recommended for Missouri, the use of mulches, has proven to be very helpful in suppressing weeds while at the same time helping regulate soil moisture and temperature and adding organic matter to the plant root zone. A layer, 4- to 6-inch in depth, of sawdust, wood chips, or similar material is beneficial in reducing weed problems, especially during the early part of the growing season. Additional control measures will normally be needed to keep the planting free of weeds during the latter parts of the growing season.

Preplant Weed Control

Controlling perennials such as johnsongrass, bermudagrass, red sorrel, etc., is best accomplished during soil/site preparation and before the blueberry plants are established. Several herbicides are available on the market to eradicate the targeted weeds. In some situations, repeated herbicide application, a combination of herbicides, or using herbicides in conjunction with cultivation may be needed to completely rid the site of weeds. All herbicides must be used with caution and in accordance with the label and soil conditions. Herbicides differ in their mode of action and in the weeds controlled. Injury to humans, blueberry plants, and the environment can result when herbicides are not properly applied. Read and follow the herbicide label!

For growers not wishing to use herbicides, frequent cultivations, planting of smother crops to suppress vegetation, covering the weed-infested area with black plastic, or employing other mechanical devices such as hoeing and hand weeding, can be used to create a weed-free planting site. Although these techniques usually require more time and effort to eliminate the weeds, they have been successfully used.

Regardless of the time required or the method used, the key is to eradicate perennial weeds from the site before planting blueberry bushes. The shallow-rooted blueberry plant does not compete well in weed-infested areas. Failure to remove these weeds before planting usually results in poor growth and berry production.

Weed Control in Established Plantings

The area between rows in established plantings is often maintained in a non-competitive grass sod, which is mowed as needed. Within the plant row, methods to control weeds in established plantings can be grouped into one of two categories, chemical control or mechanical control.

Chemical control includes the use of herbicides, which are applied to control weed growth within the row of established blueberries. Several herbicides are registered for use on blueberries, and the recommended rates and application methods vary greatly. Preemergence herbicides are applied before weeds emerge, generally in early spring. One or more herbicides may be needed to control the targeted weeds. Caution must be used on first-year plants, as newly planted blueberry bushes are very sensitive to most preemergence herbicides.

Postemergence herbicides are absorbed by growing plants and therefore are applied directly to the targeted weed. Postemergemence herbicides are often used for “spot” treatments and controlling weeds adjacent to the mulched row.

Both pre- and postemergence herbicides must be carefully applied. Herbicide rates and application methods are affected by both soil and climatic conditions. Read and follow the instructions on the herbicide label. Remember, the label is the law!

Shallow cultivation, hoeing, and hand weeding are popular methods of mechanical (non-chemical) weed control. “Weeder geese”, smothering weeds with barriers such as cardboard or “weed barrier” fabrics, and other mechanical devices have been tried, but generally have not been very successful. Several growers have purchased or, in some cases, built rotating or disc cultivators to lightly till the mulched surface around the blueberry plants. While these cultivators do a good job of removing weeds, they often damage the shallow roots of blueberries growing in the mulch.

Weed control is often one of the most expensive parts of a blueberry operation. For the organic grower, mechanical weed control and the use of mulches are methods that meet organic certification requirements. Most blueberry growers use a combination of chemical and mechanical methods to control weeds. Mulches, pre- and postemergence herbicides, some weed pulling and hoeing may all have to be used in trying to reduce the weed problems. Weed control in blueberries is a tough, laborious, expensive job that requires year-round effort.

Disease Management

In general, highbush blueberries require less intensive disease control measures than other fruit crops. The warm and humid climate in Missouri, however, is favorable to a number of pathogenic fungi that damage the stems, roots, and fruit. Viruses have also been found in a few blueberry plantings in Missouri.

Fungal Diseases of the Stem

Of the fungal diseases, the economically most important ones are those that attack the stem. Many of these diseases manifest themselves by the sudden death of a single or a few shoots in the plant during the growing season. The resulting reddening and drying of the leaves, often referred to as “flagging” or “dieback,” can be the sign of a number of stem diseases, including stem blight, stem canker, Phomopsis twig blight, and Godronia canker.

The most economically destructive of the fungal diseases in highbush blueberries is **stem blight**. Stem blight is caused by *Botryosphaeria dothidea*, a fungal pathogen that infects a large number of plant species. Stem blight affects individual canes or stems within a blueberry plant, with one or more canes dying each year until the entire plant dies. Canes infected with stem blight tend to lose vigor quickly, with leaves turning from green to yellow to red. The internal tissues of the canes exhibit a tan discoloration when cut across the afflicted area. This discoloration marks the area where the fungus invades the wood. The development of the fungus in the crown usually results in the death of the entire plant. Some cultivars of blueberries appear to have more resistance to stem blight than others, although most cultivars grown in Missouri seem to be susceptible to the disease to some degree. Young plants are particularly vulnerable to stem blight.

Stem canker is caused by the closely related pathogen *Botryosphaeria corticis*. As opposed to stem blight, stem canker has easily recognizable external symptoms on the affected branches: the area where the fungus grows is marked by swollen lesions that persist and become larger each season. The lesions develop into large necrotic cankers with fissures. These cankers usually bear small pimple-like structures that are the fruiting bodies of the fungus. When the canker girdles the stem, the whole branch dies.

Twig blight is caused by the pathogen *Phomopsis vaccinii*. This fungus causes less damage in Missouri than stem blight or stem canker, as it generally affects only the current season's growth and rarely results in the loss of entire branches. Twig blight infection occurs during flowering and the fungus rapidly develops in the succulent tissues, causing blight symptoms that resemble frost injury.

Godronia canker is relatively rare in Missouri, and is therefore of lesser economic importance. The pathogen, *Godronia cassandrea,* infects one- or two-year-old stems at leaf scars and leads to the development of reddish lesions that are composed of concentric circles of alternating color intensity. The lesions first become visible during the fall, and often bear the fruiting bodies of the fungus that look like small black pimples. The disease can result in the death of the branch in one or two years.

The most effective and practical way to control fungal diseases of the stem is to remove discolored shoots from the plant. Prompt removal of the infected shoots will eliminate the inoculum source that can lead to further infection during the current and following growing seasons. Most of these fungi overwinter and sporulate the following spring in infected plant tissues. The diseased branches should be cut out as low as possible, as these fungi often spread into the symptomless tissues below. The excised diseased shoots should be burned or buried and not left in or near the planting.

If cultural practices are inadequate to control these diseases, fungicides should be applied. The application of fungicides is critical during the spring, when the initial inoculum is released to start the primary infection cycle. Unfortunately, fungicides are not very effective in controlling stem canker and stem blight. Four sprays of a labeled fungicide are recommended at the green tip, pink bud, 25% bloom and full bloom stages. If Phomopsis twig blight is a serious problem, spray the plants with lime sulfur at the end of dormancy, preferably just before bud swell. If the impact of canker diseases is substantial and the weather is rainy, the spray schedule can be extended until leaf drop (one application every 4-6 weeks.)

Fungal Diseases of the Root System

Phythophthora root rot, caused by the pathogen *Phytophthora cinnamomi*, is a fungal disease that attacks the roots of blueberry plants. Phythophthora root rot caused extensive damage in some of the early 1970s plantings in Missouri and still remains as one of the most devastating diseases in blueberry plantings. Blueberry plants infected with Phythophthora are most frequently found in low-lying, wet, or poorly-drained areas. The above-ground symptoms of Phytophthora root rot include yellowing or reddening and subsequent dying of leaves throughout the plant. As opposed to canker diseases, the leaf discoloration occurs throughout the plant, not just on one cane or branch. In the root system, first the young roots die, followed by older roots, then the crown area begins to decay. Affected plants are commonly located in a circular area that frequently coincides with wet, poorly drained soil conditions. The key in avoiding the problems of Phythophthora root rot is good site selection and soil water management. Avoid planting sites located in drainage ways or areas where water stands for even a short period of time after a rain. Sites with minor soil drainage problems can normally be used for blueberries, if drainage is improved by incorporating large quantities of organic matter into the soil before planting, installing a drainage tile system, or setting blueberry plants on ridges or berms (a highly recommended practice). Irrigation should be carefully monitored and regulated in these soils to prevent over-watering. A second key in controlling Phytophthora root rot is to buy disease-free plants. Many of the Phytophthora root rot problems can be traced to plants propagated by non-certified nurseries. In susceptible cultivars, the only control measure is the removal of the diseased plants. A limited number of fungicides are approved for treating Phythophthora-infested soils, but they are much more effective when good soil drainage is also provided.

Fungal Diseases of the Fruit

Fungal diseases that affect the fruit of blueberries in Missouri include mummy berry and the fruit rots Botrytis, Anthracnose, and Alternaria. **Mummy berry** disease is caused by the fungus *Monilinia vaccinii-corymbosi.* The fungus infects only cultivated blueberries and closely related species of wild blueberries. Mummy berry has two distinct symptoms: 1) shoot blight that appears a few weeks after bud break with new leaves or shoots dying and turning brown, and 2) fruit rot which becomes apparent just as healthy berries begin to turn blue. The infected berries develop slowly, turn a whitish pink or salmon pink color, and fall to the ground. The fungus overwinters in infected berries on the ground.

The fruit rots appear most frequently when berry ripening occurs during wet, warm weather conditions. **Botrytis blight** (*Botrytis cinerea*) is characterized by the sudden decay of the blossoms with the appearance of gray velvety mold on the blighted tissues. Botrytis also causes blight on the young succulent shoots if weather conditions are favorable for the disease.

Anthracnose fruit rot (*Colletotrichum gloeosporioides*) infections are most common on the blossom end of the berry and may not become apparent until the berries have been harvested. Ripe berries exhibit a thin layer of pink or salmon-colored slime on the surfaces of infected areas. The anthracnose fungus can also attack new shoots, flowers, and leaves, but the infections do not usually cause serious economic losses.

Alternaria fruit rot (*Alternaria alternata*) is a black or dark green moldy growth on the blossom end of the blueberry that appears shortly before harvest. The development of fruit infections is not well understood, but overripe or injured berries are particularly susceptible to the disease.

The most effective way to control fruit diseases is by maintaining an open canopy to provide good exposure to the sun and air movement in the bushes. Under such conditions, water dries faster from the plant surfaces, and relative humidity is reduced. The lower the humidity in the plant microclimate, the less favorable it is for the fungi. Nitrogen fertilization should be applied in a judicious manner, as excessively succulent vegetative growth makes plants highly susceptible to these fungal pathogens. Prompt removal of blighted blossoms and shoots will also help reduce disease pressures by eliminating the source for subsequent cycles of fungal inoculum. Burying (by shallow soil cultivation) or complete removal of mummified berries, while the over-wintering structure of the fungus is on the ground, will greatly reduce future problems from the mummy berry disease.

Unless disease conditions are serious, the control of these pathogens does not require routine application of fungicides. Should fungal diseases become a serious problem, they can be controlled by the application of labeled fungicides.

Viral Diseases

Of the viral diseases, **necrotic ringspot** presents the most serious problem in Missouri. It is caused by tobacco ringspot virus (TRSV), one of the most common viral plant pathogens in North America. TRSV is vectored by a microscopic worm, the dagger nematode (*Xiphinema americanum*), which also is endemic in North America. Leaves infected with TRSV become puckered and display small circular necrotic spots. On certain cultivars, the leaves may become smaller, and the internodes shortened. Infected plants occur in a concentrated area that slowly increases year by year as the nematodes spread the virus. Infected plants become stunted and are unproductive. If TRSV symptoms are seen, the presence of the virus should be tested by a serological method called ELISA.

Red ringspot virus also occurs in Missouri. This disease is not as damaging as necrotic ringspot, and is not vectored by nematodes (the vector for this virus is not known.)

Viruses are fundamentally different from fungal pathogens in that they cannot be eliminated from the plant once infection has occurred. Since the only effective control of virus diseases is prevention, it is essential that the propagating stock be certified virus-free. It also is important to avoid planting in an area that was previously used to grow fruit trees and to have the soil tested for the presence of the dagger nematode. If the nematode is present, fumigation of the soil with a nematicide is a sound investment. If fumigation cannot be done, the soil should be fallowed for at least one year. Planting sudangrass or ryegrass as a cover crop will reduce the nematode population. If virus-infected blueberry plants are identified in the planting, the plants should be removed immediately to prevent the spread of the virus.

Insect Management

Insects that attack blueberry plants in Missouri have been of minor economic importance. As more plantings are established, insect damage will probably become more important and will require control measures.

Climbing Cutworms. Several species of cutworms attack blueberries, feeding on the buds during the time of bud swell (late March to early April). Most of these cutworms feed at night, resulting in small holes bored into the buds. Browning of the bud as the result of cutworm feeding habits is often mistaken for frost damage. Thorough and frequent inspections of blueberry plants, especially the buds, should be made during the buds swell period.

Cranberry fruitworm, cherry fruitworm, plum curculio. These insects feed on other fruit crops and are potential pests for blueberries. The cranberry fruitworm larvae have legs and enter the berry at the junction of the stem and fruit. The green-colored larvae feed inside the fruit and expel frass (a sawdust-like material) near the entrance hole. The cherry fruitworm larvae also have legs, but bore into the calyx end of the fruit. Initially larvae are white with black heads, turn pink and then red after feeding on fruit for a few days. During infestation, two berries are knitted together by silk-like threads. The worm then enters the second berry at the point of contact. Plum curculio adults lay eggs in crescent-shaped holes located on the side of the berry. White, legless larvae feed inside the fruit. The infested berries stop growing and fall to the ground.

Sharpnosed leafhopper (SNLH). The SNLH causes the spread of stunt disease in blueberry plantings. The adult is $^1/_8$ to $^1/_4$ inch in length, has a sharp nose, and red eyes. Blueberry plantings should be monitored for SNLH adults by placing 5 to 10 yellow, sticky traps around the field perimeter. SNLH adults normally appear in Missouri in mid-May, mid-July, or late September.

Blueberry maggot. The adult is approximately the size of a house fly but has black bands on its wings. It is similar in appearance and closely related to the apple maggot. Peak emergence for adults occurs shortly after the first fruits begin to ripen. Eggs are laid 7 to 10 days after adults emerge. Adults lay a single egg in a berry, and the immatures mature and drop out of the fruit onto the soil below to pupate. Fruit infested by this pest will become soft and leaky. Adults can be monitored with yellow sticky boards baited with ammonia or sticky spheres.

Japanese beetle. Immatures (grubs) are white with a light brown head capsule, from $^1/_{16}$ to 1 and $^1/_4$ inches long, and can be found in a curved, C-shape position in the soil. Ten of the twelve months of the life cycle of this pest are spent in the soil as grubs. Adults have a metallic green body with bronze colored outer wings. They are approximately $^{3}/_{8}$ inch long with six distinctive white tufts of hair along each side of the body. Emergence of adults from the soil begins in June and can continue into July. Individual adults can live for 30 to 45 days. After they mate with males, females lay 1-4 eggs during bi-weekly trips to the soil throughout their life cycle. A single female can lay up to 60 eggs during its lifespan. Adult Japanese beetles can cause damage to blueberry plants by skeletonizing the leaves and feeding on the fruit. Beetle grubs can feed on plant roots, damaging the entire blueberry plant.

Blueberry tip borer. Damage from this pest occurs late in the spring or early summer and can be mistaken for primary mummy berry infection. Larvae are pink in color and bore into shoots, causing leaves to turn yellow and develop red veins. Shoots wilt and become discolored, and stems turn purplish. Burrowing tunnels created by this insect can be as long as 12 inches. Damage from this insect is uncommon, especially in plantings that receive insecticide treatments.

Bird Management

Birds present one of the most serious problems for highbush blueberry producers in Missouri. Unprotected patches commonly experience fruit losses of 15% or more. Problem bird species in Missouri include robin, mockingbird, brown thrasher, several woodpecker species, mourning dove, cedar waxwing, starling, and blackbird. All bird species are protected under federal law except starling, feral pigeons, and English sparrow. A federal damage control permit is required before most protected species can be killed (consult the U.S. Fish and Wildlife Service for more information). Therefore, bird management strategies focus on chemical repellants, visual and auditory frightening devices, and exclusion.

Fig. 7. Birds are excluded from this planting with a removable net, supported by an overhead system of posts and wire.

Research and developmental work is underway to develop chemical repellants. Consult with the Missouri State University Departments of Fruit Science and Agriculture for the latest information on this subject.

Visual frightening devices include scare eye balloons, reflective tapes, raptor kites and decoys, and mirrors. Auditory frightening devices include amplified distress calls and loud sounds (cannons, cracker shells, rockets, sirens). In general, these strategies work best in combination, and with frequent changes in location or interval. Visual and auditory frightening devices can lose effectiveness as the harvest season progresses.

Exclusion is the most effective bird management strategy. Netting of several types, including nylon, cotton, polyethylene, and plastic impregnated paper, is available to exclude birds from blueberry plantings. The netting is placed over a permanent or semi-permanent support system of posts and wire. Netting is commonly placed over the planting before fruits ripen and removed after harvest. Netting is initially expensive, but the cost can be spread over the 3-10 year life of the material. Installing and removing netting is labor intensive.

Mammal Management

Deer and voles can cause extensive damage to Missouri blueberry plantings. Deer feed on foliage, buds, and fruit, which can delay production and reduce yield on young plantings. Male deer may also damage blueberry plants by rubbing and breaking branches with their antlers.

Barrier fences are the most effective deer control measure. Deer fences are commonly 8-10 feet tall and may consist of woven wire or multiple strands of high tensile smooth wire. Multiple strand fences may be electrified. Fences may be either vertical or slanted. Chemical repellants are another deer damage control strategy. Several commercial products are labeled for use on blueberries, and a variety of homemade materials are also used to repel deer. Repellants are most effective if applied before feeding damage occurs, and repeated applications are necessary for extended control.

Voles (small rodents) of several species feed on the bark and cambium of lower canes, crown, and larger roots. Voles feed at or below the soil surface. Galvanized hardware cloth cylinders, installed around the base of plants, will discourage surface feeding. Rodenticide applications are frequently used to reduce vole numbers. Rodenticides are available as grain baits and in pelletized form. Follow label regulations regarding baiting methods and rates.

Harvest

The harvest season for highbush blueberries in Missouri usually begins in mid-June. A planting that includes early, midseason, and late cultivars will produce fruit for six to eight weeks. The harvest season for a specific cultivar will usually last four to five weeks. Highbush blueberry bushes usually begin bearing fruit during the third growing season, and production normally increases for the next three to five years, then levels off. A mature, healthy bush can produce 6-15 pounds of fruit, but per-acre yields are often lower, generally ranging from 4,000-10,000 pounds.

Berries ripen 60 to 80 days after blossoming, depending on the cultivar, temperature, and rainfall conditions. The color of maturing fruit of highbush blueberries changes from green to red and then to blue. The fruit of blueberry plants is borne in clusters and individual berries in the cluster ripen in succession for several weeks. Ripe berries can be easily harvested by holding the cluster in the palm of one hand and gently rubbing off or removing the ripe fruit with the other hand. Mature, ready-to-pick berries will detach easily. The size and sugar content of mature berries continue to increase after turning blue. A delay in harvest of seven to ten days after the berries turn blue will result in riper and larger fruit; however, these berries are more easily damaged during harvest.

In Missouri, most blueberries are hand-harvested. A full crop will require 10 to 20 pickers per acre on a 5- to 7-day harvest schedule. Over-the-row mechanical pickers are available, but usually require large acreage to justify their cost. Several types of hand-held vibrating units, rubber hoses, etc., are available to aid in harvesting. Most of these mechanized procedures require additional cleaning and sorting to separate ripe berries from immature fruit, leaves, twigs, and other trash.

Prompt refrigeration is important in maintaining the quality of harvested blueberries. Fresh berries can be held for more than two weeks at 32°F, but only a few days at 72°F. Variation of more than a few degrees during cold storage can cause early spoilage of berries.

Marketing Highbush Blueberries

A marketing plan should be the first step for anyone considering a commercial blueberry planting. A sound, well-planned marketing scheme is often the difference between success and failure of a blueberry operation. A good marketing plan incorporates several factors, including the number of potential customers within a 25-30 mile radius of your planting, number and acreage of other blueberry growers in the same general area, type of market preferred (i.e., U-Pick, on-farm markets, farmer's markets), availability of labor (especially during harvest), facilities (cold storage, weighing and selling areas, parking), advertising outlets, and the location of the market in relation to the consumer. Adding "value-added" goods expands the marketing plan by offering processed blueberry products throughout the year.

Most of the Missouri blueberry crop is sold directly to consumers. U-Pick (pick-your-own) is the most popular marketing scheme used for blueberries, although several growers also sell pre-picked fruit through on-farm facilities and organized farmer's markets. Direct-marketed blueberries are sold by both weight (pounds) and volume (pint, quart, gallon, etc.). Limited opportunities for wholesale marketing through restaurants, grocery stores, and growers' marketing associations are also available to blueberry growers in Missouri. Blueberries are easily frozen for marketing throughout the year.

Many marketing opportunities are available for value-added blueberry products. Jams, cooking sauces, baked goods, dried fruit, fresh and frozen juice, vinegars, and wines are examples of value-added goods from Missouri-grown blueberries that are available to consumers.

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