UNIVERSITY OF MINNESOTA | EXTENSION

Commercial blueberry production in Minnesota and Wisconsin

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The climate of Minnesota and Wisconsin has made successful blueberry production difficult. But with the introduction of blueberry cultivars with good winter hardiness, minimum upright growth, and large fruit, commercial production of blueberries is possible. Given proper site selection and cultural methods, half-high cultivars offer growers in USDA zones 3, 4, and 5 the potential for long-term – thirty years or more – blueberry production. Half-high blueberries are crosses between high-bush blueberries (*Vaccinium corymbosum*) and low-bush blueberries (*V. angustifolium*). The short stature of half-high blueberry plants, along with their inherent cold-hardiness, allows reliable production.

Choosing cultivars

The blueberry cultivars best adapted for Minnesota and Wisconsin produce flavorful fruit on short-statured bushes that can survive typical winter temperatures. Table 1 summarizes each cultivar's characteristics. All listed cultivars require an average of five years before producing a large harvest and up to ten years, or perhaps more, before reaching mature size.

Table 1. Characteristics of half-high blueberry cultivars

Cultivar	Zones	Plant characteristics[1]	Fruit yield (lb./plant)	Fruit characteristics[2]
Northblue	3-5	20-40 inches tall, 30-60 inches wide	3-12	Large, dark blue, firm berries; good fresh flavor; superior procesed flavor
Northsky	3-5	20-40 inches wide, 10-30 inches tall	1-5	Medium, sky-blue berries; sweet, mild, aromatic fresh flavor; superior processed flavor. Ripens with 'Northblue.' Yield and berry size benefit from cross-pollination.
Northcountry	3-5	15-40 inches tall, 30-60 inches wide	2-6	Medium, sky blue berries; sweet fresh flavor similar to wild lowbush blueberries; ripens 5 days earlier than 'Northblue.' Yield and berry size benefit form cross pollination.
St. Cloud	3-5	30-50 inches tall, 40-60 inches wide	3-9	Medium, dark blue, firm berries; sweet flavor, crisp texture; good storage capability; ripens 5

Cultivar	Zones	Plant characteristics[1]	Fruit yield (lb./plant)	Fruit characteristics[2]
				days earlier than 'Northblue.' Requires second cultivar for pollination.
Polaris	3-5	20-50 inches tall, 30-60 inches wide	3-10	Medium-large berries; very firm and very very crisp texture; intense aromatic flavor; excellent storage capability; ripens 7 days earlier than 'Northblue.' Requires second cultivar for pollination.
Chippewa	3-5	20-50 inches tall, 30-60 inches wide	3-12	Medium-large berries; sky-blue color; sweet flavor; firm fruit; ripens with 'Northblue.' Yield and berry size benefit from cross pollination.
Northland	3-5	30-50 inches tall, 40-60 inches wide	3-12	Medium-large berries; mild flavor. Ripens 3 days after 'Northblue.'
Bluetta	5	40-60 inches tall, 40-60 inches wide	3-12	Medium-large berries; sweet, aromatic flavor. Ripens 7 days earlier than 'Northblue.'
Patriot	5	40-60 inches tall, 40-60 inches wide	3-12	Very large berries; tart, aromatic flavor. Ripens 5 days earlier than 'Northblue.'

[1]For plant height, width, and yield, the lower end of the range will be more likely in harsher climates, such as that of northern Minnesota. Blueberries are slow growing relative to other fruit plants and will not reach mature size for eight to ten years, even under optimal growing conditions.

[2]Ripening sequence is that observed at Becker, MN.

Plants

Most plants available from nursery sources are propagated by tissue culture rather than from cuttings. Young tissue-cultured plants are more vigorous than cutting-propagated stock and produce correspondingly higher numbers of flower buds, because of increased development of basal and lateral branches.

Several plant sizes are available, both bare root and in containers. Table 2 outlines the various types and recommended uses.

Table 2. Types of blueberry plants available

Type	Description	Application
liners	3-6"	nursebed
one year old	7-12", cup-sized rootball	nursebed or field planting
two year old	12-18", quart-sized rootball	field planting
three year old	18-30", gallon-sized rootball	field planting

Larger plants are ready for direct field planting in a prepared site. Small plants should be grown in containers or placed in nursebeds for at least one growing season before being transplanted to the field.

Nursebed

The nursebed is an intensively managed space designed to promote additional root and shoot development before field planting. Such a practice allows for the purchase of smaller, less expensive plants and thus reduces start-up costs. The nursebed is constructed by forming a raised bed of acid peat moss 8 to 10 inches deep. A support frame around the perimeter of the bed will hold the moss in place.

Transfer young plants to the bed and space eight to 12 inches apart. Remove containerized plants from their pots. Growing plants will require shading and protection from wind until they become acclimated to full sun and winds. Moisture levels must be monitored closely, and supplemental irrigation applied as needed. The use of drip tubing or soaker hose is preferable to overhead sprinklers.

The peat moss growing medium will not supply nutrients to the plants as soil might, so fertilize every two weeks during active growth with a water soluble acid-reacting fertilizer such as Peter's Acid Special (21-7-7) or Miracid (30-10-10). Micronutrient needs can be satisfied by adding a trace element mixture such as S.T.E.M. (soluble trace element mixture) at half strength to the fertilizer solution once a month. Follow label rates. Discontinue fertilizer applications in late summer when growth slows. Closely monitor soluble salts levels in the bed to prevent root damage.

Bedded blueberry plants need to be protected during winter. Snow is an excellent insulator and can be used to protect plants in the nursebed against injury caused by severe winter temperatures and drying winds. However, since timing and amount of snowfall is unpredictable, a mulch or artificial covering can be applied when plants go dormant.

Before covering plants, strip off any remaining leaves and apply a protective fungicide such as Captan. This will help prevent potential fungal infection. Uncontrolled rodents can also pose a problem. Commercially prepared poison baits containing zinc phosphide are convenient and easy to use. Controlling weeds within the nursebed and mowing the area around it will reduce rodent habitat.

The winter protection cover, consisting of two layers of plastic with a mulch layer between, may now be installed. First dig a shallow trench around the edge of the nursebed. Cover the plants with plastic. Place one foot of straw or hay on top and cover with a second sheet of plastic. Secure the border by laying edges of plastic in the trench and covering with soil. The plastic-straw-plastic sandwich will insulate the blueberry plants from extreme low temperature, prevent desiccation (drying out), and allow for easy removal the following spring.

Selecting and preparing a site

Blueberries require moist but well-drained acidic soil. Choose a frost-free, level or gently sloping site in full sun with good air circulation. Blueberries must have a consistent moisture supply, yet only a few hours of standing water can kill the plants, so surface and internal soil drainage are essential.

Soils

Open, porous soils such as sandy loams, loamy sands, and coarse sands with a high organic matter content will best provide the aeration needed. To improve the likelihood of successful establishment on most soils, add one and one-half to two cubic feet of peat per plant to the soil. Be sure to mix peat thoroughly with the soil. Clay soils that are acidic and high in organic matter may also be used for blueberry plantings. However, aeration and drainage are often poor and plants on these soils may develop root problems.

Peat and muck soils should be avoided. These soils are wet and cold in the spring, and often are located in low-lying areas, subjecting the plants to spring frost damage and standing water. In late summer, the soil releases a large amount of nitrogen, which delays the plants' hardening before winter and increases chance of winter injury.

PH

Always use soil testing to assess and adjust soil pH. A soil pH of 4.5 to 5.5 is optimum for blueberry production. A pH higher than 5.8 may cause iron chlorosis, characterized by interveinal yellowing of the leaves. If the pH is too high, add acid peat or sulfur to the soil according to soil test results. Fine-textured soils with pH values above 7.0 should not be used unless the top 18" of soil are amended with an equal volume of acid peat moss and further acidified if necessary. The peat moss will break down over time; organic mulch materials should replenish the level of organic matter in the soil as they decompose.

Elemental sulfur can be used to lower pH. Because it reacts slowly with the soil, elemental sulfur should be applied and incorporated to plow depth the year before planting. The soil type, present pH, and the desired pH are used to determine the amount of elemental sulfur needed. Table 3 provides guidelines for elemental sulfur use. Test soil pH again three to four months after initial application. If soil pH is not in the desired range, reapply according to Table 3.

Table 3. Elemental sulfur application rates to change soil pH to 4.5

initial pH	**sand or loamy sand**		**sandy loam or loam**	
	lb./1000 ft^2	lb./acre	lb./1000 ft^2	lb./acre
7.0	19	800	58	2500
6.5	15	650	46	2000
6.0	12	525	35	1500
5.5	8	350	24	1000
5.0	4	170	12	500

Iron sulfate also can be used to lower soil pH. This material reacts faster than elemental sulfur but is more expensive. Multiply the rate of elemental sulfur needed by seven to determine the amount of iron sulfate needed. Although aluminum sulfate also lowers pH, it can be toxic to roots and is therefore undesirable as a soil acidifying amendment.

Acid sphagnum peat incorporated prior to planting at the rate of one to two cubic feet per plant will provide a favorable root environment for establishing blueberries in soils with a high pH. The positive effects of acid peat will last six to ten years. Unless other measures are used, the pH of the soil will eventually increase.

Use of ammonium sulfate or urea as the nitrogen source will also help maintain a low soil pH. Refer to Table 4 for application rates of nitrogen. Do not use ammonium sulfate at rates higher than those recommended for supplying nitrogen. Excessive nitrogen available late in the growing season can increase winter injury potential.

Table 4. Nitrogen recommendations for blueberries

age of planting	amount of nitrogen (N) to apply[1] in lb./acre (lb./1000 ft^2)
first year	30
second year	40
third year[2]	50

[1]Amount in table is for mineral soils. For high organic-matter soils lower rates by ten to 20 lb./acre.

[2]Base subsequent N fertilizer applications on leaf analysis and plant vigor.

Pre-planting weed control

The year before planting, control perennial weeds, such as quackgrass, nutsedge, and Canada thistle, by fallow planting, repeated tillage, or with applications of non-residual herbicide. It is extremely difficult to control perennial weeds after the blueberries have been planted, so it's important that the field be free of perennial weed infestations before planting.

Planting

Although stock can be planted in either spring or fall, spring is preferable to benefit from spring rains, reduce the potential for winter injury and avoid loss of plants due to frost heaving. Dormant stock may be planted as early in spring as field conditions permit. Planting blueberries which have already leafed out should be delayed until frost danger has passed.

After the rows have been marked out, the holes are dug by hand or with a tractor-mounted auger. Holes should be one foot deep and not less than one foot in diameter. Space individual plants four to five feet apart in rows eight to ten feet apart, depending on the type of equipment used. Spacing plants four feet apart in rows eight feet apart yields a plant density of 1,360 plants per acre.

Planting a blueberry bush

At planting the root system should be loosened, especially if the plant has been containerized, to prevent root spiralling and girdling which can result in weakened plants five to six years after planting.

Depth of planting is also critical. Because blueberry plants possess fine, somewhat delicate root systems, planting too deep or not deep enough may cause root damage, resulting in poor plant growth and reduced plant longevity. Setting plants at the same depth they were in the container or nursebed produces the best results.

Pollination

Bees pollinate blueberries. Most of the cultivars listed in Table 1 do not require cross-pollination; however, 'St. Cloud' and 'Polaris' require a second cultivar for pollination. Even for those cultivars which do not require a second cultivar to set fruit, cross-pollination between different cultivars results in larger berries and earlier ripening. In mixed plantings, alternate cultivars every 4 rows or every 4 to 5 plants in the row. In many instances, wild bees will be present in sufficient numbers to pollinate the flowers. However, it's a good idea to bring in hives of bees to ensure adequate pollination. Large acreages will require one hive of honeybees per acre. Bumblebees, although more expensive, are more effective pollinators, and should be used when available.

Cultivation

Do not cultivate more than two inches deep, since most blueberry roots are in the top six inches of soil, especially in young plants. To reduce root injury due to cultivation, a mulch within the row or a perennial rye or red fescue ground cover between the rows can be used to keep weeds down. Mulching two to four inches deep and one to two feet around blueberry plants increases plant growth and yield by insulating roots from high temperatures, increasing organic matter, and retaining moisture. Mulching also helps control weeds. Peat moss, shredded leaves, straw, wood chips, or sawdust can be used. When using sawdust, double the nitrogen application or add two pounds of ammonium sulfate per 100 pounds of mulch. Softwood sawdust should be aged a year before application. When applying mulch, always keep the mulch a few inches away from the base of the plant. Rodent bait placed under the mulch may be necessary, since the mulch may provide suitable habitat for these pests.

Pruining

In new plantings, prune off flower buds and weak, spindly growth, leaving enough vegetative growth to support future crops. Plants should not be allowed to bear fruit the first two years after planting: if flowers develop, they should be removed. After two seasons, allow a crop to develop.

In subsequent years, pruning encourages production of large, high-quality fruit. Fruit is produced from lateral buds on two, three and four year old canes. Blueberries should be managed so that plants are made up primarily of this bearing-age wood. Pruning increases berry size and encourages earlier blooming. Plants should be pruned in late winter while they are dormant, before buds swell.

Prune mature (five years or older) plants to remove diseased and dead wood, old canes, soft basal fall growth, twiggy growth clusters, and weak lateral shoots. Remove canes five years and older each year. Pruning cuts should be to the ground or to a low-growing lateral. Allow one to three new canes to develop each year.

Fertilization

Base initial fertilizer use on the soil analysis made before planting. For established plantings, leaf analysis (discussed later), soil analysis, and observation of plant vigor indicate fertilizer needs. Avoid excessive fertilizer application, particularly on new plantings, as blueberries are very susceptible to salt injury. Fertilizer application is often necessary to provide optimum level and balance of nutrients for plant growth; however, fertilizer cannot correct severe damage due to winter injury or make up for poor site selection or cultural practices.

Of all the essential elements, nitrogen usually gives blueberries the greatest growth response. Nitrogen fertilizer requirements increase as the plant grows older and yields increase (Table 4). Nitrogen fertilizers in the ammonium form (for example, ammonium sulfate, urea) leave acid residues and are most suitable for blueberries growing on a soil with a pH greater than 4.8. Blueberries on soils with a pH less than 4.8 have responded well to ammonium nitrate fertilizer. Fertilizer containing nitrogen only in the nitrate form increases soil pH and should be avoided.

For new plantings, nitrogen should be sidedressed when the second flush of growth starts. For established plantings, nitrogen should be applied in spring. Blueberries on very sandy soils may benefit from split nitrogen applications--half the recommended rate in spring at bud break and the remainder at petal fall. Applications after July first may increase the potential for winter injury. If manure is used, reduce N fertilizer applications by about five pounds nitrogen per acre for each ton of manure applied.

When soil test results indicate a need, potassium should be applied as potassium sulfate (0-0-50) or potassium-magnesium sulfate (such as Sul-Po-Mag), and phosphorus as superphosphate or triple

superphosphate. Use potassium-magnesium sulfate if soil magnesium is low. Potassium chloride (0-0-60) should be avoided as high rates are detrimental to blueberry growth. Refer to Tables 5 and 6 for phosphorus and potassium recommendations.

Table 5. Phosphorus recommendations for blueberries[1]

phosphorus (P) soil test results (PPM)[2]	**amount of phosphate (P_2O_5) to apply (lb./acre)**
0-10	100
11-20	50
21-30	25
30+	0

[1]Recommended rates are for new and one-year old plantings. Base subsequent P fertilizer applications on leaf analysis as well as soil tests.

[2]Parts per million.

Table 6. Potassium recommendations for blueberries[1]

potassium (K) soil test results (PPM)	**amount of potash (K_20) to apply (lb./acre)**
0-25	150
26-50	100
51-75	50
76-100	25
100+	0

[1]Recommended rates are for new and one-year-old plantings. Base subsequent K fertilizer applications on leaf analysis as well as soil tests.

If soil test magnesium level is less than 50 parts per million, magnesium-containing fertilizer (potassium-magnesium sulfate or Epsom salts) should be applied. For new plantings, phosphorus, potassium, and magnesium should be applied and incorporated the year prior to planting. For established plantings, applications can be sidedressed in spring.

Nutrient- and water-absorbing roots extend out about as far as the branches of blueberry plants. Apply fertilizer in a broad band, followed by irrigation. To reduce the chances of salt injury (characterized by browning of leaf tips and margins), do not apply excessive amounts of fertilizer, avoid concentrating fertilizer near the crown of the plant, and distribute fertilizer evenly within the root zone.

Healthy, mature plants should produce several whips near ground level, laterals from four to six inches long, and up to 20 leaves per shoot. Poor vigor and leaf discoloration often indicate lack of fertilizer. These symptoms can also result from other conditions such as soil compaction, poor drainage, insects, disease,

drought,or fertilizer burn. All of these will weaken the root system of the plant. Table 7 shows the nutrient deficiency symptoms frequently found in blueberries.

Table 7. Common nutrient deficiencies in blueberries and suggested treatments

Deficient nutrient	Symptoms	Treatment
Nitrogen	Stunted growth; yellowing of older leaves followed by reddening and death of leaves.	Apply notrogen fertilizer in the form of ammonium sulfate
Iron	Interveinal chlorosis (yellowing between leaf veins), affects youngest leaves first; stunted basal growth.	Adjust soil to proper pH and use ammonium sulfate as the nitrogen source. For temporary treatment, spray foliage or treat soil with iron chelate (10% iron). **Foliar application:** use 1 lb. in 100 gallons water, spray to thoroughly cover plants. **Soil application:** 1/2 to 1lb. per 100 feet of row.
Potassium	Death of the terminal growing tip; scorching of the margins of the older leaves	Apply potassium sulfate or potassium-magnesium sulfate according to soil recommendations
Magnesium	Pale green between leaf veins and on the margins of lower leaves of very vigorous shoots; symptoms lower leaves begin at berry ripening.	Apply magnesium sulfate (Epsom salts) to the soil at a rate of about 70 lb./acre

Leaf analysis

When used properly, leaf analysis provides a valuable tool in determining fertilizer needs for established blueberry plantings. However, because many factors affect the nutrient composition of leaves, the exact causes for high or low leaf nutrient levels may not be apparent based on leaf analysis alone. Soil moisture, soil structure, native soil fertility/pH, and fertilizer practices all have direct effects on nutrient uptake. Crop load, cultivar, and cultural practices such as weed control and pruning can also alter leaf nutrient composition. Whenever possible, consider these factors when interpreting leaf analysis results.

Leaf analysis is used because maximum yields have been associated with optimum ranges of nutrients in the leaf. If the level of a nutrient falls outside this range, corrective measures should be taken. Table 8 shows nutrient concentrations for each element in blueberry leaves considered to indicate deficient, optimum, or excessive conditions.

Table 8. Foliar nutrient levels in established blueberry plants sampled during initial harvest

Nutrient	Deficient (below)	Optimum (within)	Excessive (above)
	in percent:		
Nitrogen	1.60	1.70-2.10	2.20
Phosphorus	0.08	0.10-0.40	0.80

Nutrient	Deficient (below)	Optimum (within)	Excessive (above)
Potassium	0.30	0.35-0.70	0.95
Calcium	0.20	0.35-0.80	1.00
Magnesium	0.09	0.12-0.25	0.45
Sulfur	0.10	0.12-0.30	N/A
	in parts per million:		
Iron	60	70-200	400
Manganese	25	50-600	700
Zinc	8	9-30	80
Copper	4	5-20	100
Boron	20	25-70	200

Optimum nutrient ranges in the leaves are based on samples collected at a particular growth and leaf stage maturity. Leaves sampled too early or late in the season may not be interpreted accurately using the values listed in Table 8. Obtaining a representative sample at the proper growth stage is important to avoid erroneous interpretations. The following instructions should be used as a guide for proper sampling procedures.

Leaf samples should be collected just prior to harvest or during the first week of harvest (July 1 – July 20).

At least ten plants should be sampled. Plants should be of the same age and cultivar, growing on a relatively uniform soil of the same fertility. Plants not typical of the planting should be avoided.

The most recently matured leaf from fruiting shoots should be selected. This usually corresponds to the fourth to sixth leaf from the shoot tip. Collect a total of 50 leaves from ten plants (about five leaves per plant). Leaves showing insect, disease, or mechanical damage should not be sampled. Leaves that show symptoms thought to be nutritional should be compared with leaves from healthy plants.

If leaves are dirty or dusty, rinse two or three times in deionized water. Do not let the leaves soak in the water as the nutrients can leach out. Dried leaves should not be rinsed. Place rinsed leaves in a clean perforated paper bag and dry at room temperature. Do not use plastic bags unless the samples have been previously dried.

Contact your county Extension office or local nursery dealer for information about tissue testing laboratories in your area.

Irrigation

Blueberry plants on well-drained, sandy soils will require frequent, light supplemental irrigation since the roots are fibrous and shallow, usually less than 18 inches deep. Reddened foliage, wilting, browning leaf margins, thin, weak shoots, early defoliation, and decreased fruit set are often symptoms of inadequate moisture. Research at Staples, MN on sandy soils showed that average fruit size for well irrigated

treatments during four seasons (1996-1999) was 18% larger than the dryland treatment, and total yield 69% greater.

Mulching plants with wood chips

Because the new root growth of young starter plants may be reduced by soil conditions that are either too dry or too wet, and because plants may wilt quickly in hot, dry weather until established, soil moisture content should not be allowed to become excessively dry. Addition of a surface mulch will help reduce the frequency of irrigations while protecting the young roots from excessive water evaporation and increased soil temperature during hot days. A rain gauge with a two-inch or greater diameter should be set up in the blueberry planting to track daily precipitation amounts.

It's a good idea to monitor soil moisture and only allow the soil to dry to 30 to 50 centibars of soil water tension in the active root zone between irrigations. Soil water tension describes how tightly water is held to the soil particles, and how difficult it is for roots to extract water from the soil. Tension is usually expressed in centibars and can be used to estimate the amount of soil water depletion in the soil profile. Table 9 shows estimated soil water deficits (inches of water) per foot of soil for several soil water tension levels and soil texture groups.

Table 9. Soil water deficit estimates for several soil textures and soil water tensions.

Soil texture	**Soil water tension in centibars (cbs)**						
	10	30	50	70	100	200	1500*
	soil water deficit - inches of water lost per foot of soil						
Coarse sand	0	0.1	0.2	0.3	0.4	0.6	0.7
Fine sand	0	0.3	0.4	0.6	0.7	0.9	1.1
Loamy sand	0	0.4	0.5	0.8	0.9	1.1	1.4
Sandy loam	0	0.5	0.7	0.9	1.0	1.3	1.7
Loam	0	0.2	0.5	0.8	1.0	1.6	2.4
*1500 cbs is the permanent wilting point, at which the soil deficit equals the soil's available water capacity (all available water has been lost).							

Soil water tension is best monitored by tensiometers or by electrical resistance sensors placed in the active root zone of two or three plants.

Devices for measuring soil water

Tensiometers directly measure soil water tension between 0 and 80 centibars, and work best in sandy loam or lighter textured soil. Tensiometers should be installed in the spring and must be removed before the soil freezes. Resistance sensors work in a wider range of soil water tensions and soil textures. Some, such as the Watermark granular matrix sensor, operate as well as a tensiometer in sandy soils and can be left in the soil year-round for several years. For additional information on sensors and their availability, contact your local irrigation supplier or seek out a mail order product catalog.

The soil water depletion in the rooting zone can also be estimated by using a soil probe and observing the appearance and feel of the soil. This method, however, can damage a plant's root system, if the same plant is probed each time.

Reading sensors every 1-2 days helps to keep track of soil water status

Another method to schedule irrigations for fully grown plants is the use of a open evaporation pan such as a small wash tub (20-30 inches in diameter and 10-15 inches deep). At Staples, MN a wash tub has been used for several years by University of Minnesota researchers to schedule trickle irrigation on blueberries by using the following strategy: when one inch of water has evaporated from the tub, the trickle system is operated to apply one-half inch of water. Then the wash tub is refilled with water back up to the starting point and observed until another one inch of water has been lost to the air. The tub is pierced with three quarter-inch holes around its perimeter at the fill level to allow excess water (from rainfall or overfilling) to leak out.

More information on scheduling tools is found in Bulletin FO-3875, "Irrigation Water Management Considerations for Sandy Soils in Minnesota," which can be seen on-line at or purchased from your county extension office.

Using a wash tub to schedule irrigations

Once mature plants are fully leafed out in spring, they require between .75 and 1.75 inches of water per week, depending on climatic conditions, throughout the growing season and the harvest period, to maximize berry size, quality and yield. Irrigation should continue during late summer and early fall when the fruit buds for the next year's crop are developing. Field experience suggests that between fruit sizing and late summer growth, soil moisture content in the top foot of soil should be maintained between field capacity and a soil water deficit of 30 to 40 percent (on sandy soils, a soil tension of 40 to 60 centibars).

Blueberries may be effectively irrigated by either sprinkler or trickle irrigation systems. Portable sprinkler systems such as single hand-moved lateral, solid-set, or traveling gun are cost effective and are most commonly used. Solid-set overhead sprinklers should be used if frost protection is desired during spring bloom. Layout and design criteria for sprinkler systems is discussed in the handbook #MWPS-30, Sprinkler Irrigation Systems, available for $20.00 through the University of Minnesota Department of Biosystems and Agricultural Engineering: (612) 625-9733 or www.bae.umn.edu/extens/mwps/index.html.

Overhead irrigation

Trickle or drip irrigation can also be used to apply supplemental water to the blueberry plant. Trickle systems deliver water under low pressure through small-orifice emitters regularly spaced on a plastic tube located installed either above or below ground along each plant row. In this method, water is applied only within the rooting area. Since only the row area is wetted, foliage remains dry during irrigation, and weed development between rows is reduced.

Overhead irrigation for frost protection

Emitters of some trickle products can become clogged by substances in the irrigation water. Filters must be used to remove suspended particles such as sand and silt. Chemical water treatment may also be necessary to help prevent clogging caused by algae, iron bacteria or mineral precipitation, such as calcium carbonate from the water supply.

Trickle irrigation tubing

Layout and design criteria for trickle irrigation systems is discussed in the handbook #NRAES-30, "Trickle Irrigation Systems," available for $6.00 through the University of Minnesota Department of Biosystems and Agricultural Engineering: (612) 625-9733 or bae.umn.edu/extens/mwps/index.html.

Soil moisture sensor installation

1. Prior to placing sensors in the field, cycle each sensor in clean water for one to two hours to remove air and then allow to dry for four to six hours. Repeat this step two times more. Prior to placing sensors into the soil, soak for at least five minutes. If the sensors were used in a previous season, evaluate for damage to the wire leads or the sensor surface and discard the sensor if surface appears plugged with soil or damaged.
2. Select two or more random plants in the planting for the sensors. If the planting contains trickle irrigation zones, consider selecting one or two plants in each zone to host the soil moisture sensors. All sensors should be located in a representative soil type in the field. Each sensor should be positioned within the plant row near a healthy plant in a location with a normal plant population. One sensor should be set four to six inches below the ground surface and the other nine to 12 inches below the surface.

Proper sensor positioning

3. To install a sensor in the soil, first make a hole with a soil probe or shovel to a depth a little deeper than desired in the active rooting zone. If irrigated by trickle tubing, the sensors should also be located about five to seven inches from an emitter/dripper. When covering up the sensor, to get good sensor contact with the soil, pour a little dry soil and water into the new hole. Then position the sensor in the hole at the desired depth. Fill the hole by adding a little dry soil and a little water at a time and firming the soil with each addition until the hole is filled.

Mark sensors with a flag or stake

4. Mark each sensor site with a colored flag or stake to locate the site easily. Wrap the extra lead wire around the stake. Mark each sensor's wire lead to indicate its depth with a tag or by tying knots near the wire's end to indicate depth, for example, one knot might mean a shallow and two knots a deep sensor).

Read and record results often

5. Start taking readings one or two days after installation to allow the added water to become equalized in the soil. Sensors should be read every two to three days and values recorded in a notebook or spreadsheet to track the soil water changes throughout the growing season.
6. Initiate an irrigation on sandy loam soils whenever the average of the shallow sensors reaches a desired level, such as 30 to 50 cbs. If the lower sensors do not show less tension after the irrigation event, apply a little more water the next time. If the soil is of a very light texture, it may be necessary to start the irrigation system at a lower soil tension to avoid stress to the plants.
7. Sensors should be removed before soil freezes up unless the manufacturer's literature states that they can remain in the soil year-round without damage from freezing. If removed annually, clean soil from sensor surfaces using only water pressure and hang up to dry for use next year.

Weed management

Prevent weed growth around blueberry crowns by mulching, cultivating, or applying herbicides labeled for use on blueberries. Cultivate shallowly to avoid damaging the delicate root systems. When mulching, apply three to four inches of an organic mulch such as shredded bark or wood chips in the row (see 'Cultivation' section above).

Birds

Birds can be a serious pest of blueberry fruit. Robins, starlings, blackbirds, and other species can cause physical damage to the plant and economic loss to the grower. Fruit loss may be well over 50 percent of the crop and is generally more severe in smaller plantings or in more wooded locations. Bird control measures currently fall into two categories: scare devices and physical barriers.

Scare devices include noise and visual stimuli. Propane-powered cannons produce a bang resembling a loud shotgun blast. A timer can regulate the frequency of detonations. Another noise scare system is designed to disperse birds by playback of recorded distress calls and other amplified sounds. Visual scare devices such as imitation bird predators, specially designed balloons, and flashing ribbon have all been used to disrupt bird activity. Such visual devices may need to be frequently relocated to maintain their effect. Birds habituate to scare devices over time, making such devices short-term solutions during an average season.

Protective netting is probably the best option for keeping birds from the fruit. The netting is placed over the plants as the berries begin to ripen and removed after harvest. Smaller diameter (quarter- to half-inch) nettings have two benefits, in that they pull fewer berries off the plant when the netting is removed for picking, and, as noted below, provide significant winter protection in years with light snowfall. Netting may also be placed over a frame above the plants. In either case, the netting must be secure around the edges to prevent birds from getting underneath.

Rabbits and deer may also damage blueberry plantings. Consult your county Extension office or area DNR office for appropriate control methods.

Winter protection

Winter injury can occur to half-high blueberries when temperatures reach -25 degrees F to -30 degrees F, if the plants are not protected. Prolonged cold increases the likelihood of injury. Winter wind desiccation can also damage plants, and blueberries are susceptible to sunscald injury in late winter. Typically, winter injury occurs to shoot tissue, resulting in stem dieback and crop loss. Normally plants recover by sending out new shoots but may require considerable pruning of dead shoot tissue. Crop production will be poor the summer after the injury occurs, but usually returns to normal the following season.

Recent studies have suggested that half-high blueberry plantings in northern regions benefit from use of a winter protection system in years when snow cover of at least 12 inches deep is not present. (Often, deep snow provides adequate protection, and many growers rely on snow cover.) A winter protection system provides a warmer environment than ambient air temperature in mid-winter, prevents wind desiccation and sunscald, and moderates air temperature fluctuations in late winter and early spring, resulting in less dieback of branches and improved survival of fruit buds. In a year of light snowfall, use of a winter protection system has the potential to double fruit yields.

Materials which provide significant winter protection include spunbonded polyester fabrics such as ReemayÂ® and Kimberly Farms Tree and Row CoversÂ® and quarter- to half-inch bird netting. Bird netting has the added advantage of being useful during both the growing and winter seasons, thus increasing its cost effectiveness. Bird netting can be used for several season, whereas row covers usually can be used for one season only because the fabric tears. Winter row covers that cover several rows at a time require less time and labor to apply. Winter protection materials should be applied in late fall before significant snowfall occurs and removed in early spring before bud break.

Additional winter protection strategies include selecting a site where snow fills in deeply, planting of windbreaks and shelterbelts, erecting a snow fence to catch snow, and utilizing long, narrow plantings oriented to catch maximum snow fall.

Harvesting

The harvest season for half-high blueberries extends for two to five weeks, depending on the weather, crop size, and plant vigor. Healthy, vigorous plants or plants with small crops will usually ripen most fruit in two weeks or less. Plants which are heavily fruiting, stressed, or low in vigor will take three or four weeks to ripen fruit. Selective pruning can be used to avoid overcropping and maintain plant vigor. Planting more than one cultivar can extend the harvest season.

The blueberry fruit turns blue before it is fully ripe. The acid level continues to fall for three to seven days after the fruit turns blue. The underside of the berry (the pedicel end) will turn from pink to full blue when it is fully ripe. Growers usually allow 20 to 30 percent of the crop to ripen before beginning harvest to avoid picking too much unripe fruit.

Pickers should harvest only fully blue fruit. The berries do not ripen evenly on the cluster, so it is important to recognize and pick only the fully ripe berries. Pick only when dry, and keep handling to a minimum to preserve the whitish, waxy surface bloom of the berry which protects it from fruit molds. Cool blueberries promptly and store between 32 degrees F and 40 degrees F.

A mature planting (over six years old) may produce 1,000 to 2,000 pounds per acre each week during a two - to five-week harvest period. A pick-your-own operation where each customer takes home an average of ten pounds may require 100 to 200 pickers per acre each week.

Pest management

Several insect pests and diseases attack blueberry plants and fruit, but good cultural practices will help prevent these problems. In fact, half-high blueberries are often grown commercially without any pesticide sprays. Proper planting site selection, aggressive pre-establishment weed control, amendment of soil to achieve favorable conditions, and a focus on maintaining plant health can make fungicides and insecticides unnecessary.

Prune to remove diseased, broken, and insect-infested branches and to increase air circulation around the plant. Control weeds that may harbor insects, and keep plant debris, including overripe fruit, from accumulating on the soil surface. Light tillage to incorporate fallen fruit, leaves, and twigs, or adding mulch around the plants, should help keep fungal spores covered and prevent infection.

Insects and diseases of blueberries are listed below; those that are common in Minnesota and Wisconsin are marked with an asterisk. Many generalist pests, such as plum curculio and Botrytis, are pests of blueberries. Other insects may also be important in your area. In response to an insect infestation or an outbreak of disease, a chemical spray program may be needed.

Since pesticides are routinely reviewed for safety, and some are then withdrawn for specific crops, it is essential to read the pesticide label and follow the instructions as a final authority on pesticide use. Federal law requires you to use pesticides in accordance with their labels.

Consult one of the following sources for current pesticide recommendations: *Midwest Small Fruit Pest Management Handbook* (Ohio State); *Organic Blueberry Production* (Appropriate Technology Transfer to Rural Areas, a federal program); *Fruit Spraying Calendar 2000,* Bulletin E-154 (Michigan State).

Fungal diseases

Insects and diseases of blueberries are listed below; those that are common in Minnesota and Wisconsin are marked with an asterisk.

Anthracnose, most often a postharvest fruit rot, can also be found on young twigs. The orange fungal spores of *Gloeosporium* are spread by rain and wind, and overwinter in diseased twigs and fruit.

***Botrytis Blight** (gray mold) attacks ripening fruit, twigs, blossoms, and foliage. The fungus (*Botrytis cinerea*) causes rotting of ripening fruit and produces gray-brown structures on infected tissues. The most critical period for infection is during bloom. The fungus, which overwinters in organic matter and twigs on the ground, is present every year, but causes serious losses mainly when cool, damp weather persists for several days during bloom and spring shoot growth. Cultural control methods include encouraging air circulation by proper pruning and avoiding overfertilization, which encourages growth of highly susceptible succulent tissue. Frost injury to blossoms (and leaves) will increase susceptibility to infection.

Mummy Berry (*Monilinia vaccinii-corymbosi*), a serious fungal disease, first appears on the shoots, causing them to curl up, blacken, and die. Blossom infection appears on ripening berries. The fruit turns light pink instead of blue, shrivels, hardens, and falls to the ground. The fungus overwinters in the berry and becomes active the following spring.

***Phytopthora Root Rot** is a fungal disease caused by *Phytophthora cinnamomi*, which may be identified by sudden wilting of the plant without apparent reason. Additionally, gently tugging the plant may remove it almost entirely; examination of the root system may reveal dark brown or black root color or general deterioration of the root system. Infected plants may exhibit weak growth and low vigor. To prevent Phytopthera , avoid low areas, where drainage is poor, and heavy, compacted soils. A fungicide drench may be useful in sites where plant vigor and development may have been poor.

***Powdery Mildew** (*Microsphaeria alnia var. vacinii*) is a white fungus which spreads over the upper surfaces of the leaves. It may cause leaves to become chlorotic and defoliate prematurely.

***Stem Cankers** are caused by two fungi, *Fusicoccum putrefaciens* and *Phomopsis vaccinii*. The infection usually on younger stems starts as a small reddish spot on the canes. As the spots grow they gradually girdle the stem, causing it to wilt and die suddenly. This occurs during periods of dry, warm weather, and may be confused with drought symptoms. These fungi overwinter on infected twigs and stems. Infected canes should be cut out well below the infected area and burned.

Fusicoccum Canker is found on current season shoots as well as 1 and 2 year old stems. The lesion first is a small red area on the stem and develops into an elliptical, brownish-purple lesion several inches long. In mature lesions you may see black fungal fruiting structures called pycnidia.

Phomopsis Canker is also found on one-, two-, and three-year old stems. On older stems the canker area feels flat and pycnidia are also present. Young cankers on current year stems may be only one to two inches long and red to brown. Stems infected the past year will wilt and die during dry periods the next year. Winter injury, frost, and mechanical breaking of twigs create infection entry points.

Bacterial disease

***Crown gall**, caused by Agrobacterium tumefaciens, enters roots through wounds. The bacteria causes the plant to develop galls or swellings on roots and lower stems. Infected plants are weaker and often may be stunted. Severely infected plants should be removed and destroyed.

Viral diseases

Red Ringspot Virus causes red spots with rings on the upper surface of leaves. It first appears on older leaves, and may cause red blotches on the stem. Cultural control methods include destroying infected plants, controlling sucking insects such as leafhoppers that transmit the virus, and planting virus-free plants.

Shoestring Virus causes reddish streaks of varying lengths on new shoots in spring, especially on surfaces facing the sun. Affected leaves, often at the base of the plant and on shoots left during pruning, are narrow and pointed or straplike, and may appear reddish. Ripe berries are often pink instead of blue, and production is drastically reduced. As with other viruses, symptoms appear gradually and the plant lives in a

state of reduced vigor for several years. Cultural control methods include removing and burning infected plants, controlling aphids that transmit the virus, and planting virus-free plants.

Stunt Virus causes yellowing of leaf margins and areas between lateral veins and development of smaller, cupped leaves. Often there is a proliferation of lateral shoots on infected branches. Diseased plants will live for many years, gradually declining in vigor. Cultural control methods are the same as for red ringspot virus.

Insects

Blueberry Blossom Weevil chews on the developing blossoms, causing them to turn purple, remain unopened, and drop. It may also feed on the leaves. Cultural control includes clean cultivation of the blueberry field and surrounding areas where the weevil may overwinter.

***Blueberry Leafminer** is both a leafminer and leafroller. It forms a triangular tent and feeds within it. Blueberries can sustain high populations of these insects before production is reduced.

***Blueberry Maggot** is probably the most serious insect pest of cultivated blueberries. The eggs are laid under the skin of the berry, and the maggot stays in the ripe berry. Clean harvest and prompt picking aid in its control, as immature insects are removed from the field in the harvested fruit.

Blueberry Stem Borer feeds on the inside of the cane and induces wilting of the tip. It can be controlled by cutting off wilted tips below evidence of insect work.

Cherry Fruitworm feeds on the developing berries. Prune out dead twigs, where these insects overwinter, and use clean cultivation to help control this pest.

Cranberry Fruitworm feeds on the developing berries. The larvae spin webs around the berry cluster. Clean cultivation aids in its control.

***Cranberry Rootworms** are only a problem in fields not thoroughly prepared before planting. Fields should lie fallow at least one year between blueberry plantings, with repeated disking in hot weather to destroy all roots. If wood chips used for mulch contain root chips, there is a chance that cranberry rootworm could be introduced on the mulch.

***Oblique-banded Leafroller** can move from apple to blueberry where the larvae form a characteristically webbed leaf. Although damage can occur as severe defoliation, especially on 'Northsky' or 'Northcountry,' it is rarely severe enough to warrant chemical control.

***Plum Curculio** feeds on both leaves and blossoms, and later on berries. It is most troublesome in poorly cultivated and mulched fields. Clean cultivation can provide good control.

***White grubs** may be a problem in the first two or three years after planting, if a blueberry field is established in sod.

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