The image features a 2x3 grid of punnets. The left column contains three punnets of ripe, red raspberries. The right column contains three punnets of ripe, black blackberries. The punnets are made of light-colored, fibrous material. A red rectangular box is overlaid on the top-right punnet, containing the title text. Another red rectangular box is overlaid on the bottom-right punnet, containing the logo text.

Southeast
Regional Caneberry
Production Guide

NC STATE
EXTENSION

SOUTHEAST REGIONAL CANEBERRY PRODUCTION GUIDE

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The use of brand names and any mention or listing of commercial products or services in this publication does not imply endorsement by the Southern Region Small Fruit Consortium nor discrimination against similar products or services not mentioned.

Recommendations of specific caneberry production practices and cultivars are based primarily on research and grower experiences in North Carolina, South Carolina, Georgia, Arkansas, and Tennessee. Due to variability in environmental conditions in the southern United States, growers in other states should be sure to obtain current information about caneberry production practices and varieties from their state or local Cooperative Extension centers.

Cover photo of raspberries and blackberries by theflashbulb/Bigstockphoto.com.

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1. Introduction

The caneberry (blackberry and raspberry) industry has undergone a significant change in the southern United States in the past decade. Two factors have contributed to the phenomenal growth of this industry in the region: The development of shipping-quality, fresh market blackberry cultivars and the recognition of health benefits associated with eating berries. Since the late 1990s, the acreage devoted to caneberries has increased throughout the southern United States in all grower categories:

- small-scale (less than 3-acre farms) for local and pick-your-own (PYO) sales
- medium-scale (commercial local sales and PYO)
- large-scale (farms of 5 to 10 or more acres that produce fruits for wholesale marketing)

In addition, the development of raspberry cultivars from US and international breeding programs has prompted growers to investigate the possibility of local and commercial raspberry production in new regions, particularly at high elevations, using high tunnels and other seasonal-extension techniques.

This guide was created to provide growers information on plant growth and basic production practices. Pest management for caneberry growing in the southern United States is available in the *Southeast Regional Caneberries Integrated Management Guide*, available at the Southern Region Small Fruits Consortium's IPM/Production Guides web page (www.smallfruits.org/SmallFruitsRegGuide/index.htm). The pest management guide is updated regularly to provide the most up-to-date crop protectant information for growers in the southern United States.

Types of Caneberries

Caneberries are grouped by four plant characteristics:

- growth habit (trailing, semi-erect, or erect)
- fruiting habit (primocane or florican)
- presence or absence of thorns (thorny or thornless)
- fruit color (raspberries only)

Growth Habit

There are three main types of growth habits: *trailing*, *erect*, and *semi-erect* (Figure 1). These habits refer specifically to cane growth habit.

Canes of *trailing* caneberries run along the ground. Trailing blackberries, often referred to as "dewberries" have prostrate canes that tend to produce fruit that are large, early-ripening, and some say are highly flavored. Though trailing raspberry varieties do exist, they are not readily available.

Erect caneberries produce stiff, upright canes that need summer and winter pruning. The erect growth habit is common in both raspberries and fresh market blackberries.

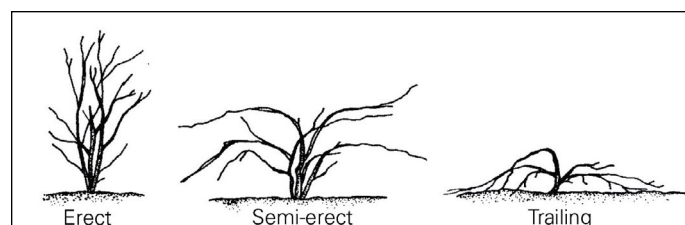


Figure 1. Caneberries have varying growth habits, from erect types to more trailing types, which determine the type of trellising system needed. Most commercial varieties have an erect growth habit.

Semi-erect caneberries produce very thick, arching canes that benefit from summer and winter pruning. These varieties will start growing upright and bend over to trail along the ground if not supported. Black raspberries tend to be semi-erect and will tip root if not pruned adequately, limiting fruit production on said canes.

Growth habit determines the type of trellis support the canes require. In some regions, erect types of both raspberries and blackberries do not require trellis support. In the southern United States, however, blackberries and raspberries benefit from a trellis for commercial production. Support becomes essential once laterals begin producing fruit. Without adequate trellising, laterals or entire canes can snap under the weight of fruit load due to windy conditions or while being picked. Fruit may also touch the ground if not trellised, which may result in the loss of saleable fruit.

Fruiting Habit

Though caneberries are perennial plants, canes of blackberries and raspberries are biennial—that is, they have two-year life cycles (see Table 1, Figure 2, and Figure 3). Most blackberry and some raspberry cultivars are *floricane-fruiting*, meaning they will bear a crop in their second year of life and in subsequent years.

The first year of a cane’s growth is referred to as the *primocane* year. During this year, the cane will grow and initiate fruit buds in the latter part of summer to early fall.

During the second year of growth, known as the *floricane* year, primocanes from the first year are now the floricanes, which will bloom and produce fruit on short laterals arising from axillary buds. Following fruiting, the floricanes will die back to the crown.

Both primocanes and floricanes will exist in the planting starting in the second year and every year thereafter. The planting will produce a full crop in the third year.

Several cultivars of red and yellow raspberries and some blackberries will bear fruit in the upper portions of the primocanes during the cane’s first year of

growth. These cultivars are referred to as “primocane-fruiting,” “everbearing,” or “fall-bearing.” The upper one-third to one-half of the primocane will bear fruit beginning in late summer and continue producing into fall. If the cane is retained for the floricane year, fruiting will occur on the part of the cane that did not fruit in the fall.

Table 1. Characteristics of the Two Caneberry Fruiting Types.

Floricane-Fruiting	Primocane-Fruiting
<i>First Year</i>	
Vegetative growth of cane	Bear fruit in upper third to half of cane in late summer and fall Fruiting portion of cane dies in fall
<i>Second Year</i>	
Flowering and fruiting Cane death	Lower portions of cane fruits Entire cane dies after fruiting
<i>Common Cultivars</i>	
Most cultivars of blackberries, black and purple raspberries, some red and yellow raspberries.	Some red and yellow raspberries, some new blackberry varieties.



Figure 2. Primocane leaves have five leaflets. In the spring and early summer, primocane foliage is usually succulent and bright green. Photo: Gina Fernandez, NC State University.



Figure 3. Floricane leaves have three leaflets. Leaves are small and darker than primocane leaves. Left: Note the presence of fruit in the axils of the leaves. Right: Floricane leaflet from a basal bud with leaflets and flower buds. The appearance of the leaves are similar to young primocane leaves, but these are floricane leaves.

Thorniness

Thorny and thornless cultivars are available for both primocane- and floricane-fruiting types of caneberrries. Most commercial blackberry growers in the South plant thornless cultivars because they are easier to manage. Most raspberry cultivars adapted to the southern United States have thorns, but the thorns are not as large as blackberry thorns and are not a significant impediment during harvest or when pruning.

Fruit Color (Raspberries)

Raspberries can produce red, yellow, purple, or black fruits (Figure 4). Red raspberries are by far the most common type and, in general, the most widely adapted for commercial production. Yellow and purple raspberries are not recommended for commercial production because available cultivars are highly perishable and do not produce high yields. Black raspberries do well in cooler parts of the region.



Figure 4. Raspberry fruit color and shape can vary from cultivar to cultivar. Colors range from yellow to red and even black. Photo: Absalom Shank, NC State University.

2. Cultivars

Early-season blackberries and floricane-fruiting raspberries ripen shortly after strawberries, making them ideal crops to extend the berry harvest season. Within this region, yields and adaptation will vary based on site. Harvest season will vary by state as well. For example, early-ripening blackberry cultivars will be harvested two to four weeks earlier in southern Georgia than in North Carolina. Size and shape of blackberry cultivars vary (Figure 5). More information on many of the blackberry cultivars listed below can also be found online at www.uaex.edu/farm-ranch/crops-commercial-horticulture/horticulture/fruits.aspx. The recommendations in Table 2 and Table 3 are based on research trials and grower experience throughout the southern United States.

Each year, new caneberry cultivars are released from various breeding programs around the world. It is best to perform small trials of new cultivars to determine whether they perform well in your area and fit into your marketing plan.

John Clark, a blackberry breeder at the University of Arkansas, has produced a number of videos that discuss the characteristics of blackberries released from his program. You can find a few of them at the URLs listed here:

- Prime-Ark Traveler: youtu.be/KTviS-YcoQY
- Prime-Ark 45: youtu.be/7Yq1gFeuzAM?list=PL5J-4aWCkaaEerH8afcmoufULeYvIW5dH
- Osage: youtu.be/EXu0_TcxGUK?list=PL5J-4aWCkaaEerH8afcmoufULeYvIW5dH
- Ouachita: youtu.be/RHG9-eLOriE?list=PL5J-4aWCkaaEerH8afcmoufULeYvIW5dH

Blackberries perform well throughout most regions of the states that are a part of the Southern Region Small Fruit Consortium. Most of the common cultivars



Figure 5. Blackberry fruit from thornless blackberry varieties. Fruit from many of these cultivars vary in size and flavor. Photo: Absalom Shank, NC State University.

have a moderate chilling requirement and tolerate the hot summer climates. Where low chilling occurs, such as southern GA, some blackberries do not perform as well. Consult your local extension service for recommendations.

Although raspberries can be grown in some regions of the South, exposure to high temperatures common in the South for extended periods will slowly weaken plant growth from year to year. Fruit perishability also increases greatly with high temperatures during harvest. In general, raspberries produce well at elevations above 2,000 feet. However, our research has shown that raspberries for local markets can be produced at lower elevations and under high tunnels in some regions, such as the western piedmont of North Carolina.

Table 2. Recommended Blackberry Cultivars for North Carolina (NC), Georgia (GA), Tennessee (TN), South Carolina (SC), Virginia (VA), and Arkansas (AR).

Variety	Growth Habit	State (region within state if applicable)								Thorns	Season	Comments
		NC	GA	TN	SC	VA	AR					
Floriscane-fruiting cultivars												
Arapaho	Erect	All	All	NR	All	All	All	All	No	Early	Lower yields; plant at higher density	
Natchez	Erect	All	Trial	Trial	Trial	Trial	Trial	All	No	Early (slightly before or with Arapaho)	Very large fruit; very high yield; tends to over produce so careful pruning is essential Winter hardiness is poor in high elevations	
Ouachita	Erect	All	All	All	All	All	All	All	No	Early to mid	Excellent flavor; high yields	
Apache	Erect	All	NR	All	All	All	All	NR	No	Mid	White drupelets can be severe; local sales only	
Osage	Erect	All	All	Trial	Trial	Trial	Trial	All	No	Mid	New cultivar with superior flavor	
Kiowa	Erect	NR	All; except high mountains	All	All	All	All	All	Yes	Mid	Low chilling; best for local sales and PYO	
Navaho	Erect	All	All	All	All	All	All	All	No	Mid to late	Stores well; excellent flavor; average size	
Von	Erect	All	Trial	Trial	Trial	Trial	Trial	Trial	No	Mid to late	Quite susceptible to orange rust; long harvest season	
Hull	Semi-erect	NR	All	All	?	All	All	?	No	Late	Holds up well in rain; high yields; average size	
Chester	Semi-erect	All	All	All	?	All	All	?	No	Very late	Good quality, but soft when ripe; local sales only	
Triple Crown	Semi-erect	All	?	All	?	All	All	?	No	Very late	Tart; average quality; very high yields	
Primocane-fruiting cultivars												
											Sweet; good yields; local sales only	

continued on page 10

Variety	Growth Habit	State (region within state if applicable)								Thorns	Season	Comments
		NC	GA	TN	SC	VA	AR					
Prime-Jan®	Erect	Floricanecrop in piedmont and coastal plain; Primocane crop in mountain only	?	?	?	?	?	?	Floricanecrop only	Yes	Very late primocane crop	Soft berries for home use only
Prime-Ark® 45	Erect	Floricanecrop in piedmont; Primocane crop in western piedmont and lower mountains	Trial	?	?	?	?	?	Floricanecrop only	Yes		Very thorny, large, nice berries for shipping.
Prime-Ark® Freedom	Erect	Trial	Trial	Trial	Trial	Trial	Trial	Trial	Trial	No	Floricanecrop very early; primocane crop earlier than Prime Ark 45	Thornless, primocane-fruiting; soft berries for home garden or local market only
Prime-Ark® Traveler	Erect	Trial	Trial	Trial	Trial	Trial	Trial	Trial	Trial	No	Floricanecrop very early; primocane crop earlier than Prime Ark 45	Thornless, primocane-fruiting; suitable for shipping

All—The cultivar is recommended for all regions of the state.

NR—Not recommended.

Trial—Not enough data; recommended for trial only.

?—No information at this time.

Table 3. Recommended Raspberry Cultivars for North Carolina (NC), Georgia (GA), Tennessee (TN), South Carolina (SC), Virginia (VA), and Arkansas (AR).

Cultivar	State/Region							Season	Comments
	NC	GA	TN	SC	VA	AR			
Floriscane-fruiting cultivars									
Mandarin	Mountains and piedmont	Mountains and piedmont	All	?	Mountains and northern piedmont	?	Early summer, before blackberries	Availability may be very limited; fruit quality inferior	
Dormanred	All	All	All	?	NR	?	Mid-summer	Attractive fruit; very low quality unless cooked	
Lauren	Mountains and western piedmont; Trial	?	?	?	?	?	?	Postharvest shelf life is poor; dark fruit; medium-large fruit; very good yield	
Moutere	Mountains and western piedmont; Trial	?	?	?	?	?	?	Attractive fruit; good yield	
Nova	Mountains and western piedmont; Trial	?	?	?	?	?	?	Shows some heat tolerance	
Primocane-fruiting cultivars									
Caroline	Mountains and western piedmont	Mountains and western piedmont; Trial	All	?	Mountains and northwestern piedmont	?	Mid-fall	Medium berries; medium red color; good quality; long season	
Heritage	Mountains and western piedmont	Mountains and western piedmont; Trial	All	?	Mountains and northwestern piedmont	?	Early fall	Small berries; medium-dark red color; late-season; average quality	
Nantahala	Mountains and western piedmont	Mountains and western piedmont	All	?	Mountains	?	Late fall	Medium berries; light red color, very good quality; excellent flavor, excellent post harvest quality	
Autumn Britten	Mountains	Mountains and western piedmont	?	?	?	?	Early fall	Large berries; dark red color	
Himbo Top	Mountains and western piedmont; Trial	?	?	?	?	?	Mid fall	Medium berries; shiny red color; long season	
Joan J	Mountains	?	?	?	?	?	Mid fall	Medium berries; darker red color	
Anne	Mountains	?	?	?	?	?	Mid fall	Medium berries; yellow berries; PYO only (very soft fruit)	

All—The cultivar is recommended for all regions of the state.

NR—Not Recommended.

Trial—Not enough data; recommended for trial only.

?—No information at this time.

3. Site Selection

General

The Southern region of the United States encompasses a range of climates, due to elevations that start at sea level and reach 3,000 feet. This wide range of climates enables growers to produce raspberries in the cooler regions and blackberries in the warmer regions from June through October. Consult Tables 2 and 3 to determine the best cultivars for your farm and marketing strategy.

Sites that are elevated above the surrounding terrain offer some natural protection from radiation frosts and disease. Frosts and fogs tend to settle in lower areas first. Planting on top of a hill in a windy area may be undesirable due to the possibility of plant and fruit damage from desiccation and cane breakage. A gentle, uniform slope may be most desirable for fruit crops. Steep slopes (in excess of 12 to 15 degrees) present challenges in establishing and maintaining the planting and can be hazardous when operating equipment on them. Soils on south-facing slopes tend to be hotter, dryer, thinner, and have a lower organic matter content than those on north to northeastern-facing slopes. The potential for winter injury and frost damage tends to

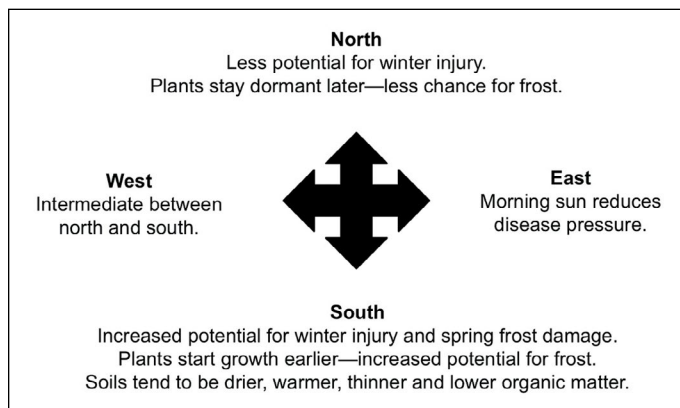


Figure 6. This diagram shows the expected conditions that can be found with sites facing principal directions.

be higher on south-facing slopes as well. While fruit may ripen earlier on a south-facing slope, the potential for crop loss is higher. Crops on slopes with an eastern aspect dry off quicker in mornings due to earlier sunlight exposure. Northern facing slopes will produce fruit later in the season and fruit will be less likely to be injured by spring frosts.

Both blackberries and raspberries grow best with full sun and a well-drained soil. The most suitable soils are high in organic matter (2 percent) and have a pH of 6.0 to 6.5. Sandy loam or loam soils are best. Blackberries

Blackberry	Raspberry
<p>Blackberries grow best in warm, temperate regions and are generally considered less hardy than raspberries. The plants flower from March in southern Georgia to May in the mountains, and bloom over a long period. Because blackberries flower late, damage to flowers from spring frosts and freezes is seldom a problem in the piedmont and coastal plain. In the mountain areas where the winters are more severe, the use of hardy cultivars and planting of blackberries on hillsides above frost pockets will help to avoid damage to the canes from the cold. In general, blackberries are recommended for areas where winter temperatures stay above 10°F.</p>	<p>Raspberry plants perform best where the growing season is long and summer temperatures are mild. They also grow best where winters are uniformly cool and long enough to satisfy their chilling requirement. These conditions are not typical of most areas in the southern United States. With careful selection of cultivars, however, coupled with good cultural practices, they can be grown successfully despite the odds. The best growing conditions in the southern United States exist in the high elevations of the Appalachian Mountains. The summer temperatures are not too hot, and the winter temperatures do not fluctuate as much as in the lower elevations.</p>

and raspberries can be grown in sandy soils if a good irrigation system is used. In general, their root systems do not tolerate wet soils. Avoid clayey, poorly drained soils in locations with high water tables or in areas prone to flooding. Use of raised beds can, in part, compensate for a periodically wet site.

Raspberries are susceptible to the verticillium pathogen, and sites with a history of the disease should be avoided. However, verticillium is not a major soil pathogen in the southern United States. Likewise, phytophthora root rot is a common problem for raspberries in other regions. Due to limited production of this crop in the region, phytophthora is not a major concern *at this time*. However, in western North Carolina, the *P. cinnamomi* species is a major cause of disease in Fraser Fir trees. Although *P. cinnamomi* is not known to infect *Rubus*, it is a highly virulent disease and could become a problem in areas that are infested.

Avoid sites where strong hot summer winds or cold winter winds prevail. Hot summer winds can dry the fruit, cause sunscald, and increase plants' water needs. In addition, fruit size and plant growth will be compromised. Cold winter winds can cause winter injury, which often results in cane breakage, cane dieback, or both. Windbreaks can be used to reduce air movement if you suspect it may damage your crop. Keep in mind, however, that good air circulation minimizes disease problems.

New caneberry plantings should be isolated as much as possible from wild raspberry and blackberry plants, which harbor diseases and insects that can devastate your crop. New plantings should be at least 100 to 200 yards from wild caneberries. Additional site recommendations related to insects and diseases can be found in the Southeast Regional Caneberries Integrated Management Guide, located on the Southern Region Small Fruits Consortium's IPM/ Production Guides web page.

Row Orientation

Wherever possible, orient rows north to south. Fruits and foliage will receive more uniform sunlight exposure throughout the day with this orientation than with other row directions, and problems with sunscald, which often occurs on the south side of east-west oriented rows, will be lessened. However, taking into account that the desired floor management system for caneberry plantings consists of a 4-foot wide clean strip in the row plus a closely mowed sod strip between rows, rows on sloping ground should be oriented perpendicular to the direction of the slope. This orientation allows for better erosion control, simpler irrigation designs, and greater precision in pesticide applications than working up and down hills. In the piedmont and mountain regions, fescue is an excellent choice for a perennial ground cover between rows. Planting on a contour, while desirable in other circumstances, presents special problems for constructing and maintaining trellises. Instead, consider planting straight rows, stopping the row when the slope within it becomes too great and restarting the row in a slightly different direction. Leaving a gap between the ends of the trellises allows for air drainage out of the field and provides turning room within the planting.

4. Site Preparation, Planting, and Establishment

Site Preparation

Thoroughly destroy perennial weeds and established sod before planting. Ideally this would occur one year before the caneberry crop is to be established. Kill wild caneberries with an herbicide and remove the residue from the field. Perform several ground tillings before planting to destroy weeds and loosen the soil. Plow the land again to prepare for planting. Preplant land preparation should be completed by mid-to late February in the coastal plain and by March or in the preceding fall in the mountains.

If possible, avoid planting caneberry fruits on a site previously planted to fruit crops, such as peaches, apples, grapes, raspberries, or blackberries. The soil could harbor pathogens from previous plantings.

Many blackberry varieties are susceptible to viruses, double blossom disease, and orange rust, so cultivated plants should not be planted near wild blackberries.

If possible, at least one year before planting caneberries, grow a summer cover crop (such as Sudangrass) or a winter cover crop of rye, oats, or wheat. A cover crop will suppress weeds and increase organic matter. Test soils for fertility and nematodes. Apply lime and nutrients according to soil test recommendations.

Fumigation and the use of black plastic on raised beds will give newly set blackberry and raspberry plants an advantage by killing most weed seeds and soil pathogens. Fumigation is highly recommended if nematodes are present in the soil, with or without the use of black plastic mulch.

The durability of black plastic mulch limits the number of years that the plastic will be useful. Over time, the plastic and drip tubes used for irrigation will break down. Check labels when using herbicides in the presence of black plastic mulch.

Soil Tests

Most roots of blackberries and raspberries are found in the upper 12 to 18 inches of the soil. Soils should be tested six months to a year or more in advance of planting to enable application and incorporation of recommended amendments. Lime, phosphorus, and potassium tend to move down into the soil very slowly, if at all. Therefore, waiting to apply needed amendments until after the planting has been established is not effective because incorporation of these amendments will no longer be an option. In most cases, the basic soil test consisting of pH, phosphorus, potassium, calcium, and magnesium plus a test for organic matter content should provide sufficient information. Knowledge of soil organic matter content will be valuable in determining how much nitrogen to apply.

Soil test at two depths—0 to 8 inches and 8 to 16 inches—to determine the status of both the topsoil and the subsoil. Knowing calcium and magnesium levels in the soil will be valuable in determining whether to apply either calcitic or dolomitic limestone. Determine the amount of lime, phosphorus, and potassium to apply by adding the recommendation for the 0- to 8-inch sample to the recommendation for the 8- to 16-inch sample. Rototill or disk this amount into the top few inches of soil and then deep plow the field to get the amended soil down into the lower depths. In the event that large amounts of lime or nutrients are needed, add two-thirds of the total recommended amount and incorporate as described. Once this is done, apply the remaining one-third to the soil and disk or rototill it in. After planting, soil test on a regular basis, perhaps every other year, to monitor soil pH levels.

Nematode Tests

Plant-parasitic nematodes cause direct damage to roots and can transmit viruses that may significantly suppress yield and fruit quality in caneberries. The only reliable way to determine if nematodes are present in a site is by collecting a soil sample and submitting the sample to a nematology laboratory for assay (see Appendix 1). Thoroughly sample fields during the summer or early fall to determine the types of nematodes that are present and their population density. Guidelines for proper sampling and sample handling procedures are available through local Cooperative Extension centers.

Planting

Order plants a year before you intend to establish your new planting. Several types of nursery stock are available (see Figure 7). Bare root dormant nursery stock or tissue culture plants are usually available from November to March. A limited amount of nurseries are able to ship for fall planting. Be sure to contact nurseries to determine shipping dates.

Purchase only stock plants from reputable nurseries to increase chances of getting healthy plants of the desired cultivars. Healthy planting stock is key to the cost-effective production of caneberries. Healthy plants will produce higher crop yields and better crop quality than common planting stock. Healthy planting stock is necessary for your planting to remain economically viable.

The most efficient approach to producing healthy planting stock is through programs that screen valuable plant selections for viruses and other diseases that can be spread by contaminated plant stock. Quarantine services provided by clean stock programs reduce the chance of introduction of exotic pests that can be difficult and costly to control. Ask your plant nursery if they are part of the National Clean Plant Network. Visit the National Clean Plant Network's website (nationalcleanplantnetwork.org/about/IMPORTANCE) for more information.

The use of clean, healthy plants cannot be emphasized enough. New bare rootstock should be purchased from nurseries that have grown plants in a greenhouse

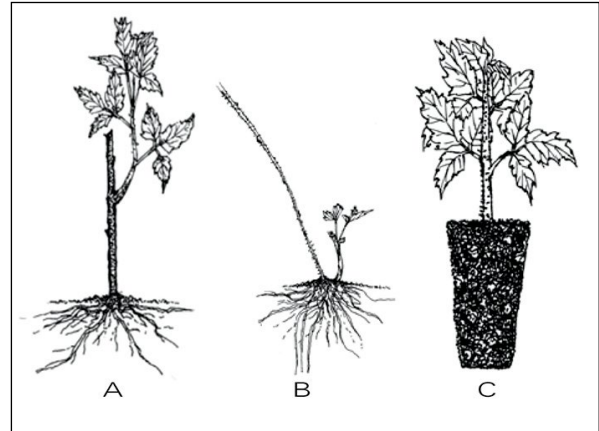


Figure 7. Three types of nursery stock. A: bare root; B: tip-layering; C: tissue cultured. Source: *Raspberry and Blackberry Production Guide: For the Northeast, Midwest, and Eastern Canada*, NRAES-35.



Figure 8. Bare root nursery stock. Photo: Jon Traunfeld, University of Maryland Extension.

or on fumigated land well isolated from other caneberries. The plants should have been sprayed regularly for insect and disease control and inspected by state officials. Early spring planting of dormant stock is acceptable in most regions. Plants set late in the spring may be adversely affected by drought or drying winds. In warmer areas, early fall planting is possible provided the soil is still warm and not excessively wet. Fall planting enables a good root system to develop. Avoid planting on wet soil. When planting both bare rootstock and tissue-culture plugs, give plants a thorough drenching with water, especially if the soil is dry and the weather is hot. After planting, cut off the stem of bare root plants at least 3 to 4 inches from the ground.



Figure 9. Tissue-culture plug plants. Photo: Karen Blaedow, NC State University.

Bare root nursery stock (Figure 8).

Plants should arrive just a day or two before planting. Do not keep plants in a cooler for an extended period of time or let the roots dry out. If the bare root plants are dry upon arrival, soak the roots in water for several hours before planting. If they will not be planted immediately, heel in the plants by digging a trench deep enough to contain the roots. Spread the plants along the trench, roots down, and cover the roots with moist soil. Plants can be held in this manner until buds begin to swell (usually in a couple of weeks). Always keep the bare roots covered and moist. To plant, dig a hole large enough for the root system to be spread in the hole. Cover the roots of bare-root plants with soil to a depth of 2 to 3 inches, and firm the soil around the roots.

Tissue-culture plug plants (Figure 9).

Tissue-culture plants should be allowed to harden off in a protected and shaded location outdoors. When planting, take only the number of plants that can be transplanted in half a day to the field. Be sure to water the plants well prior to planting. Set tissue-culture plants in holes so that the top of the root ball is even with the soil surface. Push a thin layer of soil around the top of the plug's root system. Growers have found that tissue culture plants perform well in the Southeast.

Tip layered canes.

These types of plants are produced when growing tips come in contact with the ground and form roots. Once root systems are well established, the newly formed plants are cut from the mother plant and stored for shipping at a later date. This type of propagation method is most often used in black raspberry. These plants should be hardened off similarly to the tissue-culture plants.

Root section.

A root section (root cutting) should be about 3 to 4 inches in length and $\frac{1}{4}$ to $\frac{3}{8}$ inch in diameter. Plant the root section about 2 to 3 inches in depth. New canes will originate from adventitious buds on the root section. A new planting can be established as quickly and successfully using root cuttings as it can with rooted suckers.

Establishment

Alleys

Maintain alleys with a ground cover or with cultivation in areas where soil erosion and high temperatures do not occur. Perennial grass species are preferable in most areas because they are not hosts for botrytis and verticillium. A good ground cover will serve as a deceleration/diffusion strip for run-off water and as support for equipment used in caring for the crop. If sod is allowed to develop in between rows, it should



Figure 10. A perennial grass in alleyways provides a durable surface for equipment and competes with weeds. Photo: Absalom Shank, NC State University.

be kept mowed. Tall fescue is well adapted to non-coastal plain regions of the Southeast and has proven to be an effective ground cover in the piedmont and mountains of North Carolina.

A 4-foot-wide, weed-free strip must be kept in the plant row, either by physical or chemical means, to prevent weed competition with the caneberry plant (Figure 10). Chemical weed control, used correctly, can be very effective. The choice of herbicide depends on soil type, weed species present, season of the year, herbicide application timing, and bearing status of the planting. The correct herbicide must be used at the proper time, or serious injury to the caneberry plants may result. For detailed information on managing weeds and using herbicides, see the Southeast Regional Caneberries Integrated Management Guide, located on the Southern Region Small Fruit Consortium’s IPM/Production Guides web page.

Spacing—Blackberry

Optimal spacing between plants and rows varies depending on plant type, training method (trellis type), terrain, and size of farm equipment. Allow at least 10 to 12 feet between rows to facilitate tractor operations. On sloping ground, the wider spacing is recommended. Space erect blackberries 2 to 4 feet apart in the row, and allow primocanes to fill in the spaces between plants. Both semi-erect and trailing types require 4 to 8 feet between plants to accommodate their very long canes. In southern Georgia, many cultivars have fewer canes than farther north, and a spacing of 2 to 3 feet between plants

is recommended. Generally, maximum row length should not exceed 600 feet. When planting before trellises are erected, align plants carefully in the rows to accommodate the trellises. To calculate how many plants you will need for each acre, refer to Table 4.

Spacing—Raspberry

Primocane-fruiting raspberries can be set at 2 to 3 feet apart in the row, while floricanes-fruiting types should be set at 3 to 4 feet apart within a row. The row-width range is from 8 to 15 feet, depending on equipment. However, rows should be spaced as closely as possible to ensure the highest possible planting yields.

To calculate how many plants you will need per acre, multiply the distance between plants in a row by the distance between rows and divide 43,560 square feet per acre by this number, or simply refer to Table 4.

Table 4. Number of Plants Required per Acre Using Different Spacing within and between Rows.

Spacing within Row (ft)	Spacing between Rows (ft)					
	8	10	12	13	14	15
2	2722	2178	1815	1675	1556	1425
3	1815	1452	1210	1117	1037	968
4	1360	1090	907	838	778	726
5	1090	870	726	670	662	581
6	907	726	605	558	519	484
8	680	544	453	419	389	363
10	544	435	362	335	311	290

5. Plant Growth

General

Understanding blackberry and raspberry plant growth is necessary for proper training and pruning of caneberry plants. The crown of the blackberry and raspberry plant is perennial, and canes are biennial. Management of canes varies with plant type, pruning and training, and the particular trellis system used.

Floricanes-Fruiting Blackberries and Raspberries

Both floricanes-fruiting blackberries and raspberries have a similar plant growth cycle. In the first year, primocanes grow and often branch but remain vegetative. These canes are called floricanes in the second year, and small branches—referred to as laterals—grow from the buds (Figure 11). Fruit is borne on the tips of these laterals. After the floricanes have produced a crop, they die.

Primocane-Fruiting Raspberries and Blackberries

Primocane-fruiting cultivars produce fruit on the tips of the first year's growth in the late summer and fall. Fruit production usually continues until a hard frost occurs. This portion of the cane will then die. When grown for a primocane crop, canes are usually mowed to the ground in the winter. If allowed to grow a second year, the canes will fruit just below the area that fruited during the primocane year. This production technique, however, is not recommended in the Deep South. The best results have occurred with only primocane production. Primocane-fruiting blackberries (such Prime-Ark® 45 and Prime-Ark® Traveler) have recently become available. These plants will produce fruit in late summer and early fall. Consult with your local Extension agent to find out if primocane-fruiting cultivars can be grown in your region.

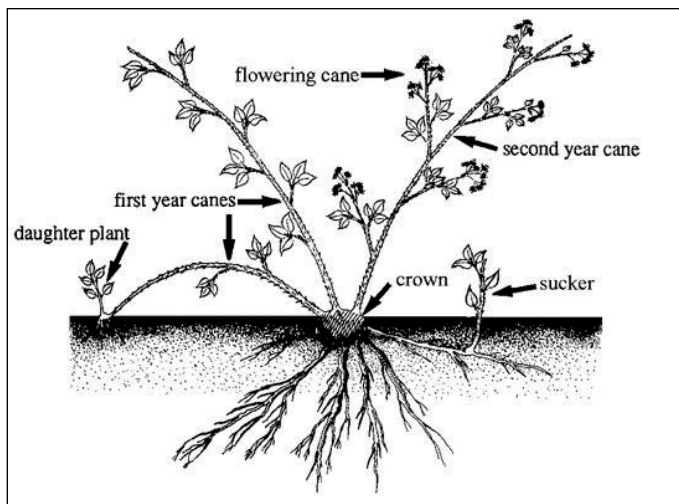


Figure 11. General plant growth including primocanes and floricanes. Daughter plants can be grown from first year canes and suckers produced from roots. Source: NSW WeedWise.

6. Pruning and Training

General

All blackberries and raspberries must be pruned and trained. Floricane-fruiting caneberries need pruning several times a year. Primocane-fruiting raspberries need to be pruned (mowed) only once a year during the winter.

Erect Floricane-Fruiting Blackberries

During the first year, plants establish root systems and a moderate number of canes. Their growth habit in the first year can be trailing, like a dewberry. Attach these flexible canes to the trellis by wrapping the canes loosely to the wire and then tying them to the wire. Growth of the primocanes in the second and subsequent years will be erect. To properly train erect types, allow the primocanes to develop in a row approximately 12 inches wide at the base during the

growing season. Most newly emerging primocanes will grow in the center of the row. While these primocanes are still flexible, encourage them to grow up in between the two sides of a T- or V-trellis by pushing them into the center of the row before they reach the trellis's bottom wire. When the new shoots of erect blackberries reach 8 to 12 inches above the top wire, they should be tipped. Tipping encourages the growth of laterals on which fruit is produced. Use your fingers to pinch off the tender new growth at the tip of the cane—known as soft tipping (Figure 12). Later on, use loppers or a mechanical hedger capable of making a clean sharp cut, known as hard tipping (Figure 13). Tipping or hedging can lead to cane blight disease, *Leptosphaeria coniothyrium*, especially if the cuts are made just before a rain event (Figure 14). Soft tipping early by pinching young growth invites less disease than hard tipping. After tipping, apply a preventative fungicide to protect cuts



Figure 12. Small diameter tipping can easily be done by hand. The resulting wound is smaller and is less susceptible to disease infection. Photo: Phil Brannen, University of Georgia.



Figure 13. Larger diameter cut made with pruners. The wound is larger and the cane is more susceptible to disease infection. Photo: Phil Brannen, University of Georgia.



Figure 14. Cane blight of blackberry. Photo: Gina Fernandez, NC State University.

from cane blight. The “Cane Blight of Blackberry” factsheet (smallfruits.org/bramble/pestinformation/caneblightfactsheetii.pdf) contains more information about this disease.

To view a video showing tipping of primocanes on blackberries, visit youtu.be/AfM64ObU_NY.

Tipped canes will grow stout and be more capable of supporting a heavy fruit crop the following year. In southern Georgia, many thornless cultivars produce only one to three large primocanes each year. In this case, tip the canes during the summer when they attain a height of 2 to 3 feet to encourage branching.

After fruiting, remove dead floricanes and thin out weak primocanes as time permits. In late winter, prune the laterals to 12 to 18 inches if needed. Pruning will increase air, sunlight, and spray penetration within the row and make harvesting more convenient and result in larger berries. Where large-diameter pruning cuts are made, stem disease has been severe in some years. A fungicide application after pruning is recommended. At the same time, remove any remaining dead and weak wood. Leave only about six to eight healthy, vigorous, evenly spaced canes spaced per linear yard (3 feet) of row. Erect blackberries must be trellised for additional support and for ease of harvest. Follow the trellising guidelines for trailing and semi-erect types using one of the trellises described in the Trellis Systems section of this publication.

To view a video about pruning caneberries, visit youtu.be/SUzC8ip5Rm0.

Semi-Erect and Trailing Floricane-Fruiting Blackberries

During the first growing season, tie semi-erect and trailing blackberry primocanes to a trellis to allow weed control under the vines. After the first season, all types of blackberries must be trained on trellises to assure clean, disease-free fruit and easy picking.

During the second season, before buds swell, bring floricanes up to the trellis wires and tie them individually with soft string or plastic tape from a hand-held device designed for tying caneberries and grapes. At the same time, prune the lateral branches to 10 to 12 inches in length. If 3 feet or more of growth was produced the first year, cropping can occur in year two. If only a small amount of growth was made the first year, cut the canes back to within several inches of the ground. This practice helps the plants become better established by preventing a severe stress on their productivity from fruiting and favors the development of sturdier, more fruitful shoots in the subsequent year. In the succeeding years, new shoot growth will be more vigorous.

Primocanes of trailing and semi-erect blackberries are extremely vigorous and need to be managed throughout the summer. Tie primocanes loosely together as they develop, and train them up through the plant to the top wire. Once they have reached the top wire, divide and tie them to the wire. This method is well suited for semi-erect and less vigorous trailing cultivars. Place plants close together and place canes uniformly over the trellis to maximize light exposure and yield.

Primocane-Fruiting Blackberries

During the late winter or early spring, remove all canes at the base before growth begins in spring. Fruit will be produced on primocanes in the late summer or fall. Primocanes should be soft-tipped (remove about 2 inches) when they reach 3 feet in height. Continue the soft-tipping process throughout the growing season as new primocanes emerge from the ground. In the western US, growers have found that yields increase when canes are soft-tipped twice, once at 1.5 to 3 feet and then each branch is soft-tipped at 1.5 feet. Hard-

tipping is not recommended as the wounds created by the cuts will increase the likelihood of infection by pathogens.

Primocane-fruiting blackberries can also be managed with the biennial system, with a first crop on the floricanes and a second crop on the primocanes. In that case, follow the recommendations for both primocane- and floricane-fruiting blackberries. However, during the winter, last years primocanes should be pruned to just below the height where fruit production stopped in the fall. Fruit will be produced on the lower parts of the cane in the subsequent summer. In the spring and summer, soft-tip the new flush of primocanes as described above. Remove floricanes by hand after harvesting the fruit.

Floricane-Fruiting Raspberries

The biennial system is the most common training and pruning system in the eastern United States for summer fruiting raspberries. In this system, primocanes are allowed to grow throughout the season. In most cases, floricanes that produced fruit are removed immediately after fruiting to increase air movement and decrease disease pressure in the canopy. However, in colder regions of the South, these canes may serve as a source of stored carbohydrates for cold protection in the winter. Growers in the mountain regions may want to consider pruning out floricanes after the coldest part of the winter is over. In early spring, top remaining canes to a convenient picking height (usually 3 to 4 feet). If canes are too dense, fruit size will be reduced. If canes are thinned too much, total yield will suffer. In early spring, remove weaker canes and thin the remaining canes to three to four canes per square foot. Leave only the most vigorous canes, those having good height, large diameter, numerous nodes in the fruiting zone, and no obvious signs of disease, insect damage, or winter injury.

Primocane-Fruiting Raspberries

During the late winter or early spring, remove all canes at the base before growth begins in spring. Primocanes will produce fruit in the fall. To produce a late-season crop at lower elevations, cut the canes to the ground in the early spring before growth begins.

When they are approximately 1 foot tall, prune the canes to near ground level a second time. Pruning in this manner will help delay harvest until late summer after the heat of the summer has passed.

7. Trellis Systems

Trellis systems are used for cane support with trailing and semi-erect cultivars to keep the fruit off the ground and with erect cultivars that will be allowed to grow tall before being topped. Positioning canes on a trellis improves sunlight exposure, air movement, and spray penetration throughout the canopy. Using a trellis system will make the planting easier to manage. Easier harvest results in cleaner picking, lessening the attraction of picnic, sap, June, and Japanese beetles that can result from the presence of overripe and rotted fruit. Trellising can also make floriculture removal easier. Construct trellises prior to the first harvest season.

Growers use a variety of trellis support systems to support canes. Your trellising goal is to minimize labor and maximize yield. Each trellis type has its advantages and disadvantages, and most can be modified according to your needs. Evaluate each trellis system to determine what type best suits your needs.

Many different types of trellis systems exist. Consider the following factors when selecting which type to use: cost of materials and construction; availability of competent, trained labor; and climatic considerations, such as the potential for cold injury.

Line posts are used to position wires at desired heights above the ground. Posts can be either wood or metal. Wood line posts stand up to stresses—such as wind perpendicular to the trellis—better than metal posts. If wood posts are used, they should be treated for in-ground use. Unless heavy metal posts are used for line posts, it is advantageous to use a wood line post every second to third post. Drive or set posts 2 feet into the ground with 5 feet remaining above ground. Wood posts should have a top diameter of about 4 inches. For hand harvested crops, set posts no more than 25 to 30 feet apart. The end posts, where wire tensioning is done, should be larger than line posts (suggest a minimum of 8 feet in length with

a 6-inch top diameter to allow them to be driven 3 feet into the ground). Generally, wood is used for end posts. Use anchors to further support end posts.

The top wire on the trellis is the load-bearing wire. Use a 12 ½ gauge high tensile electric fence wire. The lower wires are for cane positioning and do not need to be as heavy. A 14 gauge high tensile wire should be adequate.

I-Trellis

The I-trellis can be a single wire or two wires spaced apart and secured to posts at 2 and 4 feet above the ground (Figure 15). Posts can be metal or wood treated for in-ground use. They should be set at least 2 feet deep and be spaced about 25 to 30 feet apart. Secure canes loosely to the wire or tuck them in between the two wires. This trellis is relatively inexpensive and easy to build. Yields may be lower than with other trellis designs. The canopy can become crowded, resulting in added disease pressure, more difficulty in harvesting, and potentially poorer fruit quality.

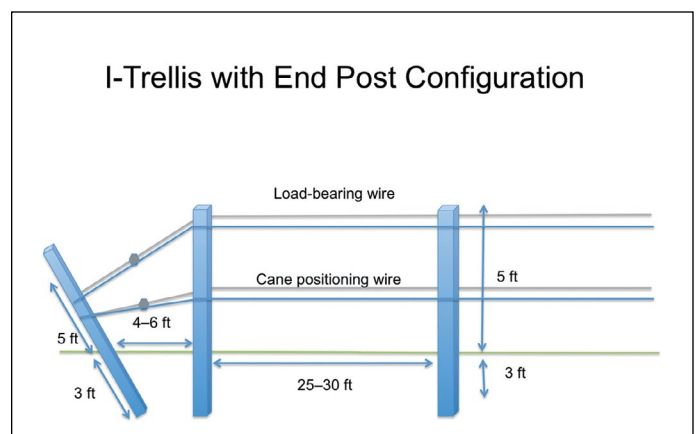


Figure 15. I-trellis (Hedgerow): use 6- to 8-foot metal fence posts, cedar posts, or pressure-treated posts (4 to 6 inches in diameter) spaced about 25 to 30 feet apart. Bury posts 24 inches in the ground.

V-Trellis (with Metal T-Posts)

The most common type of caneberry trellis is the V-trellis (Figure 16a and Figure 16b). The typical V-trellis design has steel posts set 20 to 30 degrees from vertical.

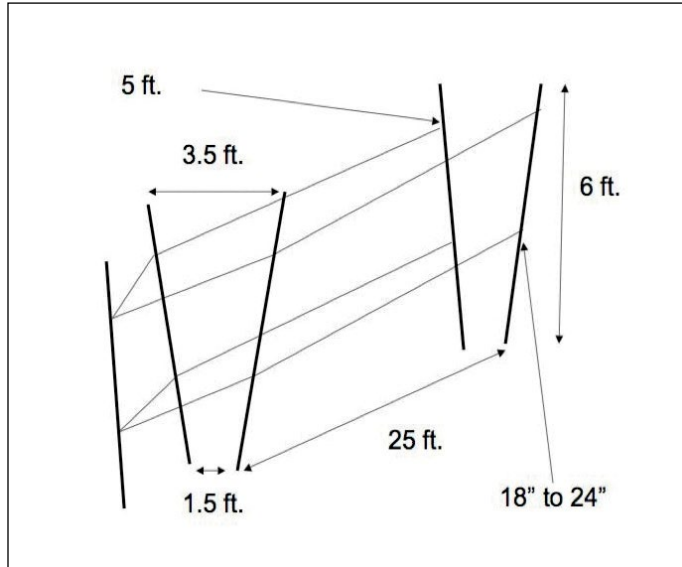


Figure 16a. V-trellis for blackberry or raspberry support.



Figure 16b. V-trellis. Photo by Gina Fernandez, NC State University.

California V-Trellis

The California V-trellis is a modification of a system developed in Norway, called the Gjerde system. In the winter, the 1-inch by 1-inch moving posts are tied nearly vertical (Figure 17a). When the buds break in the spring, new fruiting laterals on the floricanes are encouraged to grow outward (Figure 17b).

To view a video demonstrating how a California V-trellis works, visit youtu.be/lpsJqkUtDDc.

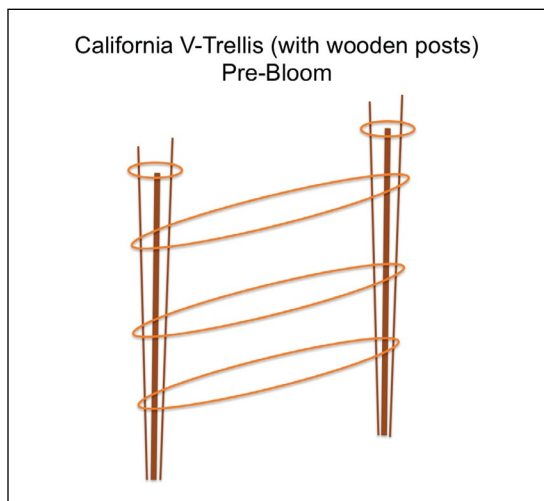


Figure 17a. California V-trellis (with wooden posts) pre-bloom.

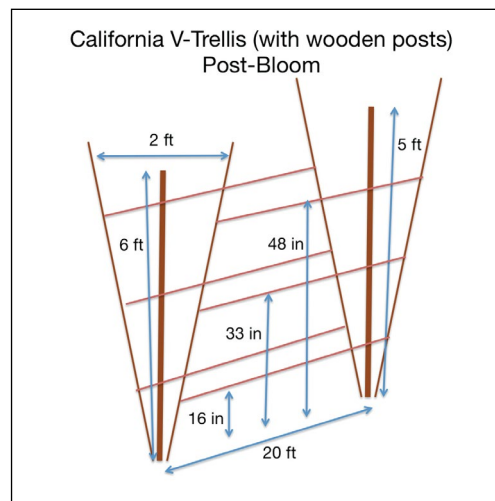


Figure 17b. California V-trellis (with wooden posts) post-bloom.



Figure 17c. California V-trellis. Photo by Gina Fernandez, NC State University.

T-Trellis (with Rebar)

The T-trellis is a divided canopy design where floricanes are secured to wires on either side or both sides of the trellis, creating room for primocanes to grow upright between the wires (Figure 18a and Figure 18b). The main post is made of ½-inch rebar while the cross arms are 3/8-inch rebar. Because primocanes and floricanes are separated in the canopy, more sunlight can reach the developing crop. Harvest and floricanes removal following harvest are easier due to the separation of floricanes and primocanes. This type of system is suitable for primocane-fruiting raspberries.

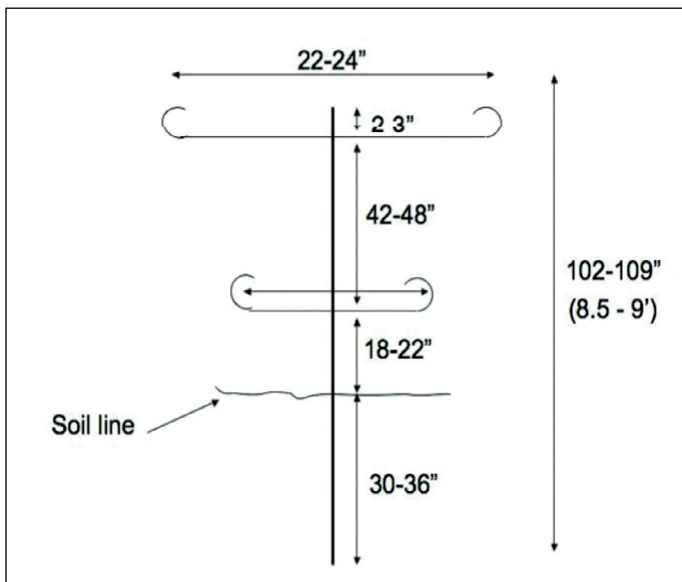


Figure 18a. Rebar T-trellis.



Figure 18b. Rebar T-trellis.
Photo by Gina Fernandez, NC State University.

T-Trellis (with Wood)

This trellis functions similarly to the rebar T-trellis, but it is made of wood (Figure 19a and Figure 19b). Set 8-foot posts made from pressure-treated lumber or cedar 2 feet into the ground. Use 2-inch by 4-inch pressure treated lumber for cross arms. Set posts 20 to 30 feet apart in the row.

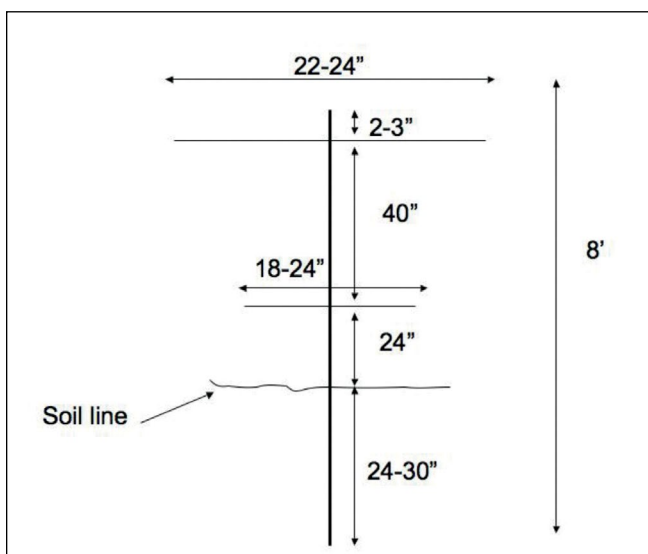


Figure 19a. Wood T-trellis.



Figure 19b. Wood T-trellis.
Photo by Gina Fernandez, NC State University.

Shift Trellis and Rotating Cross-Arm Trellises

Both of these trellis systems move the position of the canes during the year. In the early spring, the trellis is moved to a horizontal position. Once the flowering shoots have begun flowering, the canopy is moved beyond the vertical position for harvest. In both of these systems, fruiting occurs primarily on one side of the trellis. Both systems require intensive management of the primocanes.

The shift trellis is made of wood and pivots in an arc from one side of the row to the other (Figure 20a and Figure 20b).

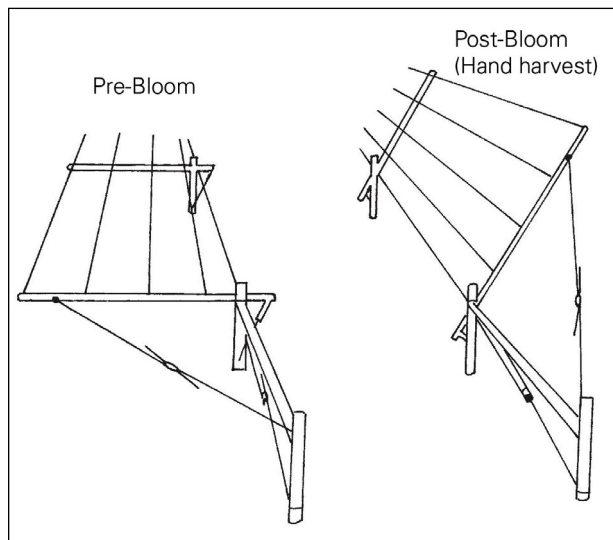


Figure 20a. Shift trellis. Graphic courtesy of Virginia Technical University, scholar.lib.vt.edu/mirrors/vaes/vaes99-1.pdf.



Figure 20b. Shift trellis. Photo and videos by Gina Fernandez, NC State University.

Commercial rotating cross-arm trellises are constructed of fiberglass reinforced plastic components manufactured by the pultrusion process.

“The trellis consists of a post (~50 cm) (a) which has two plates (b) attached at the top (Figure 20c). A long (c) and a short (d) cross-arm are secured between the two plates with detent pins. Both cross-arms are rotatable. There are two cane training wires (e1 and e2) that are threaded through holes in the plates. Additional trellis wires (f) are threaded through both cross-arms and secured to end trellis assembly arms. The wires in the foreground are connected to a

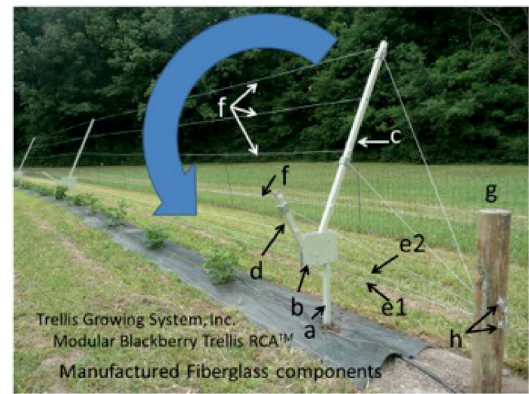


Figure 20c. Rotating cross-arm trellis.



Figure 20d. Blackberry plants on the rotatable cross-arm trellis at bloom.

wooden tie-back post (g). The primocanes are placed on the training wire below the short cross-arm (e1). Wires terminate at the wooden tie-back post and on end trellis assembly arms on the first and last posts of each row with a “Quik-End” tensioner (h) which has internal spring-loaded clamps. In winter, the canes are pushed over to the training wire under the long cross-arm (e2).

“When plants are in bloom, the long cross-arms are oriented horizontally (Figure 20d-A). Note the top of the post (arrow) on left side. The lateral canes that were secured to the wire on the long cross-arms have produced flower shoots and all have grown upward.

Flower shoots that develop from axillary buds oriented down on the lateral canes will curve and grow upward between lateral canes. Soon after all the flower shoots have a few open flowers, the cross-arms can be rotated upward and beyond vertical (Figure 20d-B). By this time, the rachis (inflorescence axis) is woody and will not curve upward. The upward rotation of the cross-arms positions the fruit on one side of the row.” (Takeda, Glenn, and Tworkoski 2013, 24-40)

To view a video showing a shift trellis, visit youtu.be/DzpSgr_Q8dY.

Table 5. Advantages and Disadvantages of Each Type of Caneberry Trellis System.

Trellis Type	Advantages	Disadvantages
I-Trellis	Easy to build and maintain Economical	Lower yield Crowded canopy increases disease pressure and makes harvest more difficult
V-trellis (with metal T-posts)	Allows greater light penetration into the canopy; higher yields than a single post Air circulation is greater; decreased disease pressure Using fence posts, horizontal wires can be moved up or down to accommodate a cultivar’s vigor	Higher cost than a simple I-trellis
California V-Trellis	Fruit develops on outer parts of canopy enabling easier harvest Increases light and air circulation in canopy	Labor intensive and expensive Sprayers can knock off blooms Spray penetration not great when canopy is closed
T-trellis (with rebar)	Posts can be reused and are therefore economical Easy cane removal after harvest Allows greater light penetration into the canopy; higher yields than a single post Air circulation is greater; decreased disease pressure	Cannot be higher than 4 feet; some potential yield is forfeited May not be able to support heavy crop load May not hold up in ice storms
T-trellis (with wood)	Opens canopy for higher yields and improved air circulation Can retrofit from an I-trellis without having to install new posts	Wire height cannot be adjusted once cross arms are installed Wires set too high establish fruiting zone beyond reach of labor
Shift trellis and rotating cross-arm trellis	Easier harvest; all fruit is on one side of the canopy Less sunscald on fruit Can be covered in winter to minimize cane injury	Expensive Harder to learn how to train and prune

8. Tunnel Production

High tunnels are semi-permanent structures made of steel pipe arches and covered with polyethylene plastic to create a protected environment for plants. Raspberries and blackberries benefit from growing in high tunnels, which can extend the harvest season, improve fruit quality and yield, and enable growers to harvest fruit when it is raining (Figure 21). The tunnels are 10 to 15 feet high and 20 to 30 feet wide. Assembling tunnels side-by-side to cover areas of several acres adds some stability against wind damage. Plastic is typically used, and it is rarely in place on a given tunnel for more than one to three years. In cooler locations, end walls can be used to retain heat during the fall when nighttime temperatures can damage fruit.

In most eastern US systems, a primocane-fruiting raspberry produces fruit in mid- to late summer and fall for three to four growing seasons. At the end of each growing season, the canes are mowed to the ground. To prevent damage to the tunnel during the windy winter season, the plastic is often temporarily removed. In the western United States, a shorter intensive cropping system is used whereby plants are in the ground 18 to 24 months, and fruit is produced on both primocanes and floricanes.

Studies in North Carolina and Arkansas have shown that primocane-fruiting raspberry cultivars grown in tunnels resulted in high yields during the first growing season. Compared to field-grown raspberries, tunnel-grown yields were 30% greater or more, depending upon location and growing conditions. In cold winter locations, tunnels may also extend the normal summer harvest season into the fall.

Production practices for blackberry tunnel production are still in the developmental stages. In North Carolina, tunnels did not result in significantly greater yields or an increase in desirable post-harvest attributes. Primocane-fruiting blackberries have done well in tunnels in the western United States, but they did not perform well at high elevations in North Carolina due to early season frosts.



Figure 21. Floricane-fruiting blackberries (right) and raspberries (left) in a high tunnel. Photo by Absalom Shank, NC State University.

9. Water Management

General

Irrigation is recommended for caneberry production. Water is the most critical factor for optimal fruit growth and primocane development. Water is essential for minimizing plant loss and establishing healthy roots and shoots during the first few months. A newly set plant has shallow roots and therefore needs frequent irrigation. Any restriction of growth in the first year negatively impacts both the current season's and the following year's crops. A shortage of water during primocane development in any year will limit fruit size and the number and diameter of primocanes.

Nearly all of the moisture used by blackberries and raspberries comes from the top 6 inches of the soil, which is the primary rooting zone. If moisture is applied by overhead irrigation, blackberry and raspberry plants generally need at least 1 inch of water during each seven-day interval of the growing season. Higher irrigation amounts are required with sandy soils and in southern Georgia.

Trickle Irrigation

Trickle irrigation, either from a tape or tube, is recommended for caneberry production in the southern region. Set up trickle irrigation systems before plants are set in the ground. When using plastic mulch during establishment, it is common to place two lines of drip tape on either side of the row. Replace drip tape with tubing one or two years after plant establishment. Place drip tubes on wires about 12 to 18 inches above the soil surface.

Trickle irrigation reduces fruit rot because water is applied to the soil under the plants instead of overhead. It is important for the water to be clean and the system to be maintained properly so that the trickle system does not become clogged. Test both well water and surface water from ponds or streams for chemical and biological impurities, and provide recommended treatment and filtration for optimal function of a drip irrigation system. Contact your local Extension center for more information on how to collect a sample and where to take it for an evaluation.

Mulching

Mulches can help conserve moisture. Large volumes of material and many hours of labor are required to apply mulch to a field, and some mulch must be replaced each year. Mulches may also introduce weed seeds, encourage rodent infestation and crown gall, and be a fire hazard. However, weed-free mulches of small-grain straw or other suitable materials conserve moisture, minimize erosion, aid in weed control, and add organic matter to the soil. Do not use hay because it may contain the chemical picloram (Grazon) or aminopyralid (Milestone). Give mulches serious consideration when growing blackberries on lighter soils with low organic matter. Black plastic is a good mulching option in locations where orange velvet algae is a serious problem. Black plastic mulch has been observed to reduce algae problems by reducing soil splashing and providing a drier microclimate around the base of the bush. For more information on orange velvet algae (orange felt) see University of Georgia Extension's "Orange Felt (Orange Cane Blotch) of Blackberry" fact sheet (www.smallfruits.org/Bramble/pestinformation/OrangeFelt.pdf).

10. Integrated Pest Management and Pollination

For information about integrated pest management and pollination, see the Southeast Regional Caneberries Integrated Management Guide, located on the Southern Region Small Fruits Consortium's IPM/Production Guides web page (www.smallfruits.org/SmallFruitsRegGuide/index.htm).

11. Fertility Management

General

As stated in chapter 3, *Site Selection*, the ideal soil pH for caneberries is 6.0 to 6.5. Preplant soil testing, discussed in chapter 4, should be done a minimum of six months to a year in advance of planting to allow adequate time to make all the necessary amendments to the soil. The only economically feasible time to amend a low soil pH, a low phosphorus level, and to a lesser extent, potassium, in the subsoil is before plantings are established. At that time, soil amendments can be applied, worked into the upper few inches of soil by disking or rototilling, and followed by deep plowing to move the amended soil to a lower depth. Failure to adequately prepare the site from a nutritional site could compromise performance of the planting throughout its life.

Nitrogen is the element most likely to need to be applied every year. Use good records from previous years and observations on leaf color, cane growth, and crop load in the current year to refine the rates of nitrogen suggested below. In an established planting, use leaf analysis to decide which, if any, other plant nutrients need to be applied.

General pre-plant soil optimum nutrient contents are given in Table 6.

Blackberry Fertilization

Year of planting. Apply a total of 25 to 50 pounds of actual N per acre over the entire season. Make applications beginning about 30 to 60 days following planting and continuing every four to six weeks until late July/early August, at which time applications

Table 6. Soil nutrient content in lb/acre at pre-plant (based on University of Arkansas recommendations)

Nutrient	Soil Nutrient Content (lb/acre)
Phosphorous	40-60
Potassium	200-400*
Calcium	1000-2000**
Magnesium	100-250
Sulfur	21-40
Iron	101-200
Manganese	51-200
Zinc	1.1-3
Copper	1.1-3
Boron	1.0-2.0

*Recommendations from Oregon State for potassium are higher (300-600 lb/acre). Because this mineral is not mobile in the soil, growers might want to use the higher rates, but take care not to cause "salt" injury to new plantings.

**Optimum calcium levels depend on soil type. Liming the soil usually supplies enough calcium.

should be discontinued. The higher rates are suggested for sandy soils. When fertilizing individual plants, apply fertilizer in a circle around the plant, or make applications in a narrow strip about 12 inches wide in the weed-free zone on each side of the row, taking care to keep the fertilizer at least 12 inches away from the base of the plants.

Second year. Use a total of 50 to 80 pounds of actual nitrogen per acre using a split application. Apply 1/2 to 2/3 of the total amount being applied in spring when primocane emergence begins and make the second application immediately following harvest for floricanefruiting cultivars. Make applications in the weed-free area on each side of the row.

Third and subsequent years. Use a total of 60 to 80 pounds of actual N per acre in a split application as outlined above for second year plants.

NOTE: It is assumed that the planting is under irrigation.

Raspberry Fertilization

Year of planting (first year). Use a total of 25 to 55 pounds of actual nitrogen (N) per acre in a split application. Apply about 1/2 to 2/3 of the total amount at least 30 days after planting and the remainder about 60 to 90 days later.

Second year (summer-bearing cultivars). Use a total of 40 to 80 pounds of actual N per acre in a split application. Broadcast 1/2 to 2/3 of the total amount at the onset of bloom, with the remainder being applied immediately after harvest. Applications should be made to the weed-free strip and on each side of the row.

Second year (primocane-fruited cultivars). Use a total of 50 to 60 pounds of actual N per acre in a split application. Apply 1/2 to 2/3 of the total amount when new primocanes begin to emerge and make the second application 60 days later.

Third and subsequent years (summer bearing cultivars). Use a total of 40 to 80 pounds of actual N in a split application. Apply 1/2 to 2/3 of the total amount

at the onset of bloom and the remainder immediately after harvest.

Third and subsequent harvest (primocane-fruited cultivars). Use a total of 40 to 80 pounds of actual N per acre in a split application. Apply 1/2 to 2/3 of the total amount when the first new primocanes begin to emerge and the remainder about 60 days later.

For established plantings, spread fertilizer uniformly across the row in the weed-free zone or side-dress on each side of the row in a 3-foot wide band. If using fertigation, utilize weekly applications beginning at the onset of bloom and going through harvest for summer-bearing cultivars and until late August for primocane-bearing cultivars.

Leaf Analysis

In an established planting, the correlation between soil test results and the actual nutrient status of the plant tends to be poor. However, soil testing at regular intervals is needed to monitor soil pH, as this can impact nutrient availability. Leaf analysis provides an accurate measure of the nutrient status of the plant. A combination of routine soil testing, annual leaf analysis, good records from previous years, and observations of plant growth and fruiting are all needed to develop and maintain a good fertilization program.

With leaf analysis, as in soil testing, the validity of the test results depend strongly on collecting good samples for analysis. Consider the following when collecting leaf samples:

1. Collect leaves from only one cultivar per sample, preferably from plants of about the same age.
2. Take the most recently matured leaf on primocanes shortly following harvest for summer-bearing cultivars.
3. Collect leaves from healthy plants. Those leaves showing signs of disease or arthropod damage, or different growth characteristics should be sampled separately.
4. Collect a total of about 50 to 100 leaves (one leaf per cane) located on the sixth to tenth nodes of primocanes in mid- to late-July. The area represented by a single sample should not exceed

5 to 10 acres. Variations in plant growth and terrain within a field may reduce the area that should be represented by a single sample .

5. In primocane-fruiting cultivars, sample the most recent fully expanded leaf on primocane branches at the green to red fruit stage (usually late July to August).
6. Collect leaf samples before a spray application as opposed to shortly after one.
7. If leaves are dusty or have spray residue, rinse them briefly in distilled water, blot dry, and place them in a clean paper bag. Let the leaves air dry in a dust-free area prior to sending them to the lab for analysis. Use the procedures outlined by the lab you will be using to obtain samples for analysis. Because different labs use different methods, use the same lab to interpret the values received from the analyses. General foliar sufficiency recommendations are given in Table 7.

Table 7. Macro- and micro-nutrient sufficiency ranges for fruit crops.

Nutrient	Range
	--- % ---
N	2.00–3.00
P	0.25–0.40
K	1.50–2.50
Ca	0.60–2.50
Mg	0.60–0.90
S	NA
	--- ppm ---
Fe	50–200
Mn	50–200
Zn	20–50
Cu	7–50
B	20–50

12. Fruit Development

General

Nearly all caneberry cultivars are self-fruitful, and therefore self-pollination or pollination by the same cultivar will result in fruit development. Commercial growers should consider placing one or two hives of honeybees per acre grouped into units of five or ten hives per location.

The time from flowering to fruit harvest can vary significantly for both blackberries and raspberries. Keep records of peak bloom and harvest each year to help manage your harvest (see Table 8 for an example for blackberries). Over time you should be able to estimate when harvest will start, peak, and end. Simply record the dates that you observe the stages of development from flowering through fruiting on three or more fruit. We suggest flagging the fruit with colored tape and returning to the same fruit each week to observe and record changes. Flagging three or more fruit ensures that you will have fruit by the end of the season to observe, as fruit can be lost from accidental picking or other mishaps. A step-by-step protocol for monitoring flower to fruit development is available at NC Cooperative Extension’s Team Rubus blog

(teamrubus.blogspot.com/2015/03/monitoring-flower-to-fruit-development.html). Print out a copy of Table 9 to use as a record for each cultivar.

Blackberry

As the fruit ripens, it grows in size and weight. Color changes from green to red to black. Blackberries take 35 to 45 days to mature once they are pollinated.

Raspberry

Flavor and sugars increase as the fruit grows, and the fruit will soften and loosen from the receptacle when ripe. About 85 percent of the fruit size is gained in the last days of maturation. Development at this time depends on adequate supplies of carbohydrates and water; any limitation will adversely affect fruit size.

Raspberry fruit also grows in size and weight. Color changes from green to light red to red. Raspberries mature approximately 30 days after they are pollinated. Ripe fruit separates from the plant, leaving the torus (or core) attached to the plant.

Table 8. Days from Flowering to Fruit Development of Erect Thornless Floricane-Fruiting Blackberries in Clarksville, Arkansas.

	Osage	Apache	Natchez	Navaho	Ouachita
50% Bloom	2 May	8 May	29 April	7 May	6 May
Peak Fruiting	26 June	6 July	17 June	1 July	29 June
Number of Days	55	59	49	55	54

(Source: Hort Sci. 2013. 48: 909-912. Hort Sci. 2005 40: 259-260).

Table 9. Monitoring flower to Fruit Development in Your Field. (Enter the dates that you observe each stage for three flowers of each cultivar.)

Stage	Flower 1	Flower 2	Flower 3	Comments
Full bloom				
Petal fall				
Green				
Green-Red				
Red-Green				
Red				
Shiny black				
Dull Black				

13. Harvesting and Postharvest Management

General

The primary objective of postharvest handling of blackberries and raspberries is to maintain fruit quality. Follow the general guidelines below for harvesting blackberries and raspberries:

- Pick in the morning while the temperature is still cool and the berries are firm.
- Avoid picking when raining.
- Pick and handle the fruit carefully to avoid crushing or bruising.
- Place harvested fruit directly into the picking container.
- Have a separate container for culled fruit. Fruit culled for cosmetic reasons may be frozen or used in processing.
- Gently place the berries no more than two to three berries deep in berry baskets or picking containers to avoid further bruising during storage. For this reason, half-pint containers are recommended.
- Cool the fruit as soon as possible after harvest. Coolers should be set at 33°F to 35°F with 90% to 95% relative humidity. Use room cooling or forced air cooling.
- Approximately six to eight trained pickers are usually recommended per acre.
- A variety of picking containers are available from your local distributor. Each one has its advantages and disadvantages. Decide which type of basket suits your individual needs:
 - Pulp baskets are inexpensive, have ventilation holes for cooling, and can absorb water from fruit harvested wet; however, they absorb juice on the bottom, which may be undesirable.
 - Polystyrene baskets are lighter, absorb less water, and can be printed with a label.
 - Commercial growers most commonly use clamshells. Clamshells are sturdy, plastic, vented boxes with hinged lids that allow boxes to be stacked without crushing the fruit. An

absorbent pad is placed in the bottom of each clamshell to absorb excess juice and moisture from the fruit.

- Use picking stands to prevent containers from contacting the ground.

Blackberry

Harvest blackberries at least twice a week. For pick-your-own and local sales, it is better to pick when the color has a dull appearance to maximize flavor. At this stage, berries will have higher sugars but reduced shelf life and are best suited for local markets. For shipping, pick blackberries when they are shiny black for acceptable flavor and longer shelf life (Figure 22).

Postharvest handling of blackberries is critical when selling fruit to retail or wholesale markets. Fruit reddening is a manifestation that can occur in stored blackberries. It is characterized by one or several bright red drupelets that detract from the attractiveness of the berries. Although the exact cause is not certain, possible causes include cultivar, early harvest date, temperatures above 77°F during picking, immature fruit, chemical composition, and condensation on the fruit.



Figure 22. Shiny black (right) and dull black (left) Ouachita fruit. Photo by Penelope Perkins-Veazie, NC State University.

Raspberry

Harvest raspberries daily. Raspberry fruit are very soft and even more perishable than blackberries. Recent studies have shown that fruit can be harvested at the pink or light-red stage for fresh market sale or at full redness for immediate sale at pick-your-own operations (Figure 23). Fruit that was picked unripe (yellow-pink) achieved full color, soluble solids content, acidity, and flavor (tasted at random) after six days of storage. Fruit picked pink was much firmer and less leaky than berries picked at the normal commercial fresh market ripe stage. However, they found that fruit picked at this stage was 4 to 20 percent smaller, depending on variety and relative ripeness at harvest. Growers will have to determine whether extended shelf life or fruit size is more important.



Figure 23. Ripe and unripe (UR) berries on the day of harvest (day 0) and eight days after harvest. Photo by Penelope Perkins-Veazie, NC State University.

14. Handling to Avoid Contaminants

Recent outbreaks of food-borne illnesses have increased public awareness of food contamination. Although these outbreaks have been linked to other products, take steps to avoid contamination of your crop. Contaminated produce can lead to significant financial loss.

Growers of all sizes should abide by Good Agricultural Practices (GAPs). By implementing GAPs, growers minimize food safety hazards. More information on GAP practices and how to become certified can be found at the NC State Extension's Good Agricultural Practices web page (ncfreshproducesafety.ces.ncsu.edu/ncfreshproducesafety-good-agricultural-practices/).

For information specific to caneberries, refer to the NC State Extension's "Good Agricultural Practices for the Production of Strawberry, Raspberry, Blackberry, and Blueberry" factsheet (ncfreshproducesafety.ces.ncsu.edu/wp-content/uploads/2014/03/berries.pdf?fw=no).

Appendix 1. Nematode Diagnostic Services

Arkansas

Arkansas Nematode Diagnostic Laboratory
www.uaex.edu/farm-ranch/pest-management/plant-disease/nematodes.aspx
 362 Highway 174 North
 Hope, AR 71801
 Phone: 870-777-9702, Ext. 128 or 119
 Email: rbateman@uaex.edu or choward@uaex.edu
 To submit a sample: dddi.org/ua/
 Services and Fees: General—\$10; soybean—\$20; pinewood—\$25; nursery—\$25; rice grain—\$25; rice grain certified—\$75. Out-of-state samples accepted.

South Carolina

Clemson University
 Nematode Assay Laboratory
www.clemson.edu/public/regulatory/plant_industry/pest_nursery_programs/plant_prob_clinic/
 511 Westinghouse Road
 Pendleton, SC 29670
 Phone: 864-646-2133; Fax: 864-646-2178
 Email: nemalab@clemson.edu
 Services and Fees: In-state—\$10; out-of-state—\$30.

North Carolina

North Carolina Department of Agriculture and Consumer Services Agronomic Division
 Nematode Assay Section
www.ncagr.gov/agronomi/index.htm
 4300 Reedy Creek Road
 Raleigh, NC 27607
 Phone: 919-733-2655
 Fax: 919-733-2837
 Services and Fees: In-state—\$3; Out-of-state, pinewood, research, PCR—\$10.

Georgia

Extension Nematology Laboratory
plantpath.caes.uga.edu/extension/clinic.html
 2350 College Station Rd.
 Athens, GA 30602
 Phone: 706-542-9144
 Email: gjbagd@uga.edu or jcross@uga.edu
 Services and Fees: All samples submitted through GA County Extension Office—\$12; all samples not submitted through County Office and out-of-state—\$25; root-knot nematode species—\$35; free-living at genus level—\$45.

Virginia

Nematode Assay Laboratory
www.ppws.vt.edu/extension/nematode-laboratory/index.html
 115 Price Hall
 Virginia Tech
 Blacksburg, VA 24061-0331
 Phone: 540-231-4650
 Fax: 540-231-7477
 Email: jon@vt.edu
 Services and Fees: Routine assays—\$11; routine plus cysts (usually for soybeans and tobacco)—\$19.00

Tennessee

Testing is not done at this time.

Appendix 2. Fertility and Nutrients

Fertility 101

A healthy blackberry planting will produce higher yields, be more competitive for water and nutrients, and be more resistant to pests and diseases. One way to guarantee the health of plants is to make sure the nutritional needs of the plant are met. Nitrogen is the main nutrient needed by the plant, but it is not the only nutrient needed (Table 2-1). The optimum time for fertilizer applications depends on factors such as the soil type, the crop, the nutrient, and the climate. For example, nitrogen fertilizers are often a brief and limited source of nutrients because of the mobility of nitrates, which mostly dissolve in soil water. The same happens with the nitrogen provided by microorganism feeding after applying high levels of organic matter. Also, climate and temperature influence nitrogen availability because microorganism populations increase nitrification in spring. Therefore, crops respond positively after nitrogen applications in spring.

Perform a soil test at least one year before planting to allow pH adjustment to 6.5 and nutrient amendment. Biennial soil and foliar testing can provide valuable information by identifying nutrient deficiencies and pH imbalances. Base all fertilizer and soil amendment applications in an established planting on foliar and soil analysis results. This practice will eliminate problems with nutrient imbalances and save money because fertilizer is only applied when needed. Table 2-2 gives the sufficiency ranges for the various elements in blackberry leaves. For foliar analysis, collect 50 to 100 mature leaves from primocanes in the section six to ten nodes from the terminal in mid-to-late July. Contact your local Extension agent or fruit specialist for more information on how to collect samples and where to send them.

Nutrient availability in the soil is dependent on pH, soil type, moisture content, nutrient mobility, and nutrient concentration. Most nutrients are available between

a pH of 6.0 to 7.0. Iron, boron, copper, manganese, and zinc are unavailable in soils with a high pH. Calcium, potassium, magnesium, and molybdenum deficiencies, as well as aluminum, manganese, and iron toxicity, are common in acidic soil. Heavy nitrogen fertilization will lower a soil's pH over time, increasing its acidity. Certain soil types have a greater ability to hold and supply nutrients because of a high cation exchange capacity (CEC). Soils high in clay and organic matter have a high CEC, while sandy soils have a low CEC. Sandy soils require higher fertilization rates because of the lower CEC. Many nutrients rely on water to move them towards and into the roots, so adequate soil moisture is necessary for uptake.

The interaction among elements is also important. For example, high levels of phosphorus can lead to zinc deficiencies, so take care when using poultry litter, which is high in phosphorus, as a fertilizer. High potassium concentrations will limit magnesium uptake, resulting in deficiency. Excess nitrogen can induce calcium, potassium, and magnesium deficiencies.

Nutrients

Nitrogen (N)

Nitrogen is one of the most important elements for growth of most plants. It has a dynamic cycle in the soil, water, and air and is usually the element in the lowest levels in the soil compared to crops' needs. Generally, caneberries need more N than soil can provide to support plant growth and fruit production, and nitrate is preferred instead of the ammonium N form. Because it is the nutrient element most demanded for blackberry cultivation, N is the focus of any fertilization program. Erect blackberries require about 25 pounds per acre in the first year of the planting. In the second year, they require about 40 pounds per acre, and they require about 50 pounds per acre in year three and all following years.

Manures and Other Organic Materials for Nitrogen

Manures and composts are good sources of N and organic matter but have varying concentrations of N, P, and K. Because of the varying numbers, an accurate recommendation rate is difficult to make. Only half of the N in manure or compost will be available to the plant in the year it is applied. The remaining N will be released in subsequent years. Account for this holdover when figuring fertilization rates. Ideally, apply manure during late fall or winter to allow time for adequate decomposition. Fresh manure cannot be applied within 120 days of harvest if fruit will come into contact with the ground or is likely to be splashed with soil. Apply fully composted manure at anytime and at higher rates than uncomposted manure. Another advantage of using composted manure rather than fresh is that the composting process breaks down many of the weed seeds present in fresh manure.

Cottonseed meal (7-2-2) is a predictable source of N that is easy to spread within a row. Blood meal is a more expensive alternative, but it has higher N levels (12-1.3-0.7) and is readily available to the plants. In order to apply approximately 60 pounds of N, use 860 pounds of cottonseed meal or 500 pounds of blood meal per acre. Feather meal (10% N) can be used at 500 pounds per acre. If the aisle cover crop is contributing N to the soil, this should be taken into consideration before applying supplemental N.

Beyond Nitrogen

All nutrients other than N should only be added as needed, based on soil and foliar analysis:

Phosphorus (P) is an important macronutrient for caneberry commercial production because it is required in relatively large amounts, and it often becomes deficient in commercial orchards. However, compared with other crops, caneberries require low levels of P. Excessive P can obstruct micronutrients uptake. Thus, base accurate P_2O_5 applications on leaf analysis, soil pH and nutrient content, CEC, the desired yield, and other factors. Soil pH directly impacts P availability. Phosphate ions react with carbon and magnesium in alkaline soils and with aluminum and iron in acidic soils, generating few soluble substances. Phosphorous does not have good mobility in soil, so surface banding of P is not as effective as subsurface

banding. The development of roots is necessary for P fertilization in caneberries because roots absorb this nutrient from soil solution. Increased plant root mass will aid P uptake. Due to its immobility in the soil, preplant application and incorporation of P, if needed, may satisfy the needs for this element for the life of the planting.

Potassium (K) is utilized to transport nitrates from roots to leaves and to regulate stomata for proper gas exchange (carbon dioxide, water vapor, and oxygen) with the atmosphere. In caneberries, base proper K_2O applications on leaf and soil analysis and soil parameters because excessive amounts of banded K may burn new roots, especially in sandy soils. Uptake of K occurs essentially through diffusion, so root mass is needed to improve K plant uptake. Soil chemistry affects the availability of K. Soil supplies K due to its cation exchange capacity (while clay particles are negatively charged, K cations are positively charged). Potassium becomes more effective when it is broadcast into soils before plants are established. Potassium is mostly required during fruit development and affects fruit quality. Adequate K content in the plant is usually reflected in appropriate fruit firmness. In caneberries, no relationship has been found between K content in soil and K levels in leaves. Potassium content fluctuates in leaves during the growing season, and it decreases as fruiting increases.

Calcium (Ca) is an essential nutrient for cell wall membrane structure, permeability, and for several physiological processes. Calcium is usually present in sufficient amounts in both soils and in plant tissue, and it is rarely applied to blackberries. Calcium levels in blackberries are between 0.2% and 1.0%. Calcium deficiency is not commonly observed. Foliar Ca applications work well when corrections are needed. In 'Cheyenne' blackberries, Ca fertilization increased plant growth after two growing seasons.

Magnesium (Mg) is essential for chlorophyll production and N metabolism. Plant concentration of Mg ranges from 0.1% to 0.4%. Studies have demonstrated that leaf Mg concentration is positively correlated with Mg content in the soil. Through leaf analysis, various types of relationships have been observed between Mg and other nutrients. For example, leaves with a high Mg foliar content show lower Ca levels.

Sulfur (S) and N are both key components of proteins. Sulfur in the sulfate form (SO₄) is moderately mobile in soil. Deficiency symptoms are similar to those of N deficiency. Sulfur applications are usually not required; however, if it is needed, 20 to 50 lb S/acre could be sufficient for making nutritional corrections. Overall, proper amounts of plant S concentration are between 0.1% and 0.5% with a common N:S ratio of 15:1.

Boron (B) is important for auxin activity. In caneberries, B is necessary for bud break and fruit. Boron promotes plant growing tips and roots. When it is deficient in soils, roots do not grow properly thus limiting other nutrient uptake. Boron, which is present in very small amounts, has high mobility in soils. Boron deficiencies can promote plant abnormalities such as reduced yields, small berries, and in extreme deficiencies, cane dieback. For predicting B needs in fruit crops, soil test is less accurate than tissue test. Postplant application of B and other micronutrients should be based on

tissue analysis, not soil tests. To correct nutritional problems in caneberries, either broadcast or foliar spray may be used. B rates between 1.0 and 1.5 lb B/acre broadcast and 0.1 and 0.15 lb B/acre foliar may be used. Foliar applications are preferred over broadcast. Annual growth applications of B should not be used. Take care not to over apply B because toxicity can occur rapidly.

Copper (Cu) is required for carbohydrate and protein synthesis: it activates numerous enzymes and enhances respiration. Plant tissue concentration of Cu typically varies between 5 and 20 ppm. Copper soil content is often sufficient for caneberry growth. However, if deficiencies occur, foliar applications may be used, but only if necessary. Constant applications of Cu increase soil content to excessive amounts.

Manganese (Mn) is necessary for P and Mg uptake. Manganese deficiency in caneberries is rarely

Table 2-1. Nutrients Needed for Proper Blackberry Growth.

Nutrient	Function	Soil Mobility	Limiting pH	Plant Mobility	Deficiency Symptoms
Nitrogen	Basic plant growth	Very mobile	None	Very mobile	Yellowing of foliage; stunting (cane height and diameter); lower leaves turn red or fall off
Phosphorus	Metabolism; stimulate root growth	Immobile	Very high	Mobile	Stunted, dark green foliage; purple hue in older leaves
Potassium	Stomatal opening and closing; movement of nitrates	Very mobile	Low	Very mobile	Small necrotic spots on older leaves; interveinal chlorosis on young leaves
Calcium	Cell wall formation; cell division and elongation	Very immobile	Low	Very immobile	Tip burn in unfolding leaves; chlorotic young leaves; blossom end rot
Magnesium	Chlorophyll production; nitrogen metabolism	Immobile	Low	Mobile	Interveinal chlorosis starting at leaf tips, margins of older leaves
Boron	Auxin activity	Mobile	None	Immobile	Deformed fruit; delayed bud break
Zinc	Auxin production	Immobile	High	Immobile	Rosette of terminal leaves; reduced leaf size; short internodes
Iron	Chlorophyll production	Very immobile	High	Very immobile	Chlorotic young leaves; brown leaf margins; apical bud growth suppressed
Sulfur	Hardening off for cold/drought tolerance	Mobile	None	Immobile	Thin stems; stunting; yellow leaves (similar to nitrogen deficiency)
Manganese	Phosphorus and magnesium uptake	Immobile	High	Immobile	Dull, interveinal chlorosis in older leaves; spotting or gray specks
Molybdenum	Nitrogen metabolism	Mobile	None	Immobile	Interveinal chlorosis; leaf dieback; deficiencies uncommon

observed; however, in soils where pH is greater than 7.0, Mn deficiency is probably present. Instead of soil applications, several foliar sprays during the growing season at rates between 1.0 and 2.0 lb Mn/acre will be effective.

Zinc (Zn) is regularly present in small quantities in fruit plants. It is a component of organic substances and complexes such as proteins and auxins. Zinc concentrations in caneberries should be between 20 and 50 ppm⁻¹. A common observable symptom of Zn deficiency is a terminal leaf with a rosette shape and light green, yellow, or white interveins, mainly in older leaves. Foliar applications are frequently used, but soil applications of this nutrient, either broadcast or banded, can be effective. Rates between 5 and 20 lb Zn/acre, applied broadcast, are recommended if deficiencies of this element occur.

Iron (Fe) is a component of several organic substances, such as enzymes. It is involved in chlorophyll synthesis; thus, chlorosis is a typical symptom of Fe deficiency. In plant tissue analysis, proper content of Fe varies from 50 to 250 ppm. When it is needed, foliar sprays are the best method to apply Fe. Foliar rates of 1.0 lb Fe/acre are effective. Similar to Mn, Fe is both strongly and easily tied-up or fixed by the soil.

Table 2-2. Macro- and Micronutrient Foliar Sufficiency Ranges for Blackberries.

Nutrient	Range
	-----%-----
Nitrogen	2.00–3.00
Potassium	1.50–2.50
Phosphorus	0.25–0.40
Calcium	0.60–2.50
Magnesium	0.30–0.90
Sulfur	0.10–0.50
	-----ppm-----
Manganese	50–200
Iron	50–200
Boron	30–50
Zinc	20–50
Copper	5–20

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