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SOUTHEASTERN BLACKBERRY PRODUCTION on the Rotating Cross-Arm (RCA) Trellis

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Origin of this Guide and How to Use It

This handbook is meant to guide new users in efficiently managing blackberries on the Rotating Cross-Arm (RCA) trellis. Additional video resources for RCA and blackberry production are available on our YouTube Channel UAEX Fruit and Vegetable.

We appreciate the early efforts of Herb Stiles in developing and later Fumi Takeda in advancing this novel trellising technique for blackberry production. Subsequently our research here in Arkansas has developed the fan training method and produced more data on crop yields, fruit quality and economics for Arkansas and the surrounding region. Many of the results and recommendations that we have developed since our trials began in 2017 are presented in the guide.

Scan the QR code to be redirected to our Rotating Cross-Arm Trellis (RCA) for Blackberry webpage.

Limitations in SE Blackberry Production and Opportunities for RCA and Moveable Trellises

Blackberries are native to the Southeastern U.S. and grow wild throughout the state of Arkansas and many other states. However, environmental conditions such as extreme temperature fluctuations, high humidity and heavy rainfall can stress plants and reduce fruit quality. Extreme freeze events in winter, resulting in cane death and reduced blackberry production, commonly occurs in the Southeast. Winter temperatures below -6°F will cause blackberry cane damage or death (Takeda 2017). In addition, 'blackberry winter' or spring frosts or freezes that kill blackberry blooms have regularly reduced blackberry crops in the Southeast in recent decades.

On the other hand, excessively warm climate conditions in spring and summer can increase the incidence of diseases and disorders that impact profitability of blackberry production (Figure 1). In 2010, for example, white drupe disorder caused a 30% loss of fresh-market blackberries in Southeastern states (Takeda et al. 2013). While there is a genetic component to this disorder, climatic conditions such as high light, temperature, or humidity can exacerbate this disorder (Henderson 2020, Martin et al. 2017). For more information on identifying and understanding the causes of fruit disorders please see "What is wrong with my blackberry? Identifying Fresh-Market Blackberry Disorders" (McWhirt et al. 2023).

Cultural practices such as trellising and pruning can dramatically reduce abiotic, biotic and insect stressors while improving plant productivity (Schoneberg et al. 2021). Trellising manipulates a blackberry canopy to allow improved air movement and light penetration. This increase in air and light can lower canopy humidity and temperature and help foliage dry more quickly after rain events. This manipulation of the blackberries canopy environment via trellising will make the canopy less favorable for pests and environmental disorders, limiting population sizes and slowing the spread of diseases (Henderson 2020, Diepenbrock and Burrack 2016).

Proper pruning also improves canopy and fruit quality. Heavily pruned blackberry plants (25-50% canopy reduction), for example, showed an 8-33% reduction in intracanopy spotted wing drosophila (SWD) populations when compared to unpruned plants. An 80% reduction in intracanopy SWD populations was observed when heavy pruning was combined with a trellising system that lowered canopy humidity (Schoneberg et al. 2021). With zero tolerance for SWD infestation of fruit in fresh markets, growers must take a very proactive approach to dealing with this pest, beginning with effective pruning and trellising.

Figure 1. Blackberry fruit affected by several fruit quality disorders.

Growers utilize a variety of trellising and pruning methods in blackberry production. Methods vary in structure, design, cost, and degree to which the canopy can be manipulated. The I-, T- or V-trellising methods are common blackberry training systems. These structures are comparatively inexpensive to construct and easy to learn. These systems offer growers limited canopy environment control with moderate labor input. Plant canopies, however, remain dense, particularly when new primocanes reach maturity. As a result, the interior canopy humidity and temperature remains high and interior foliage can remain wet for extended periods after rain or heavy dew, creating ideal environments for diseases and insect populations. These limitations motivated researchers to explore and develop trellising systems that offered growers more control over canopy environment.

What are Moveable and Rotating Cross-Arm (RCA) Trellises?

Recently, movable trellising systems like the Rotating Cross-Arm trellis, or RCA, have grown in popularity among blackberry growers in the Southeast to help combat extreme weather impacts on blackberry production. It is estimated that more than 300 acres of blackberries are currently utilizing the RCA in the Southeast. The trellis arms and cane-training method of the RCA allow the blackberry canopy to rotate 130° (Figure 2). This results in the ability to physically change the orientation of the canopy and to manipulate canopy environmental conditions. When the canopy is rotated so it lays on the ground it can easily be covered with a row cover, protecting buds and flowers from damaging cold temperatures during the winter and early spring. During flowering, the canopy can be rotated so that 95% of developing berries are positioned on the sun exposed side of the trellis long-arm. Another rotation position will place 95% of berries on the shaded north side of the trellis during the hot summer months, reducing fruit temperature by 14°F (Takeda et al. 2013). Additionally, lateral branches on the RCA are trained vertically and tightly, creating a narrow, single pane canopy which improves both the air movement within the canopy as well as foliar light absorption, while lowering canopy temperature. (Henderson 2020). All this will reduce the favorability of the canopy environment for diseases and insects. When compared to plants grown on a T-trellis, research has shown that RCA plants experienced a 6-11% reduction in cull fruit (McWhirt et al. 2020, Henderson 2020), and lower average SWD egg counts on fruit (Henderson 2020). This has been attributed to lower humidity and cooler temperatures within the blackberry canopy when trained on the RCA compared to plants trained on a T-trellis (Duncan et al. 2023). **While there are higher initial material costs and labor needs associated with the RCA, growers in Arkansas and southern Missouri have adopted the RCA for blackberry production due to faster harvests, the ability to protect canes and flowers from freeze and frost events, and improved fruit quality.** Additionally, 'pick-your-own' operations have found the RCA trellis to be useful as a marketing technique. Customers are drawn to the wall of fruit that is easily picked in the shade (Figure 2 and 3).

Figure 2. View of blackberries grown on a Rotating Cross-Arm (RCA) trellis in Arkansas. Rows are oriented east and west. The trellis on the left is in the bloom position while the trellis on the right is in the harvest position. Fruit develops only on the shaded (north side) of the trellis.

Benefits

Frost Protection:

The ability of the RCA to mitigate environmental stress factors that have historically limited production has prompted the expansion of blackberry production into new areas (Takeda 2012). The RCA gained popularity in the Northeastern U.S. for its ability to protect plants from damaging freezing conditions in winter. The additional frost protection offered by row covers enables covered canes to remain viable when winter temperatures reached -22°F (Mettler and Hatterman-Valenti 2018). During recent, and multiple freeze events, Arkansas growers have successfully protected blackberry blooms from spring frosts using the RCA. Canes positioned horizontal to the ground with a row cover experienced less winter injury, had an increased number of flower clusters, and an increased fruit yield compared to uncovered upright plants (Takeda and Phillips 2011). In 2014/15, Ohio growers utilizing a covered RCA reported a 5% crop loss due to freezing winter conditions compared to the 100% loss reported by other blackberry growers (Strik et al. 2017). With row covers, growers in colder climates have achieved consistent yearly blackberry production by using the RCA (Takeda 2012). Selecting a cultivar that performs well in the desired production area will increase the extent of protection offered by row covers (Mettler and Hatterman-Valenti 2018).

Sun and Heat Protection:

The popularity of the RCA is increasing in the southeastern U.S. due to the trellis' ability to shade developing fruit. Among the environmental factors that could cause white drupe, exposure to UV light or high light intensities are leading contributors (Stafne et al. 2017). Protecting the fruit from direct sunlight by rotating the fruit into a shaded position will help prevent sunscald and white drupe (Henderson 2020).

Canopy Thickness:

When trained properly, primocanes and floricanes remain separated on the RCA, creating a single plane of fruit compared to a double plane on a T- or V-trellis (Figure 4). In addition, when attaching lateral canes to the RCA training wires, canes can be spaced and prevented from crossing each other. Combined, these factors reduce canopy density and thickness compared

Figure 3. Blackberry fruit is positioned on a single side of the RCA trellis.

Figure 4. View of a blackberry grown on a V-trellis. Notice the double plane of the fruiting wall. New primocanes will grow and fill the space between the two fruiting planes, which creates a dense canopy.

to standard T- or V-trellises. This narrower canopy heavily influences canopy temperature and humidity. Temperature in the upper canopy is reduced while humidity throughout the entire RCA canopy is lower when compared to the same locations on a T-trellis

(Duncan et al. 2023). This change in canopy environment will reduce climate favorability for some diseases and insects. (Henderson 2020). In addition, penetration and coverage of pesticides into the canopy is also greatly improved on the RCA. An RCA spray study conducted at the University of Arkansas showed that a ½ volume spray application resulted in similar foliar coverage as a full volume spray on the RCA (Cato et al. 2023). These results indicate that the RCA may allow growers to reduce the volume of water used during pesticide applications, which could save time and money. Growers should recalibrate sprayers speficically for the RCA to minimize lost spray material in a thinner canopy. For more infomation on recalibration see this guide from Dr. Jason Deveau. **In Arkansas, blackberries grown on the RCA have experienced a reduction in pest pressure and the amount of culled fruit, this is likely related to improved spray coverage and reduced canopy humidity and temperatures.**

Figure 5. Full canopy coverage of Osage blackberry canes on the RCA trellis in Arkansas. This picture shows the historically recommended "bending" training method with a 5 foot plant spacing.

Harvest:

With the canopy in the bloom position during bud break all fruiting laterals grow upward towards the sun, all in the same direction. When rotated to the harvest position, 95% of fruit will develop on a single side of the canopy (Figure 3). This makes harvest easier. Research conducted by Dr. Amanda McWhirt estimates a 33-40% reduction in harvest labor hours for fruit picked on the RCA compared to the T-trellis. Easier access to the fruit and the shady harvesting conditions makes harvesting the RCA easier on pickers. One grower reported a 30% increase in harvest efficiency (Takeda et al. 2013).

Improved Yields, Fruit Size and Quality:

Comparing yields between trellising systems can be challenging. While a floricane plant will yield significantly more per plant on the RCA compared to a standard T-trellis, yields per meter of plant row on the RCA are similar or lower than the T-trellis. In research conducted at the Fruit Research Station in Arkansas, lower yields per foot of row were observed on the RCA when canopy fill was poor. Maximizing canopy coverage by ensuring all available trellis space is filled will improve per foot of row yields on the RCA. Good cultivar selection and maintaining plant health and vigor will help increase canopy coverage (Figure 5). Closer plant spacing could also improve canopy coverage.

Fruit size and quality can be greatly enhanced by the RCA. Both 'Osage' and 'Ouachita' cultivars have shown significantly larger fruit size when grown on the RCA compared to a T-trellis (Henderson 2020). Larger fruit size is attributed to several aspects of the RCA training protocol, such as increased exposure of foliage and canes to light as well as the retention of fewer primocanes (Henderson 2020, Takeda et al. 2003a). While cultivar selection will impact cull rates, plants grown on the RCA have shown significant reductions in cull weight. In one study, RCA plants lost 11% of their yield to common blackberry disorders (such as anthracnose and white drupe) while the same cultivars experienced a 26% loss to these disorders on the T-trellis (Henderson 2020).

Limitations

Labor:

A higher demand for labor is arguably the greatest limitation to production on the RCA. Historically, the method for training on the RCA required bending and training new primocanes starting in the early spring and continuing into the summer, often overlapping with harvest. Once started, bending needs to be done every 2 or 3 days to maintain horizontal primocane growth along the bending wire and avoid breaking primocanes, requiring a significant amount of labor hours. A new labor-saving method for training on the RCA, referred to as the fan method, was developed at the University of Arkansas, however even this new method has a higher labor demand when compared to a T-trellis. While the new RCA training method reduces training labor needs, especially during the harvest period, labor shortages could make training at the necessary times impossible (Takeda et al. 2003a). Extra labor is also necessary during the off-season to apply protective row covers, especially if covers are not secured properly and are blown off during winter storms. Further details on labor hours and cost will be covered later.

Cane Breakage:

While young primocanes are flexible, canes begin to lignify and stiffen as they age. These more rigged canes are susceptible to cracking and breaking when rotated. This is expressly true for thick erect cultivars. The fan training method, which will be detailed later, has shown limited cane cracking compared to the standard bending training method.

Cost:

In addition to extra labor costs, construction of an RCA system can cost more per acre than other trellis systems. When compared to the cost of constructing a standard T-trellis, the RCA is estimated to be as much as 30-60% higher. Further details on construction and establishment costs will be covered later.

Economics

There is little published economic data on the RCA. It is generally acknowledged that the construction of an RCA trellis costs more per acre than a standard T-trellis. Estimates received from Arkansas growers in 2021 estimated a cost between $3,500 - $6,800 per acre for an RCA system compared to just under $3,000 for a standard T-trellis. The large range in cost for the RCA could be partly explained by whether a prefabricated kit was purchased or a trellis was custom built, and the number of plants per acre.

Per plant yields on the RCA are higher than yields on the T-trellis. However, average yields per foot of trellised row for the RCA vs T-trellis have, on average, been comparable. Blackberry yields per foot of row on the RCA tend to be higher in years with severe freeze and cold injury. **In trials led by Dr. Amanda McWhirt in 2018-2021 in Arkansas, average yields on the RCA ranged from 0.9-3.2 lbs per foot of row compared to 0.64-3.17 lbs per foot of row on the T-trellis.** Based on these results, it is recommended that growers decrease plant spacing from 5 feet to 3 feet on the RCA to improve canopy fill and increase yields per row foot.

A study conducted at the University of Arkansas recorded a 76% increase in labor hours needed for cane training and pruning for the RCA compared to a T-trellis, when the standard bending training method was utilized. This demand was reduced by 26% with the fan method (Table 1). On the other hand, harvest labor hours were reduced by 38% for the RCA (regardless of the training method utilized) compared to the T-trellis. Additionally, fruit quality and berry size were both improved on the RCA and a lower percentage of fruit was lost to pre-harvest fruit disorders. With this labor-saving harvest and the reduction in cane training hours with the fan method, the RCA could prove profitable. As yield is directly affected by canopy fill on the RCA, proper plant nutrition and spacing will be essential to achieve profitability.

Table 1. Comparing total annual labor hours (in minutes) for two modified RCA training methods and T-trellis to the standard RCA training method.

Training Method	Labor Input (min per linear row foot)	% Labor Change Compared to the Standard Method
Fan Method (RCA)	10.5	**26% decrease**
Bending Method (RCA)	14.2	**Baseline**
T-trellis	3.4	**76% decrease**

RCA Trellis Design and Components

There are several manufacturers of moveable and rotating trellis systems. Trellis Growing Systems manufactures a fiberglass model, and Atlas Greenhouses produces an aluminum model. Both are in use in Arkansas. A Trellis Growing Systems trellis was used in much of the research conducted in Arkansas and has worked well. Some cracking was observed on the fiberglass side plates, but with a simple patch the plates held up. There is no patent on the Rotating Cross-Arm trellis design and many growers around the country have used local fabricators to build their own designs. To ensure a trellis functions properly, and to avoid unnecessary damage, follow the assembly and installation instructions provided by the manufacturer.

In general, the components should include and follow these guidelines (Figure 6):

- Long-arms should be about 64 inches long.
- Short-arms should be about 29 inches long.
- The ground post should be offset from the middle of the side plate.
- Some models include an underground stabilizer plate that runs parallel with the row and attaches to the post to prevent the post from twisting in the ground.
- The side plate should have places to allow for placing the arms at the three main positions (Figure 7). Detent or quick release pins can allow for quick adjustments.
- The supportive arms of the RCA can rotate a blackberry canopy into three different positions (Figures 8 and 9). To see all rotation positions throughout a growing season, visit the University of Arkansas' Fruit and Vegetable Program website. A short description of each position is included below.

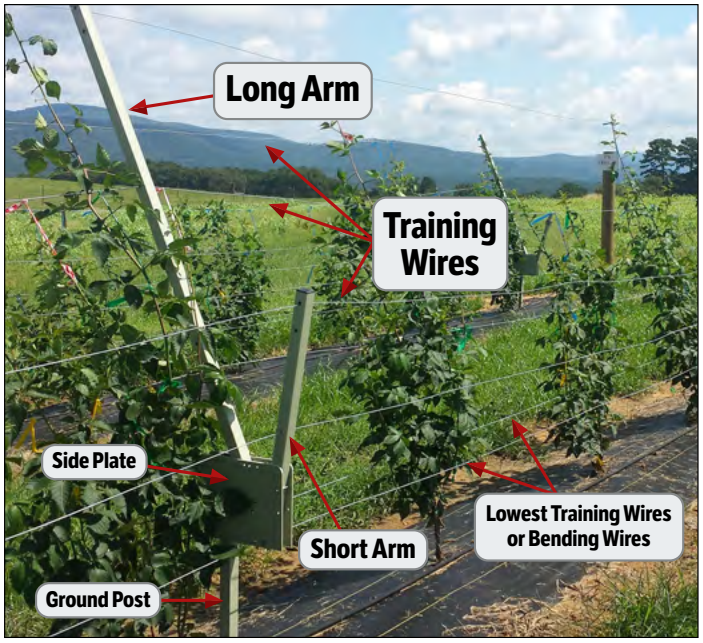

Figure 6. Overview of the components of the Rotating Cross-Arm (RCA) Trellis.

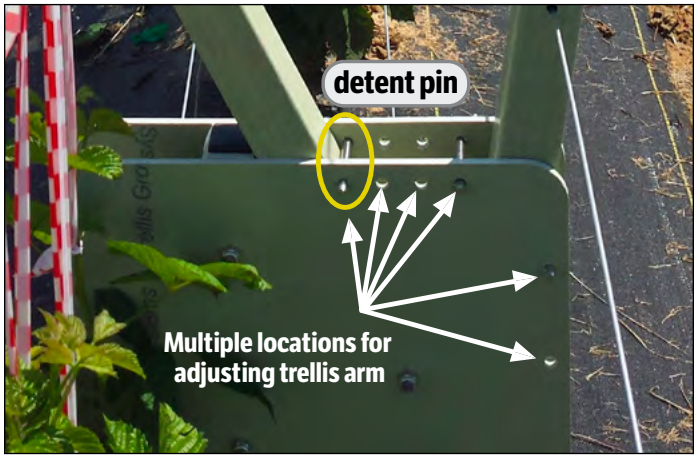

Figure 7. Side plate with multiple places to secure a detent or quick release pin so both the long and short trellis arm can be quickly rotated to the three main positions.

Rotation Positions

- Winter Position: In this position, plants rotate until they are nearly horizontal on the ground. This places them in a position where a floating row cover can easily be applied, and plants can be protected from damaging freezing conditions.
- Bloom Position: In the early spring, plants are rotated from the horizontal winter position to a position at a 90° angle from the ground. This forces nodes to grow upward towards the sun and blooms to open on one side of the trellis, the side exposed to sunlight.
- Harvest Position: When most flowers have opened, or petal fall is occurring on the king blossoms, plants are rotated to a 2 o'clock position, placing all developing fruit on a single side of the trellis. This makes fruit easily reachable during harvest and places both the fruit and harvester in the shade.

If not trained correctly canes can crack or break while rotating the trellis arms. The timing of the rotation is also critical for proper management of the RCA. Rotating from the bloom to harvest position too early would result in fruit developing on both sides of the trellis, complicating harvest and lowering the impact of the protective shade on fruit quality.

Tips on RCA Trellis Construction

- Tie-back posts should be placed at the beginning and end of each row. These should be sturdy and capable of supporting a significant amount of weight. A 5 inch diameter or greater fence post is a good option. Whatever material is selected, the posts should be buried no less than 48 inches in the ground with no less than 30 inches of the post above ground.
- End frame and center frame posts should be offset from the row center by 4 inches. The offset direction will depend on the orientation of the rows. For example, for rows with an east-to-west orientation posts should be offset 4 inches to the north.
- End frame posts should be no less than 72 inches from the tie-back posts.
- Add turnbuckles on trellising wires in-between the tie-back post and end frame posts for easy tightening of the wire.
- Trellis posts should be buried at least 20 inches below ground for adequate stability.
- A maximum distance of 30 feet between trellis posts.
- Do not overtighten the training wires. If over tightened the end trellis arms will begin to twist and bend toward each other, and side plates could crack.
- Visit the University of Arkansas' Fruit and Vegetable Program website for an introduction video on trellis installation.

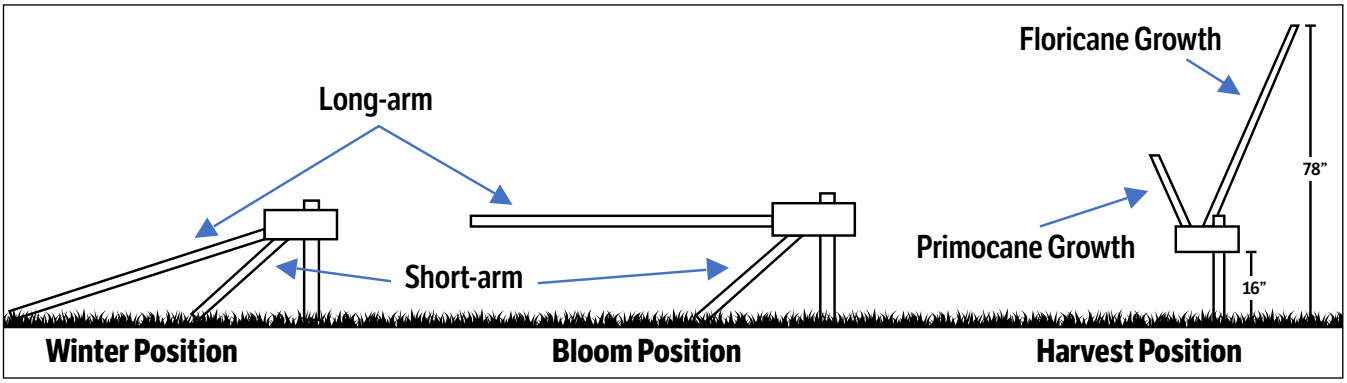

Figure 8. Rotation positions for the RCA. Image adapted from Trellis Growing Systems

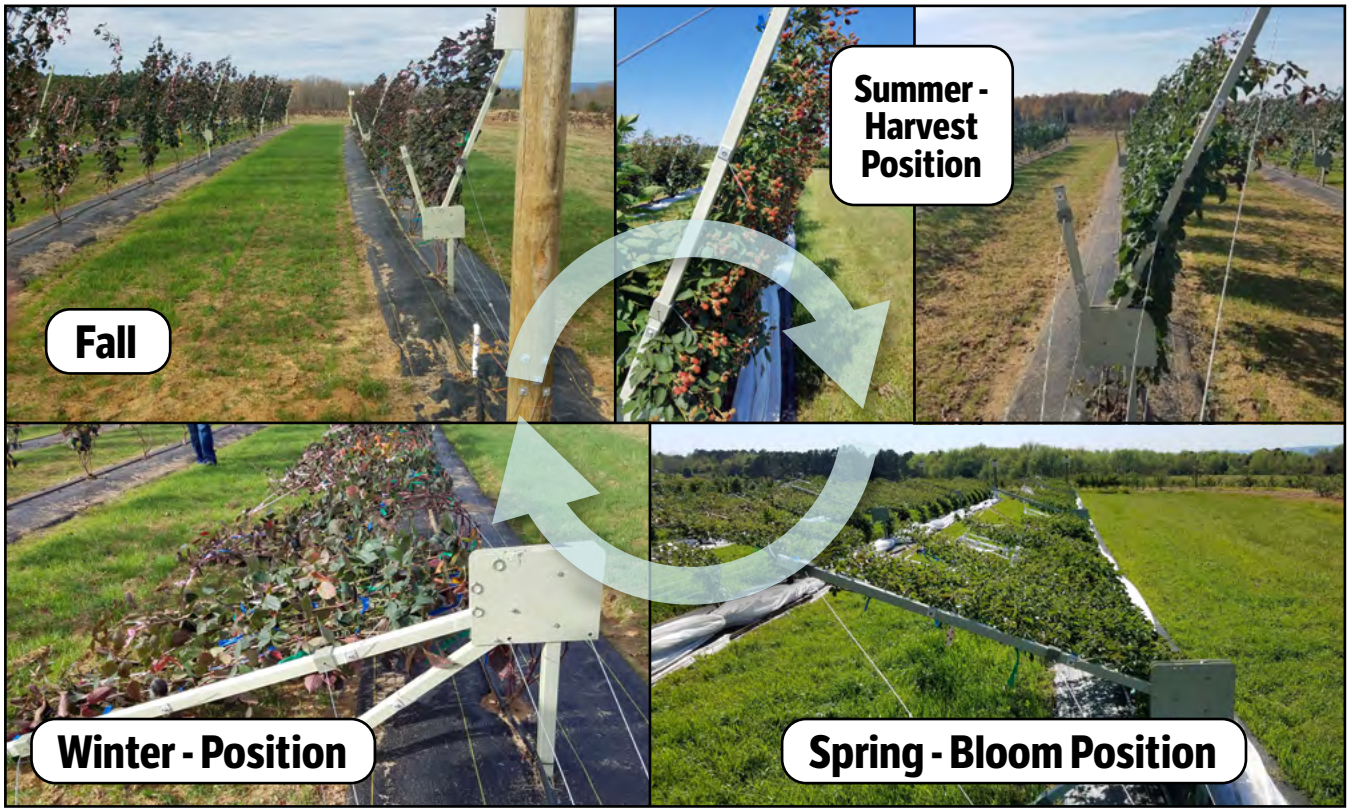

Figure 9. View of the three main trellis positions of the rotating cross-arm trellis through a season.

Getting Started with RCA Trellising for Blackberry

While blackberry production will be covered briefly, a more comprehensive overview can be found in the Southeast Regional Caneberry Production Guide.

Blackberry Plant Characteristics

Blackberry canes are biennial, meaning they have a two-year life cycle, with two distinct cane types. First year canes, called primocanes, emerge from the crown in the late spring and grow vegetatively throughout the summer. Physiological changes in the buds during the fall and winter months transition vegetative primocanes to fruit bearing floricanes. Floricanes will flower and fruit in the summer of the second year on floricane-fruiting cultivars. After fruiting, floricanes die and will need to be removed after harvest. Each year while floricanes are flowering and fruiting, new primocanes will emerge from the crown (Figure 10). These new primocanes will transition into a floricane during the winter months and will flower and fruit the following year.

Pruning is required to achieve maximum yields on blackberry plants. Tipping, or the removal of the growing point of the primocanes, is arguably the most important part of blackberry pruning due to its influence on blackberry yields. Primocanes that are left un-tipped will develop a single large inflorescence at the end of the floricane the following year. Buds below this large inflorescence will not differentiate into reproductive buds (Taketa et al. 2020). By tipping a primocane, the plant's energy is redirected from vertical growth to lateral branch growth (Figure 10). Each bud on these lateral branches can develop into a fruiting lateral (supporting an inflorescence) and flower the following season. With each lateral branch producing multiple fruiting laterals, the yield potential of a tipped plant increases dramatically. Tipping height varies depending on the trellising technique, blackberry fruiting type, cultivar growth habit and grower preference. A standard erect blackberry grown on a T-trellis, for example, is tipped around 4 feet. As lateral branches grow upward, this tipping height on the main primocane places much of the canopy at an easy harvesting height. Whether using the standard bending method or new fan method, pruning protocols on the RCA, when done correctly, increases the amount of trellis space occupied by yielding canes and encourages longer lateral branches. This increases the yield potential for each lateral branch and blackberry plant (Figure 11).

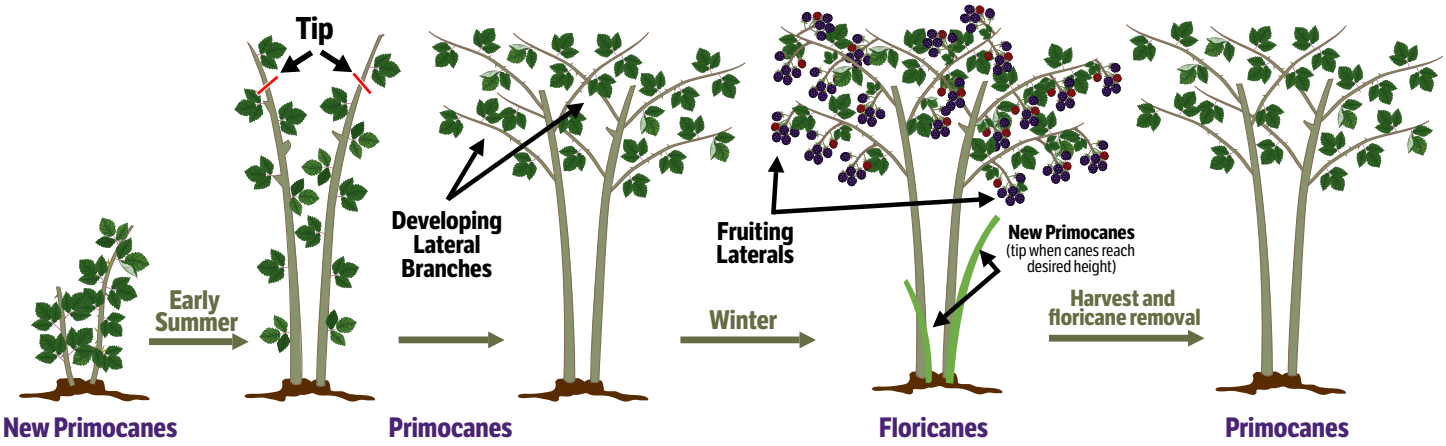

Figure 10. Simplified depiction of biennial growth of blackberries showing the life cycle of a primocane starting in March or April and ending in August the following season. Image by Taunya Ernst, Christina Telfer and Emily Davis.

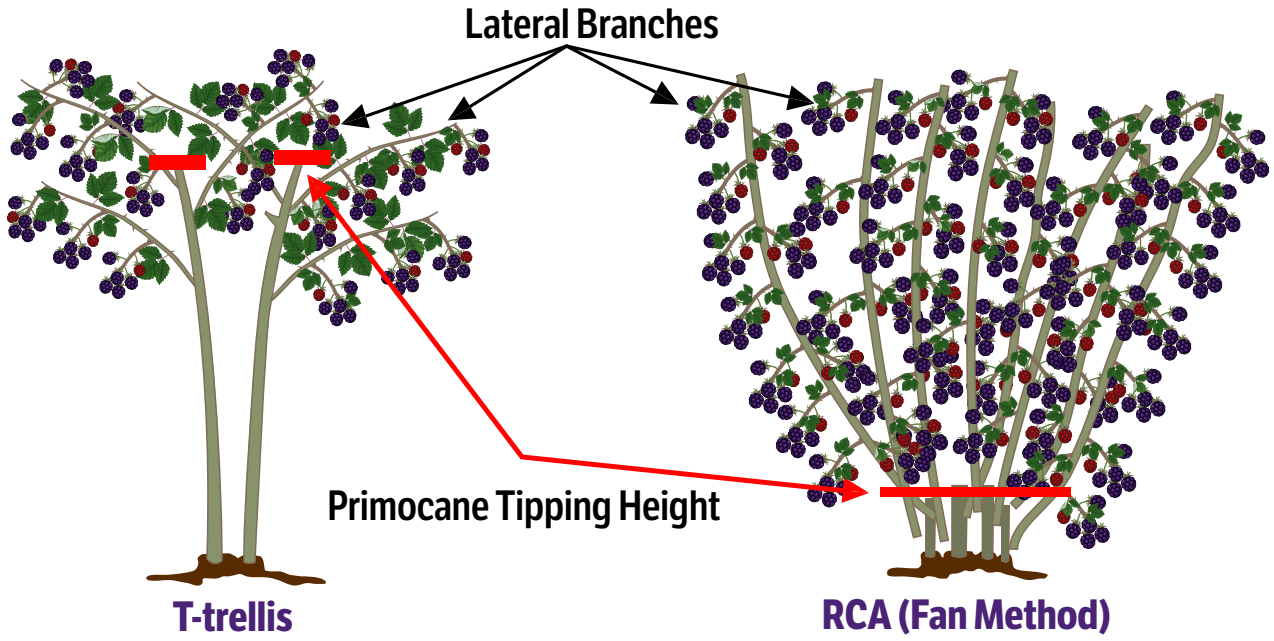

Figure 11. Difference in canopy architecture between blackberry plants trained using the standard T-trellis pruning method and the new fan method on the RCA. Image by Taunya Ernst, Christina Telfer and Emily Davis.

Cane Growth Habit

There are three blackberry growth habits: erect, semi-erect and trailing. Blackberry cultivars that produce sturdy, self-supporting upright canes are erect types, while those that produce flexible canes that tend to grow along the ground are trailing types. Trailing cultivars need trellis support to keep fruit and canes off the ground, while erect cultivars can support themselves. For erect cultivars, trellises are primarily used for the manipulation of the canopy environment by increasing light penetration and air circulation. In the establishment year, erect cultivars will exhibit a trailing growth habit and will require a trellis for support to keep fruit and canes off the ground.

Fruiting Type

Most blackberry cultivars are 'floricane fruiting' meaning they flower and fruit on two-year-old canes (Figure 10). In 2004, blackberry cultivars that produced fruit on first year primocanes were released from the University of Arkansas' blackberry breeding program (Clark 2008). These cultivars, referred to as 'primocane fruiters' or 'primocane producing' cultivars, can have drastically different pruning techniques than their floricane producing counterparts. While there are advantages to growing primocane producing cultivars (Clark 2008) in the Southeast, these cultivars suffer from high heat during primocane bloom in mid-summer, which heavily reduces fruit set. Research conducted on primocane cultivars grown using the RCA indicates these cultivars may not be as suitable for RCA production (Henderson 2020).

Preparing for Blackberry Production

Site Selection:

Blackberries can tolerate a variety of soil types and conditions. To optimize plant vigor and growth, select a location with sandy loam soil that drains well and has 2-3 of soil depth for unobstructed root growth (Carol 2014). Planting on raised beds can improve drainage if soil type or other field conditions inhibit or limit drainage. A moderate slope (less than a 3% grade) will have better air movement, however avoid areas where rows must follow a curve as this will put unnecessary torsion on the RCA trellis arms. A row orientation of east to west is preferred to achieve the shading benefits of the RCA (Thompson 2017).

The site should have access to a reliable irrigation source. Possible irrigation sources include municipal water, well water, or surface water reservoirs (ponds, rivers, or lakes). Surface water sources are more affordable and easier to access, but also have greater

amounts of contaminants and irrigation systems will require adequate filtration to avoid clogging lines (Ernst et al. 2023). If available, municipal water is clean of contaminates, but more expensive as a primary water source. Whatever water source is used, acquire a water test early (before planting) to avoid potential food safety concerns (Thompson 2017).

Site Preparation:

Preparing a site for blackberry production, if done properly, can take up to a year. Rushing to plant could result in poor plant vigor, lower yields, and a shortened lifespan for the planting (Carol 2014). Adjusting soil pH, for example, is a slow process taking as long as six months to a year before lime (raise pH) or sulfur (lower pH) can affect the chemistry of the soil (Thompson 2017). The season before planting, collect a soil sample to determine soil nutrient and pH levels. It is recommended to collect and combine a minimum of ten subsamples per field with the same soil type and cropping history (Pitts and Hanson 2017). Most soil testing laboratories will provide fertilizer and pH adjustment recommendations with the results of the soil test. Incorporate organic matter, such as compost, before planting. If additional drainage is needed, planting rows can be raised using specialized bedding equipment.

Perennial weeds can become a systemic problem in any production field. Perennial weeds should be removed and eliminated before planting when possible. Chemical or manual removal of the weeds is easier and less risky before planting, due to the limited number of available herbicides that can be used once the crop is planted. Increasingly, Arkansas growers are using landscape fabric laid with bedding equipment onto raised rows. Good quality fabric will last the life of the planting and will greatly reduce weed pressure and retain moisture.

Cultivar Selection:

There are many good blackberry cultivars or varieties available. Plant vigor, fruit size, quality, flavor, and pest resistance vary between cultivars. Cultivars with both a trailing and erect growth habit have performed well on the RCA (Henderson 2020, Takeda et al. 2003). Floricane producing cultivars are the dominant blackberry type in commercial production in the Southeastern US. While there are advantages to primocane producing cultivars, they did not perform as well as their floricane counterparts when trialed on an RCA in Arkansas during preliminary studies. Further studies are needed to better analyze the potential of primocane fruiting cultivars on an RCA system (Henderson 2020). Growers should consider fruit quality characteristics and harvest timing when selecting which cultivars to plant. For cultivar recommendations see the Small Fruit Cultivar Recommendations for Arkansas for more information.

Blackberry Cultivars that have performed well on the RCA in Arkansas:

- **'Ouachita'**: An erect, thornless cultivar that produces large, firm berries with a good flavor. Fruit size increased when grown on the RCA. Laterals were shorter on 'Ouachita' compared to other cultivars, which could negatively affect canopy fill. 'Ouachita' shows resistance to white drupe disorder (Henderson 2020)
- **'Osage'**: An erect, thornless cultivar with sweet, round fruit. A very good producer on the RCA, with long laterals that easily reach the top training wire. Fruit size was increased when grown on the RCA.
- **'Ponca'**: Produces large fruit with outstanding flavor. A heavy producer, including a good basal bud yield, that easily fills the trellis space. Currently being trialed in Arkansas.
- **'Natchez'**: A vigorous cultivar that has performed well on the RCA. Producing very long lateral branches, 'Natchez' easily fills the canopy space. The high vigor of this cultivar will require careful monitoring of nutrient management and pruning to prevent overcropping.
- **'Caddo'**: Produces a heavy crop of large fruit with a good, sweet flavor. It may be necessary to reduce in-row plant spacing to achieve a good canopy fill. Currently being trialed in Arkansas.
- **'Von'**: This cultivar has performed well on the RCA. Canes tend to remain more flexible than other cultivars which works well on an RCA system. 'Von's' growth is less vigorous in the planting year, but appears to rebound in the second year. Currently being trialed in Arkansas.

Acquiring Plants:

Starting a planting with healthy, disease and virus tested plants is crucial for long-term vigor of a blackberry field (Carol 2014). Sick plants can experience low vigor, poor fruit quality, low yields and potentially plant death. Acquire plants from a reputable nursery that can ensure healthy virus tested plants. **In Arkansas, most growers now choose to plant virus tested tissue culture plug plants instead of bareroot planting stock.** Growers report improved plant vigor and strong yield the first year after planting with plug plants.

Planting and Crop Establishment:

Planting is most often done in the early to late spring. Planting of bareroot stock can be done anytime during the dormant season. However, plug plants have live green tissue and should be planted after the chance of frost has passed. When possible, plant before rain is expected, or plan to water newly established plants. When laying out rows, make sure there is enough space between rows to accommodate not only farm equipment, but the length of the trellis when in the winter position. In the original protocol for the RCA, it was recommended to space plants 5 feet within the row with 12 feet between rows (Henderson 2020, Takeda et al. 2013). Cultivar selection and plant health will impact vigor and canopy fill, which should be used to determine plant spacing. To achieve full canopy coverage and maximize yields, recent studies support a closer plant spacing, such as 3-4 feet between plants, on the RCA (McWhirt et al. 2019). **We recommend 3 feet between plants for most cultivars.**

Labor:

Blackberry production has a high demand for labor. Labor requirements are influenced by the trellising system utilized. The RCA will require additional labor hours in the spring and summer compared to traditional trellising methods. The 'fan' training method, which has become the preferred RCA training method for Arkansas growers, and will be described in detail later, reduces this labor need, but does not eliminate it. Even with the fan method, be aware that there are annual periods of increased labor demand to maintain a blackberry crop (i.e. pruning and harvest), and a new grower must ensure a secure source of labor is available during these critical times. Primocane tipping and training on the RCA, for example, must be done as canes grow and cannot be corrected later. Delayed tipping will not allow lateral branches to grow to their full length the first year which will negatively affect the following seasons yields. Neglected or improperly cared for plants can become unruly and overgrown and plant health, fruit quality and crop load could be affected for multiple years. High labor times for the RCA include primocane management in the spring and summer, harvest, and floricane removal and transferring primocane lateral branches to the long-arm in the fall.

Pest Control:

Blackberries are a hardy plant compared to other fruiting crops; however, they are still susceptible to a variety of diseases and insect pressures. Early implementation of a thorough IPM program can ensure plant longevity. Consistent scouting and early identification of an issue paired with a well-researched fungicide spray schedule can greatly improve pest management efforts. Many good spray guides have been developed to assist growers in chemical selection and application timing (see the annually updated Southeast Regional Caneberry Integrated Management Guide)

Fertilizing:

Crop nutrient management can be complex for the perennial blackberry. A good annual nutrient management program is essential to maintain plant health and productivity from year to year. Annual leaf tissue sampling in late July should be conducted to monitor crop nutrient status. Refer to the Southeast Caneberry Guide for recommendations on leaf tissue sampling and nutrient sufficiency ranges for monitoring crop health. In addition to foliar testing, soil testing should be done every 2-3 years to help monitor soil pH and significant changes in soil nutritional levels (Strik, 2017). Fertilizer can be applied with irrigation water (fertigation) or banded down the sides of the row in split applications, with the first application in early spring to help encourage and support new primocane growth and fruit development. The timing and quantity of subsequent applications will vary, depending on irrigation strategies and production type (floricane or primocane producer). A higher requirement for nitrogen and potassium has anecdotally been observed for plants grown on the RCA. This is likely due to the higher fruit load per plant however, no studies have been conducted.

Cane and Canopy Management for Blackberry on the RCA

Below is a description of the new training and pruning protocols for the RCA developed at the University of Arkansas. See figure 6 for a description of the main parts of the RCA trellis (Figure 12).

Timeline for RCA Cane Training

The standard bending training method (Figure 12 (single bend)) for the RCA was developed at the Appalachian Fruit Research Station in Kearneysville, West Virginia by Dr. Fumioni Takeda. Developed initially to help prevent the loss of a blackberry crop to extreme winter conditions, it has been adapted by Southeast blackberry growers to assist in protecting the crop from extreme summer conditions. While the many benefits of the RCA have led growers to install this trellising system, the initial training process for the RCA is labor intensive, severely affecting the profitability of an RCA production system. Detailed instructions on this standard bending training system and Rotating Cross-Arm trellis technology for blackberry production is outlined by Takeda and Glenn (2013) and a training video can be found at the University of Arkansas' Fruit and Vegetable Program website.

In response to this labor issue, researchers at the University of Arkansas looked for alternative training methods that would utilize the benefits of the RCA while easing the need for labor. The study conducted at the University of Arkansas compared two modified training systems with Dr. Takeda's original protocol. The first method, called the "Two-way bend", is similar to the standard training method but differed in that primocanes were bent in both directions on the trellis and tipped at 2.5 feet (Figure 12). It was hypothesized that canopy fill would improve, and labor time reduced as the bent primocanes would reach tipping length more quickly. The second method, referred to as the fan method, eliminated primocane bending, instead primocanes were tipped at 10–12 inches and laterals fanned over the long-arm of the trellis (see Figure 12).

The fan method resulted in a two-year average reduction of 26% in labor hours, while bending canes in both directions increased labor hours by 20% the first year but reduced labor by 11% the second year when compared to the standard single bend method. In addition to reducing labor demands, there was also a reduction in observed cane cracking when utilizing the fan method. The promising results of this two-year research trial demonstrate that the fan training method can reduce labor while still achieving good canopy fill. Due to this, many Arkansas growers have already begun adopting the fan method for training primocanes in their RCA fields with good results.

It is not recommended that growers installing an RCA trellis use either bending method due to the high labor requirements. Training protocols for the fan method are outlined in detail below, and growers are encouraged to use this method of training. A training video on the fan method can be found at the University of Arkansas' Fruit and Vegetable Program website.

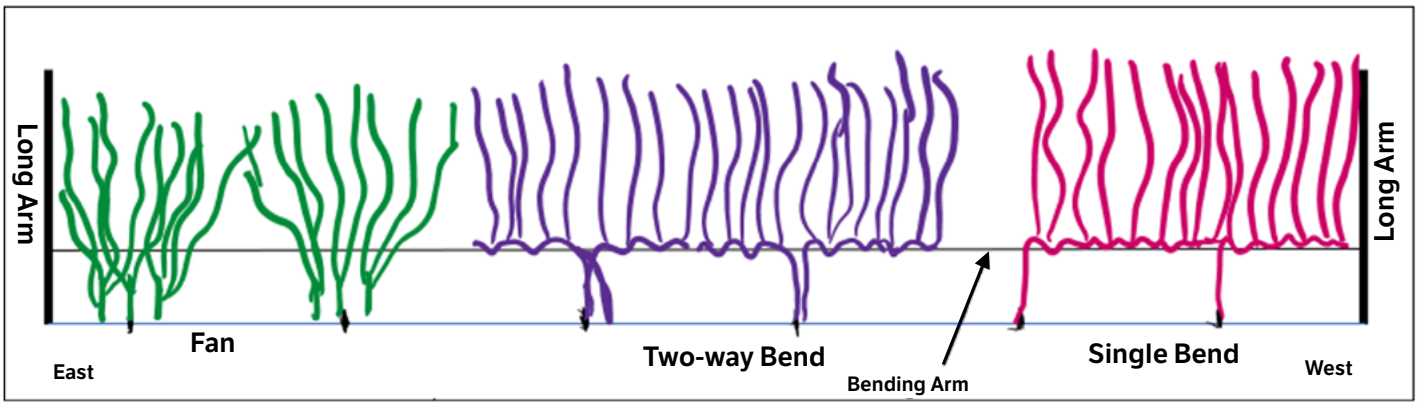

Figure 12. Visual description of the Fan and two-way bend training systems for the RCA.

Fan Method

Planting season

Spring and Summer:

Canopy management is simplified in the planting year due to the unique growth habits of first-year primocanes. First-year primocanes behave like lateral branches in that buds on these canes develop fruiting laterals along the full length of the cane and not only at the growing point. Due to this growth habit, first-year canes do not require primocane tipping. Instead, with the trellis in the harvest position, attach growing canes to the training wires on the trellis long-arm. Canes should be directed to grow between the two bending wires to prevent breakage when plants are rotated. Ensure canes do not cross or tangle with neighboring canes, and space them so they are about 2 inches, or a fist width, apart on the upper training wires. Canes will be spaced closer together on the bending wire. Orchard clips or flexible training tape can be used to loosely secure the canes to the wires. This will give the plant a fan-like appearance (Figure 13). If canes extend over the top of the trellis, wait until growth ceases in the fall then top (cut the end off) canes 6-8 inches above the top wire. Topping can also occur in the late winter or early spring.

Canopy coverage is directly related to yield. If there is unoccupied space on the trellis, instead of topping canes that grow past the top trellis wire, they can be arched over to grow down the trellis to fill that empty space. In initial trials conducted at the University of Arkansas, yields per row foot were often lower on the RCA than the T-trellis despite the per plant yields always being higher. Poor canopy coverage on the RCA is thought to be responsible for these lower yields. Optimizing canopy coverage therefore will increase yields per foot of row on the RCA and improve profitability. **To achieve optimal canopy coverage using the fan method, it is recommended to reduce plant spacing to 3 feet between plants.**

Figure 13. Fanning of year 1 canes.

Fall:

In northern areas when growth ceases in the fall, the canopy can be rotated to the winter position (Figure 14). Before rotating, detach any canes that have been secured to the lowest training wire. Canes attached to the lowest wire risk breaking or cracking when rotating as this forces them to bend at a harsh 90° angle (Figure 15).

Figure 14. Canopies rotated to the winter position in the fall (A) and late winter (B). Plants covered by floating row covers (C).

Figure 15. Canes that were not un-clipped from the north bending wire while the long-arm is bent over into the winter position. The canes show some cracking due to un-due rotation at a sharp angle.

Winter:

In much of Arkansas, winter temperatures tend to be mild, lessening the need for added winter protection. If temperatures remain above 10°F, it is recommended to leave the trellis in the harvest position. Only when temperatures are predicted to drop to or below 10°F should the trellis be lowered to the winter position and covered with a frost cloth. A blackberry cane can experience damage when temperatures drop below 10°F (McWhirt and Clark, 2021). In the winter position, a row cover is easily applied over a single row of the canopy to protect canes and buds from these damaging winter temperatures. **Be sure that plants rotated to the winter position are covered with a frost cloth. Cooler temperatures have been observed at ground level resulting in more cold damage to plants that have been rotated to the ground and left uncovered.**

Figure 16. Row cover blown off a section of RCA row by high winds.

When using a row cover, high winds can quickly become a nuisance if row covers are not well secured. Winds can lift row covers off plants, leaving them exposed to the cold damaging temperatures (Figure 16). Various methods can be used to secure row covers including sandbags, cinderblocks, T- or wooden posts and alligator clips. To keep row covers from resting directly on plants, PVC hoops can be placed at each trellis post, with row cover pulled over these hoops (Figure 17). PVC hoops made the covering and removal of the row covers faster and easier and did less damage to the plants. Covering single rows rather than multiple rows with one big row cover has seen better success but is more labor intensive.

Figure 17. Hoops made of 1.4" PVC pipe and attached to the long-arm of the RCA. Row cover held above the plant canopy by the PVC hoops.

Season 2 and on

Spring:

When early signs of bud break are observed, rotate the trellis to the bloom position (Figure 18 and cover photo). This forces new shoots and flowers to develop only on the sun-exposed side of the trellis. The canopy should stay in the bloom position until king flower buds have opened. Blackberry production in Arkansas is often threatened by spring frosts that can damage or kill tender buds and flowers. If temperatures are forecast to drop below 28°F while plants are blooming, rotate plants to the winter position and protect them with a row cover (Henderson 2020).

Figure 18. Blackberry canopy rotated to the bloom position. Flowers and new growth develop on sunny side of the trellis.

Early Summer:

From the first flush of emerging primocanes in April or May, select 5-6 healthy canes for tipping. When primocanes reach 12-14 inches in height, remove the growing tip with a pair of clippers or pinch off with your fingers, leaving about 10-12 inches of cane. The timing of primocane tipping is critical for the success of the fan method. Tipping by the third week of May in Arkansas is recommended as this allows the majority of selected primocanes to reach above the bending wires (Figure 19). Tipping at this time also ensures enough primocanes are present at the appropriate height so most tipping can be done in just a few passes through the field. Delays in tipping (beyond June 1st) will prevent lateral branch canes from growing to the top training wire by late summer. The resulting inadequate fill of the trellis canopy space will negatively impact yields.

When selecting primocanes for tipping, choose canes that are growing in-between the two bending wires (Figure 20). Canes outside the bending wires will be unable to rotate without breaking. The removal of the cane tip will create a large open wound where diseases could enter and infect the plant (Figure 20). To protect the plants from disease infection, apply a broad range fungicide, such as Captan, immediately after tipping. If possible, avoid tipping 12 hours before or after a rainstorm to reduce the exposure of newly opened wounds to diseases.

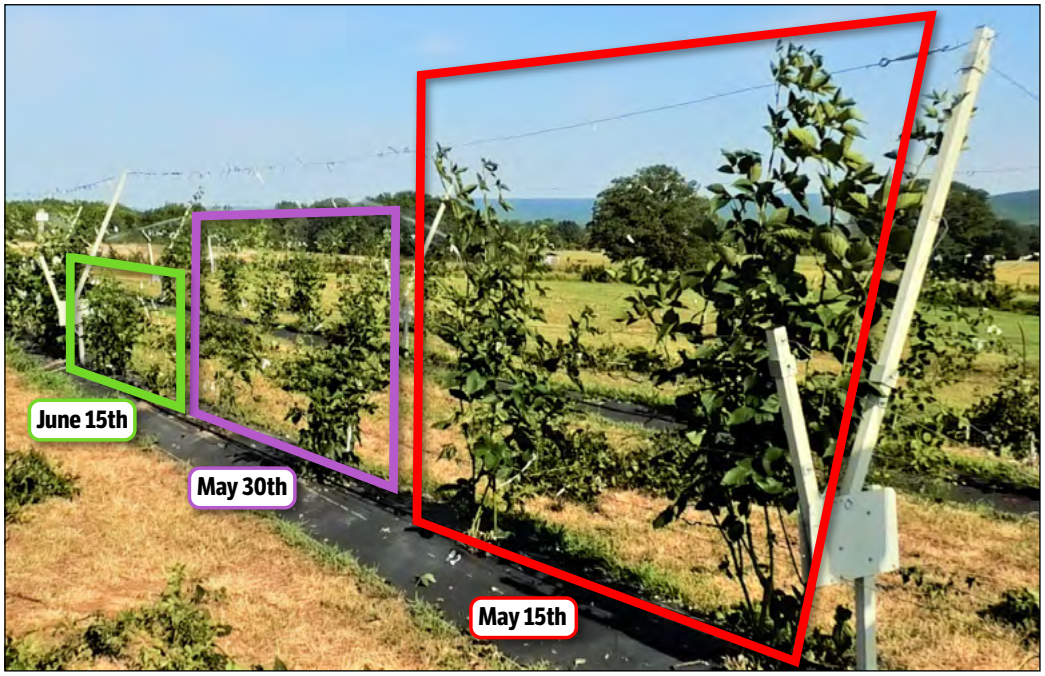

Figure 19. The effect of primocane pruning timing on lateral branch length for blackberries trained in the fan method. The date below the colored boxes indicates the day the primocanes were tipped. It is recommended to tip primocanes no later than May 15th.

Often, the trellis will be in the bloom position while new primocanes are reaching tipping height. These growing primocane will poke through the floricane canopy (Figure 21). These canes can be

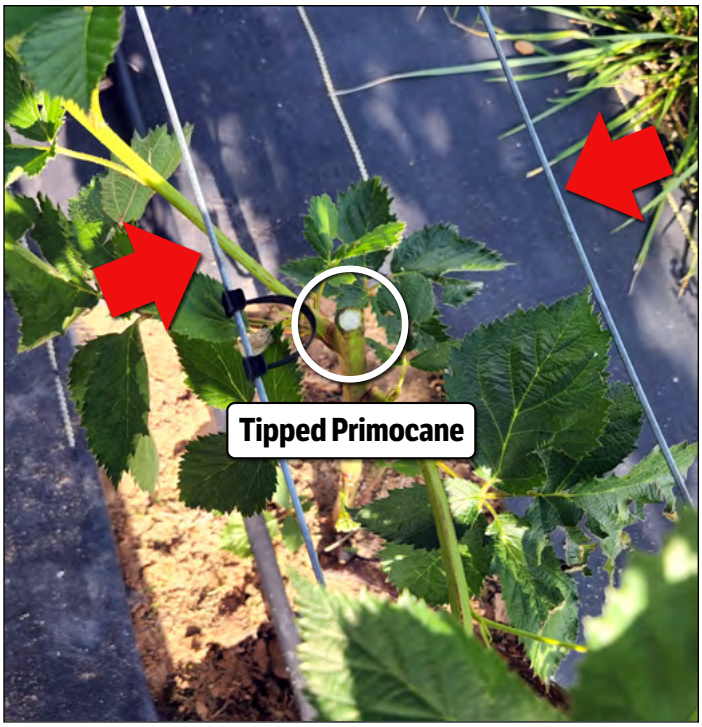

Figure 20. Tipped primocane growing in-between the bending wires (indicated by the red arrows) on the RCA.

Figure 21. Primocane growing through the floricane canopy on the RCA in bloom position.

tipped before standing the trellis up into the harvest position. Once the trellis is in the bloom position, the cane and any lateral branches on the tipped primocanes can easily be pulled to correct side of the trellis and between the two bottom bending wires.

Summer

Rotate the canopy to the harvest position during bloom, when petal fall occurs for the king flowers (Figure 22). After tipping, lateral branches will begin to grow from buds along the remaining sections of the primocanes.

Figure 22. Floricanes in full bloom while in the harvest position (A). Ripening fruit while in the harvest position (B) on the RCA.

Once a week, monitor lateral branches and ensure they are growing in-between the two bottom bending wires. Young lateral branches growing outside the bending wires can easily be maneuvered into the correct position, but this will become more difficult as lateral branches stiffen with age. Attach growing lateral branches to the training wires on the short-arm of the trellis, if needed, using Orchard clips or flexible training tape. Some trellis manufacturers no longer include a short-arm on the trellis plate. In this case, ensure laterals do not interfere with harvest or mowing activities. Orchard clips will make transferring of the lateral branches easier in the fall (see Fall section below). Using clippers, remove laterals that cannot be manipulated into the correct position or are growing in the wrong direction, such as into the floricane canopy or outside the bending wires.

New primocanes will continue to emerge throughout the summer. If additional lateral branches are needed for canopy fill, continue tipping new primocanes. If there are enough lateral branches to achieve a complete canopy fill, cut out and remove additional new primocanes at ground level.

Figure 23. Floricane removal in late summer on an RCA trellis and primocanes waiting to be transferred to the long-arm. Notice how the new primocanes and previous year's floricanes are attached to the back side of the wire and rest on the wire in the harvest position.

While laterals are being trained on the short-arm, blackberries will develop and be harvested on the long-arm. If the trellis was rotated correctly, 95% of fruit will develop on the shaded side of the trellis (Figure 22).

Fall:

After harvest has concluded, the floricanes attached to the long-arm are detached from the wires, cut at the crown, and removed from the field. Primocane laterals are then transferred from the short-arm to the long-arm (Figure 23). Laterals that are outside the bending wires will break when transferred or rotated. Using clippers, remove laterals growing outside the bending wires. When attaching laterals to the long-arm attempt to not cross or tangle laterals with each other, and space them about 2 inches, or a fist-width, apart on the upper wires. Lateral training will continue until growth ceases in the fall or the canopy is rotated to the winter position. Follow the same tipping practices as described in "Year 1."

Common Problems

The three most common issues with the RCA are suboptimal canopy fill, cane breakage during rotation or improper trellis installation. Cane breakage can occur for several reasons but is usually related to not allowing enough space for the canes to rotate between the two bending wires when laying the trellis arms over (Figure 24). Canes are more flexible during warm weather and sunny days, and more brittle during cold days and winter months.

Poor canopy fill is a particular issue when using the bending training method as fewer and shorter lateral branches grow near the tipped end of the cane (Figure 25). Poor cane fill can be avoided in the fan method with closer plant spacing, timely tipping of the canes and proper plant nutritional management. Additionally, ensuring canes are unclipped from the bottom bending wire before rotating will allow canes space to flex between the bending wires and reduce breakage (Figure 15).

Finally, take care when installing the trellis arms so that the two bottom bending wires fall evenly on either side of the plants in the bed top (Figure 26). If the canes do not have enough room between the two bending arms to flex and bend at greater than a 90° angle, the likelihood of cane breaking or cracking is increased. In some cases, the trellis will be installed after the plants are planted. In this case, care must be taken to ensure correct placement of the trellis relative to the plants. **The plants should fall directly in between the two bottom bending wires.**

Summary

The Rotating Cross-Arm trellis offers growers additional control over the blackberry canopy, lowering disease and insect pressure. Furthermore, the narrow canopy improves pesticide penetration and coverage. The rotation of the canopy allows canes to be protected during freezing winter temperatures and spring frosts, while shading ripening fruit in the summer preventing heat-related disorders. The fan training method reduces labor hours needed in the spring and summer for primocane training, compared to the standard RCA training, while maintaining the reduced harvest labor hours compared to a standard T-trellis. When full canopy coverage is achieved and the fan method is used for training primocanes, economic yields are possible.

Figure 24. A dead lateral cane caused by a cracked or broken main cane (left) and a bent main cane that cracked while the trellis was rotated (right).

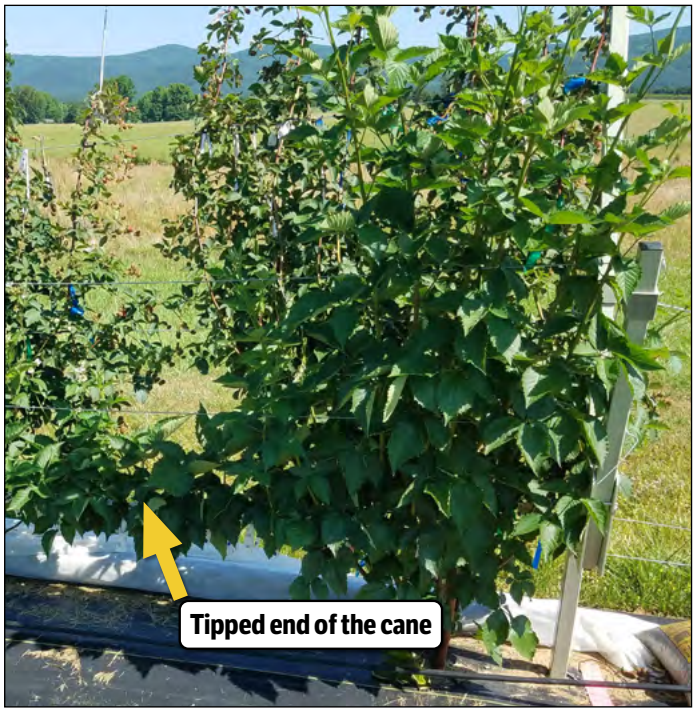

Figure 25. Poor canopy cover on a tipped bend primocane. The few lateral branches are short, leaving large areas of the trellis empty.

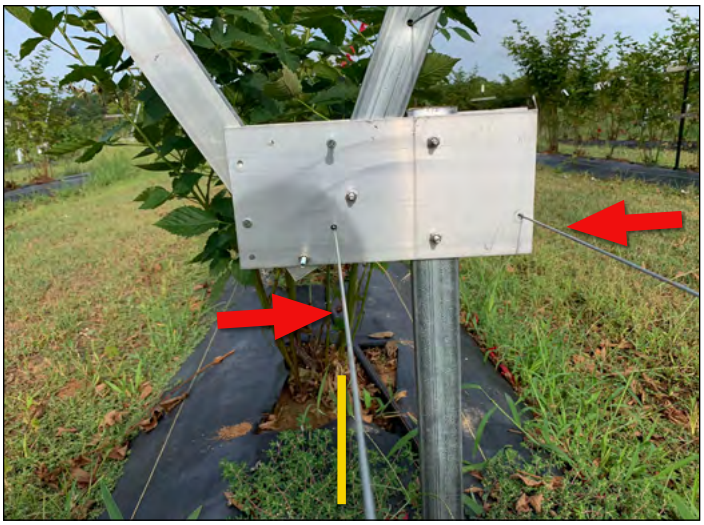

Figure 26. Canes coming up outside the two bottom training wires (identified by red arrows), due to the trellis arms being set too far to the right of the midline (yellow line) resulting in the two bending wires not falling on either side of the plants. In this case, the trellising was installed after planting and the trellis ground posts were set too high in the ground and placed too far to the right of the bed top.

References

Babu A., Rodriguez-Saona C., and A. A. Sial. 2022. Factors Influencing the Efficacy of Novel Attract-and-Kill (ACTTRA SWD) Formulations Against Drosophila suzukii. Journal of Economic Entomology, 115(4): 981–989. https://doi.org/10.1093/jee/toab273

Bolda, M. P., Goodhue, R. E., and F. G. Zalom. 2010. Spotted wing drosophila: potential economic impact of a newly established pest. Agricultural and Resource Economics Update, 13(3), 5-8.

Bristow, P. R. and B. Williamson. 2017. Fruit and Flower Diseases Caused by Fungi: Botrytis Fruit Rot and Blossom Blight, p 34-37. In: R. R. Martin, M. A. Ellis, B. Williamson and R. N. Williams (eds.). Compendium of Raspberry and Blackberry Diseases. APS, St. Paul, MN.

Carol, B., 2014. Blackberry Commercial Blackberry Production. Oklahoma State University, Fact sheet. https://extension.okstate.edu/fact-sheets/print-publications/hla/commercial-blackberry-production-hla-6239.pdf

Cato, A. 2022. Stink Bugs Offending Arkansas Blackberries. Arkansas Fruit, Nut, Vegetable and Nut Update: University of Arkansas, Research and Extension, Cooperative Extension Services. https://www.uaex.uada.edu/farm-ranch/crops-commercial-horticulture/horticulture/ar-fruit-veg-nut-update-blog/posts/stinkbugs_in_blackberries.aspx

Cato, A. J., McWhirt, A., Henderson, E., Keiffer, R. and L. Herrera. 2023. Impact of Trellising on Spray Coverage and Spotted-wing Drosophila Infestation: Comparing the Rotating Cross-Arm Trellis to the T-trellis. Acta Horticulture.

Clark, J. R. 2008. Primocane-Fruiting Blackberry Breeding. HortScience 43(6), 1637-1639. https://doi.org/10.21273/HORTSCI.43.6.1637

Diepenbrock, L.M., and Burrack, H.J. 2016. Variation of within-crop microhabitat use by Drosophila suzukii (Diptera: Drosophilidae) in blackberry. J. of Applied Entomology. 141 (1-2), 1-7.

Duncan, M., Lay-Walters, A., Herrera, L., McWhirt, A., Cato, A. and R. Threlfall. 2023. Impact of trellis system on blackberry crop canopy architecture and microclimate with implications for pest management. Acta Horticulturae. In-press.

Edgley, M., Close, D. C. and P. F. Measham. 2020. Red drupelet reversion in blackberries: A complex of genetic and environmental factors. Scientia Horticulturae 272(243). doi: 10.1016/j.scienta.2020.109555.

Ellis, M. A. 2017. Fruit and Flower Diseases Caused by Fungi: Leaf and Cane Rust, p 43-44. In: R. R. Martin, M. A. Ellis, B. Williamson and R. N. Williams (eds.). Compendium of Raspberry and Blackberry Diseases. APS, St. Paul, MN.

Ernst, T., McWhirt, A., Zimmerman, T., Henderson, E., Duncan, M. and A. Lay-Walters. 2023. Basics of Drip Irrigation and Fertigation for Specialty Crops. University of Arkansas, Division of Agriculture, Research and Extension FSA6160. https://www.uaex.uada.edu/publications/PDF/FSA6160.pdf

Henderson, E. 2020. Comparison of a T-trellis and a Rotating Cross-Arm Trellis for Arkansas Blackberry Production. Graduate Theses and Dissertations Retrieved from https://scholarworks.uark.edu/etd/3922

Isaacs, R., Titten, B., Van Timmeren, S., Wise, J., Garcia-Salazar C. and M. Longstroth. 2013. Spotted Wing Drosophila Management Recommendations for Michigan Raspberry and Blackberry Gowers. Michigan State University – Extension – AgBioResearch. http://52.5.24.1/ipm/uploads/files/SWDManagement-MichiganRaspberryBlackberry-Aug-2013.pdf

McWhirt, A. J. Lee, R.T. Threlfall and T. Ernst. 2019. Effects of rotating cross arm trellis on first year blackberry yield, fruit quality and pest pressure. Acta Horticulturae 1277. DOI:10.17660/ActaHortic.2020.1277.31.

McWhirt, A., Ernst, T., Cato, A., Threlfall, R. and E. Henderson. 2023. What is Wrong with My Blackberry? Identifying Fresh-Market Blackberry Disorders. U of A Division of Agriculture Research and Extension, University of Arkansas System – Publication. https://www.uaex.uada.edu/publications/pdf/MP574.pdf

Mettler, D. and H. Hatterman-Valenti. 2018. Rotating Cross-Arm and Winter Rowcovers for Floricane Blackberry (Rubus Subgenus Rubus Watson) Production in North Dakota, HortScience, 53(12), 1810-1813.

Pritts, M. and E. Hanson. 2017. Site Preparation, Soil Management, and Planting, p. 118-130. In: H.K. Hall and R.C. Funt (eds.). Blackberries and their hybrids. CABI, Boston, MA.

Pszczolkowski, J. A., Chastain K., Veenstra R. and K. L. Martin. 2019. Blackberry Cultivar Feeding Preference of Adult Japanese Beetles. HortScience 54(5): 885-889. https://doi.org/10.21273/HORTSCI13763-18

Rebollar-Alviter, A. and R. N. Williams. 2017. Part II. Arthropod Pests: Spotted Wing Drosophila, p.107-109. In: R. R. Martin, M. A. Ellis, B. Williamson and R. N. Williams (eds.). Compendium of Raspberry and Blackberry Diseases. APS, St. Paul, MN.

Schöneberg, T., Lewis, M. T., Burrack, H. J., Grieshop, M., Isaacs, R., Rendon, D., Rogers, M., Rothwell, N., Sial, A. A. Walton, W. M. and K. A. Hamby. 2021. Cultural control of Drosophila suzukii in small fruit—current and pending tactics in the US. Insects, 12(2), 172.

Shanovich, H. N., N. D. Ashley, R. L. Koch and E. W. Hodgson. 2019. Biology and Management of Japanese Beetle (Coleoptera: Scarabaeidae) in Corn and Soybean. Journal of Integrated Pest Management 10(1): 1-14. doi: 10.1093/jipm/pmz009

Stafne, E. T., Rezazadeh, A., Miller-Butler, M., and B. J. Smith. 2017. Environment Affects White Drupelet Disorder Expression on Three Blackberry Cultivars in South Mississippi. HortTechnology, 27(6): 840-845. https://doi.org/10.21273/HORTTECH03880-17

Strik, B. C. 2017a. Plant Nutrient Management, p. 146-168. In: H.K. Hall and R.C. Funt (eds.). Blackberries and their hybrids. CABI, Boston, MA.

Strik, B. C. 2017b. Growth and development, p. 17-34. In: H.K. Hall and R.C. Funt (eds.). Blackberries and their hybrids. CABI. Boston, MA.

Strik, B. C. and Bryla D. R., 2015. Uptake and Partitioning of Nutrients in Blackberry and Raspberry and Evaluating Plant Nutrient Status for Accurate Assessment of Fertilizer Requirements. HortTechnology 25(4): 452-459.

Strik, B.C., Takeda F., and G. Gao. 2017. Pruning and training, p. 169-201. In: H.K. Hall and R.C. Funt (eds.). Blackberries and their hybrids. CABI, Boston, MA.

Takeda, F. 2017. Climatic Requirements, p. 35-48. In: H.K. Hall and R.C. Funt (eds.). Blackberries and their hybrids. CABI, Boston, MA.

Takeda, F., Glenn D. and T. Tworkoski. 2013. Rotating Cross-Arm trellis technology for blackberry production. Journal of Berry Research 3(1):25-40. DOI:10.3233/JBR130044.

Takeda, F., Hummell A. K., and D. L. Peterson. 2003a. Effects of cane number on yield components in 'Chester Thornless' blackberry on the rotatable cross-arm trellis. HortScience 38(3):377-380. https://doi.org/10.21273/HORTSCI.38.3.377.

Takeda, F., Hummell, A. K., and D. L. Peterson. 2003b. Primocane Growth in 'Chester Thornless Blackberry Trained to the Rotatable Cross-arm Trellis. Hortscience 38(3): 373–376.

Takeda, F. and J. Phillips. 2011. Horizontal cane orientation and rowcover application improve winter survival and yield of trailing 'Siskiyou' blackberry. HortTechnology 170–175. https://doi.org/10.21273/HORTTECH.21.2.170.

Thompson, E. 2017. Site Selection, p. 113-117. In: H.K. Hall and R.C. Funt (eds.). Blackberries and their hybrids. CABI, Boston, MA.

Travis, J. W. and B. Williamson. 2017. Part I. Diseases Caused by Biotic Factors: Anthracnose, p 8-11. In: R. R. Martin, M. A. Ellis, B. Williamson and R. N. Williams (eds.). Compendium of Raspberry and Blackberry Diseases. APS, St. Paul, MN.

USDA, NASS. 2021. Non-citrus Fruits and Nuts 2020 Summary. ISSN: 1948-2698. https://downloads.usda.library.cornell.edu/usda-esmis/files/zs25x846c/sf269213r/6t054c23t/ncit0521.pdf

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