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Reproductive Growth and Development of Blueberry[1]

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Flower Bud Initiation

One of the most important developmental processes occurring in blueberry fields during late summer and fall is flower bud initiation and development. During vegetative growth, one bud develops on the stem for each leaf that is produced. The bud is located just above the point where the leaf petiole meets the stem. These axillary buds are vegetative when they first develop. Depending on day length, temperature and plant condition, some of them will convert to flower buds during the late summer and fall. Flower buds develop first on the older current-season's wood that grew during the spring and last on the vigorous upright growth that develops after post-harvest pruning. As flower buds develop, they become larger and rounder. They can be easily distinguished from vegetative buds during December and January.

Research has shown that the conversion of vegetative buds to flower buds is controlled by day length and temperature. Day length is measured by special plant pigments contained in the leaves and buds. As days shorten during the fall, vegetative buds gradually convert to flower buds. Experiments have shown that high temperatures reduce flower bud initiation, even when days are short enough to induce flower bud initiation. Moreover, flower buds initiated under high temperatures are smaller and develop less fully than those initiated under lower temperatures.

Blueberry leaves are the major organs that produce photosynthates and perceive changes in day length. They are therefore extremely important for flower bud initiation and development in blueberry. Research has shown that southern highbush blueberry leaves must remain healthy and attached at least through early November in Florida for good flower bud initiation and development. When plants defoliate prematurely in the fall, flower bud number is greatly reduced and flower bud development is impaired. Preventing early fall defoliation requires proper fertilization, summer pruning, and a judicious summer leaf spot spray program.

Pollination and Fruit Set

Pollination is the transfer of pollen grains from anthers to stigmas. Cross-pollination (pollen of one cultivar transferred to the stigmas of another cultivar) is essential for high yields in rabbiteye and southern highbush cultivars grown in Florida. Pollination can be affected by many factors including weather, cultivar mix, and bee population and activity.

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Bees, either native or domesticated, are essential for blueberry pollination and fruit set. Each blueberry flower consists of the corolla tube, the pistil, and the anthers. The corolla tube is made up of five fused petals, is white or pink, and is the most visible part of the flower. The corolla is important in protecting the other flower parts from rain and dew. The pistil consists of three parts:

1. the sticky stigma, which normally reaches out as far as the opening in the end of the corolla tube;
2. the style, which is the long, slender stalk that attaches the stigma to the ovary; and
3. the ovary, which contains the seeds and ripens into the berry.

The anthers are yellow sacks of pollen that are attached at the base of the corolla tube, and are situated so deep inside the tube that most insects cannot reach them. Pollination occurs when pollen is deposited on the stigma where it quickly germinates, producing pollen tubes that grow down the style and into the ovary. This process of pollen tube growth requires 2 or 3 days and is essential for seed development and natural fruit set.

Blueberry flowers are so constructed that pollination is very limited without insects, even though the pollen, stigma, and seeds are all situated close together within the flower. Insects that sonicate flowers are the most effective blueberry pollinators. Sonication occurs when a bee places its head inside the corolla and vibrates its wings at a high frequency. This causes the pollen to pour out of the opening of the anther onto the face of the bee. By visiting flower after flower, bees pollinate blueberry flowers by covering the stigmas with pollen it has extracted from anthers. Two native bees that pollinate blueberry flowers in Florida are bumblebees (*Bombus* spp.) (Fig. 1) and the southeastern blueberry bee (*Habropoda laboriosa*).

Pollinators

Although many bee species are known to visit blueberry flowers in the southeastern United States, the only bees in sufficient abundance to aid in rabbiteye blueberry pollination are the honeybee (*Apis mellifera)*, various species of bumblebees, and the southeastern blueberry bee. Honeybees are inefficient pollinators of rabbiteye blueberries. Therefore, blueberry growers should implement strategies to maximize bumblebee and southeastern blueberry bee populations in or near their fields. Nearby wooded areas may be nesting sites for native bees and should be left as undisturbed as possible.

Figure 1. Bumble bees sonocates flowers and efficiently transfers pollen from one flower to another.

The southeastern blueberry bee has one generation per year with adults active during blueberry flowering. They may emerge prior to flowering and require other sources of nectar and pollen. Possibilities include native blueberries, redbud, rapeseed, turnips, collards and many other early-flowering plants.

Bumble bees establish new colonies each spring from over-wintering queens. The number of queens that emerge during the spring to pollinate blueberries depends on how many potential queens are produced during the previous season and how many successfully overwinter. Colony productivity requires a reliable succession of suitable pollen and nectar sources from March through October. There are many trees, shrubs, vines and herbaceous plants (too many to list), both native and domestic, that can provide a continuous source of nectar and pollen needed for bumble bee colony establishment.

In recent years, bumblebees have been domesticated, and colonies can be purchased for use in blueberry pollination. These bees are rather expensive, but due to their high efficiency in

blueberry pollination, they are increasingly being used by blueberry growers.

Rabbiteye Pollination

Pollinator abundance and activity is very important to rabbiteye blueberry growers for several reasons: 1) pollination of blueberry requires the assistance of insects and is required for seed development and natural fruit set; 2) most rabbiteye cultivars are largely self-incompatible (they require cross-pollination from another cultivar); and 3) more seeds per fruit results in larger fruit and earlier fruit maturity.

Southern Highbush Pollination

Southern highbush blueberries planted in solid blocks will set fruit, but will not perform up to their full potential. Cross-pollination of southern highbush blueberries increases seed content, fruit size and accelerates fruit development. Experiments have shown that Sharpblue fruit cross pollinated with Gulf Coast were larger, had more seed per fruit, and matured earlier than self-pollinated Sharpblue. Pollinator activity (number of bee visits per flower) also affects fruit set and development. Ten or more bee visits per flower increase percent fruit set compared to 5 or less visits. Berry weight is increased and fruit development accelerated by multiple bee visits compared to single visits. Current research suggests that 5 or more bee visits per flower may be required for high yields or large, early fruit.

Growers have asked whether mixing pollen from rabbiteye and southern highbush blueberries will affect yield, maturity date, and fruit quality. Studies indicate that southern highbush blueberries set equally well and produce equally large early fruit as early when pollinated with rabbiteye pollen compared with southern highbush pollen. However, the reverse may not be true. In one study, rabbiteye plants pollinated with highbush pollen had longer fruit development periods, and greatly reduced berry weight, seed number, and fruit set compared to rabbiteye plants pollinated with rabbiteye pollen.

Fruit Development and Yield

Fruit carrying capacity. A proper balance of vegetative and reproductive buds is required to maximize yields of high quality fruit (Fig. 2). If there are too few flower buds, there will not be enough flowers to maximize yield. If there are too many flower buds relative to the number of vegetative buds, the number of berries may exceed what can be supported by the bush. The result could be poor leafing, small berries, delayed harvest, poor fruit quality, and plant stress or even death. The negative consequences from over-fruiting are common on poorly managed southern highbush cultivars such as Misty and Avonblue while too few flower buds often develop on some rabbiteye cultivars such as Bonita and Beckyblue.

Figure 2. A proper balance of berries and leaves are needed to produce high-quality fruit for the early market.

Healthy foliage is essential for adequate flower bud development. If a leaf abscises from a blueberry plant before the associated axillary bud has converted

to a flower bud, that bud will never convert (Fig. 3 and Fig. 4).

Figure 3. Blueberry cane that was defoliated in mid-September has very few well-developed flower buds.

When leaf diseases cause premature defoliation of blueberry plants, flower bud numbers can be greatly reduced. Post-harvest pruning to promote new, healthy shoots and fungicide applications to protect new growth are extremely important to flower bud initiation and development (Fig. 5 and Fig. 6). Frequent, light fertilizer applications through the summer and early fall may help promote vegetative growth into the fall. However, excess fertilization after September may reduce flower bud formation. Using under-the-bush irrigation instead of overhead irrigation will reduce leaf wetting and may reduce the incidence of leaf diseases. For overhead irrigation systems, it is probably best to irrigate between 4:00 am and 10:00 am so that leaves dry quickly.

Figure 4. Blueberry cane that retained its leaves through early November has a full compliment of flower buds.

Plant Growth Regulators

Plant growth regulators (PGRs) are synthetic or naturally occurring compounds that can be used to modify plant growth and/or development processes, such as flowering, fruit set, fruit ripening, branching, and fruit and leaf abscission. Plant responses to PGR applications are often inconsistent and unpredictable. This is because PGRs are usually effective at very low concentrations and they must be precisely delivered to specific tissues (sites) in plants at the right stages of plant growth. Too much or too little PGR, or a PGR applied at the wrong stage of plant growth and development, will not result in the desired growth response and in fact may result in a number of undesirable responses. Since PGRs must be absorbed by plant tissues, environmental conditions at the time of application play an important and often underappreciated role in treatment efficacy. As with

Figure 5. Non-pruned blueberry plant showing weak summer growth and early fall defoliation.

Figure 6. Summer pruned blueberry plant showing a vigorous summer growth flush and healthy leaves entering the full season.

pesticides, blueberry growers should read and follow all label instructions when using PGRs.

Dormex (hydrogen cyanamide)

Dormex (a commercial formulation of hydrogen cyanamide) is a plant growth regulator that became available for commercial use in Florida blueberries during 2000. Experiments and grower observations have shown Dormex to be a useful tool for stimulating earlier and stronger spring leafing of several southern highbush (and Climax rabbiteye) cultivars in Florida. Where spring leafing has been significantly advanced by Dormex, berries were often harvested earlier than would otherwise be possible. Increased berry weight (size) and a slight increase in total yield have also been noted in some cases, but the main advantage seems to be earlier berry harvests.

Dormex Rates

If misapplied, Dormex has the potential to damage flower buds. Therefore, it is very important that growers follow the label directions exactly. The label calls for up to 1.5% (v/v) Dormex in 50 to 100 gallons of spray per acre using up to 0.5% (v/v) of one of the nonionic surfactants, Latron B1956 or Agri-Dex. Higher Dormex spray concentrations have resulted in significant flower bud thinning and have reduced total yields. Dormex applied at 1.5 % (v/v) has consistently shown increased leafing and earlier fruit ripening of Misty without significant flower bud thinning. Dormex applied at 1.5 % (v/v) has actually increased total yields in some cases. This is probably a result of increased fruit size combined with minimal, if any, fruit thinning. The effect of Dormex is very localized on plants. Therefore thorough coverage is essential.

Timing Dormex Applications

The Dormex label calls for applications to be made 30 or more days prior to natural budbreak. Additionally, Dormex is most effective when applied to dormant plants after significant winter chilling has occurred. Although the calendar should not be used as the sole determinant to time Dormex spray applications, in Alachua County, late December is usually about 30 to 40 days before flowering for most cultivars grown there. During the last 2 to 3 years, applications of Dormex made in Alachua County between about December 20 and January 3 have usually increased vegetative budbreak and advanced fruit harvest of responsive cultivars. During "normal" winters thus far, differences within this time frame in Alachua County have not been significant. Of course the onset of dormancy, chill accumulation, and the timing of natural budbreak will vary from year to year and from one location to another in Florida. Hence, the timing of Dormex applications should be based on the weather and anticipated date of natural budbreak, not the calendar date.

Application of Dormex to plants that have received little or no chilling resulted in less efficacy and more injury to stems and flower buds. This emphasizes the importance of restricting application of Dormex to the dormant period when some chilling is likely to have occurred, but before flower bud swell has progressed past stage 2 (before flower bud scales begin to separate). Delaying application until, or just prior to, the beginning of flowering (usually mid- to late January in Alachua County) has resulted in serious flower bud thinning and yield reduction. The application time for maximum benefit will depend on the winter weather and location of the site.

Cultivar Response to Dormex

This is a very important consideration, and one for which information is still being developed. Most research in Florida has been conducted with the cultivar Misty and to a lesser extent on Gulfcoast, Star, Southmoon, and the rabbiteye variety Climax. Increased vegetative bud break and earlier ripening from Dormex have been demonstrated under a range of environmental and climatic conditions during several seasons in Florida for the variety Misty. On other cultivars, similar though perhaps less dramatic results have been obtained. Generally, those cultivars that are naturally slow or weak at leafing in the spring should benefit most from Dormex. Some examples of weak or slow leafing cultivars that should benefit from Dormex applications during most years are Misty, Millennia, and Santa Fe. Dormex should not be applied to Sharpblue because Sharpblue flower buds are more susceptible to injury (spray burn) from Dormex than are flower buds of most other cultivars. Flower buds of Windsor have also been damaged by Dormex applications. Dormex can be safely applied to numerous blueberry cultivars currently grown in Florida, however, if a cultivars tolerance to Dormex is unknown, it should be tested and evaluated before Dormex is used on that cultivar.

When used correctly, the potential benefits from Dormex include strong spring bud break and vegetative growth, shorter fruit development periods with earlier harvest periods, increased berry weight (size), and increased yield. These benefits will generally be more prevalent on varieties that are naturally slow or weak to leaf out in the spring. The concentrated bloom and harvest periods and shortened fruit development periods obtained with Dormex could help with disease and insect control and potentially reduce the number of annual pesticide applications needed in Florida blueberries. On the other hand, when applied incorrectly, Dormex can result in flower bud injury, excessive fruit thinning and yield reductions. Also, potential users should be aware that Dormex is classified as a restricted use pesticide. Extreme caution should be used when handling and applying this material and ALL LABEL DIRECTIONS SHOULD FOLLOWED EXACTLY.

Gibberellic Acid (GA)

Gibberellic acid (GA_3) is a naturally occurring PRG that can influence fruit set of many crops, including blueberry. Fruit drop of rabbiteye berries is a perennial problem in Florida and can significantly reduce yields. Following petal fall, unfertilized berries may look normal for one or two weeks. Berries that are 1/8 inch or less in diameter 2 to 2 1/2 weeks after petal drop usually begin to drop. The berry normally detaches at the point where the pedicel attaches to the raceme. One way to minimize fruit drop following inadequate pollination is to apply

gibberellic acid (GA_3, trade name = ProGibb) during bloom. During normal pollination, developing seeds synthesize gibberellic acid and the application of GA_3 during and immediately after bloom mimics this natural process. The increase in rabbiteye blueberry fruit set from GA_3-treated plants over non-treated plants depends on how much natural fruit set is achieved. Under conditions of high natural fruit set, the increase in fruit set from GA_3 application is of no practical benefit. When natural fruit set is low, GA_3 could increase fruit set and yield substantially.

In addition to increasing fruit set and yield, GA_3 applications consistently decrease average berry weight (size) and increase the fruit development period. The decrease in average berry weight appears to be a direct effect of GA_3 application; not merely a response to heavier crop loads. Increase in fruit development period from GA_3 application varies with year and cultivar but GA_3 application can delay harvest by 5 to 15 or more days.

For rabbiteye fields that have a history of low percent fruit set, current recommendations call for initial GA_3 application when 40 to 50% of the flowers have opened and been worked by bees. About 10 % of the petals should have fallen. A second application should be made about 10 - 18 days later. When two cultivars with different bloom dates are planted together, good results may be obtained by spraying alternate rows of different cultivars and directing your treatment at the cultivar in bloom. Using this method, four spray applications can be used. The total amount applied at each application is 20 grams of active ingredient per acre since the sprayer targets only alternate rows, or the equivalent each time. The sprays are usually spaced about 10 days apart. The first and second sprays are directed at the first cultivar to bloom. Some GA_3 will also reach the adjacent cultivar and help the early flowers to set fruit. The third and fourth sprays are directed toward the later-blooming cultivar. The last flowers to open in the early-flowering cultivar will receive spray drift from the last two sprays. The total amount of GA_3 applied for the season should not exceed the recommended label rate. Night applications will increase the drying time, and may increase GA_3 absorption and effectiveness. If possible, do not apply GA_3 within 18 hours of rain.

The greatest benefits to fruit set from GA_3 application are obtained under conditions of low natural fruit set. Growers should assess the potential for fruit set on their particular farm (overlapping bloom of pollinizers, population and activity of bees, weather, etc.) when deciding whether or not to apply GA_3. Although GA_3 may increase fruit set and yield of rabbiteye blueberry, it may also delay fruit maturity and decrease average berry size. Because of the high costs and possible negative effects of GA_3 application, growers with fruit set problems should try to find out why their fields are not being pollinated properly. More bees, better bee management in the field, and controlling flower thrips can often reduce problems with fruit set. GA_3 should not be used on southern highbush blueberries until more research has been done. Several trials of GA_3 on southern highbush have resulted in over-cropped bushes and small, late-maturing berries.