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Some Factors Associated with Fruit Maturity Range in Cultivars of the Semi-erect, Tetraploid Thornless Blackberry

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Additional index words. *Rubus* spp., fruit maturation, flowering

Abstract. **Flowering occurred over a 5-week period in semi-erect, tetraploid thornless blackberries (*Rubus* spp.) (cvs. Black Satin, Hull Thornless, and Dirksen Thornless). The harvest durations were slightly longer. The terminal flower bud of the primary axis (A_1) of the inflorescence was first to open, followed by the terminal flower bud on one of basal secondary axes (A_2). Remaining terminal flower buds on A_2 axes opened sequentially in acropetal direction at a constant rate (two flowers/day). However, bloom pattern of flower buds located laterally on A_2 axes was less definite. Within a floricane, the bloom on the primary fruiting laterals began at the distal end and progressed basipetally to the cane base. Ripening sequence of berries in a cluster followed that of the bloom. The time difference in anthesis between fruiting laterals and among flower buds within inflorescences was a major factor affecting the range of fruit maturity.**

Semi-erect, tetraploid cultivars of thornless blackberries (*Rubus*, subgenus *Eubatus*), derived from 'Merton Thornless', are highly productive, and their fruit quality is acceptable for fresh market and processing (3). Berries are large and firm and have good flavor and keeping quality. Many large berries per inflorescence and numerous fruiting laterals per cane contribute to high yielding capacity (4). Another characteristic of these cultivars is a harvest period >5 weeks. In order to develop this crop for the processing industry, a concentrated range of fruit maturity and/or a selective mechanical harvesting system is needed to reduce the cost of labor-intensive harvest.

A modified training system in which primocanes and floricanes are separated so floricanes can be mechanically harvested without interference of primocanes has been recommended (15). In other *Rubus* crops, alternate-year harvesting reduces problems associated with annual straddle harvesting (6, 16). The wide range in fruit maturity encountered in the semi-erect thornless blackberry increases the numbers of passes required to remove the bulk of the crop. This problem has not been addressed. Preliminary work conducted at this station indicated that the separation pull force of thornless blackberries appears to decrease at a rate insufficient to allow adequate mechanical harvest differentiation between the stages of black-ripe and red berries (D.L. Peterson, unpublished data). Morris et al. (9) in Arkansas reported that (2-chloroethyl)phosphonic acid (ethephon) applied prior to harvest accelerated color development and abscission zone formation of thorny blackberries, so the bulk of the crop could be harvested in two pickings. Lipe (5), however, reported that growth regulators produced no beneficial effect in Texas. Thorny blackberries used in these studies yield less than do the semi-erect thornless types, and a complete harvest normally can be accomplished in four or five passes (5, 8–10).

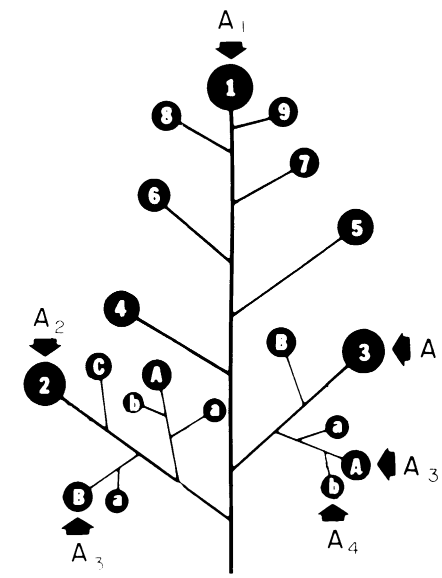

Fig. 1. Illustration of inflorescence structure and bloom pattern in semi-erect tetraploid thornless blackberry. Axes of inflorescence are denoted by A_1 (primary), A_2 (secondary), etc. Tertiary (A_3) and quaternary (A_4) axes were present on many A_2 axes. For clarity, A_3 and A_4 axes are shown only on the two basal A_2 axes. Numerals, uppercase letters, and lowercase letters denote the bloom order of terminal flowers of A_1 and A_2 axes, terminals of A_3 axes, and flowers positioned laterally on A_3 or terminally on A_4 axes, respectively.

The morphology of the raspberry fruiting cane and the relationship between various measurements of lateral vigor, productivity, and the position of the fruiting lateral on the floricane are well documented (2). In contrast, these relationships are not completely understood in the semi-erect thornless blackberry. The purpose of this study was to characterize growth of fruiting laterals, time of flowering, and fruit maturation to determine the growth components associated with fruit maturity range. This information would aid in developing strategies to enhance mechanical harvesting systems of semi-erect thornless blackberries.

'Dirksen Thornless' blackberry growing at the Western Maryland Research and Education Center, Sharpsburg, was used in 1983 and 1984. Fifteen fruiting laterals, each developing from primary axillary buds in the top, middle, and bottom one-third of 2-m-long upright floricanes, were tagged to determine the overall bloom pattern on floricanes as well as the specific pattern within

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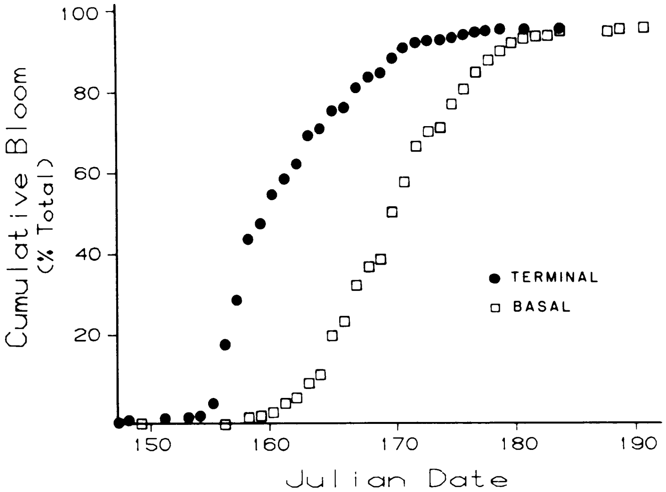

Fig. 2. Bloom distribution as percent of total buds to open on semi-erect tetraploid thornless blackberry in terminal (●) and basal (□) portions of floricane at various dates in 1983.

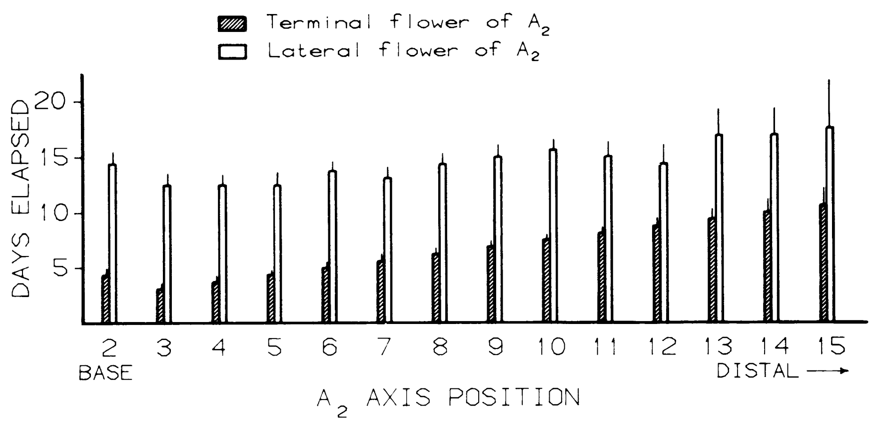

Fig. 3 The relationship of bloom dates among flowers in an inflorescence. The bloom date of the terminal flower of the inflorescence is expressed as day 0. Bloom dates of the terminal flower (solid bars) and the second flower (open bars) to open on the A_2 axes are expressed as days elapsed from the time the terminal flower of the inflorescence bloomed. Data were collected from inflorescences ranging in size from 5 to 14 A_2 axes (Vertical lines represent the means ± 2 SE).

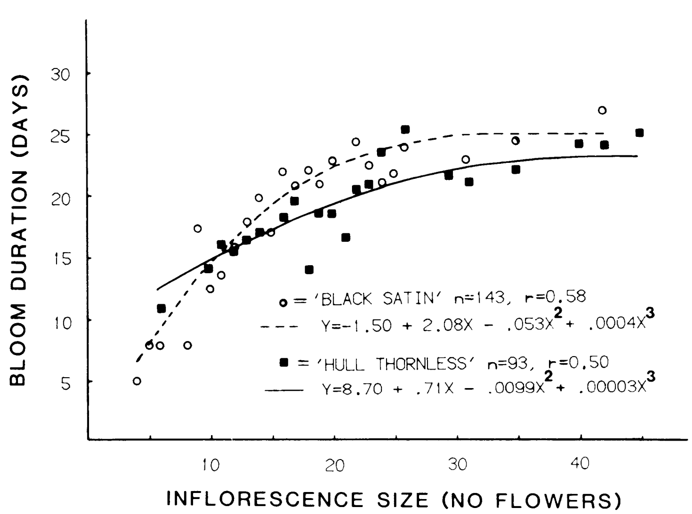

Fig. 4. Relationship between flower number and duration of inflorescence bloom in 'Black Satin' (○) and 'Hull Thornless' (■) blackberries. Each point represents the mean bloom duration for given inflorescence size. The lines were fitted to a cubic equation of each cultivar's bloom duration.

an inflorescence. The flower number and the position and bloom date of each flower in the inflorescence were recorded. To determine the range of maturity in fruit from flowers having the same bloom date, 15 berries developing from flowers that bloomed 7, 14, and 21 June and positioned terminally on the secondary (A_2) axes (see Fig. 1) were harvested at 7- to 10-day intervals. Fruit samples were weighed and visually sorted by color. See Table 1 for the eight-category rating system used.

The study in the third year (1985) was conducted on 3-year-old 'Black Satin' and 'Hull Thornless' vines growing at the Appalachian Fruit Research Station, Kearneysville, W. Va. (≈32 km south of the first site). Field observations also were made on 'Dirksen Thornless' plants at this site. Plants were trained at 15° to the vertical on a 2.1-m-high "V" trellis or horizontally on a 0.8-m-high "T" (Lincoln canopy) trellis. In both trellis types floricanes and primocanes were spatially separated to minimize shading. Data were evaluated by regression analysis.

Budbreak occurred in late March for 'Black Satin' (3). Emergence of fruiting lateral shoots from the primary axillary buds occurred uniformly along the length of floricane. Bloom initiation among the inflorescences, however, began at the distal end of the floricane and proceeded basipetally. A difference of about 15 days between anthesis of the flowers on distal and basal laterals was noted in 2-m-long upright floricanes (Fig. 2). This pattern of anthesis appears to be related to the fact that laterals toward the proximal end of the floricanes are progressively longer; thus, the period from budbreak to the time laterals ceased growth and began flowering was extended. When the primocanes of 'Hull Thornless' were trained horizontally on a T-trellis, a trend in increased vigor in distal fruiting laterals and decreased vigor in basal fruiting laterals was observed the following year (data not presented). However, the growth changes did not improve the bloom synchrony among fruiting laterals on the floricane.

The bloom sequence within an inflorescence began with the terminal flower of the A_1 axis, and this was followed by the terminal flower on one of the basal A_2 axes (Figs. 1 and 3). Subsequent bloom of terminal flower buds on A_2 axes progressed acropetally at a constant rate. Many of A_2 axes had several A_3 branches. Flowering among the A_3 axes began, generally, with the most basal axis, about 6 to 10 days after the terminal flower on the A_2 axis had bloomed (Fig. 3). Quatenary axes (A_4) were present occasionally in large inflorescences. Bloom on them occurred about 8 days after the A_3 flower had opened. On any given A_2 axis there were only a few A_3 and/or A_4 axes (one to three), so a clear directional pattern could not always be established.

Bloom duration within an inflorescence and the number of flowers in the inflorescence were curvilinearly related (Fig. 4). Beyond about 25 and 35 flowers per inflorescence in 'Black Satin' and 'Hull Thornless', respectively, the bloom durations were almost constant at about 24 days. Inflorescence size (number of flowers per inflorescence) explained less than half of the variability in bloom duration. Another factor affecting bloom duration within an inflorescence may be the number of axes involved in the arrangement of flowers. As shown in Fig. 3,

Table 1. Regression equations describing the relationship between fruit coloration[z] and days from anthesis for berries from three different bloom dates. Number of days to full maturity were predicted using the regression equations.

Bloom date	Regression equation[y]	R^2	Predicted days to maturity (color = 11)
7 June	$Y = 2.51 - 0.216X + 0.008X^2$	0.89	50
14 June	$Y = 0.80 - 0.020X + 0.004X^2$	0.91	55
21 June	$Y = 0.73 + 0.033X + 0.002X^2$	0.83	61

[z] Fruit color was determined by comparing the sample drupe color to that of reference fruits assigned the following values: (1 = green; 3 = three-fourths green; 5 = three-fourths red; 8 = half black; 9 = three-fourths black; 10 = shiny black; and 11 = dull black).

[y] Where X and Y represent days from anthesis and fruit color, respectively.

<5 days elapsed from the time the terminal flower of the inflorescence and the terminal flower on one of the basal A_2 axes opened. The remaining terminal flowers of the A_2 axes opened at a rate of two flowers/day. However, after the terminal flower of the A_2 axis opened, at least 6 to 10 days elapsed before any of the lateral flowers on those axes began to bloom (Fig. 3). Our data suggest that, given a same number of flowers per inflorescence, an inflorescence possessing a longer A_1 axis and only terminal flowers on A_2 axes, such as a simple raceme, may have a shorter bloom duration than a paniculate or branched racemose inflorescence. For example, an inflorescence with 15 flowers, composed of only terminal flowers on A_1 and A_2 axes, would require about 10 days to bloom. However, an inflorescence with the same number of flowers but composed of the terminal flower of A_1, and seven A_2 axes each having a terminal and lateral flower, would require nearly 15 days to bloom (Fig. 3).

A wide range in fruit maturity seems to be normal in many fruit crops, and only a small correlation exists between bloom and maturity date. Such is the case with the stone fruits, which have a short bloom period but the fruit maturity range is greater when they ripen (1). 'Dirksen Thornless' blackberry also exhibited a slight increase in color variability, as indicated by larger SEs, when berries approached maturity. As in the apple (11) and strawberry (7), the fruit size was smaller with successively later bloom dates. Also, the maturation rate (color) declined slightly with later bloom dates (Table 1). Fruits with bloom dates of 7, 14, and 21 June were predicted to require 50, 55, and 61 days, respectively, to reach full maturity (Table 1). These results indicate that bloom date affects the onset of fruit development as well as maturation rate, as represented by the increased number of days to maturity with the later date blooms. This evidence supports the work of Stiles (14), who reported that coefficient of linear regression for soluble solids and the number of days to harvest in four thornless blackberry cultivars are small and negative.

Table 2. Summary of linear regression and correlation coefficients (r) between fruit color and bloom date for terminal flowers of A_1, A_2, A_3, and A_4 axes of 'Black Satin' and 'Hull Thornless' blackberry clusters.

Terminal flower of axes	Fruit sampled (Julian date)	r
Black Satin		
A_1	182	−0.84
A_2	189	−0.72
A_3	197	−0.45
A_4	203	−0.16
Hull Thornless		
A_1	190	−0.61
A_2	197	−0.55
A_3	204	−0.40
A_4	204	−0.49

Within inflorescences, the berries appeared to mature in the same sequence the buds opened. Clusters of berries, previously labeled for bloom sequencing studies, were harvested in July. Berries were categorized by axillary position and rated for color. In the early harvests of 'Black Satin' clusters, when the mature berries consisted of those on A_1 and A_2 axes, the degree of fruit maturity was correlated with bloom date. The bloom date accounted for ≈50% of the variability in berry color (Table 2). At the later harvest dates, the association between bloom date and fruit color was lower for berries that developed from flowers that bloomed later, and were generally on A_3 and A_4 axes. In the more vigorous 'Hull Thornless' blackberry, the relationship between the bloom date and fruit maturity was less defined (Table 2) than in 'Black Satin'.

The microclimate within the crop canopy influences growth patterns and fruit quality. Shading has been shown to reduce fruit size, soluble solids and acid contents, and color development in apples, thornless blackberries, and cherries (12, 13, 15). In this experiment, some of the berries were shaded by leaves and by other berries in the clusters, so the exposure to light was not uniform. Those on A_3 and A_4 axes, in particular, were generally positioned in the middle of the cluster and shaded more than those on A_1 and A_2 axes positioned on the cluster periphery. Therefore, the degree of shading is another parameter to consider when studying factors accounting for variability in berry maturity.

The results presented here indicate that the extended bloom is a major factor accounting for the wide fruit maturity range in the semi-erect tetraploid thornless blackberry. We have shown that the extended bloom resulted form (1) nonsynchronous bloom of fruiting laterals and (2) relatively long bloom durations of larger inflorescences. Perhaps concentrated ripening can be achieved if fruiting lateral vigor can be controlled and inflorescences contain only A_1 and A_2 axes. Dale and Topham (2) have presented evidence that there were red raspberry genotypes with relatively uniform fruiting lateral vigor along the length of the floricane. Cultural practices might offer alternative methods of affecting bloom through modifying growth characteristics. However, modification of cane orientation did not affect bloom synchrony (data not presented). Additional research, including the applications of bioregulators and further studies on growth characterization, may provide solutions to modifying the semi-erect tetraploid thornless blackberry to reduce fruit maturity range.

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Plant Parasitic Nematodes Associated with Highbush Blueberry in Arkansas

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Additional index words. *Vaccinium corymbosum, Xiphinema americanum, Paratrichodorus christiei,* mulching

Abstract. **Soil samples for a nematode assay were taken in 1983 within the root zone of highbush blueberry (*Vaccinium corymbosum* L.) plants in mature experimental and commercial plantings. *Xiphinema americanum* Cobb and *Paratrichodorus christiei* Allen were the predominant nematode species found. Nematode populations were not affected by cultivar. Mulched plots had significantly fewer *P. christiei* while *X. americanum* populations were similar in mulched and nonmulched plots.**

The highbush blueberry has become an important crop in northwest Arkansas, and production is increasing rapidly. Research has contributed significantly to the development of the blueberry industry, with extensive programs in cultivar evaluation and cultural management. However, only limited research has been conducted to determine plant parasitic nematodes associated with highbush blueberry in this region.

Nematodes in the genus *Tetylenchus* have been reported to be associated with blueberry in New Jersey and Massachusetts (4, 9). Zuckerman (8) reported in vitro parasitism of blueberry roots by *Trichodorus christiei* Allen. Converse and Ramsdell (2) found *Pratylenchus* spp. the most common nematode in Oregon blueberry fields, followed by *Xiphinema americanum* and *Trichodorus* spp. The original genus, *Trichodorus,* has been divided into *Trichodorus* and *Paratrichodorus* (7). Only one root-knot nematode has been found specific to blueberry, *Meloidogyne carolinensis* Eisenback (3). McGuire and Wickizer (6) reported *X. americanum* populations of up to 4000/liter of soil in samples taken from commercial blueberry fields in northwest Arkansas. Their samples were analyzed as part of a research project on necrotic ringspot disease, caused by tobacco ringspot virus, which is transmitted by *X. americanum* (5). Our study was undertaken to survey blueberry fields for plant parasitic nematode species, and to determine their relative populations and the effect of cultivar and mulch on these populations.

In Feb. 1983, soil samples were taken within the root zone of mature (5 or more years in the field) highbush blueberry plants in one experimental and five commercial plantings in northwest Arkansas. 'Bluecrop', 'Blueray', 'Bluetta', 'Collins', and 'Coville' were sampled in the commercial plantings, and all of these cultivars except 'Bluetta' were sampled in the experimental planting. The plants in the experimental planting were established in 1964, on a Captina silt loam soil (mixed, mesic, typic Fragiudult) with pH adjusted with elemental sulfur to 4.8 and spaced at 1.2 × 4.8 m. There were two four-plant replications of each cultivar and mulch treatment arranged in a split-plot design. The mulched plots had been mulched at planting, and the mulch had been maintained at a depth of 12 cm. The mulch used was 20-year-old hardwood sawdust, applied to the surface of a 1.2-m-wide band centered on the plant row. A 2-cm-diameter soil probe was used in taking the nematode samples. Ten probes were taken from each plot in the experimental planting and in each sample in the commercial fields. Samples also were taken from the sod area between the blueberry plant rows in the experimental planting. Probes were taken to a depth of 25 cm. Plant parasitic nematodes were analyzed from a 250-ml aliquot of soil from each sample. Nematodes were extracted by a modification of Cobb's sieving baerman funnel method (1). Nematodes were identified and counted after 2 and 7 days, and the counts were combined for a sample total. Data from experimental plots were analyzed by analysis of variance with mulch as the main plot, cultivars as the subplot, and nematode species as the sub-subplot.

Five genera of plant parasitic nematodes were associated with mature blueberries in experimental and commercial plantings (Table 1). The ectoparasitic species, *X. americanum* and *P. christiei,*, were predominant in these samples. *Helicotylenchus pseudorobustus* (Steiner) Golden, *Pretylenchus* spp., and *Paratylenchus projectus* Jenkins were found at low population levels in a few samples. Samples from the same field had 5- to 10-fold differences in nematode populations.

The frequent high levels of *X. americanum* and *P. christiei* in the samples indicate that highbush blueberries in northwest Arkansas are rather limited as to nematode species that flourish in the root system. This fact is further substantiated by the nematode species found in the sod middles, 2.3 m from the plant rows. All samples from the middles contained *Meloidogyne* spp. (48–368/liter of soil) and *Pratylenchus* spp. (256–480/liter of soil.) The environment in the area of the blueberry root system apparently was not conducive to the development of other species. Sample data from a 2-year-old planting (J.R.C., unpublished data) support the limited species association also. The 2-year-old planting had rather low levels of *X. americanum* and *P. christiei,* but we predict that populations of these species will increase as the planting matures. Further research is underway to monitor species and population development in a young planting.

The analysis of data from the replicated planting revealed a significant F test for mulch, predominant nematode species, and mulch × nematode interaction. No significance was found among cultivars or other interactions. The interactive effects of mulch and nematode species and populations are

Table 1. Plant parasitic nematode species, frequency, population range, and mean population level associated with mature highbush blueberries in northwest Arkansas from samples taken from one experimental and five commercial plantings.

Species	Frequency[z]	No./liter of soil[y]	Mean no./liter of soil	SE
Xiphinema americanum	31	0–5088	636	180
Paratrichodorus christiei	26	0–4464	1051	180
Helicotylenchus pseudorobustus	5	0–64	35	9
Pratylenchus spp.	4	0–32	26	4
Paratylenchus projectus	2	0–48	40	8

[z] Number of samples containing the species from a total of 32 samples.
[y] The range, in total nematodes recovered, among samples within each species.

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