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Heritability of Flowering and Harvest Dates in *Vaccinium corymbosum* L.

J. F. HANCOCK M. SAKIN AND P. A. CALLOW[1]

Abstract

Six highbush cultivars with varying flowering dates and fruit development periods were crossed in a diallel fashion to measure the heritability of flowering and harvest dates. Significant levels of general combining ability were observed for both of the traits, along with high levels of heritability. 'Bluejay' and 'Spartan' show promise as parents which can both delay flowering and hasten harvest.

Introduction

Spring frost damage is of major concern in the highbush blueberry production regions of North America. It is an unusual year when there is not at least some damage across the region and the degree of crop loss in the leading producing state, Michigan, has ranged from a few percentage points to as much as 30% over the last decade (6, 8).

From a breeding perspective, there are two solutions to this problem: 1) blossom tolerance to frost can be increased, or 2) flowering date can be delayed until the chance of frost is minimal. Several studies have shown that there is little variation among cultivars in blossom tolerance *per se*, but there is a large amount of variation in the developmental rate of buds and their subsequent flowering date (8, 9, 10). This makes breeding for a delay in bloom the most feasible strategy.

Unfortunately, most of our early ripening cultivars are also early flowering, making them highly subject to frost damage. To avoid this problem, breeders will have to reduce the strong positive association between flowering and harvest date. This has already been done in a few instances, as 'Spartan' is one of the earliest ripening cultivars in Michigan, but also has a later than average bloom date (8). Similar claims have been made for the recently released 'Duke' (Draper, pers. com.). It appears that there are no physiological barriers to combining late flowering with early ripening.

In this study, we measured the heritability of flowering and harvest dates among six northern highbush types as a prelude to developing a new generation of late flowering/early ripening cultivars. Lyrene (9) had conducted a similar study on rabbiteye types and

[1]Department of Horticulture, Michigan State University. This study was supported in part by the Michigan Agricultural Experiment Station.

found high levels of additive variation for both characteristics. Of particular interest was the possibility of transferring the late flowering/early ripening characteristic of types like 'Spartan' into new highbush cultivars.

Materials and Methods

Six cultivars which have been shown to have differing flowering dates and fruit development periods were selected as parents (8). They were crossed in the field in a one direction diallel. All flowers were emasculated before pollination and were covered with gauze for 10 days after receiving pollen. The pollen was collected fresh in the field on the day of crossing.

Seeds were collected from ripe fruit and were germinated using standard procedures (3). Fifteen randomly selected seedlings of each cross and 10 clones of each parent were planted individually into 3 liter plastic pots and were placed in a completely randomized design in an unheated greenhouse at Michigan State University, East Lansing, Michigan. They were grown for 3 years and given adequate winter chilling before forcing for flower and fruit harvest. The first 10 open flowers of each genotype were pollinated every 3 days with a composite mixture of pollen using a camel hair brush. Dates of the first open flower and the first fully ripe fruit (100% blue) were recorded for each genotype in two successive years. A Griffing's (5) diallel analysis was used to measure specific and general combining ability in each year using the equations of Gilbert (4). Midparent regressions were also performed to measure heritability.

Results and Discussion

Considerable variation is available to alter bloom and harvest dates. Significanat levels of general combining ability were discovered for all the traits examined (Table 1) and these were mirrored by high heritability measurements (Table 2). Harvest dates also showed significant levels of specific combining ability. The levels of GCA were much higher than SCA indicating that considerable progress can be accomplished by exploiting additive genetic variance.

It is likely that late flowering can be combined with early ripening. Flowering and harvest dates were significantly correlated ($p < 0.05$) among hybrids

Table 1. General (GCA) and specific (SCA) combining ability for flowering and harvest dates.

Trait	Year	Source of variation	df	Mean square	F value
Flowering date	1989	GCA	5	2267	74.8°°°[y]
		SCA	14	43	1.4
		Error	167	30	
	1990	GCA	5	1167	14.7°°
		SCA	14	70	0.9
		Error	164	79	
Harvest date	1989	GCA	5	4422	52.3°°°
		SCA	14	595	7.0°
		Error	148[z]	85	
	1990	GCA	5	4611	74.7°°°
		SCA	14	305	4.9°
		Error	164	61	

[y]Statistically significant at 5% (°) or 0.1% (°°°).
[z]Sample sizes were smaller in 1989 than 1990 due to poor fruit set in some genotypes. All these individuals fruited in 1990.

Table 2. Heritability estimates of flowering and harvest dates from regression of offspring on mid-parent values.

Character	Year	h^2
Flowering date	1989	0.32 ± 0.05
	1990	0.67 ± 0.11
Harvest date	1989	0.79 ± 0.16
	1990	0.76 ± 0.10

in both years, but the relationship was quite low (1989: r = 0.17, df = 148; 1990: r = 0.21; df = 164). Both 'Spartan' and 'Bluejay' were outliers that produced progeny with later than average flowering dates and earlier than average ripening dates (Figure 1). In general, cultivars ranked similarly for their phenotype and general combining ability (Table 3). The progeny of 'Elliot' were also late flowering, but they had the latest date of harvest. This late-flowering/late ripening association in 'Elliot' can probably be broken by crossing it with an early-flowering/early-ripening cultivar and then intercrossing or selfing F_1 hybrids.

The high levels of additive variation are rather interesting, as the examined

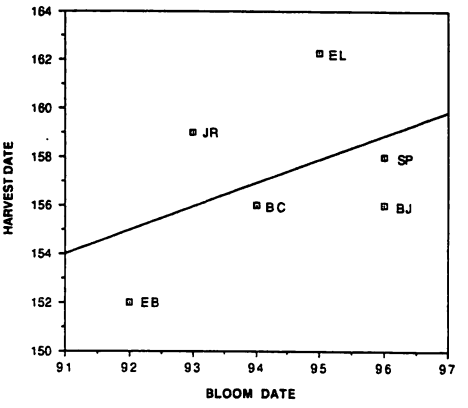

Figure 1. Parental values for bloom and harvest date based on the Julian calendar. Two years of data are combined. Initials represent: BC = 'Bluecrop,' BJ = 'Bluejay,' EB = 'Earliblue,' EL = 'Elliot,' JR = 'Jersey' and SP = 'Spartan.' y = 66.18 + 0.96x, r = 0.21.

cultivars are closely related and were based on only three original wild selections–'Brooks,' 'Rubel' and 'Sooy' (7). Apparently these three genotypes were highly divergent. This is not surprising as they came from 3 different sites in New Hampshire and New Jersey (2), and high levels of variation have been previously noted in wild populations of highbush blueberries for both iso-

Table 3. Phenotype and general combining (GCA) effects of different parents for flowering and harvest dates.

		Phenotype (Julian date)		GCA effect	
Character	Parent	1989	1990	1989	1990
Flowering date	Earliblue	90.0	88.4	-11.2	-22.3
	Bluecrop	96.9	93.3	-1.2	-7.3
	Jersey	99.0	95.0	-6.5	-2.3
	Elliot	98.7	102.1	+4.8	+12.7
	Bluejay	94.0	96.7	+6.4	+11.7
	Spartan	95.0	97.8	+7.9	+11.7
Harvest date	Earliblue	149.0	141.3	-13.5	-24.5
	Bluecrop	151.4	155.1	-17.5	-19.5
	Jersey	164.0	162.8	+8.5	+6.5
	Elliot	166.1	172.1	+26.5	+39.5
	Bluejay	153.0	154.9	-5.5	-4.5
	Spartan	151.0	148.6	+1.5	+2.5

zyme (Krebs and Hancock, In review) and morphological traits (1). The cross 'Earliblue' x 'Spartan' was a BC_1, but we observed little reduction in vigor or fertility.

In conclusion, sufficient additive variation exists to produce northern highbush types with late flowering, but early ripening dates. 'Spartan' and 'Bluejay' show the highest promise as parents. We cannot be sure that our pot studies will reflect realities in the field, but previous studies have shown that 3-5 year old plants accurately reflect the developmental patterns of mature plants (8).

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Fall Freeze Damage to 30 Genotypes of Young Pecan Trees[1]

WILLIAM D. GOFF AND TED W. TYSON[2]

Abstract

Following a severe early fall freeze in their second growing season, cold damage to 30 pecan (*Carya illinoinensis* (Wangenh.) C. Koch) cultivars or selections were rated according to the extent of phloem discoloration and bark splitting. 'Houma,' 'Melrose,' and 'Shoshoni' were among selections damaged most, while USDA 63-16-182, 'Gloria Grande,' and 'Cheyenne' were among those damaged least.

Index Words. *Carya illinoensis*, Cold hardiness, winter injury, nut crops, cold injury.

Introduction

Cold damage to pecan has been reviewed (11), and available information suggests that cultivar (5, 6, 7, 11), trunk type (12), acclimation (11), nutrient levels (9), date of budbreak (5), crop load and carbohydrate reserves (16), soil type (5), and tree size and age (1) may influence severity of damage. Regarding cultivar susceptibility to early or midwinter freezes, Smith

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[2]Respectively, Associate Professor, Department of Horticulture, and Extension Agricultural Engineer, Dept. of Agric. Engineering.