Pollination Requirements of Three Highbush Blueberry (*Vaccinium corymbosum* L.) Cultivars

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ABSTRACT. The effects of pollination treatments on fruit set and five berry characteristics [mass, diameter, number of apparently viable seeds (well-developed, plump with dark seed coat), total seed number (includes apparently viable and partially developed seeds), and harvest date] were examined on three highbush blueberry cultivars. Pollination treatments included unpollinated, open pollinated, emasculated, and three hand pollinations that used pollen from the same flower, from the same cultivar, or from a different cultivar. Berries matured earliest and were smallest with the most apparently viable seeds in 'Northland', 'Patriot' had the greatest fruit set and smallest seed number, and 'Bluecrop' matured the latest. Fruit set was greater, berry size larger, seed number smaller, and maturation later in 1990 than 1991. For all three cultivars, berries were generally smallest, latest maturing, and had the fewest seeds when pollination was prevented and were largest with the most seeds and earliest maturing in open visitation. Emasculatation resulted in berries similar to those from unpollinated flowers. For berry characteristics, cross-pollination was of benefit for 'Patriot' and possibly 'Northland' but not 'Bluecrop'. Thus, commercial highbush blueberry planting designs must be based on the pollination requirements of the particular cultivar. 'Northland' berries almost always had seeds, while 'Patriot' showed high levels and 'Bluecrop' low levels of parthenocarpy.

At least 80% of flowers must set fruit to achieve a commercial crop of highbush blueberry (Merrill, 1936). Insects, especially bees, are required for pollen transfer. To ensure pollination, growers commonly rent colonies of honey bees during bloom (McGregor, 1976; Robinson et al., 1989). The pollination requirements of highbush blueberry are quite variable. Even though early work recognized the plant as generally being self-compatible, everything from parthenocarpy to complete self-incompatibility can be found (Coville, 1921; Merrill, 1936; Merrill and Johnston, 1939; Morrow, 1943; White and Clark, 1939). Large, early maturing fruit have been associated with cross-pollination in several studies (Bailey, 1938; Beckwith, 1930; Coville, 1921; Meader and Darrow, 1944, 1947; Morrow, 1943; Vander Kloet and Lyrene, 1987; White and Clark, 1939). However, good production can result from self-pollination (Merrill, 1936; Merrill and Johnston, 1939). Even though it is not a recommended practice (Pritts and Hancock, 1992), many commercial plantings consist of solid blocks of single cultivars. This practice will probably continue unless cross-pollination can be shown to be of great economic advantage.

Poor production is often attributed to poor pollination in blueberries. If poor pollination results from inadequate pollinator abundance, little pollen is transferred and few seeds are produced. Pollen quantity and quality and seed formation vary among cultivars, and poor pollen germination and seed development due to incompatibility problems occur (Bell, 1957; Brewer and Dobson, 1969a, 1969b; Eaton, 1966; Vander Kloet and Lyrene, 1987). Seed number has been correlated with fruit size in highbush blueberry

(Brewer and Dobson, 1969a; Darrow, 1958; Dorr and Martin, 1966; Filmer and Marucci, 1963; Moore et al., 1972; White and Clark, 1939). Fruit enlargement is thought to be stimulated by growth hormones produced by fertilized ovules or developing seeds (Mainland and Eck, 1968; Meader and Darrow, 1944, 1947). Viable seeds are large and plump with a single-layered, heavily lignified seed coat, while flat, partially developed seeds as a result of the collapse of the ovules can be caused by self-pollination (Morrow, 1943). Cultivar differences may explain some of the inconsistencies found in studies of blueberry pollination and fruit production noted above. More research is needed on different cultivars to enhance our understanding of this topic. This study examined the pollination requirements of three highbush blueberry cultivars. In particular, the benefits of cross-pollination and the degree of parthenocarpy were studied.

Materials and Methods

POLLINATION TREATMENTS. The pollination requirements of 'Bluecrop', 'Northland', and 'Patriot', were studied in 1990 and 1991 on a small demonstration plot of 30 mature highbush blueberry bushes growing in the Cornell Univ. Orchard, Ithaca, N.Y. For 'Northland' and 'Patriot', all three plants available at the site were used. Of the ten 'Bluecrop' plants growing at the site, three plants adjacent to one another were chosen for the study to have an arrangement similar to that for the other two cultivars.

Flower clusters on the three plants of each cultivar were bagged before anthesis with a close-weave cotton material to prevent insect visitation and then numbered. To ensure that treatments were evenly distributed around the bush, for each plant, clusters were systematically assigned to pollination treatments—1) unpollinated = bagged during the entire bloom period, 2) open = unbagged during the entire bloom period, and 3) emasculate = stamens removed before or at very early anthesis—and three hand pollination categories, which used pollen from different sources—2) self = pollen from the same flower to be pollinated, 2) cultivar = pollen from the same cultivar but a different plant, and 3) cross = pollen from a different cultivar. It should be noted that highbush blueberry is clonally propagated; thus, pollen from the self and

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Table 1. Average temperature and precipitation in Ithaca, N.Y. (data from the Northeast Regional Climate Center).

Month	Temp (°C)			Precipitation (cm)		
	Avg.	1990	1991	Avg.	1990	1991
April	6.6	8.4	9.3	7.4	9.7	9.7
May	12.7	12.1	16.5	8.4	12.1	3.9
June	17.7	18.6	19.3	9.6	6.0	2.7
July	20.3	20.5	20.8	8.8	9.9	10.1
August	19.4	19.5	20.5	8.7	11.1	6.6

cultivar treatments should be genetically similar. In 1990, the cross pollen source was either 'Spartan' or 'Coville'. In 1991, 'Patriot' and 'Bluecrop' were used to pollinate each other, while 'Coville' was used to pollinate 'Northland'. The same pollen donor could not be used for all pollinations because of differences in flowering phenology. Pollen was collected directly from anther sacs in 1990. In 1991, pollen was collected by vibrating a flower with a tuning fork (392 Hz). To pollinate, the stigma was gently patted into the collected pollen. To identify the resulting berries, a colored thread was tied on the pedicel of the treated flowers. For each pollination category, at least four and usually five flowers were treated per cluster, with the remaining flowers left to develop normally. The clusters were rebagged after treatments were completed. Four or five flowers per cluster were also selected for the open and unpollinated treatments. In 1990, two clusters per plant for 'Northland' and three for 'Patriot' and 'Bluecrop' were used for each treatment. Early bloom was missed in 'Northland'; therefore, fewer clusters were used than with the other two cultivars. In 1991, six clusters per treatment per plant were used for all three cultivars. After flowering was finished, bags were removed from the clusters and berry maturation was monitored.

BERRY HARVEST AND EVALUATION. Harvest began as soon as the first ripe fruit was seen and continued every 3 or 4 days until all berries were picked. To protect the fruit from bird damage, clusters were bagged with a loose netting once berries began to ripen. For each harvest day, all treatment berries that appeared ripe and well colored (blue with no apparent red) were picked and placed into separate vials or bags. Berries were weighed individually and their

diameters were measured as soon as possible after harvest. They were then frozen until seeds were counted. The number of apparently viable seeds (fully developed, plump with a dark seed coat) and partially developed seeds (flat with a light seed coat) were counted.

STATISTICAL ANALYSIS. Fruit set was calculated as the number of berries produced divided by the number of flowers treated per cluster and, before analysis, the proportions were arcsine transformed to achieve normality. Harvest dates were converted to Julian dates before analysis. The SAS statistical package (SAS Institute, Cary, N.C.) was used for data analysis.

A comparison among cultivars and years was done by nested ANOVA [cultivar, year (cultivar), pollination type (cultivar, year, plant)] and Scheffe's multiple comparison test (Zar, 1984) when a significant F test was found. Levels of parthenocarpy in 'Bluecrop' and 'Patriot', calculated for each year as the number of seedless berries (berries with neither apparently viable nor partially developed seeds) divided by the total number of berries harvested per cluster for each pollination type on each plant, were compared by nested ANOVA [cultivar, year (cultivar), pollination type (cultivar, year, plant)] and Scheffe's multiple comparison test (Zar, 1984) when a significant F test was found. 'Northland' was not included in this analysis because only two seedless berries, both from the unpollinated treatment in 1990, were collected.

A nested ANOVA [plant, pollination type (plant)] was used to assess the effects of the pollination treatments within each cultivar in the 2 years. Fruit set per cluster and for the individual fruit characteristics [mass, diameter, number of apparently viable seeds, total number of seeds (apparently viable plus partially developed seeds), and date of harvest] were compared. To separate pollination treatment effects, Scheffe's multiple comparison test (Zar, 1984) was run when a significant F test was found.

Results

FIELD CONDITIONS. Flowering for 'Northland', the earliest cultivar, began ≈15 May 1990 and 1 May 1991. Harvests also began later in 1990 than in 1991. In 1990, the first picking was 13 July for 'Northland' and 'Patriot' and 16 July for 'Bluecrop', while 24 June

Table 2. A comparison of fruiting among three highbush blueberry cultivars in 1990 and 1991.

Category	Clusters (no.)	Fruit set (%)	Berries (no.)	Mass (g/berry)	Diam (cm)	Apparently viable seeds (no.)	Total seeds (no.)	Harvest date
Cultivar								
Bluecrop	145	56 b ^a	403	0.87 a	1.16 a	15.7 b	64.4 a	1 Aug. c
Northland	133	52 b	334	0.62 b	1.00 b	19.9 a	53.6 b	13 July a
Patriot	153	66 a	486	0.84 a	1.14 a	5.3 c	24.1 c	24 July b
Pooled SE		2		0.02	0.01	0.6	1.3	0.7
Year (cultivar)								
1990	135	68 a	455	0.93 a	1.23 a	6.9 b	37.5 b	9 Aug. b
1991	296	54 b	768	0.71 b	1.04 b	16.1 a	50.1 a	14 July a
Pooled SE		2		0.01	0.01	0.5	1.1	0.5
Pollination type (cultivar, year)								
Unpollinated	71	39 b	137	0.63 b	1.04 b	1.1 d	8.4 c	7 Aug. c
Emasculate	69	26 b	89	0.62 b	1.04 b	1.1 d	5.6 c	4 Aug. c
Self	72	67 a	233	0.68 b	1.05 b	9.3 c	42.8 b	25 July b
Cultivar	72	68 a	242	0.73 b	1.09 b	12.6 bc	45.9 b	20 July a
Cross	74	67 a	246	0.91 a	1.17 a	24.4 a	63.2 a	18 July a
Open	73	79 a	276	0.97 a	1.19 a	14.8 b	62.6 a	21 July a
Pooled SE		3		0.02	0.01	0.9	1.9	1.0

^aMean separation (in each category of a cultivar in a column) by Scheffe's multiple comparison test, $P < 0.05$.

was the first day of harvest for all three cultivars in 1991. Weather conditions in the 2 years were responsible for these differences. April through August in 1990 was, on average, cooler and wetter than the same period in 1991 (Table 1). In addition, especially in 1991, clusters and branches were broken due to heavy storms, and some berries were lost due to bird damage.

CULTIVAR AND YEAR COMPARISONS. Statistically significant differences between cultivars and years were seen (Table 2). Fruit set in 'Patriot' was greater than the other two cultivars. 'Northland' had the smallest and earliest maturing berries with the greatest number of apparently viable seeds. 'Bluecrop' and 'Patriot' were similar in berry size, although 'Bluecrop' had more seeds and matured later than 'Patriot'. Fruit set was greater, berry size larger, seed number smaller, and maturation later in 1990 than 1991. The least number of fruit and seeds per fruit were found in the unpollinated and emasculated treatments, which also matured the latest. Cross and open pollinations produced berries that were larger with more total seeds than the other four categories, and berries from cross-pollinated flowers had the most apparently viable seeds.

The three cultivars also differed in the degree of parthenocarpy (Table 3). Only two seedless berries were collected from 'Northland'. 'Patriot' had significantly more seedless berries than 'Bluecrop'. The unpollinated and emasculate treatments had levels of parthenocarpy of $\approx 75\%$, greater than the manual and open pollinations.

EFFECTS ON INDIVIDUAL CULTIVARS. Although there were statistically significant effects due to plant in all three cultivars in both years, means for plant data are not presented as these are of little interest for this paper. These data are reported in MacKenzie (1994). For fruit set, there were significant differences among plants only in 'Northland' in 1991. However, fruit characteristics were significantly different among plants in all cases except berry mass and seed number for 'Bluecrop' in 1990 and apparently viable seed number for 'Patriot' in 1991.

Statistically significant differences due to pollination type were found in all three cultivars and in both years (Table 4). In general, open-pollinated berries were among the largest with many seeds, whereas no pollination (unpollinated and emasculate treatments) produced the smallest berries with the least seeds. A diverse bee fauna was found at this site (MacKenzie and Eickwort, 1996), so it is likely that open-pollinated flowers were visited, probably multiple times, by several bee species.

For 'Bluecrop', cross-pollination was of little benefit. All three hand pollinations were similar for all berry characteristics except that cross-pollinated berries matured later self-pollinated berries in 1990, while in 1991, the berries from cross-pollination matured earlier than those from self-pollination and had significantly more seeds than the other two hand pollinations and open pollination.

For 'Northland', fruit set was poor ($\leq 20\%$) when pollination was prevented. In 1990, there were no significant differences between the hand pollinations for 'Northland', while in 1991, self-pollination and open-pollination produced berries that were smaller, later maturing, and had fewer seeds than cross-pollination.

'Patriot' showed some beneficial effects of cross-pollination. Berries produced from cross-pollination had more apparently viable seeds than open pollinations or the other two hand pollinations in both years of the study. Berries produced from cross-pollination were also heavier than those produced by open pollination in 1990 and heavier and earlier maturing than those from the other two hand pollinations in 1991. Self- and cultivar pollinations produced berries that were similar in size and seed number to those from no pollination (unpollinated and emasculate treatments) in both years.

Discussion

Weather appeared to be very important to productivity in this study. Bloom and harvest were earlier in 1991 when the spring and summer were warmer than in 1990 (Table 1). However, 73% of the flowers that were open to pollinators during bloom set in 1991 compared with $\approx 90\%$ in 1990 (Table 4), and fruit set was significantly lower in 1991 than 1990 (Table 2). Even though 1991 was warm and dry, providing better conditions for pollinator flight than the wet weather in 1990, bloom was early and shorter than in 1990. Sufficient pollinators may not have been available due to this short, early season. A brief flowering duration means fewer days for pollination and less likelihood of multiple visitation, which has been shown to be beneficial to blueberry production (Danka et al., 1993; Lang and Danka, 1991; MacKenzie, 1994). A second, and probably more important factor, may have been the dry conditions in 1991. Differences in production between years are common and can be related to conditions during flowering, fruit maturation, or even during the previous winter (Howell et al., 1972; Merrill, 1936). Blueberries require a constant supply of moisture from budbreak in the spring to the beginning of senescence in the fall, including moisture equivalent to 40 mm of rainfall per week from fruit set to harvest (Eck, 1988; Pritts and Hancock, 1992). No irrigation was available where the experimental plots were located. Therefore, plants may not have been able to bear a heavy crop in 1991, resulting in lower fruit set than in 1990. Differences in fruiting between the 2 years supports this hypothesis. Even though berries matured earlier and had significantly more seeds, they were smaller in 1991 than in 1990 (Tables 2 and 4). This is contrary to expectations, as berries with more seeds tend to be larger than those with fewer seeds (Darrow, 1958; Dorr and Martin, 1966; Filmer and Marucci, 1963; Moore et al., 1972; White and Clark, 1939). Without supplemental water, however, the berries in 1991 remained small even given their ample seed number.

Some of the differences seen between cultivars in this study, in particular differences between open pollination and cross-pollination on 'Patriot', may be explained at least in part by cultivar preference by pollinators. Honey bees prefer certain cultivars over others due to differences in blossom shape and nectar production

Table 3. Degree of parthenocarpy in two highbush blueberry cultivars.

Category	Flower clusters (no.)	Degree of parthenocarpy (%)
Cultivar		
Bluecrop	33	20 b ²
Patriot	36	58 a
Pooled SE		3
Year (cultivar)		
1990	36	43
1991	33	36
Pooled SE		3
Pollination type (cultivar, year)		
Unpollinated	11	74 a
Emasculate	10	75 a
Self	12	41 b
Cultivar	12	23 b
Cross	12	18 b
Open	12	11 b
Pooled SE		5

²Mean separation in each category in the column by Scheffe's multiple comparison test, $P < 0.05$.

Table 4. Effects of pollination type on fruit set and fruit characteristics in three highbush blueberry cultivars in 1990 and 1991.

Category	Clusters (no.)	Fruit set (%)	Berries (no.)	Mass (g/berry)	Diam (cm)	Apparently viable seeds (no.)	Total seeds (no.)	Harvest date
1990 Bluecrop								
Unpollinated	9	67	31	0.83 bc	1.18 bc	1.3 b	14.8 c	19 Aug. bc
Emasculate	8	44	17	0.58 c	1.04 c	0.6 b	10.5 c	24 Aug. c
Self	8	72	29	1.10 ab	1.34 ab	8.1 b	67.7 ab	6 Aug. ab
Cultivar	8	55	22	0.93 bc	1.24 bc	4.0 b	43.4 bc	18 Aug. abc
Cross	8	80	35	0.87 bc	1.20 bc	6.4 b	57.9 ab	22 Aug. c
Open	8	90	37	1.40 a	1.45 a	24.0 a	79.9 a	6 Aug. a
Pooled SE		11		0.07	0.04	1.8	6.2	2.9
1991 Bluecrop								
Unpollinated	15	17 bc	11	0.44 c	0.89 d	1.5 c	13.4 c	11 Aug. c
Emasculate	14	10 c	7	0.37 c	0.89 cd	0.3 bc	3.1 c	15 Aug. c
Self	16	62 a	51	0.69 bc	1.04 bcd	13.4 bc	63.8 b	28 July bc
Cultivar	17	72 a	60	0.75 abc	1.08 abc	20.1 b	88.3 a	19 July ab
Cross	18	52 ab	42	0.87 ab	1.15 ab	40.5 a	77.7 ab	15 July a
Open	16	75 a	61	0.91 a	1.17 a	20.4 b	88.8 a	19 July a
Pooled SE		19		0.07	0.04	3.5	6.9	3.1
1990 Northland								
Unpollinated	6	20 b	6	0.39 c	0.94 d	2.0 b	13.3 b	11 Aug. c
Emasculate	6	13 b	4	0.45 bc	0.92 cd	1.2 b	14.0 b	7 Aug. bc
Self	6	65 ab	18	0.74 bc	1.13 bcd	5.8 b	49.5 a	28 July abc
Cultivar	6	69 ab	19	0.78 bc	1.17 abc	8.9 b	49.8 a	26 July ab
Cross	6	80 ab	23	0.92 ab	1.24 ab	14.3 ab	57.9 a	20 July a
Open	6	90 a	26	1.05 a	1.31 a	19.7 a	55.8 a	20 July a
Pooled SE		34		0.26	0.04	2.7	4.3	2.8
1991 Northland								
Unpollinated	17	14 b	9	0.37 b	0.78 c	9.0 b	45.4 bc	22 July c
Emasculate	14	10 b	7	0.45 ab	0.84 abc	1.7 b	12.3 d	13 July abc
Self	17	73 a	62	0.52 b	0.92 bc	18.1 b	53.7 bc	9 July b
Cultivar	15	59 a	45	0.55 ab	0.96 ab	34.3 a	59.7 ab	2 July a
Cross	17	67 a	55	0.65 a	1.01 a	35.6 a	67.4 a	2 July a
Open	17	73 a	60	0.47 b	0.88 c	13.3 b	48.8 c	15 July c
Pooled SE		6		0.04	0.03	2.9	3.6	2.2
1990 Patriot								
Unpollinated	9	78	36	0.66 c	1.11 c	0.1 c	1.4 b	22 Aug. b
Emasculate	9	53	24	0.79 bc	1.19 bc	0.0 bc	0.3 b	15 Aug. ab
Self	8	82	29	0.59 c	1.04 c	0.0 c	2.7 b	22 Aug. b
Cultivar	8	77	31	0.81 bc	1.20 bc	0.2 bc	8.5 b	8 Aug. ab
Cross	7	73	30	1.49 a	1.47 a	11.2 a	53.9 a	30 July a
Open	9	91	38	1.12 b	1.32 ab	5.3 b	46.2 a	5 Aug. a
Pooled SE		10		0.07	0.03	1.1	3.9	3.3
1991 Patriot								
Unpollinated	15	59 ab	44	0.59 c	0.98 c	0.0 c	0.0 b	20 July c
Emasculate	18	33 b	30	0.64 c	1.01 c	2.3 bc	4.8 b	16 July bc
Self	17	55 ab	44	0.65 c	1.01 c	0.4 bc	10.5 b	16 July c
Cultivar	18	74 a	65	0.70 c	1.05 bc	0.4 c	14.8 b	14 July bc
Cross	18	71 ab	61	0.90 b	1.14 b	24.0 a	59.0 a	6 July a
Open	17	72 a	54	1.15 a	1.25 a	8.4 b	51.6 a	8 July ab
Pooled SE		8		0.05	0.02	1.8	4.1	1.6

^aMean separation (in each category of a cultivar in a column) by Scheffe's multiple comparison test, $P < 0.05$.

(Dorr and Martin, 1966; Filmer and Marucci, 1963; Marucci, 1967), while preference in native bees is less marked (Marucci, 1967; Wood et al., 1967). Fewer bees were seen foraging on 'Patriot' than on the other two cultivars in both years (K. MacKenzie, personal observation), thus, poorer pollination would have resulted. Pollinator preference should be considered by plant breeders as one aspect of new highbush blueberry cultivar evaluation.

Differences between cultivars in their pollination requirements

are well known and can reflect their parentage. For example, of two southern highbush cultivars studied, only 'Sharpblue' benefited from cross-pollination (Lang and Danka, 1991). 'Gulfcoast', which did equally well with either self- or cross-pollination (Danka et al., 1993), has a higher proportion of self-compatible highbush blueberry germplasm than 'Sharpblue'. 'Northland' was developed through interspecific hybridization of lowbush and highbush blueberries (Johnston and Moulton, 1967). Lowbush blueberries are

self-incompatible (Aalders and Hall, 1961). Therefore, cross-pollination may be beneficial in this cultivar. However, there was only weak evidence supporting this hypothesis, and 'Patriot' showed the most benefits of cross-pollination of the three cultivars studied. The advantages of cross-pollination were evident when data from all three cultivars were pooled (Table 3), even though there were no benefits to 'Bluecrop' when analyzed individually (Table 4). To achieve maximum production, highbush blueberry growers should plant at least two cultivars in their fields unless, as in 'Bluecrop', there is evidence that shows cross-pollination to be of no advantage. This confirms recommendations already made for other highbush cultivars and on rabbiteye blueberry (Coville, 1921; Eck, 1988; El-Agamy et al., 1981; McGregor, 1976; Morrow, 1943; White and Clark, 1939). Research should be directed to identify cultivars that flower concurrently and are good pollen sources for each other so that growers can make better choices for new highbush blueberry plantings.

Some of the results in this study are inconsistent (e.g., berries resulting from cross-pollination of 'Bluecrop' matured late in 1990 and early in 1991). Some of the inconsistencies may be due to weather differences in the 2 years, incompatibility with the pollen source, or poor methodology of the hand pollinations in 1990. Pollen parent can be very important, and even with cross-pollination variation in fruit set and size can be notable (Eck, 1988; Hellman and Moore, 1983; Krebs and Hancock, 1988; Lang and Parrie, 1992; Merrill, 1936). The effect of pollen parent seems to vary with cultivar. In a study similar to this one, pollen source had no effect on any fruiting character measured in 'Gulfcoast' southern highbush blueberry (Danka et al., 1993), while it was important for a second cultivar, 'Sharpblue' (Lang and Danka, 1991). Pollen viability has also been correlated with the number of apparently viable seeds and fruit size (Vander Kloet, 1983). Each seed had a larger impact on berry size when pollen viability was low. Pollen viability of donor plants was not checked in this study and compatibility was not considered, as little information on the cultivars in question exist. More study is needed to determine the effect of pollen donor on productivity in highbush blueberry. In addition, flower age when pollen transfer occurs is important. Even though the flower can remain receptive up to 8 d after anthesis, adverse affects on fruit mass and seed number were seen when pollination occurred as little as 2 days after opening (Moore, 1964). Flowers used in this study were not monitored for age, and this could also have affected the outcome.

It is generally accepted that few parthenocarpic fruit form in most highbush blueberry cultivars. However, considerable parthenocarp and decline in productivity have been noted in 'Jersey', an extensively planted cultivar (Eck, 1988). Parthenocarpic fruit tend to be small and late maturing, never reaching marketable size. So, even though fruit set appears good, production, especially during the early season, will be poor. Considerable parthenocarp was seen in 'Patriot' and this seemed to be tied to poor pollination in this cultivar as well. 'Patriot' is a very hardy cultivar that is often recommended for home gardens and local production (Hepler and Draper, 1976). As production of highbush blueberry expands into more northern areas of the northeastern United States and Canada, 'Patriot' could become an important cultivar because of its winter hardiness, and pollination problems may occur.

Self- and cross-pollination resulted in larger berries than open pollination in some cases in this study and in others (Merrill, 1936; Merrill and Johnston, 1939). However, care must be taken when making pollination recommendations based solely on results from studies where pollen is applied to receptive stigmas in relatively large amounts and multiple times if deemed desirable. This is

especially true of greenhouse studies where optimum conditions for pollen germination and growth and for berry development can be maintained (Meader and Darrow, 1947). While benefits due to cross-pollination may be demonstrated, it can be difficult to duplicate these results in an actual cropping situation where pollinators and weather are important factors. Pollinator movement and behavior greatly affects pollen transfer. Planting designs and cultivar characteristics as they relate to pollinators need to be assessed properly to determine if cross-pollination will actually be achieved in the field. Current recommendations, which maximize the ease of management, are to plant two or more cultivars having similar bloom periods in alternating pairs of rows (Pritts and Hancock, 1992). This may not be the optimum scheme for maximizing cross-pollination, because bees tend to move down rows rather than across lanes (Free, 1960; Mayer et al., 1989). Other types of planting designs which combine two or more cultivars in a single row are more likely to result in cross-pollination and should be explored.

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