

Seed Set, Berry Weight, and Yield Interactions in the Highbush Blueberry Cultivars (*Vaccinium corymbosum* L.) 'Bluecrop' and 'Duke'

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Abstract

Yields and berry weights of two widely grown, commercial, highbush blueberry (*Vaccinium* spp.) cultivars, 'Bluecrop' and 'Duke', were evaluated for three or more harvests every season over ten years, and seed set was determined at each harvest over the last four. Across 10 years, yield and berry weight had no significant correlation. Under our study conditions, the limitations of yield for 'Bluecrop' did not include pollination. In fact, pollination (expressed as seed/gram fresh weight) had an inverse relationship to yield. For the years in which replicated seed counts were made, we found, in general, that 'Bluecrop' berry weight and seed/fruit decreased linearly between Harvest 1 and Harvest 3, and berries with similar seed numbers varied in weight as much 39% among years. Hence, reduced berry weight was not necessarily due to poor pollination. For 'Duke', trends of berry weight and seed/fruit across harvests were inconsistent, but 'Duke' appeared to have sufficient environmental plasticity to produce fruit with increased berry weight between successive harvests given favorable inputs. For 'Duke', berries with similar seed numbers varied in weight as much as 86% among years. A cyclical yield variation was seen in 'Duke' that generally followed a high-medium-low pattern.

Early in the production season, blueberry (*Vaccinium* spp.) growers often question whether small berry size is the result of poor pollination that will result in a reduced yield, or whether small berry size is the result of the plant being overcropped. Indeed, many studies have documented that fruit weight is positively correlated with seed number in highbush blueberry, *Vaccinium corymbosum* L. (2, 10, 18, 19). Among these studies, Eaton (10) found an overall correlation of 0.59 between fruit size and seed number across a group of 13 highbush cultivars and selections. Similarly, Moore et al. (19) found a correlation of 0.64 across 13 cultivars of highbush blueberry. Positive correlations have also been documented between seed number and fruit size in *V. angustifolium* Ait. (1, 16) based on measurements both within and among cultivars. In rabbiteye (*V. virginicum* Ait.), correlations of seed number with fruit weight ranging from 0.38 to 0.80 have been reported (12, 17, 19). Seed number is also of importance because it affects time of

ripening. Fruit resulting from self-pollination are generally later to ripen because of their reduced seed numbers (7, 15, 18, 20).

In balance to the previous observations, Brewer and Dobson (2) concluded that other factors besides seed number contribute significantly to variability in fruit size, indicating that a certain number of seed was needed to produce normal-sized fruit, but beyond that, additional seeds changed fruit size little. Similarly, Eaton (10) found that when conditions favored cross-pollination, at least 60% of variability in fruit weight was due to factors other than seed number.

Blueberry is a perennial plant with yield influenced by many factors. Under circumstances where pollination is limiting, increases in pollination can increase yield (3, 4, 6). Studies have also shown that cross-pollination resulted in improved seed set and fruit set (15, 22). Plant structure may also contribute to yield. Siefker and Hancock (23) found canes per bush and berries per cane significant contributors to yield in compari-

sons across nine cultivars. Further studies by Hancock (14) evaluated several other morphological factors across six cultivars and determined that path coefficients for laterals/cane and flowers/bud were the most significant contributors to yield.

Additional factors affecting source-sink relationships may also contribute to yield variation. In a seminal study, Brightwell and Johnston (5) concluded that pruning of any kind reduced yield, although fruit size increased. In contrast, Siefker and Hancock (24) concluded that under Michigan conditions, as many as 40% of the buds could be pruned from a plant with no significant change in yield.

Considering the many factors affecting and interacting with yield, many possibilities exist for how yield, fruit size, and seed number are related from year to year. Seed number bears a strong relationship to fruit size, but it is unclear if it relates in any way to yield in a well-managed planting. To answer these questions, yields and berry weights of two widely grown, commercial, highbush blueberry cultivars, 'Duke' and 'Bluecrop', were evaluated for three or more harvests every season over ten years, and seed set was evaluated at each harvest over four of these years.

Materials and Methods

'Duke' and 'Bluecrop' are standard commercial cultivars in NJ and many parts of the northern temperate areas in which highbush blueberries are grown and represent a significant amount of the total commercial crop in these areas. 'Duke' is an early season cultivar known for its consistent high yields and firm fruit quality (9). 'Bluecrop' is a standard mid-season cultivar known for its consistent yield, broad adaptation, and long harvest season (8).

The cultivars were grown in a replicated planting of elite clones and standard cultivars that was established in 1996 at Variety Farms, Hammonton, N.J., and consisted of four replicates of five plants each in a ran-

domized complete block design. The Variety Farms site was located in USDA Plant Hardiness Zone 6, on soil that was primarily Atsion sand containing 3-5% organic matter. Cultural practices at Variety Farms included incorporating peat into the planting holes, mulching with pine bark, and the use of solid-set overhead sprinklers for both irrigation and frost protection. Fruit were harvested by hand, weekly, beginning at the first appropriate harvest time for 'Duke' (approximately 40% ripe) and continuing through the end of the respective ripening seasons for 'Duke' and 'Bluecrop'. For 'Duke' this typically meant three regular harvests and a final stripping of all ripe and green fruit. For 'Bluecrop', four harvests and a final stripping were typical.

For seed counting, fruit samples were collected from bulked 5-plant yield samples within each replicate. A sample of intact, whole fruit weighing as close as possible to 200 g was taken and precisely weighed. Numbers of fruit in each bulk sample were counted to allow calculation of mean berry weight. Fruit were then gently mashed in a beaker with 1ml of concentrated food-grade pectinase (Pectinase Smash XXL, Novozymes North America, Franklinton, NC). Beakers were then covered with clear plastic wrap and incubated overnight at room temperature to optimize digestion. The next day, the pulp was given a final manual maceration to guarantee that as much seed as possible was freed from the pulp. Seed was then separated by dilution of the pulp with water, and subsequent gentle decanting of the supernatant pulp. Seed remained at the bottom of the beaker, and was repeatedly washed until seed was clean and minimal debris remained. To optimize recovery of the seed, all of the supernatant pulp and water were collected and decanted two additional times and the residual seed from each decanting was collected. Ultimately, the seed from the initial decanting and the two additional cycles of decanting was combined. This seed was drained of excess water by filtering through coarse

Table 1. Berry weight and yield/plant from 1998 to 2007 for 'Bluecrop' and 'Duke' blueberry.

Year	Bluecrop		Duke	
	Yield/plant (kg) ^z	Berry wt. (g) ^y	Yield/plant (kg) ^z	Berry wt. (g) ^y
1998	5.4	1.8	6.3	2.1
1999	6.0	1.6	7.4	1.6
2000	4.5	1.3	4.7	1.2
2001	3.7	1.7	3.5	1.8
2002	5.7	1.3	6.0	1.4
2003	5.5	1.9	4.7	2.3
2004	3.9	1.5	4.4	1.5
2005	7.0	1.8	6.6	1.5
2006	4.6	1.9	5.9	1.7
2007	5.6	1.9	4.2	1.7
Avg.	5.2 ± 1.0	1.7 ± 0.2	5.4 ± 1.2	1.7 ± 0.3

^z Yields derived from harvests of RCBD plots of 4 blocks with 3 plants per block

^y Berry weights calculated by weighted average of berry weights across harvests

filter paper. After draining, the filter paper and seed were placed on aluminum pans, the seed spread shallowly on the filter paper, and air-dried for approximately 2 days before being transferred to vials for storage. Prior to counting, dry seed was sieved using a #26 mesh screen (0.63 mm). This sieve separated seed into two groups, one containing larger and well-developed seed, the other containing poorly developed and unviable seed. If this sieving did not occur, and all seed were counted, the seed counts between different harvests were negligible (limited trial). Seed counts were made in triplicate on the larger seed that did not pass through the sieve using a Count-a-pak seed totalizer (Seedburo Equipment Co., Chicago, Ill.).

For the evaluation of yield versus berry weight across 10-yr (1998 - 2007), an average berry weight was determined across the harvest season. Correlations were then calculated of average berry weight (across all harvests) vs. total yield, and of berry weight at three individual harvests (H1, H2, H3) versus total yield. For the years in which seed counts were made (2003-2006), correlations were made of total yield versus: seed/gram fresh weight (s/gfw), seed per fruit (s/f), and berry

weight in grams/fruit (g/f) for each harvest for that set of years. Correlations were also determined of total yield versus overall s/gfw, s/f, and grams/fruit (i.e. values averaged across harvests). Regressions were calculated for berry weight and s/f relationships across harvests and across years. Correlations and regressions were performed using MSTAT-C statistical software (Michigan State University, East Lansing, Mich.). In 2007, seed count data were collected on a single block of the yield trial from both cultivars. These data were used to supplement to the 2003-2006 data to further evaluate relationships.

Results and Discussion

Yield and berry weight relationships. Yields across 10 yr ranged from 3.7 to 7.0 kg/plant for 'Bluecrop' and from 3.5 to 7.4 kg/plant for 'Duke'. 'Bluecrop' and 'Duke' exhibited relative yield peaks in 1999, 2002, and 2005 (Table 1). Over the same years, average berry weight varied from 1.3 to 1.9g/f for 'Bluecrop' and from 1.2 to 2.3g/f for 'Duke'. Across 10 yr, correlations of yield and average berry weight were not significant for either cultivar; $r = 0.18$ ($p=0.61$) for 'Bluecrop'; $r = -0.07$ ($p=0.84$) for 'Duke'

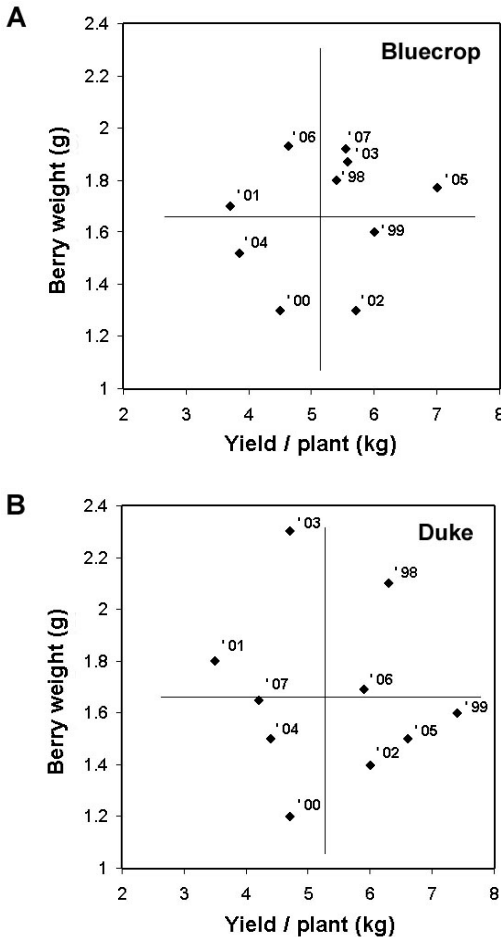


Fig. 1. Relation between berry weight and yield per plant over 10 yr for a) 'Bluecrop' and b) 'Duke'. Lines in graphs represent 10-year means for berry weight and yield.

(Figure 1a, 1b). Correlations of total yield vs. average berry weight at H1, H2, and H3 across 10 yr were also non-significant for both cultivars (data not shown). 'Bluecrop' had a prolonged ripening period with 29, 26, and 20% of the total crop harvested at H1, H2, and H3, respectively ($\Sigma = 75\%$), with another 25% of the crop harvested typically in a H4 and stripping, whereas 'Duke' had a relatively concentrated ripening period with 39,

36, and 21% of the total crop harvested at H1, H2, and H3, respectively ($\Sigma = 96\%$).

Relationships between yield and berry weight should be examined with an expectation of a possible inverse relationship between yield and berry weight. Based upon such typical relationships, expected outcomes might range in a broadly linear manner between: 1) low berry weight with high yield (over-cropped) and 2) high berry weight with low yield (under-cropped) (Fig. 1a, 1b, upper left and lower right quadrants). Relatively balanced responses would lie in the middle. Less likely outcomes might be: 3) high berry weight with high yield or 4) low berry weight with low yield (light crop with inadequate pruning). In fact, compared to the 10-year means for both of these characters, all of these outcomes occur for both cultivars (Fig. 1a, 1b). It should be recognized, however, that both yield and berry weight values represent fluctuations around a commercial average, and it is likely that these fluctuations do not fully represent the more severe possible scenarios.

Berry weight and seed per fruit (s/f) relationships across harvests and across years. Seed per fruit at H1 for 'Bluecrop' ranged from 23.7 to 49.7 s/f (mean = 37.8), and for 'Duke' from 20.8 to 42.0 s/f (mean = 28.3). Average berry weight at H1 for 'Bluecrop' ranged from 1.58 to 2.30 g/f (mean = 2.00), and for 'Duke' from 1.05 to 2.27 g/f (mean = 1.52). The ratios of these values suggest that for the H1 interval, 'Bluecrop' and 'Duke' had virtually identical mean s/gfw ratios (18.9 vs. 18.6, respectively) (Tables 2, 3).

For 'Bluecrop', berry weight and s/f always decreased between successive harvests (Table 3, Figure 2). Berries with similar s/f values (as extrapolated by calculating the maximum distance between harvest trend lines from different years) varied in weight as much as 39% between years (2004 vs. 2005 at an x-axis value of approximately 28

Table 2. Average seed per fruit (s/f) and average berry weights for successive harvests of ‘Bluecrop’ blueberry, 2003-2007.

Year	Harvest 1		Harvest 2		Harvest 3	
	s/f ± s.d. ^z	Berry wt. (g) ^y	s/f ± s.d. ^z	Berry wt. (g) ^y	s/f ± s.d. ^z	Berry wt. (g) ^y
2003	49.4 ± 2.7	2.30	36.1 ± 1.6	1.87	33.3 ± 3.2	1.67
2004	23.7 ± 3.1	1.58	16.9 ± 3.0	1.19	7.2 ± 0.6	0.97
2005	49.7 ± 3.6	2.00	36.4 ± 2.7	1.54	26.0 ± 3.1	1.50
2006	28.3 ± 4.5	2.12	12.8 ± 1.4	1.43	7.6 ± 0.3	1.21
2007 ^x	51.9	2.20	33.2	1.40	22.1	0.76
Avg. '03-'06	37.8	2.00	25.6	1.51	18.5	1.34
Change from previous harvest	-	-	-12.2	-0.49	-7.1	-0.17
% change vs. H1	-	-	-32.3 %	-24.5 %	-18.8 %	-8.5 %

^z Number of seed per fruit ± standard deviation based on triplicate counts of 200 g samples from four replicates

^y Berry weight derived from 200 g fruit sample used for seed counting

^x 2007 values are based upon a single replicate sample (3 plants) sampled across all three harvests; these samples do not enter into calculations

s/f). A regression of 2003-2006 s/f and berry weight was highly significant ($F = 27.03$, $P = 0.0004$, $r^2 = 0.73$) and produced the equation:

$$\text{berry weight (g)} = 0.024 (\text{seed number}) + 0.972.$$

For ‘Bluecrop’ (Table 2), the percent change in s/f between H1 and H2 was approximately double that between H2 and H3 (-32% vs. -19%); while the percent change in berry weight between these same two sets of harvests was approximately a threefold difference (-25% vs. -9%).

‘Duke’ exhibited less consistent trends between berry weight and s/f across harvests (Table 3, Figure 3). In fact, its responses might be considered remarkably diverse. Although s/f always decreased between sequential harvests, berry weight response was less consistent than in ‘Bluecrop’. In two of four years, ‘Duke’ berry

weight exhibited atypical trends in that berry weight increased either between H1 and H2 (2005) or between H2 and H3 (2004). For ‘Duke’, berries with similar s/f values (extrapolated by calculating the maximum distance between lines) varied in weight as much as 86% between years (2003 vs. 2005

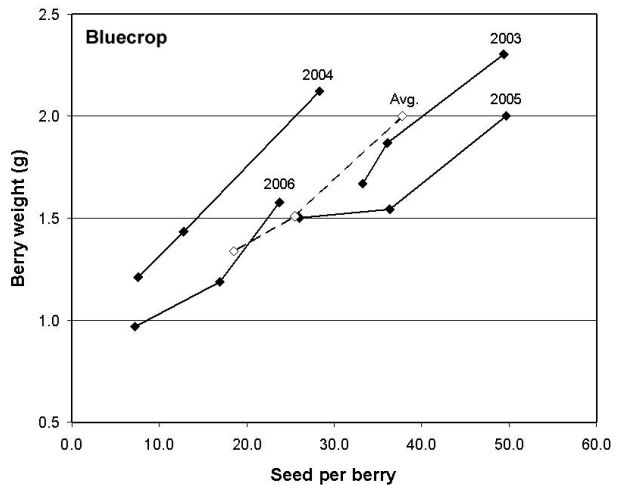


Fig. 2. Berry weight versus seed per berry for ‘Bluecrop’ at Harvest 1 through Harvest 3 in 2003 to 2006. Harvest 1 is always farthest right.

at an x-axis value of approximately 29 s/f). A regression of 2003-2006 berry weights on s/f was not significant ($F = 3.52$, $P = 0.09$, $r^2 = 0.26$). The graph of the average response of 'Duke' across years (Figure 3) shows that it exhibits a much flatter response across harvests on average than 'Bluecrop' (Figure 2). For 'Duke', there was a large percent change (approximately three-fold difference) in s/f from H1 to H2 versus H2 to H3 (-43% vs. -17%), while the percent change in berry weight between these two sets of harvests was virtually identical (approximately -5%).

Overall, the percent decreases in s/f between H1 and H2 and between H2 and H3 are comparable in 'Bluecrop' and 'Duke' (-32% and -19% for 'Bluecrop'; -43% and -17% for 'Duke'). The same cannot be said for percent decreases in berry weight between H1 and H2 and between H2 and H3; (-25% and -9% for 'Bluecrop'; -5% for both in 'Duke'). The per-

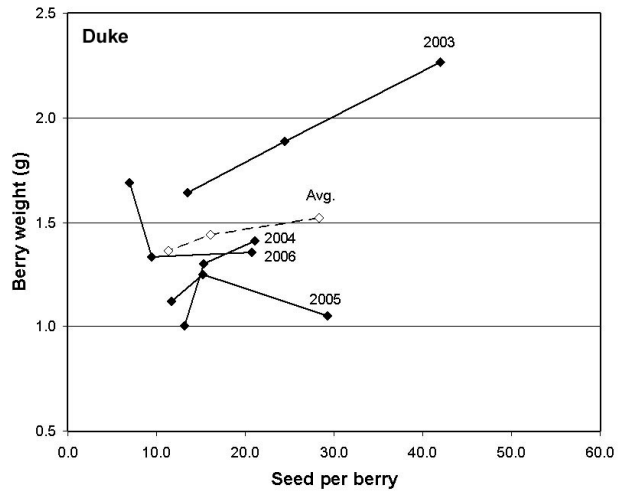


Fig. 3. Berry weight versus seed per berry for 'Duke' at Harvest 1 through Harvest 3 in 2003 to 2006. Harvest 1 is always farthest right.

centages indicate relatively large and ongoing decreases in berry weight for 'Bluecrop', whereas for 'Duke' those differences were smaller and virtually identical between harvests. These results reinforce the observation that s/f has a greater influence on berry weight in 'Bluecrop'. In contrast, the inconsistent berry weight trends in 'Duke' suggest

Table 3. Average seed per fruit and average berry weights for successive harvests of 'Duke' blueberry, 2003-2007.

Year	Harvest 1		Harvest 2		Harvest 3	
	s/f \pm s.d. ^z	Berry wt. (g) ^y	s/f \pm s.d. ^z	Berry wt. (g) ^y	s/f \pm s.d. ^z	Berry wt. (g) ^y
2003	42.0 \pm 2.3	2.27	24.5 \pm 2.3	1.89	13.5 \pm 0.6	1.64
2004	21.1 \pm 5.0	1.41	15.4 \pm 1.0	1.28	13.2 \pm 1.7	1.01
2005	29.2 \pm 5.5	1.05	15.2 \pm 3.8	1.27	11.7 \pm 1.3	1.12
2006	20.8 \pm 9.1	1.36	9.5 \pm 2.7	1.33	6.9 \pm 2.7	1.69
2007*	14.4	2.01	12.2	1.40	2.9	0.76
Avg. '03-'06	28.3	1.52	16.2	1.44	11.3	1.37
Change from previous harvest	-	-	-12.1	-0.08	-4.9	-0.07
% change vs. H1	-	-	-42.8 %	-5.3 %	-17.3 %	-4.6 %

^z Seed per fruit \pm standard deviation based on triplicate counts of 200 g samples from four replicates

^y Berry weight derived from 200 g fruit sample used for seed counting

* 2007 values are based upon a single replicate sample (3 plants) sampled across all three harvests; these samples do not enter into calculations

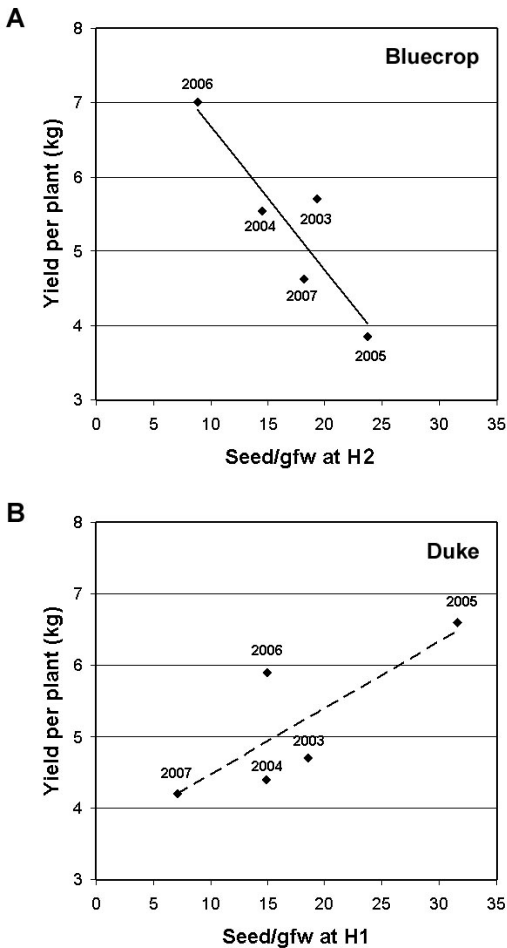


Fig. 4. Yield per plant versus seed/gram fresh weight at a) Harvest 2 for 'Bluecrop', and b) Harvest 1 for 'Duke'. Line in 4b is a non-significant trend line.

greater variability in response to factors such as nutrient sources in relation to berry weight during the ripening period. It also demonstrates that under favorable circumstances 'Duke' can produce later-harvest fruit with increased berry weight, although the factors that lead to these increases are not clear.

Yield and seed parameter relationships. 'Bluecrop' and 'Duke' were evaluated for correlations of total yield with s/gfw, s/f, and g/f at each harvest, and also for correlations

of total yield versus the average values of these parameters (i.e. across harvests, H1-H3) for the four years in which fully-replicated seed counts were conducted (Table 4).

For 'Bluecrop' in 2003-2006, the highest correlation occurred for total yield vs. s/gfw at H2 with a value of $r = -0.93$. This value was non-significant ($p=0.08$) due to the small sample size, but hint at a possibly significant relationship of s/gfw to yield. Inclusion of the limited-replication count from 2007 yielded a correlation value of $r = -0.91$ ($p=0.03$) (Fig. 4a). For 'Bluecrop' this is a negatively correlated relationship, with yield decreasing as s/gfw increased at H2. A similar relationship for 'Bluecrop' was observed at H1, but correlation values were lower ($r = -0.85$, $p = 0.15$). For 'Bluecrop', 29% and 26% of the crop was harvested at H1 and H2, respectively. Thus, 'Bluecrop' yield was inversely correlated to s/gfw across all harvests. For 'Bluecrop', correlations of total yield on s/gfw averaged across H1-H3 were $r = -0.71$ ($p=0.01$). Paradoxically, these values imply that pollination is less critical to yield in 'Bluecrop', and may also imply that yield compensation will occur if pollination is poor (i.e. yield increases as pollination decreases). Compared to previous reports regarding seed number and fruit size correlations, this seems counter-intuitive, but it should be noted that the present comparison relates total yield and s/gfw, not fruit size and seed number as do many earlier studies.

A further consideration is that the yield-test block in general might be expected to have had superior cross-pollination, and that the yield range examined represents generally optimal yield conditions and environments, not extremes.

For 'Duke', the highest correlations with yield occurred for yield vs. s/gfw at H1 with values of $r = 0.72$ ($p=0.28$) (note, s/gfw, not s/f). This value was not significant due to the small sample size, but again hints at a possi-

Table 4. Pearson correlation coefficients of seed and fruit parameters with total yield in 'Bluecrop' and 'Duke' blueberry over 4 years (2003-2006). Correlations are non-significant unless otherwise noted.

Parameter	Harvest	Bluecrop	Duke
g/fruit	1	0.19	-0.66
	2	-0.10	-0.44
	3	-0.34	0.03
	All	-0.06 ^z	-0.38 ^z
seed/gfw	1	-0.85	0.72
	2	-0.93	-0.33
	3	-0.60	-0.30
	All	-0.71 (p= 0.01) ^z	0.15 ^z
seed/fruit	1	-0.60	-0.16
	2	-0.73	-0.50
	3	-0.51	-0.54
	All	-0.50 ^z	-0.20 ^z

^z Correlation based upon 12 values (4 yr x 3 harvests)

bly significant relationship of s/gfw to yield. Inclusion of the single-replicate count from 2007 yielded an r value of $r = 0.80$ ($p=0.10$) for 'Duke' (Fig. 4b). Unlike the situation in 'Bluecrop', for 'Duke' this is a positively correlated relationship, with yield increasing as s/gfw at H1 increased. It is, however, also necessary to point out that this relationship was irregular (non-significant). Correlation of total yield on s/gfw averaged across H1-H3 was only $r = 0.15$ ($p=0.70$) for 'Duke'.

In this study, on average, 39% of the 'Duke' crop was harvested at H1 (2003-2006), and it thus makes empirical sense that pollination is critical to the H1 harvest. The positive relationship of total yield and s/gfw does not apply for later harvests, and yet in some of these harvests, berry weight compensation (i.e. increased fruit size at some later harvests) occurs. When we further evaluated this fruit size phenomenon by examining yield vs. average berry weight at sequential harvests within any single year or across years, we saw no consistent trends. For 'Duke' it should be noted, however, that in the two situations where berry weight increased (between H1-H2 in 2005 and between H2-H3

in 2006), the yield change between these harvests was either nil (-1.5%) or yield increased (+14.3%), respectively (data not shown). This suggests that for 'Duke' berry weight may be a contributing (or modulating) factor to yield in specific circumstances. 'Bluecrop', exhibited fluctuations in yield between harvests in different years (data not shown), but berry weight decreased in a relatively uniform manner between all harvests in all years (as visible in Figure 2) and thus berry weight is not seen as a contributing factor to yield variation in 'Bluecrop'.

Both of these cultivars are recognized as being productive and able to be planted in large solid blocks. To rationalize these results in terms of reproductive strategies, 'Bluecrop' is traditionally regarded as less self-fruitful and benefiting more from cross-pollination (11). This cross-pollination (especially in our mixed test block) yields larger seed, but our results also suggest that 'Bluecrop' has more significant parthenocarpic tendencies. This is supported by empirical observations of sub-normal-sized parthenocarpic fruit in years in which pollination was poor (personal observation). 'Bluecrop' is also thought to have

high yields due to its long harvest season (13). 'Duke' by contrast is regarded as being substantially self-fruitful and capable of self-pollination (11). This may result in successful pollination, but may also produce reduced-size seed (yielding lower seed counts).

Cyclical variations in yield. As noted earlier, both 'Bluecrop' and 'Duke' exhibited relative yield peaks in 1999, 2002, and 2005. In conjunction with these peaks, 3-year yield cycles occurred for 'Duke', with peak years followed by two years of declining yields (H-M-L). For 'Duke', on average (across three such cycles), yields fell 29% in the first year following a peak and another 20% in the second year (compared to the peak year). Although 'Bluecrop' had identical peak years it had inconsistent aftermaths. For 'Bluecrop', 1999 was followed by two years of steep declines (-54% in 2000 and another -15% in 2001), 2002 was followed by a mild and steep decline (-9% in 2003 and -31% in 2004), and 2005 was followed by a decline and rebound (-36% in 2006 and an 18% rebound from the lowest value in 2007) (Table 1). It is unlikely that the cycles for either cultivar occur with absolute consistency since they are likely caused by the interaction of many factors (crop load, weather, pruning, pollination, and other cultural factors to name a few), nonetheless the cycles (especially for 'Duke') are interesting in that their phase is counter-intuitive. A peak year followed by a trough and a gradual rebound over time (L-M-H) would be a likely expectation, but these trends suggest that the opposite occurs with some regularity. Thus, a grower might be dismayed when yields decline a second straight year, but this, nonetheless, appears to be a typical occurrence in New Jersey based upon this study. One would expect that altered management practices might be able to improve this situation if the critical causative or management factors can be identified.

Overall conclusions. This study showed that yield and average berry weight had no significant correlation, but suggested that s/gfw may have a previously unrecognized re-

lationship to yield. For 'Bluecrop', under our study conditions, the limitations on yield did not include pollination. In fact, pollination (as expressed as s/gfw) had an inverse relationship to yield; if pollination decreased for the H2 interval, yield increased. According to our derived relationship, across all harvests, each decrease of 10% in seed numbers yields an increase in yield averaging 5%. Realistically, there must be a threshold on both ends of this relationship, but within the limits observed in this study the results were significant and linear.

Conversely, in our study, yield at H1 for 'Duke' was broadly responsive to pollination, but seed number was not a factor that could predict yield in a consistent way (a positive, but non-significant correlation). The weak correlation appears to be due to the fact that 'Duke' has sufficient environmental plasticity to produce fruit with increased berry weight across successive harvests given favorable inputs. These increases are counter to its changes in seed number (i.e. in these cases, the "typical" relationship was uncoupled, and berry weight increased even though seed number decreased). Pollination is a factor in berry weight, but plant resources (positive and negative) also appear to play a significant role. These results are in line with those of Eaton (10) and Brewer and Dobson (2) who suggested that factors other than seed number contribute to fruit size.

When considering the berry weight trends in either cultivar, it is important to recognize that the total crop is already set at H1, such that, H2 and H3 berries are, in fact, competing for nutrients with H1 berries, and vice versa. For 'Duke', there are cases where H2 and H3 berries are apparently more competitive for resources than comparable H2 and H3 berries in 'Bluecrop', thus increasing their own weight while (possibly) reducing berry weight of earlier harvest (earlier ripening) berries. It is also important to recognize that designations of "harvests" are really just constructs; the fruit within any given harvest (H) are simply those ripe at that point

in time. In truth, we know little about their pollination chronology, although it seems unlikely that later-pollinated fruit (even if well-pollinated) would ripen significantly earlier than early-pollinated fruit. Nonetheless, fruit resulting from self-pollination are generally found to ripen later because of their reduced seed numbers (7, 15, 18, 20).

Cyclic variations in yield in highbush blueberry are a previously undocumented phenomenon. It is unclear whether this cyclic variation is specifically a result of local test-plot management or whether it is a response to broader environmental influences or maternal resource depletion and recovery dynamics. Agricultural statistics for the state of New Jersey (21) show relative yield peaks in 1999 and 2002 for Atlantic County, and an elevated yield in 2005 with a continuing rise in yield thereafter through the most recent year reported (2008). It is difficult to draw conclusions from these statistics however, because they represent relatively raw data that confounds changing acreage, multiple cultivars, different age plantings, multiple locations, and multiple management systems.

As a whole, the information from this study enriches our understanding of 'Bluecrop' and 'Duke' as commercial cultivars and highlights how different they are with regard to pollination responses and the physiology of fruit development. Pollination is always a critical factor in overall fruit set and development, but these data show varied and surprising results for berry weight, seed number, and yield relationships that suggest that several paths may lead to superior commercial yield.

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NEW NEMATODE RESISTANT WALNUT ROOTSTOCK

This is the first report on a new walnut rootstock that can be readily cloned, has high vigor, reduces nematode feeding and reproduction within the root terminus, and is currently available to California growers. VX211 is a highly vigorous Paradox hybrid clone that outgrew other walnut seedlings in the presence of nematodes. A four-year trial involving Paradox VX211 and a standard Paradox selection, AX1, demonstrated that the damage threshold level of *Pratylenchus vulnus* on commercially available walnut rootstocks is < 1 nematode/250 cc of soil. Using 1 as the initial population level (Pi) within an inoculation zone of 80 L of soil, the *P. vulnus* population level increased 2,500-fold in the first year of growth. Three years after inoculation, soil population levels of *P. vulnus* on VX211 were significantly reduced compared to that of the moderately vigorous AX1. Growth of VX211 was 35% greater than that of AX1. Examination of stained roots revealed that feeding and reproduction by *P. vulnus* on VX211 was primarily ectoparasitic. Paraphrased from Buzo et al. 2009. J. Nematology 41(3):211-216.



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