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# Yield Component Interactions in Cultivars of the Highbush Blueberry

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*Abstract.* **Yield component analysis of 9 *Vaccinium corymbosum* L. blueberry cultivars indicated that yield was more strongly determined by canes per bush and berries per cane than by berry weight. High numbers of berries per cane were associated with low berry weights in all cultivars. Component interactions ranged from slightly additive in 'Bluecrop' and 'Spartan' to highly compensatory in 'Rubel' and 'Berkeley'. The consideration of component interactions in cultivar trials may enhance the accuracy in identification of desirable genotypes.**

In attempting to discover ways to maximize productivity of crop species, researchers have found it useful to separate yield into components. Engeldow and Wadham (5) first represented yield as the algebraic product of a small number of metrical components that were interrelated and highly "fluctuable". Leng (11) found that the heritabilities of yield components were much higher than the heritability of total yield. Adams (1) demonstrated that negative correlations can develop among yield components as a result of competition for a limited environmental resource. Rasmusson and Cannell (14) reported that the efficiency of component selection for yield depended on the selected component.

Yield component analyses may be useful in blueberries (2, 12). Not only could knowledge about the deployment of bush resources in different genotypes be useful for purposes of evaluating and selecting breeding material, but such an analysis also would more accurately represent the effects of cultural modifications. In this study, we explored the components of total fruit yield and their interactions in 9 cultivars of highbush blueberry. We were interested in 2 questions: 1) What are the most important components influencing yield in blueberries, and 2) are there genotypic differences in component interactions?

## Materials and Methods

Nine highbush blueberry cultivars established in 1966 at Grand Junction, Mich. were studied. The cultivars were represented by 3 plants per plot in each of 3 replications in a completely randomized design. The cultivars were selected on the basis of their commercial importance.

The planting was maintained according to established procedures (10). Plants were pruned annually by removing diseased and damaged canes and those >2.5 cm in diameter. In Spring 1981 and 1982, the canes of each bush were measured at 10 cm above ground level and the numbers of canes in 0.5-cm size classes were recorded. Ripe fruit were harvested by hand-picking or with a hand-held shaker. After harvesting by shaker, the fruit were sorted and the weight of undamaged, ripe fruit was recorded. Two pickings were made on each bush in each season. For each picking, mean berry weights were calculated by dividing the weights of cup samples by the number of berries in the samples. Mean berry weights for the season were calculated as the weighted average of the berry weights for the 2 pickings. Total yields were recorded for each bush. The variable (berries per cane) was calculated by dividing yield per bush by the number of canes per bush and berry weight.

Similar data were collected in 1982, 1983, and 1984 from 3 commercial 'Jersey' plantings near Holland and Fruitport, Mich. Twenty-four 3-bush plots were taken at random from the outer 5 to 7 rows of each planting.

To determine the contribution of different-sized canes to yield, a multiple regression for yield was performed using the numbers of canes in 8 different 0.5-cm size classes as independent variables. The partial regression coefficients obtained for the different variables indicated that canes <1.0 cm in diameter made negative, but nonsignificant, contributions to yield. The coefficients for the size classes >1.0 cm in diameter were all positive and significant ($P < 0.05$). By combining the larger canes into a single variable, a simple, significant predictor of yield was obtained ($P < 0.01$). Making such a distinction on the basis of size seems reasonable, because 1.0 cm is above the diameter at which canes begin to produce fruit (6). Throughout this analysis, the yield component "canes per bush" will refer to the number of canes >1.0 cm in diameter.

The "W" statistic of Hardwick and Andrews (9) was calculated for each cultivar as a function of the variance–covariance matrix. This value quantified the overall relationship among components. Values of W approaching 0.5 indicate independence of components, while values near 0 indicate compensation and values near one indicate additivity.

Path coefficients or standardized partial regression coefficients were calculated to measure the interrelationships among yield components (7, 8, 13, 15). To achieve additivity of the components, the data were logarithmically transformed and standardized to 0 mean and unit variance (4). The multiple regression equations were based on the path diagram in Fig. 1. In this diagram, yield is represented as the product of its components (berry weight, number of berries per cane, and number of canes per bush). Unresolved variability for berries per cane and berry weight is represented by $U_1$ and $U_2$, respectively. Since no significant differences were observed between years, the data from individual years were combined.

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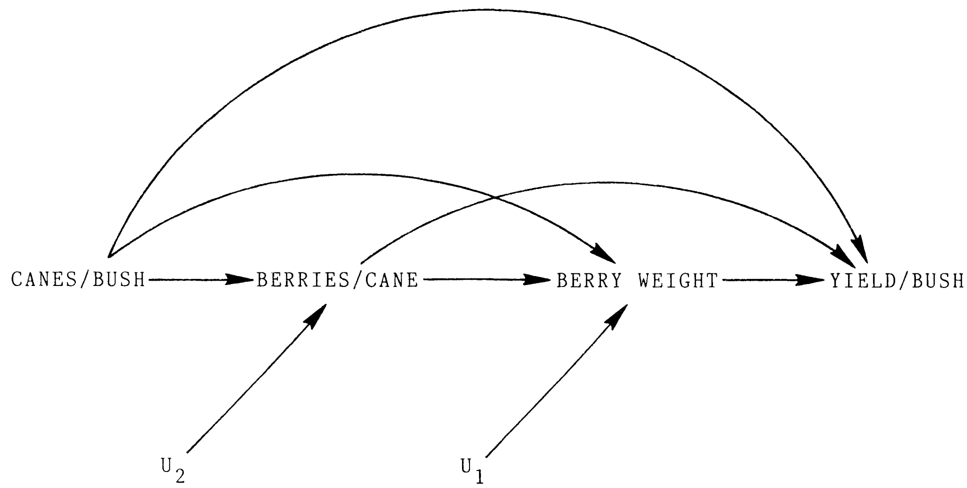


Fig. 1. Path diagram illustrating the relationships among yield and the components of yield assumed in this study.

## Results and Discussion

The cultivars varied significantly in their mean values (Table 1). Among the cultivars grown at Grand Junction, the number of producing canes per bush varied from 6.5 for 'Earliblue' to 11.1 for 'Blueray'. Berries per cane ranged from 274.3 for 'Spartan' to 626.1 for 'Northland'. 'Rubel' had the smallest mean berry weight at 1.41 g, while 'Spartan' had the highest mean at 2.85 g. 'Elliot' was the highest yielding cultivar with 10.43 $kg \cdot bush^{-1}$ and 'Jersey' had the lowest yield, 5.48 $kg \cdot bush^{-1}$. The number of productive canes in the commercially grown 'Jersey' was much higher than those in the cultivar trials, while the number of berries per cane, berry weight, and yield were all lower.

Because berry number per cane was calculated from berry weight and total yield, it was not possible to estimate the significance of the path coefficients between yield and berry number per cane, individual berry weight, and canes per bush. However, canes per bush and berries per cane appeared to be more important in determing yield than was berry weight. The effects of cane number and berries per cane on yield were consistently higher, and often much higher than the effect of berry weight (Table 2).

The direct effects of berry weight and berries per cane on yield were very similar between the commercially grown 'Jersey' and those in the cultivar trial, although the direct effect of cane number on yield was much lower in the commercial planting. The low correlation between cane number and yield in the commercial 'Jersey' indicated that the bushes may have been approaching or beyond the density of maximum production (3).

Table 1. Yield component means and degrees of component interaction (W) for 9 cultivars from research plots at Grand Junction, Mich. and 3 commercial plantings of 'Jersey' (Jersey–CP).

| Cultivar | W | Canes per bush (no.) | Berries per cane (no.) | Berry weight (g) | Yield per bush (kg) |
|---|---|---|---|---|---|
| Berkeley | 0.18 | 7.5 | 492 | 2.6 | 8.7 |
| Bluecrop | 0.54 | 9.5 | 346 | 2.4 | 7.5 |
| Blueray | 0.28 | 11.1 | 296 | 2.8 | 8.7 |
| Earliblue | 0.28 | 6.5 | 554 | 2.0 | 6.4 |
| Elliot | 0.36 | 9.2 | 584 | 2.1 | 10.4 |
| Jersey | 0.19 | 9.7 | 334 | 1.9 | 5.5 |
| Jersey–CP | 0.26 | 21.3 | 257 | 1.2 | 5.1 |
| Northland | 0.24 | 7.3 | 626 | 2.1 | 7.3 |
| Rubel | 0.18 | 8.9 | 601 | 1.4 | 6.2 |
| Spartan | 0.68 | 9.4 | 274 | 2.8 | 7.2 |
| SE | | 1.1 | 76 | 0.2 | 1.1 |

Berries per cane had a negative direct effect on berry weight in all cultivars, but the effect was significant in only 4. In 'Earliblue' and 'Blueray', the direct effect of number of canes on berry weight was negative and significant, indicating compensation. This effect was positive and significant in 'Spartan', which implies that both number of canes and berry weight were responding in the same way to environmental variability.

The correlation between yield and cane number was positive for all cultivars. This correlation was significant for all cultivars except 'Earliblue', 'Berkeley', and 'Rubel'. The values for 'Berkeley' and 'Rubel' were reduced by the large negative indirect path through berry number. The low correlation for 'Earliblue' was probably due in part to the low direct effect of cane number on yield.

The correlation between berries per cane and yield was positive in all cases, but, in general, it was not as high as that between cane number and yield. This correlation was highest for 'Earliblue' because of the large direct effect of berry number per cane on yield and the relatively small negative indirect effects.

The correlation between berry weight and yield was quite variable, ranging from 0.45 for 'Berkeley' to −0.50 for 'Blueray'. The variability in this correlation appears to be due to the highly variable indirect paths through berry number per cane and through cane number.

''W'' values for most of the cultivars were below 0.5, indicating that their response to favorable environmental conditions was reduced because an increase in one yield component was partially offset by a decrease in another yield component. Either the maximum yield potential of the cultivars was reached or some environmental resource was limiting. The W values for 'Bluecrop' and 'Spartan' were above 0.5, indicating additivity among the yield components. It is interesting that these genotypes are now the most widely planted mid- and early season cultivars in Michigan.

The W values of 'Jersey' in the test planting (W = 0.19) and the commercial planting (W = 0.26) were very similar,

Table 2. Correlation ($r$) and path coefficients ($\rho$) of 9 cultivars from a cultivar trial at Grand Junction, Mich. and 3 commercial plantings of Jersey (Jersey–CP). Subscripts are defined as follows: 1 = yield, 2 = berry weight, 3 = berries per cane, 4 = canes per bush. Values underlined are significant at the $P < 0.05$ level.

| | Correlation coefficients | | | | | Path coefficients | | | | | | Unresolved variability | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $r_{12}$ | $r_{13}$ | $r_{14}$ | $r_{23}$ | $r_{24}$ | $\rho_{21}$ | $\rho_{31}$ | $\rho_{41}$ | $\rho_{32}$ | $\rho_{42}$ | $\rho_{43}$[z] | $U_1$ | $U_2$ |
| Berkeley | 0.46 | 0.47 | 0.23 | −0.11 | 0.08 | 0.51 | 1.17 | 0.97 | −0.11 | 0.01 | $\underline{-0.67}$ | 0.99 | 0.74 |
| Bluecrop | −0.20 | $\underline{0.73}$ | $\underline{0.83}$ | $\underline{-0.50}$ | −0.12 | 0.21 | 0.65 | 0.68 | −0.50 | 0.01 | 0.27 | 0.87 | 0.97 |
| Blueray | $\underline{-0.50}$ | $\underline{0.56}$ | $\underline{0.78}$ | $\underline{-0.60}$ | −0.40 | 0.35 | 0.80 | 0.94 | $\underline{-0.61}$ | $\underline{-0.42}$ | −0.03 | 0.68 | 1.00 |
| Earliblue | −0.46 | $\underline{0.91}$ | 0.41 | −0.47 | $\underline{-0.67}$ | 0.42 | 1.05 | 0.58 | $\underline{-0.41}$ | $\underline{-0.63}$ | 0.10 | 0.65 | 0.95 |
| Elliot | 0.29 | 0.40 | $\underline{0.74}$ | −0.46 | 0.21 | 0.47 | 0.74 | 0.77 | −0.43 | 0.13 | −0.17 | 0.89 | 0.99 |
| Jersey | 0.04 | 0.35 | $\underline{0.60}$ | $\underline{-0.58}$ | 0.20 | 0.46 | 1.08 | 1.00 | −0.62 | −0.08 | −0.46 | 0.80 | 0.89 |
| Jersey–CP | 0.06 | $\underline{0.81}$ | 0.14 | −0.24 | −0.12 | 0.39 | 1.11 | 0.58 | −0.32 | −0.23 | −0.36 | 0.93 | 0.94 |
| Northland | 0.30 | 0.13 | $\underline{0.79}$ | $\underline{-0.68}$ | $\underline{0.60}$ | 0.22 | 0.79 | 1.05 | $\underline{-0.52}$ | 0.34 | $\underline{-0.49}$ | 0.73 | 0.87 |
| Rubel | 0.08 | 0.45 | 0.44 | −0.24 | −0.12 | 0.47 | 1.10 | 1.06 | −0.40 | −0.33 | $\underline{-0.51}$ | 0.89 | 0.86 |
| Spartan | 0.20 | $\underline{0.58}$ | $\underline{0.93}$ | −0.46 | 0.34 | 0.14 | 0.46 | 0.77 | $\underline{-0.58}$ | $\underline{0.50}$ | 0.26 | 0.70 | 0.96 |

[z] $\rho_{34} = r_{43}$.

even though the sites varied greatly in the number of canes per bush (9.7 and 21.3, respectively). This similarity suggests that the overall relationship between components (W) was not strongly affected by environmental variation.

When evaluating the performance of highbush blueberry cultivars, researchers have generally recorded data on yield and berry size. By making use of one more easily obtainable datum (canes per bush), it was possible to identify significant compensatory interactions among components and to demonstrate variability among cultivars for such interactions. For example, cane number per bush and individual berry weight were negatively associated in ‘Earliblue’ and ‘Blueray’, but not in ‘Spartan’, suggesting that pruning may be more critical to berry weight in ‘Earliblue’ and ‘Blueray’ than ‘Spartan’.

The consideration of component interactions may also aid in the selection of breeding material. ‘Bluecrop’ and ‘Spartan’ showed additivity among yield components (W > 0.5), indicating a higher yield threshold than other genotypes. A cross of these cultivars with others with higher berry numbers (e.g., ‘Elliot’) might increase yield. Such approaches have been successfully employed in agronomic crops (1, 14).

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