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A Crop Estimation Technique for Highbush Blueberries

JAMES F. HANCOCK,[1] PETE CALLOW,[1] REBEKAH KEESLER,[1]
DAN PRINCE[1] AND BRUCE BORDELON[2]

Abstract

This report describes our attempts to develop yield prediction methods for 'Bluecrop' and 'Jersey' highbush blueberries. Considerable variability was observed across years in number of flower buds per shoot, fruit set, individual fruit weight, cane diameter and number of laterals per cane. However, there was a significant association between the weight of green fruit at the second stage of development and ripe fruit weight at harvest. Among five different sampling strategies, tedious counting of all the fruit in individual bushes was most tightly correlated with individual bush yields, but the quickest estimate, based on counting the number of fruit within a 625 cm^2 surface (hoop counts), was also significantly associated. Hoop counts were used to estimate yields on growers fields when the bushes were at bloom, the fruit were in stage II of development, and 30% of the fruit were ripe. The estimates made at the stage II and 30% ripe stages were significantly associated with actual yields, but were 15-40 % high depending on developmental stage and cultivar.

Introduction

Crop estimates of blueberries are currently done on a "guesstimate" basis by growers and marketing association personnel. These individuals subjectively look at the developing crop and make estimates based on their previous experience. While some individuals have an uncanny ability to estimate yield, most guesstimators do not have the experience or clarity of memory to be accurate. This has led to many inaccurate predictions of regional and national yields.

Predictions of the blueberry crop are not only limited in accuracy by the experience of the estimators, but also by seasonal variation. What may have been an accurate prediction at one stage of plant development can be radically altered by later negative environmental impacts. There are several key periods when yields are most likely to be adversely effected (4): 1) Late summer/ fall, when conditions are poor for flower bud development, 2) winter, when extreme cold damages flower buds, 3) spring, when conditions are too cool for adequate pollination or frost damages flower buds, and 4) summer, when excessive heat or drought negatively influences fruit growth.

In the early 1980s, we initiated work to estimate blueberry yields. We began by trying to determine the critical yield components associated with yield (3, 6, 7). We found that number of laterals per cane, % fruit set and individual fruit weight were extremely variable across years, and that number of flowers per bud and buds per lateral were more stable, but still varied significantly in some years. This variability led us to believe that several yield components would have to be incorporated into any yield estimation technique to accurately predict yield. Herein, we describe how individual bushes can be sampled to accurately determine yield, and then we demonstrate that the simplest method works on growers' fields, if corrected for harvest losses.

Materials and Methods

Development of sampling strategies

These studies were conducted at the Variety Trial plot of MBG Marketing in Grand Junction, MI. Seventeen cultivars were planted in 1966 in a completely randomized design, with five, four-bush repli-

[1]Department of Horticulture, Michigan State University, East Lansing, MI 48824.
[2]Department of Horticulture and Landscape Architecture, Purdue University, West Lafayette, IN 47907.

cates of each cultivar. All the measurements described below were made on the middle three bushes of each plot. Bush spacing was 1.2 m within rows and 3 m between rows. Bushes were maintained according to standard cultural practices (5).

To measure the amount of variability within bushes for their various yield components, flower buds on ten randomly selected shoots were counted in 1987 from the top, middle east, middle west, bottom east and bottom west parts of the 'Bluecrop' bushes in three plots. Fruit set was determined on the same laterals about six weeks later. In addition, flowers were counted, and percent fruit set was determined at the top and most basal buds of each shoot.

To determine if cane diameters accurately predict yield potential, the number of flower buds were counted on ten randomly selected canes in 3 'Jersey' plots in April of 1981, 1983 and 1985 at Grand Junction and their diameters were recorded at the base of the crown.

To determine how variable flower numbers and fruit set varied between years and to discover if green fruit can be used to approximate final fruit size, the number of flowers emerging from 50 randomly selected buds from 3 plots of each cultivar were counted in 1987 and 1988. In midsummer of both years, the percentage of these flowers which produced fruit was also recorded. One-cup samples of green fruit were randomly plucked from each bush at seven to ten day intervals after bloom for 50 days, and the sampled fruit were weighed and counted. Random one cup samples of ripe fruit were also collected from these bushes when 30% of the fruit were ripe and again when all fruit were ripe. Average fruit weights were determined at both stages.

Yield estimation techniques

Several different yield estimation techniques were tested in 1989 on individual 'Jersey' bushes at Grand Junction: 1) volume or hoop – number of fruit in a 625 cm^2 (25 cm x 25 cm) surface at mid-bush height, 2) 1/4 bush – number of fruit in the upper east 1/4 of a bush, 3) single lateral – number of fruit on a randomly selected lateral, 4) random cane – number of fruit on a randomly selected cane, and 5) cane sample – number of fruit on 3 randomly selected canes. The estimates were made when 30% of the fruit on each bush were blue and then correlated with yields measured by hand harvests of all the ripe fruit from each bush.

After determining that the hoop method of yield estimation appeared most promising (see below), we tested its utility in growers' fields, by selecting nine 'Bluecrop' fields in 1995 that represented a broad geographical range from Fruitport, Michigan to Elkhart, Indiana. These fields were further studied in 1996 and 1997, along with 9 additional 'Jersey' fields. The cooperating growers were: Nelson (Mishawaka, IN), LeDuc (Paw Paw, MI), Clark (Revenna, MI), Paul (Muskegon, MI), DeGrandchamp (South Haven, MI), Wright (Grand Junction, MI), VanderKlooi (Zeeland, MI), Groenhof (Holland, MI) and Brower (Holland, MI). Each of the fields represented one to two hectares.

To track crop potential through the major developmental stages, yield predictions were made at full bloom, three to four weeks after full bloom and when 30% of the fruit on the bushes were ripe. Our observations at Grand Junction and that of Eck and Childers (2) had indicated that fruit expansion typically reaches its second stage three or four weeks after bloom. At this point, active cell division has presumably ceased, and unpollinated flowers and damaged fruit have dropped.

Predicted yields per acre were calculated using estimators from three developmental stages and the following equations: 1) yield at full bloom = bushes per acre x flowers per bush x the average fruit weight. 2) yield at stage II green fruit = bushes per acre x green fruit per bush x weight of green fruit x average increase in fruit weight between stable green and harvest, and 3) yield at 30% ripe fruit = bushes per acre x average weight of all fruit x the average increase in fruit weight between harvests.

Table 1. Influence of shoot and bud location on flower number per bud and percentage fruit set in 'Bluecrop.' Means followed by different letters in the same column are significantly different at $p < 0.05$ using the Duncan's Multiple Range Test.

	Flowers per bud	% Fruit set
Shoot location		
Top	7.0c	73
Middle east	6.3b	75
Middle west	6.4b	68
Bottom east	5.7a	67
Bottom west	5.4a	69
Bud location		
Apical	6.6b	72
Basal	6.0a	72

Ten to twelve bushes were randomly selected in each field and the area of each bush's bearing surface was estimated by measuring the height and width of plants. To estimate yields per acre at full bloom, the number of flower buds was counted within 25 cm x 25 cm (625 cm^2) hoops on the top and sides of the selected bushes and the number of flowers per bud was measured on 10 random buds within each hoop. These values were multiplied together to estimate the total flowers per hoop and this value was multiplied by the average fruit weight and fruit set previously determined for 'Bluecrop' and 'Jersey' in the yield component studies. Three to four weeks after full bloom, the number of green fruit per hoop was counted, a sample of 100 green fruit was weighed and the average weight in 'Bluecrop' and 'Jersey' was multiplied by the average amount stage II green fruit were found to gain in the yield component study. A day or two before each producer harvested her/his bushes, the number of berries were counted in each hoop. Average individual fruit weights were calculated from random samples of 100 blue fruit from each bush. The total yield of each bush was calculated by multiplying the number of hoop areas per bush by the various estimates of yield per hoop. Total yields per field were calculated by multiplying the average yield per bush by the number of bushes in the field. To determine the accuracy of our estimation procedures, actual grower yields were regressed on our estimate from various stages of development. Most of the fields were harvested first by hand and then by machine.

Table 2. Association between 5 different yield estimation techniques and actual yields (25 bush samples) in Jersey bushes.

Estimator[1]	Correlation coefficient (r)	Probability
Volume	0.431	<0.05
1/4 bush	0.501	<0.05
Single lateral	0.201	n.s.
Single cane	0.428	<0.05
Cane sample	0.488	<0.05

[1]Volume – number of fruit in a 625 cm^2 of surface at mid-bush height; 1/4 bush – number of fruit in a 1/4 bush; single lateral – number of fruit on a randomly selected lateral; single cane – number of fruit on a randomly selected cane; cane sample – number of fruit on 3 randomly selected canes.

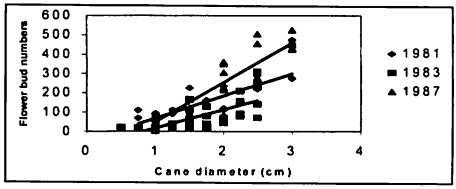

Figure 1. Relationships between cane diameter and flower bud numbers in 'Jersey' blueberry in 1981, 1983 and 1985 at Grand Junction, MI. The regression equations were: 1981 ($y = 203.7x - 153.3$; $R^2 = 0.81$), 1983 ($y = 115.6x - 46.8$, $R^2 = 0.61$), and 1987 ($y = 95.04x - 78.19$, $R^2 = 0.43$).

Results

Variation in yield components

While percentage fruit set did not vary significantly within the 'Bluecrop' bushes that were studied, the number of flowers per bud was significantly higher at the top than the middle and bottom of bushes, and at the apical vs. basal locations of the inflorescence (Table 1). The number of flowers per inflorescence in bush middles were about the average (6.35) of the top and bottom samples (6.28).

Cane diameter was significantly associated with bud numbers, but the number of

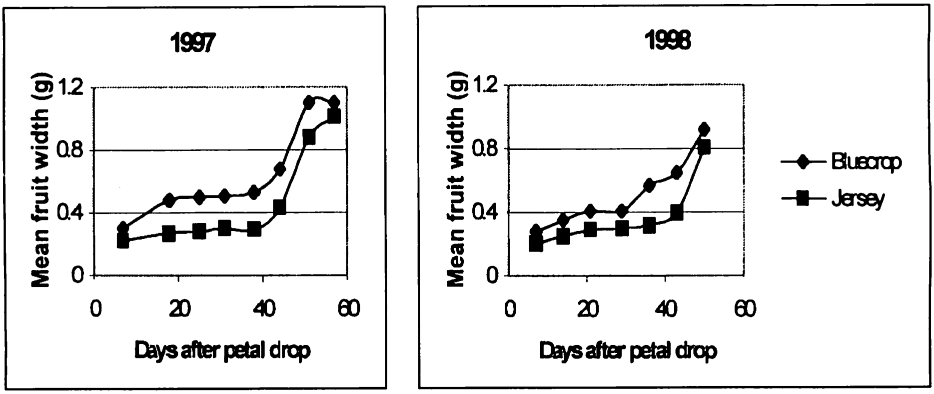

Figure 2. Pattern of fruit development in 'Bluecrop' and 'Jersey' blueberries in 1987 and 1988 at Grand Junction, MI.

buds per cm cane diameter varied greatly between years (Figure 1). Average bud numbers per cm diameter varied from 48 in 1983, to 89 in 1981 and 127 in 1985.

'Bluecrop' and 'Jersey' did not have significantly different numbers of flowers per bud or percentage fruit set in 1986 or 1987. Flowers per bud averaged 7.3 in 'Bluecrop' and 7.8 in 'Jersey.' Fruit set averaged 69.5% in 'Bluecrop' and 74% in 'Jersey.' In both years, the second stage in fruit development began about 21 days after petal drop, and lasted 9-20 days depending on cultivar and year (Figure 2). In 1987, the average gain in fruit weight for 'Jersey' and 'Bluecrop' was 1.0 and 1.38 g , while in 1988 the gain was 0.70 and 1.06 g. In both cultivars, the weight of blue fruit at 30 % ripe was 10% larger than the weight of blue fruit averaged across both harvests (data not shown).

Four of the five sampling techniques were significantly correlated with single bush yields (Table 2). The 1/4 bush technique was most closely associated, followed by the cane sample, hoop and single cane measurements. The single lateral technique was not significantly correlated with yield.

Yield estimation

Flowers per bud in 'Bluecrop' averaged 8.2 in 1995, but in the other years varied between 5.4 to 5.8 in both cultivars (Table 3). Fruit set in 'Bluecrop' averaged 72% in 1995, but in the other years it exceeded 84% in both cultivars. Flowers per bud and flowers per plant were not significantly associated with fruit set in any year (data not shown), but in 1995 fruit set was very low in 'Bluecrop,' the same year that flowers per bush were unusually high.

The average green fruit weight of 'Bluecrop' ranged from 0.39 g in 1995 to 0.49 in 1997, while in 'Jersey' it was 0.28 g in both years. The average blue fruit weight of 'Bluecrop' ranged from 1.31 g in 1995 to 1.72 in 1997, while in 'Jersey' it was 1.21 in 1996 and 1.34 in 1997. Flowers per bud and flowers per plant were not significantly associated with green or blue fruit weight in any year (data not shown). In both cultivars, the weight of blue fruit at

Table 3. Average value for yield components measured in each year. Means with different letters within columns are significantly different at $p < 0.05$ using the Duncan's Multiple Range Test.

Cultivar	Year	Flowers per bud	Fruit set (%)	Green frt wt (g)	Blue frt wt (g)
Bluecrop	1995	8.2b	72a	0.39b	1.31b
	1996	5.8a	84b	0.41b	1.46c
	1997	5.6a	87b	0.49c	1.72d
Jersey	1996	5.4a	94c	0.28a	1.21a
	1997	5.7a	88bc	0.28a	1.34b

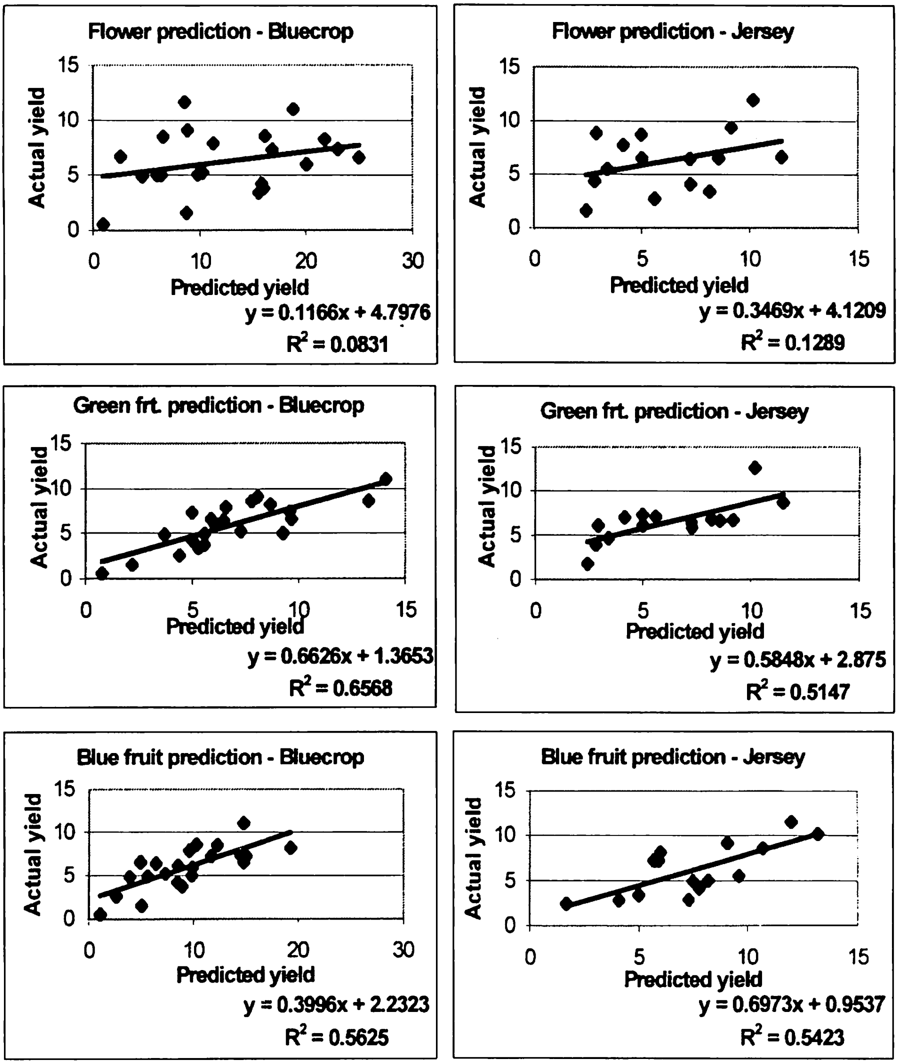

Figure 3. Comparison of actual grower's yields with predictions made when blueberry bushes were at full bloom, all the green fruit at stage II, and 30% ripe fruit. Yields are expressed as kg/bush. The data were collected for three years in 'Bluecrop' and two years in 'Jersey.'

30% ripe was about 10% larger than the mean fruit weight across both harvests.

The crop estimations made at the green fruit and 30% ripe stages were significantly correlated with the actual growers' yields across years, although the bloom predictions were not (Figure 3). While significantly correlated, the predictions made at stage II fruit and 30% ripe were higher than the actual growers' yields. The green fruit estimates were 15% high in 'Jersey' and 20% high in 'Bluecrop.' The blue fruit estimates were 20% high in 'Jersey' and 40% high in 'Bluecrop.'

Discussion

Since all of the yield components of blueberries can vary substantially from

Table 4. A Blueberry Yield Assessment Procedure for 'Bluecrop' and 'Jersey.'

1. Make assessments during stage II of fruit development (20 - 30 days after full bloom) or when the bushes are 30% ripe.
2. Select 10 representative bushes in different parts of the field.
3. Count the number of berries at three locations on each bush. Make the berry counts in 9 x 9 in hoops (size of open coat hanger) on the top and sides of the selected bushes.
4. Average the 3 hoop counts from each bush.
5. Determine the height and width of each bush's bearing surface and calculate its total surface area.
6. Divide the hoop area into the total surface area to determine the number of hoops per plant.
7. Multiply the number of hoops per plant by the average number of berries per hoop to obtain an estimate of the total number of berries per bush.
8. Collect a representative sample of 100 fruit from each bush and weigh them. Divide the total weight by 100 to determine the average sample weight.

9a. For a green fruit prediction, multiply the sample weight by 3.2 in 'Bluecrop,' and 4.5 in 'Jersey' (these are the average rates of fruit expansion in these cultivars)

9b. For a blue fruit prediction, multiply the sample weight by a factor of 0.90 to estimate average fruit weight (this compensates for late-ripening fruit that is generally smaller than that fruit that is picked first).

10. Multiply the total number of berries per bush by the 100- berry factored weight to obtain the total bush yield.

11a. For a green fruit prediction, multiply the total bush yield by 0.80 in 'Bluecrop' or 0.75 in 'Jersey' (these values correct for harvest losses).

11b. For a blue fruit prediction, multiply the total bush yield by 0.60 in 'Bluecrop' or 0.80 in 'Jersey' (these values correct for harvest losses).

12. Average the total corrected bush yield of the 10 sampled plants to obtain average corrected bush yield.
13. Multiply the number of bushes per acre times the average bush yield to determine the appraised yield per acre.

year to year, they must be considered together in any crop prediction equation. We were able to successfully do this by counting the number of fruit in 625 cm^2 areas at several locations within bushes (Table 4). Our equations accurately predicted yield at the stable green and 30% blue fruit stages, as long as the values were corrected for apparent harvest loses. Our prediction at bloom failed.

Most of the need for correction in the green and blue fruit stages may be due to harvest losses by growers, particularly during mechanical harvesting. Cargill and Nelson (1) found typical harvests losses to range from 8 to 18% per harvest, depending on machine speed and cultural practices. This is exacerbated in years like 1995 when a hot, wet summer led to a considerable yield of losses due to fungal disease and fruit drop. The bloom estimations probably failed, not only due to grower losses, but also because the plants were subject to the vagaries of nature longer than for the later estimations, and we were forced to estimate fruit weight from seasonal means rather than the size of green or blue fruit.

Other important sources of error might have been: 1) whether the mid-bush placement of hoops accurately represents bloom and flower densities at other locations within the bush, 2) whether bush volumes were accurately measured, and 3) the difficulty in making accurate hoop counts when the canes begin to be weighed down by fruit. This was a particular problem in 'Bluecrop' and may have caused the greater crop overestimations in this cultivar.

Another potential source of error may have been that a sample of ten bushes per one to two hectares was too small to accurately represent a field. While this is possible, all of our estimates were higher than grower yields. If our sample sizes were too small, we would have expected variation both above and below actual yields, not just above. In addition, our estimates were significantly correlated with grower yields, indicating that our predictions were reflecting actual upward and downward trends. The most likely reason for our consistent yield overestimates remains that a large fraction of the berries were lost during harvesting.

While we can improve the accuracy of our crop predictions by correcting them for crop losses, the most effective way to use these sampling strategies is for individual growers to make the hoop counts at the various developmental stages in the same fields year after year. These counts can then be directly compared to values generated in previous years. For example, if a grower had 50% fewer flowers this year than last year, she would know that there was 50% less crop potential than the previous year. Of course, the ultimate yield would be dependent on how much compensation there is between fruit numbers and size, and future environmental conditions, but the grower would have a numerical value to add to his experience in making these judgements.

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