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Genetic and Morphological Factors Influence Mummy Berry Blight Resistance in Highbush Blueberry Cultivars

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Abstract. **The resistance of 48 highbush blueberry cultivars and selections to the blight phase of mummy berry disease, incited by the fungus *Monilinia vaccinii-corymbosi* (Reade) Honey, was examined in relation to percent *Vaccinium angustifolium* Ait. ancestry, season of fruit maturity, and shoot growth during the primary infection phase. Correlations of percent blighting with percent *V. angustifolium* ancestry were significant across 3 years, but correlations with fruit maturity were significant in only 2 of 3 years. Correlations of percent blighting with early shoot growth were significant in both years measured, with *r* values of 0.54 in 1994, 0.83 in 1995, and 0.83 across years. A multiple regression found only shoot growth highly significant for susceptibility and rendered *V. angustifolium* ancestry and season of fruit maturity nonsignificant. Resistant cultivars exhibiting early shoot elongation suggest that resistance can be either biochemically or escape based.**

Mummy berry is the most important widespread fungal disease of blueberry in North America (Eck, 1988). The fungus overwinters on the soil surface as a pseudosclerotium (mummy) that produces apothecia in early spring. Ascospores produced by the apothecia are capable of inducing blight on newly emerging leaf, stem, and flowerbud growth (Batra, 1983). The conidia subsequently produced on blighted tissue are carried by bees or wind to stigmas where they germinate, grow down the style into the ovary, and eventually produce a mummified fruit to complete the life cycle.

Mummy-berry-resistant highbush blueberry cultivars offer an alternative to chemical control, which depends on two fungicides, N,N´-[1,4-piperazinediylbis(2,2,2-trichloroethylidene)]bisformamide (triforine) and methyl 1-(butylcarbamoyl)-2-benzimideazolecarbamate (benomyl). Resistant cultivars could complement proven cultural control practices, making it possible to eliminate or reduce fungicide use. Several studies have demonstrated that various levels of resistance to *M. vaccinii-corymbosi* are present in highbush blueberry cultivars (Nelson and Bittenbender, 1971; Pepin and Toms, 1969; Varney and Stretch, 1966). In a previous study (Stretch et al., 1995), we reported the blighting resistance of 52 *Vaccinium corymbosum* L. (highbush) blueberry cultivars. Preliminary observations of blight susceptibility suggested that cultivar susceptibility might be related to any of the following factors: the relative proportion of *V. angustifolium* (lowbush blueberry) ancestry of a cultivar, its shoot length, its total number of shoots, and earliness of ripening relative to other cultivars. In this study, our objective was to determine the relationship of these factors to blight susceptibility.

Materials and Methods

A group of 52 cultivars and selections assembled as a screening population for blight resistance and the methodology used to evaluate them have been described previously (Stretch et al., 1995). A subset of 48 cultivars and selections (with the addition of 'Nelson' and 'Legacy') for which complete data on genetic composition and season of maturity could be reliably determined were used in this study (see Table 1). The percent shoot blight data in 1993 and 1994 were taken from Stretch et al. (1995) and was supplemented with measurements in 1995 from further evaluations. Blighted shoots were evaluated between 26 Apr. and 14 May 1993, 12 Apr. and 19 May 1994, and 20 Apr. and 18 May 1995.

In 1994 and 1995, vegetative shoot development was measured for all cultivars and selections in the blighting evaluation. Plants were evaluated in two replications (one plant per replication) at opposite ends of the experimental plot by measuring five shoots per plant and calculating an average value. In 1994, initial measurements focused on measuring the longest shoots; however, by 20 Apr., emphasis shifted to determining a value that represented the average shoot growth of the plant. Plants were evaluated three times a week between 11 Apr. and 2 June 1994 and 10 and 21 Apr. 1995, representing the period from initial vegetative budbreak through the period of *M. vaccinii-corymbosi* apothecial viability in both years and the entire season of blight occurrence in 1994.

Percentage of *V. angustifolium* germplasm for cultivars and selections was determined using tables from Hancock and Siefker (1982) and Ehlenfeldt (1994). Information on season of fruit ripening was adapted from information by Hancock et al. (1986) and was supplemented, as necessary, by information from release notices and other sources.

Statistical analyses were performed using MSTAT-C statistical analysis software (Michigan State Univ., East Lansing). Analysis of cultivar shoot length used means of shoot length across the first full week of the experiment, the period during which apothecia were most prevalent. Average shoot lengths for cultivar groups in Fig. 1 were calculated using the Tukey–Kramer method for calculating minimum significant distance (Sokal and Rohlf, 1981).

Results and Discussion

Each of the three years exhibited different degrees of blighting, with ranges of 1% to 78%, 0% to 43%, and 7% to 92% in 1993, 1994, and 1995, respectively (Table 1).

An initial concern was to determine whether cultivars or selections with many shoots were more likely to become infected simply because more foliage was present as target tissue. This question was examined through correlations of shoot blight percentage vs. total shoot count. This correlation was significant in 1994 ($r = 0.30$, $P = 0.045$) but not in 1993 ($r = 0.04$, $P = 1.000$) or 1995 ($r = 0.14$, $P = 0.303$). The significance in 1994 may reflect that infection was lower and cultivars with more shoots intercepted more inoculum. Because of this difference between years, subsequent analyses dealt separately with 1993, 1994, 1995, and 3-year-average infection ratings.

Percent *V. angustifolium* ancestry was examined as a factor in susceptibility because several of the most severely infected cultivars were known to contain significant percentages of *V. angustifolium* germplasm (Table 1). Correlation of blight incidence with percent *V. angustifolium* germplasm was highly significant ($P < 0.001$) for 1994, 1995, and the 3-year average but had marginal significance in 1993 ($P = 0.042$) (Table 2). The lesser significance in 1993 suggests that germplasm composition at the species level may be a factor in blight susceptibility but may not be a reliable indicator. Indeed, some cultivars, such as 'Rancocas' and 'Bluetta', that have one-quarter or more *V. angustifolium* germplasm are relatively resistant to blighting.

Season of ripening generally would not be considered a factor correlated with shoot blighting because fruit maturity would seem to be largely independent of shoot growth. Pepin and Toms (1969), however, noted that blight-resistant cultivars were generally late ripening, although late ripening itself did not guar-

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antee resistance. Our studies were in general agreement with their study: early ripening cultivars appeared to be generally more susceptible to blighting than later-maturing cultivars (Table 1). Correlation of blight incidence with season of ripening was significant for the 3-year average ($r = –0.52$, $P < 0.001$), 1994 ($r = –0.37$, $P = 0.011$), and 1995 ($r = –0.54$, $P < 0.001$) but not for 1993 ($r = –0.26$, $P = 0.076$) (Table 2). Part of the relationship may be due to the fact that season of ripening and *V. angustifolium* composition are strongly correlated ($r = –0.45$, $P < 0.001$).

Because we suspected that some cultivars, such as 'Bluejay', may derive a measure of resistance to blighting via escape, shoot length during the infection phase was examined. Pepin and Toms (1969) found "no consistent relationship between…opening of buds…and disease rating." Our data exhibited a highly significant correlation between blight incidence and the first-week average shoot length for 1994 ($r = 0.54$, $P < 0.001$), 1995 ($r = 0.83$, $P < 0.001$), and combined years ($r = 0.83$, $P < 0.001$) (Table 1).

A multiple regression, incorporating percent *V. angustifolium* ancestry, season of ripening, and average early shoot growth (length) across 1994 and 1995 against the average percent blight in corresponding years, produced a multiple regression coefficient of $r = 0.85$. The standard partial regression coefficients for *V. angustifolium* composition ($r = 0.19$, $P = 0.054$), season of ripening ($r = –0.01$, $P = 0.450$), and early shoot growth ($r = 0.70$, $P < 0.001$) indicated that shoot length is the most significant single factor and that the significant individual factor correlations with blight incidence (Table 2) are due to their relationship to shoot length.

A comparison of shoot length data for the most resistant cultivars, the most susceptible cultivars, and the cultivars overall revealed that shoots of the most susceptible cultivars were 32% longer than the overall values for cultivars and selections during the first week in 1994 and 91% longer in 1995 (Fig. 1). In contrast, the most resistant cultivars exhibited 18% less shoot development than the cultivars overall during the first week in 1994 and 42% less in 1995. These differences suggest that, in some cases, resistance may be partially due to escape and that a threshold shoot length range exists that may limit susceptibility. Analysis of shoot length data shows statistical differences between cultivars (Table 1) but is best characterized as exhibiting broad overlap. Relatively resistant cultivars, such as 'Bluetta', 'Elizabeth', 'Darrow', 'Pioneer', and 'Duke', show no statistical differences from several susceptible cultivars with longer shoots, such as 'Bluegold', 'Northsky', and 'Croatan'. However, 'Bluejay', the most resistant cultivar, shows the least shoot growth (along with 'Elliott') and, thus, may derive some or all of its resistance from escape. This finding implies that there are two aspects to resistance, a morphological component and a biochemical component. If this assumption is correct, cultivars with true biochemical resistance would express resistance regardless of shoot length,

Table 1. Ranking of highbush blueberry cultivars for blight susceptibility, percent *Vaccinium angustifolium* ancestry, season of ripening, and shoot length.

Cultivar or selection	3-Year mean blight rating (%)	*V. angustifolium* ancestry (%)	Season of ripening[z]	2-Year mean shoot length (mm)[y]
Northblue	64.8	26.6	1	10.3 a–c
Bluehaven	63.9	25.0	3	12.2 a
Bluegold	60.5	14.1	5	8.6 a–g
Northsky	49.7	26.6	1	8.6 a–h
Croatan	46.6	6.3	1	8.6 a–h
Harrison	46.1	6.3	2	9.4 a–e
Morrow	43.6	3.1	1	8.0 b–i
Sierra	42.7	2.4	3	6.9 c–l
Patriot	40.5	28.1	3	11.6 a-b
Murphy	39.4	6.3	2	10.0 a–d
Blueray	35.6	6.3	4	3.7 l–n
Coville	34.8	0	5	3.8 k–n
Spartan	33.4	6.3	2	4.9 h–n
Bluechip	32.1	6.3	3	9.3 a–e
June	29.2	25.0	2	3.4 l–n
Bluecrop	28.2	6.3	4	4.9 g–n
Northland	27.9	25.0	3	7.5 c–k
Legacy	27.5[x]	1.6	5	6.1 e–n
Weymouth	27.1	12.5	1	7.8 c–j
Berkeley	25.7	0	4	4.2 j–n
Angola	25.5	6.3	1	8.3 b–i
Wareham	24.0	0	5	4.1 j–n
Cabot	23.5	0	3	8.9 a–f
Herbert	21.6	0	4	3.5 l–n
Sunrise	20.0	17.2	2	5.4 f–n
Atlantic	19.4	0	5	3.1 m–n
Rancocas	19.2	25.0	4	4.6 i–n
Earliblue	18.3	6.3	1	4.2 j–n
Nelson	18.1[x]	3.1	5	5.8 e–n
Dixi	16.7	0	5	4.3 j–n
Meader	16.6	6.3	4	5.3 f–n
Ivanhoe	15.1	6.3	5	4.6 i–n
Pioneer	14.9	0	4	6.5 d–m
Lateblue	14.4	0	7	3.9 k–n
Bluetta	13.8	28.1	1	5.5 f–n
Toro	13.4	6.3	4	3.6 l–n
Burlington	12.2	0	6	4.1 j–n
Elizabeth	12.1	0	6	5.5 f–n
11-104	9.6	0	4	3.5 l–n
Rubel	9.1	0	4	3.3 l–n
Katherine	8.1	0	4	3.6 l–n
Jersey	7.8	0	5	2.5 n
Pemberton	7.0	0	4	3.1 m–n
Darrow	5.9	3.1	6	5.3 f–n
Stanley	5.9	0	5	3.4 l–n
Duke	4.5	3.9	2	7.7 c–j
Elliott	3.6	0	7	2.9 m–n
Bluejay	2.5	0	3	2.9 m–n

[z]1 = very early, 2 = early, 3 = early midseason, 4 = midseason, 5 = late midseason, 6 = late, and 7 = very late.
[y]Mean of values from first week of evaluation. Mean separation by least significant difference test at $P = 0.05$.
[x]Values represent 2 years of data only. These cultivars were not included in statistical analyses that used 3 years of data.

Table 2. Correlation coefficients among *Monilinia vaccini-corymbosii* blight incidence, percent *Vaccinium angustifolium* ancestry, season of ripening, and shoot length.

Variable	Season of ripening[z]	2-Year shoot length[y]	Blight incidence (%) 1993	1994	1995	3-Year avg
V. angustifolium ancestry (%)	–0.45***	0.52***	0.30*	0.56***	0.53***	0.57***
Season of ripening		–0.52***	–0.26	–0.37*	–0.54***	–0.52***
Shoot length 1994				0.54***	---	---
Shoot length 1995					0.83***	---
Shoot length (2-year average)						0.83***, [x]

[z]Ripening values based on numerical rating from 1 to 7, with 1 = very early and 7 = very late.
[y]Correlations based on mean values from first week of evaluation.
[x]Correlation based on blighting data from 1994 and 1995 only.
*, ***Significant at $P < 0.05$ or 0.001, respectively.

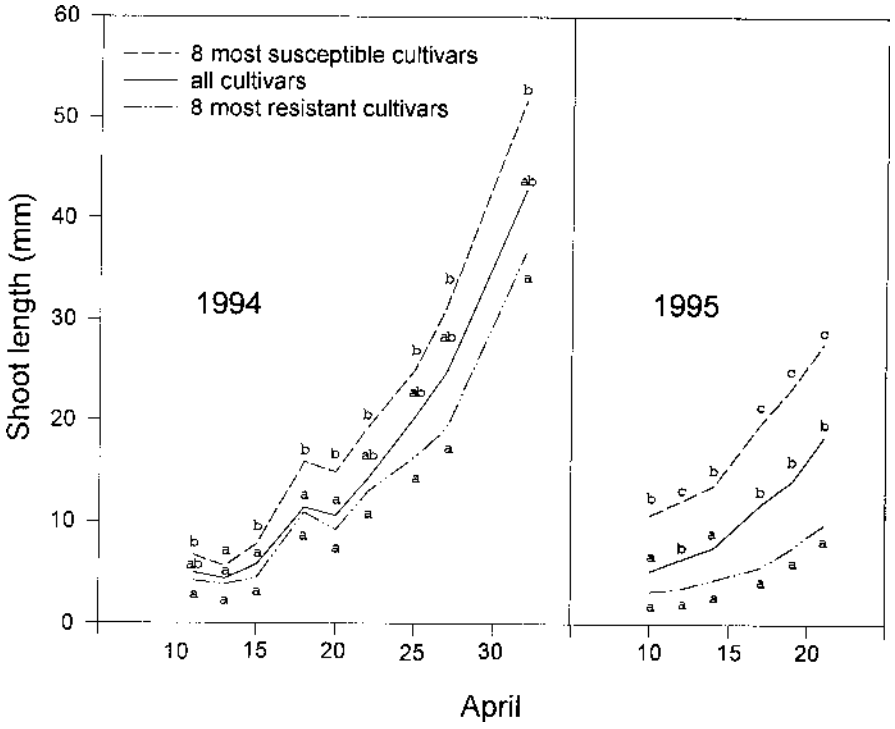

Fig. 1. Average shoot length of highbush blueberry cultivars during the 1994 and 1995 infection periods. Each cultivar had five measurements per plant in two replications. Means were tested for each date at $P \leq 0.05$ using a Tukey–Kramer procedure for calculating minimum significant difference at a given date.

whereas cultivars with lesser biochemical resistance may become infected to a greater or lesser degree depending on shoot length. Very susceptible types would have no biochemical resistance and consistently early vegetative shoot growth. 'Duke', a recently released and widely planted cultivar, has shoot growth similar to some of the most susceptible cultivars, yet is among the most blight resistant. This study suggests that although some of the resistance identified may be due to escape, some is true resistance usable in breeding.

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