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Photosynthetic Heat Stability in Highbush Blueberries and the Possibility of Genetic Improvement

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Abstract. **Seven highbush blueberry *(Vaccinium corymbosum* L.) cultivars were evaluated for their photosynthetic heat stability. Ail showed significant reductions in CO_2 assimilation rates (A) as leaf temperatures were raised from 20 to 30C, although 'Bluecrop', 'Jersey', 'Elliot', and 'Rubel' (- 22% to - 27%) were significantly less affected than Spartan', 'Bluejay', and 'Patriot' (-41% to -51%). To determine whether temperature adaptations of highbush types can be broadened through hybridization with native, heat-tolerant species, 'Bluecrop' was crossed with the *V. darrowi* Camp. selection Florida 4B, and F_2, BC_1, and BC_2 populations were generated. This approach showed promise as genotypes were identified in all the derivative populations that were more heat tolerant than 'Bluecrop' and had a high A.**

The highbush blueberry cultivars grown most commonly in the northern portion of the United States are derived almost exclusively from three native clones of tetraploid *Vaccinium corymbosum* endemic to relatively cool, moist, wetland conditions (Hancock and Siefker, 1982; Luby et al., 1991). In contrast, many southern highbush cultivars contain genes from the diploid evergreen blueberry, *V. darrowi,* a species found on hot, dry, sandy scrublands in central Florida (Lyrene and Sherman, 1980). Fertile tetraploid hybrids between *V. darrowi* and *V. corymbosum* have been produced, involving unreduced gametes (Draper et al., 1982).

Vaccinium darrowi has been used primarily in southern breeding programs to reduce the chilling requirement of highbush types (Ballington, 1990), but it has several other attributes that could be of horticultural importance. Genotypes with a high proportion of *V. darrowi* genes are more tolerant of dry, upland soils (Chandler et al., 1985; Erb et al., 1991), and they maintain high rates of photosynthesis at temperatures as high as 30C (Moon et al., 1987a, 1987b).

While heat tolerance is generally considered most important in the southern United States, this characteristic could also be an asset in the north. The leading cultivars, Bluecrop and Jersey, have temperature optima <20C; the maximum temperature on a typical summer day in Michigan can be > 30C (Moon et al., 1987a). The overall productivity of northern highbush might be expanded through interploid crosses with *V. darrowi,* if new types could be generated with a broader range of temperature optima. This seems likely, as when Moon et al. (1987b) screened just a few backcrosses of US75 to highbush, they found one, US245, that maintained a flat response curve from 15 to 30C.

In this study, we were interested in two specific questions: 1) whether any of the commonly grown highbush cultivars of *V. corymbosum* have higher photosynthetic heat tolerance than 'Bluecrop' and 'Jersey'; and 2) whether the high heat tolerance of *V. darrowi* could be transferred into the highbush background. We compared the heat tolerance of seven cultivars (Bluecrop, Bluejay, Elliot, Jersey, Patriot, Rubel, and Spartan), and searched for heat tolerance in several derivative populations of *V. darrowi* × 'Bluecrop'.

Dormant, l-year-old rooted cuttings of the seven cultivars and the *V. darrowi* selection Florida 4B (Fla 4B) were transplanted into 10-liter pots in a mixture of 1 sand : 1 peat (v/v) in Apr. 1987. Three replicates of each genotype were grown in a completely randomized design in a glasshouse. Temperatures fluctuated normally, and a dormancy period occurred when temperatures dropped to <5C during the winter months. Maximum day air temperatures ranged from 22 to 40C in the summer, while night temperatures ranged from 22 to 28C. Midday light intensities during the growing season varied from 600 to 950 $\mu mol \cdot m^{-2} \cdot s^{-1}$.

Four types of crosses were made: 1) Fla 4B × 'Bluecrop' (F_1); 2) US75 selfed (F_2); 3) 'Bluecrop' × US75 backcross (BC_1); and 4) 'Bluecrop' × MSU7 backcross (BC_2). US75 was previously identified by Moon et al. (1987) as a heat-tolerant, tetraploid hybrid of Fla 4B × 'Bluecrop', while we found MSU7 to be the most heat-tolerant progeny of 'Bluecrop' × US75 backcross (BC_1). Seeds were germinated according to standard practices (Galletta, 1975) and l-year-old seedlings were transplanted to 10-liter pots. These were maintained in the greenhouse for 1 year as described above. Progeny from the first three crosses were planted in 1987, while those from the fourth cross were set in 1989. All of the hybrids were self-fertile, and their large leaves suggested they were tetraploid.

To measure photosynthetic heat tolerance, the plants were placed together into a walk-in growth chamber at 20C, 850 $\mu mol \cdot m^{-2} \cdot s^{-1}$ photosynthetic photon flux, and a 14-h photoperiod. After 10 to 14 days of acclimation, photosynthetic response curves were determined before 1:00 PM by raising the temperature of the growth chamber from 20 to 30C over 1 h, then dropping it back to 20C over the same interval. In previous studies of 'Bluecrop', US75, and Fla 4B, photosynthetic response curves were linear across this temperature range (Moon et al., 1987a, 1987b). After each step change (5C) in treatment level, gas exchange rates were measured on the oldest leaf of 6- to 10-week-old terminal shoots using an Analytical Development Co. portable photosynthesis unit (Hoddesdon, U.K.). The two values taken at 20C were averaged for the low temperature reading to compensate for diurnal fluxes [The CO_2 assimilation rate (A) gradually diminishes during the day in blueberries]. Each genotype was tested on at least three separate occasions. The asexually propagated cultivars and progeny from Fla 4B × 'Bluecrop', US75 selfed, and 'Bluecrop' × US75 were analyzed in 1988. Progeny from 'Bluecrop' × MSU7 were tested in 1990. Carbon dioxide assimilation rates were calculated using computer programs developed by Moon and Flore (1986).

All the highbush cultivars showed a substantial decrease in A as the temperature of the ambient air was raised from 20 to 30C (Table 1), but some were less affected than others. Carbon dioxide assimilation rates in 'Jersey', 'Elliot', 'Rubel', and 'Bluecrop' were least affected by temperature increases (22% to 27% reduction), while 'Spartan',

Table 1. Carbon dioxide assimilation rate (A) of leaves of seven highbush blueberry cultivars at 20C and its reduction following raising of the ambient air to 30C.

Cultivar	A ($\mu mol \cdot m^{-2} \cdot s^{-1}$) at 20C	Reduction at 30C (%)
Jersey	8.7	22.3
Elliot	10.5	23.7
Rubel	9.6	26.3
Bluecrop	10.3	27.3
Spartan	9.7	41.3
Bluejay	9.8	46.7
Patriot	8.3	51.3
LSD (0.05)	1.2	11.7

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Table 2. Carbon dioxide assimilation rate (A) of leaves of 'Bluecrop', *V. darrowi* (Fla 4B), and a series of crosses at 20C and its change following raising of the ambient air to 30C.

		A (μmol·m^{-2}·s^{-1}) at 20C			Change (%)		
Parent or cross	Number	Mean	CV^z	Highest rate	Mean	CV^z	Most tolerant
Bluecrop	1	10.3	---		−29	---	
Fla 4B	1	7.2	---		−1	---	
F_1, Fla 4B x Bluecrop	8	8.5	17	11.8	−25	73	−2
F_2, US75^y selfed	10	8.5	21	13.1	−14	101	10
BC_1, Bluecrop x US75^y	10	9.3	18	11.7	−25	46	−8
BC_2, Bluecrop x MSU7^x	8	9.6	14	10.6	−17	72	−14

[z] Coefficient of variation among progeny.

[y] US75 was the most heat-tolerant progeny of Fla 4B x 'Bluecrop' (F_1). There was a 2% decrease in A as temperature was raised from 20 to 30C.

[x] MSU7 was the most heat-tolerant progeny of 'Bluecrop' x US75 (BC_1). There was an 8% decrease in A as temperature was raised from 22 to 30C.

'Bluejay', and 'Patriot' were the most severely affected (41% to 51% reduction).

Fla 4B was significantly less affected by temperature increases than 'Bluecrop' (- 1% vs. -29%), and all the hybrid populations contained at least a few individuals that were more heat tolerant than 'Bluecrop' (Table 2). Within the F_1 population, US75 was the most tolerant, with only a 2% reduction in A between 20 and 30C. The selfed population of US75 yielded one individual whose A actually increased by 10% as the temperature was raised. The backcross progeny (three-fourths highbush, one-fourth *V. darrowi)* were in general less tolerant than F_1 progeny, but a few individuals were still more tolerant than 'Bluecrop'; one selection in the BC_1 population showed a reduction of only 8%, while another in BC_2 was reduced by 14%. Coefficients of variation in the derivative populations ranged from 46% to 101%, indicating considerable geneticvariability existed in the populations.

Mean maximum A in all the hybrid populations was higher than that of Fla 4B. All were found between 8.5 and 9.6 μmol.m$^{-1}\cdot$s^{-1}, with the BC_1 population having the highest rate and the F_2 population having the lowest. There was a significant correlation ($P < 0.05$) between mean A and heat stability across populations ($r = 0.82$, df = 5), but there was no significant correlation between these traits within any of the populations.

These results lead us to the following conclusions: 1) highbush cultivars are in general poorly adapted to high temperatures, although some are more tolerant than others, and 2) *V. darrowi* can be used as a source of genes for photosynthetic heat tolerance. Although progeny numbers were small, the broad segregational patterns of all the derivative populations indicate that the response to temperature may be a polygenic trait. Heat-tolerant individuals can be recovered in backcross populations, and selfing can be used to fix heat-tolerant genes. The most effective breeding strategy may be to use the most heat-tolerant F_2 genotypes as parents for backcrossing. It should be relatively easy to recover horticulturally acceptable genotypes in the backcross generations, as many southern highbush cultivars are composed of high percentages of *V. darrowi* genes (Ballington, 1988).

Whether *V. darrowi* can be used to increase the heat tolerance of northern highbush blueberries will depend on the cold hardiness of the hybrids. The genes regulating heat tolerance will have to be separated from those associated with low chilling and sensitivity to cold. Genotypes will also have to be identified with high rates of A at both high and low temperatures, and the effect of temperature on respiration needs to be investigated. Comprehensive surveys of winter hardiness have not yet been made, but at least one backcross hybrid, US344, has been planted at Grand Junction, Mich. (winter lows -15 to -25C) for 10 years, and in most years it has produced a significant crop. Field-planted populations need to be further evaluated to determine whether heat and cold tolerance can be combined in the same highbush background, and whether photosynthetic heat tolerance is related to yield.

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