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Breeding Northern Highbush Blueberries for Climate Change

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Abstract

Due to climate change, the northern highbush blueberry production regions will be faced with increasing average temperatures and greater environmental variability. Highbush breeders will need to be cognizant of these changes and develop new cultivars that are more heat tolerant than our traditional ones and less subject to varying temperatures in the spring and fall. There is probably a readily available source of genes to meet these needs in southern highbush cultivars, which were developed by crossing wild southern blueberry species with cultivated northern highbush types.

Blueberry production in Michigan will be greatly challenged by the increases in global temperature associated with the rises in atmospheric CO_2 concentrations (GLISA, 2022). The native progenitor of the highbush blueberry, *Vaccinium corymbosum*, evolved long ago in the northeastern US under much cooler temperature regimes. Since just 1951, annual average air temperatures have increased by 1.3°C, and by 2100, average air temperatures are projected to rise by 3.3° to 6.1°C.

The blueberry Industry will also be challenged by the extreme variations in rainfall and temperature patterns associated with global warming. To maintain the productivity of blueberries in today's and tomorrow's wildly fluctuating environment, breeders will need to be much more cognizant of the potential range of environments that the cultivars will face. They will need to take care not to release cultivars that are too narrowly adapted to average conditions. (Lobos and Hancock, 2015).

Cultivars well adapted to "average conditions";' often do not have sufficient plasticity to perform well under the range of conditions now being faced: 1) Unusually warm springs can lead to very early floral development, and when temperatures return to normal later in the spring, a high percentage of flowers can be damaged by frost, 2) Unusually hot summers can result in reduced CO_2 assimilation rates and the fruit of most cultivars can become too soft for extended storage, 3) Unusually hot summer temperatures can also place plants under greater water deficits that can reduce their productivity, and 4) Unusually warm temperatures in winter can lead to early de-acclimation of floral buds and high percentages of damage when temperatures return to normal.

To breed northern highbush for climate change in Michigan: 1) We will need to increase their heat tolerance and 2) We will need to develop later flowering cultivars that acclimate more rapidly to cold temperature in the fall and de-acclimate more slowly in the spring. The ticket to accomplishing these goals, will likely be to backcross genes from southern highbush cultivars into northern highbush cultivars.

Development of Southern Highbush blueberries

Until the 1970s, highbush blueberry cul-

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tivation was limited to the northern half of the USA, as *V. corymbosum* required more than 1000 chilling hours. It wasn't until breeders hybridized native southern species of blueberry with *V. corymbosum* that a southern highbush industry was born (Retamales and Hancock, 2019). Ralph Sharp at the University of Florida led the way in the 1960s by making 10,000 crosses of *V. corymbosum* with *V. ashei*, 500 with *V. mysinites* and 1,600 with *V. darrowii*. Out of this work came the first three southern highbush species – 'Avonblue', 'Flordiablue' and 'Sharpblue'. Their genomes all contained 5 to 29 % genes of *V. darrowii* and 8 to 15% *V. ashei* (Table 1). No hybrids with *V. myrsinites* were maintained.

Three other breeders subsequently worked to incorporate genes from native southern species into the background of *V. corymbosum*, including Arlen Draper at the USDA, Jim Ballington at North Carolina State University and Sharp's replacement at the University of Florida, Paul Lyrene. Draper generated hybrids containing virtually all the native species of the eastern seaboard and released complex hybrids that were adapted to both the north ('Sierra') and south ('Biloxi') (Hancock and Galletta, 1995). Ballington was a prodigious collector and hybridizer of wild species in the southeastern USA and incorporated genes from *V. ashei, V. constablaei, V. elliottii and V. pallidum*. Paul Lyrene was the father of the breakthrough southern highbush cultivars 'Star' (1981), 'Emerald' (1991) and 'Jewel' (1998). He made liberal use of all the southern highbush species in section Cyanococcus, particularly *V. elliottii* and *V. darrowii*, and even incorporated genes from *V. arboreum* in section Batodendron.

Temperature tolerances of northern and southern highbush species

When the breeders used southern species to reduce the chilling requirement of the northern highbush, they likely also increased heat tolerance. The southern highbush species are now grown at locations where mean summer high temperatures range from 33 to 36 °C, while high temperatures across the northern highbush growing region range from 25 to 30 °C (Lobos and Hancock, 2015). The temperature 30 °C has been shown to be an important threshold, as carbon assimilation rates of leaves of northern highbush cultivars decline from 22 to 51% between 20 and 30 °C (Hancock et al., 1992).

One of the most important wild species used in the development of southern highbush types was *V. darrowii*. It is in the background of almost all of the important commercial cultivars. Moon *et al.* (1987) found CO_2 assimilation rates in V. darrowii to be reduced by only 5% between 20 and 30 °C, while those of 'Bluecrop' and 'Jersey' were reduced by 20 to 30 %. When Hancock *et al.* (1992) crossed 'Bluecrop' and *V. darrowii* and generated a series of F_1, F_2, BC_1 and BC_2 families, they were able to recover progeny in all these families with greater heat tolerances than the mid-parent value.

Development of heat tolerant northern highbush cultivars

In crossing southern highbush cultivars with northern highbush to increase heat tolerance, breeders will need to be careful to maintain winterhardiness and at the same time develop types less subject to dramatic temperature shifts in the spring and fall. Previous work has shown this to be possible. Hancock *et al*. (2018) crossed the northern highbush cultivar 'Draper' with the southern highbush 'Jewel' and examined the performance of progeny in Florida, Georgia, Oregon and Michigan. Some individuals were found that survived the winter with minimal winter damage in Michigan and also had high a high chilling requirement. Progeny were also found with a late bloom date and early ripening. It was discovered that flowering could be delayed by up to 7 days, while only delaying harvest date by 1 to 2 days. In another study Hanson *et al.* (2007) measured seasonal flower bud hardiness in controlled freezing studies, and found Draper's 'Sierra'

Table 1. Species background of representative northern and southern highbush cultivars. Abbreviations of programs: MSU (Michigan State University), NCSU (North Carolina State University), UA (University of Arkansas), UF (University of Florida), UG (University of Georgia) and USDA (United States Department of Agriculture). Abbreviations of species: ANG (*V. angustifolium*), ARB (*V. arboreum*), CON (*V. constablaei*), COR (*V. corymbosum*), DAR (*V. darrowii*), ELL (*V. elliottii*), FUS (*V. fuscatum*), TEN (*V. tenellum*) and VIR (*V. virgatum*). Adapted from Retamales and Hancock (2018).

			Northern species			Southern species					
Type & Cultivar	Program	Year	COR	ANG	CON	DAR	ELL	FUS	TEN	VIR	ARB
Southern											
Avonblue	UF	1976	86	1		5				8	
Sharpblue	UF	1976	56	2		29				15	
Floridablue	UF	1976	62	1		22				15	
Star	UF	1981	78	8		7			2	8	
Millennia	UF	1986	81	9		1		13		2	
Misty	UF	1989	86	1		6			1	6	
Emerald	UF	1991	82	2		14			< 1	2	
Snowchaser	UF	2007	65	5		8	19		1	2	
Flicker	UF	2010	66	< 1		12	19		1	1	
Meadowlark	UF	2010	75			13					12
O'Neal	NCSU	1987	83	10		2					
Sampson	NCSU	1998	75	11		13					
Carteret	NCSU	2005	71	4			25				
N. Hanover	NCSU	2005	78	2		14				6	
Reveille	NCSU	1990	90	4		3			< 1	2	
Biloxi	USDA	1998	47	2		33		7		11	
Magnolia	USDA	2008	76	6		10			1	8	
Ozarkblue	UA	1996	76	4		12				8	
Camelia	UGA	2005	74	2		20				4	
Rebel	UGA	2006	78	5		15				2	
Northern											
Rubel	USDA	1911	100								
Jersey	USDA	1928	100								
Bluecrop	USDA	1952	87	13							
Elliott	USDA	1973	100								
Duke	USDA	1986	96	4							
Sierra	USDA	1988	48	2	15	20				15	
Legacy	USDA	1988	75			25					
Chandler	USDA	1994	97	3							
Cara's Choice	USDA	2005	50		12.5	25				12.5	
Hannah's Choice	USDA	2005	63	12				25			
Draper	MSU	2003	90	6		2			< 1	1	
Liberty	MSU	2003	100								
Huron	MSU	2012	75			25					
Osorno	MSU	2014	95	3		13			< 1	< 1	
Calypso	MSU	2014	87	3		1			<1	<1	
Katahdin	MSU	2020	89	4		7			< 1	< 1	
Capella	MSU	2022	85	4		8			< 1	3	

with a high composition of southern species genes, acclimated just as fast or faster than straight northern highbush species, and it de-acclimated at about the same rate.

Path forward

There is likely sufficient genetic diversity in southern highbush to produce a new generation of northern highbush better adapted to climate change. In today's era of DNA markers and genomic selection the progress should be rapid. It is also possible that breeding for heat tolerant northern highbush has already been initiated by Draper in his release of 'Legacy" and 'Sierra', which contain high proportions of genes from wild southern blueberry species in a northern highbush background. Likewise, the breeding program at Michigan State University has released a series of cultivars with significant contributions of southern blood including 'Draper', 'Huron', 'Osorno', 'Katahdin' and 'Capella'(Table 1). Experiments need to be performed to determine whether any of these releases are indeed more heat tolerant and have greater tolerance to environmental variation than the earlier established cultivars.

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