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Role of Plant Growth Regulators in Southern Highbush Blueberry Production Under Low-chill Conditions

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Abstract

Early-season blueberry production continues to expand rapidly in the low-chill regions of the southeastern United States. This expansion is driven by high market prices received for early-season southern highbush blueberry (*Vaccinium corymbosum* hybrids) (SHB) fruit produced during periods of high demand and low supply. The major low-chill SHB blueberry production region in the southeastern U.S. extends from south-central Florida north into southeast Georgia. Highly variable winter chill accumulation and late winter freezes (during bloom and early fruit development) present significant challenges for attaining consistent and profitable yields. Winter chill accumulation in this region is often insufficient for good production without the aid of dormancy-breaking compounds, even with the low-chill cultivars that are currently available. Hydrogen cyanamide (H_2CN_2) is commonly used to mitigate the negative effects of insufficient chill accumulation of blueberries grown in Florida and Georgia.

Southern highbush blueberries are widely grown in subtropical regions of the world where early harvest can be achieved during periods of high demand and low supply. In Florida and southeast Georgia, blueberry growers target a lucrative market from mid- to late-March through mid-May using SHB cultivars that range in chill requirements from ≈ 200 to 600 h (Williamson et al., 2002; Williamson et al., 2014). Winter chill accumulation is highly variable among years and throughout the southeastern U.S. and is often insufficient to satisfy cultivars' chilling requirements, especially in the more southern production regions of central and south-central Florida (Williamson and England, 2012). Inadequate winter chilling can limit production of SHB and remains one of the greatest challenges for subtropical blueberry production (Lyrene, 2006). Hydrogen cyanamide (HC) is a dormancy breaking compound that is used on a variety of temperate fruit crops including grapes, apples, peaches, blackberries and blueberries (Dokoozalian and Williams, 1995; Erez, 1987; Shulman et al., 1986; Sieler et al., 1991; Williamson et al., 2002). Several studies have found that HC applications can advance bud break and fruit harvest of SHB and rabbiteye blueberries (*Vaccinium virgatum* Aiton) (Arias et al., 2010; Stringer et al., 2004; Williamson et al., 2002). Consequently, HC is often used by blueberry growers in sub-tropical and warm temperate regions of the southeastern U.S. to mitigate the negative impacts of inadequate chill accumulation and encourage earlier berry harvest (Williamson et al., 2012).

The purpose of this paper is to review the

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Information presented in this paper does not imply or constitute recommendations for HC use.

effects of HC use on low-chill blueberry production in sub-tropical and warm temperate regions of the southeastern U.S.

Production systems. Southern highbush blueberries are typically grown using one of two production systems in low-chill regions of the southeastern U.S. The traditional deciduous system whereby plants enter winter dormancy and exposure to chilling temperatures is required to resume normal growth the following spring is the most common production system. However, in central and south-central Florida, and under tunnels in north-central Florida, a non-dormant or "evergreen" production system is sometimes used to avoid winter dormancy and the problems associated with satisfying chilling requirements for dormant plants needed to resume growth in the spring (Williamson et al., 2014). Hydrogen cyanamide is widely used in conjunction with the more common traditional deciduous SHB production system where dormancy is not averted and chill accumulation is needed to resume normal growth in the spring.

Winter weather. Winter weather is highly variable and unpredictable in the subtropical and warm temperate production regions of the lower southeastern U.S. Inadequate chill accumulation and late winter freezes during or after bloom can severely limit SHB production (Williamson and England, 2012). Table 1 illustrates the high variability in winter chill accumulation for two consecutive winters compared to the long-term averages in north-central (Alachua) and central (Lake Alfred) Florida. Chill accumulation during the 2010-2011 winter was well above the long term averages at both locations. Conversely, chill accumulation during the 2011-2012 winter was well below the long-term averages at both locations. Deviations from the long-term averages were greater for the central Florida location than for the north-central location. This was especially true for 31 Dec. when the chill accumulation in 2010-2011 was more than 10-fold that in 2011-2012. Chill accumulation prior to HC application can have a pronounced effect on plant response after treatment. Using walk-

Table 1: Chill accumulation on specific dates in north and central Florida beginning November 1.[z]

Date	Long-term average		Winter 2010/2011		Winter 2011/2012	
	Alachua	Lake Alfred	Alachua	Lake Alfred	Alachua	Lake Alfred
15 Dec.	182	46	346	146	139	15
31 Dec.	283	85	520	254	195	22
15 Jan.	384	127	664	307	275	81
15 Feb.	583	203	870	373	452	112

[z] Reprinted from Williamson (2012).

Table 2: Effect of hydrogen cyanamide (H_2CN_2) spray concentration and pre-treatment chilling on the percentage of flower bud mortality of 'Misty' blueberry.[z]

H_2CN_2 spray conc. (%)	Pre-treatment chilling (h)			Significance[y]	
	0	150	300	Linear	Quadratic
0	1.0	1.5	0.1	NS	NS
1	20	11	2.3	***	NS
2	38	26	19	**	NS
Significance					
Linear	***	***	***		
Quadratic	NS	NS	**		

[z] Reprinted from Williamson et al. (2001).

[y] NS, *,**,*** = nonsignificant, or significant at $P \leq 0.05$, 0.01, or 0.0001, respectively.

in coolers, Williamson et al. (2001) reported that 150 and 300 h of continuous chill accumulation before HC treatment reduced SHB flower bud mortality compared with no pre-chilling (Table 2). Moreover, flower bud mortality decreased within a given HC rate as chill accumulation increased before HC treatment. The effect of chill accumulation before HC treatment on the reduction of flower bud mortality has been substantiated by numerous observations from growers and researchers where high levels of flower bud mortality were observed following HC treatments during mild winters when low chill accumulation occurred before treatment (J.G. Williamson, unpublished data). Additionally, plant injury from HC application is more often reported in central and south-central Florida where less chill accumulation occurs than in north-central Florida. The amount of chill accumulation needed prior to HC application to avoid significant flower bud injury is unknown and is difficult to determine due to factors such as varying cultivar susceptibility to HC injury, as well as the difficulties of quantifying effective chill accumulation in warm winter climates with fluctuating temperatures. Apart from reduced flower bud injury, Stringer et al. (2004) reported more vegetative bud break of SHB and rabbiteye blueberry from HC treatments following exposure to 75% of their chill requirement compared with only 50% of their requirement. Hydrogen cyanamide sprays are timed with crop phenology and are typically applied during mid- to late December or early January in Florida. A paradox exists some years, especially in the warmer regions of Florida, when very little chilling occurs yet flower buds swell during hot weather in November and December and rapidly approach a developmental stage that is no longer safe for HC application.

Timing of HC sprays. Product labels call for HC to be applied to blueberry 30 days or more before natural budbreak. In Florida, this typically occurs from mid- to late December through early January when most flower buds have not progressed past stage 2 (swollen floral buds with bud scales still closed) (Spiers, 1978) in their development. Williamson et al. (2001) reported significant damage to rabbiteye flower buds from HC applications that were made when > 30% of these buds were at stage 3 (bud scales separated, apices of flower petals visible) or greater in their development. As mentioned previously, during some winters, especially in central and south-central Florida, flower bud development may begin to progress past stage 2 before substantial chilling accumulation occurs. This was the case during the 2011-2012 winter when only 22 h of temperatures < 7.2°C occurred in Lake Alfred by 31 Dec. (Table 1). However, extended periods of warm weather during December resulted in flower bud development progressing beyond what is considered safe for HC treatment. In these situations, growers are forced to either spray plants that have received very little chilling or forego HC treatment altogether. If growers choose to use HC in these situations, they may treat only specific cultivars, and apply lower rates than would be used during colder winters with greater chill accumulation.

Rates and cultivar response. Williamson et al. (2002) reported increasing vegetative budbreak of ‘Misty’ SHB and ‘Climax’ rabbiteye with increasing rates of HC. Although ‘Misty’ is generally considered a HC-tolerant cultivar, significant flower bud injury and reduced yields were noted at rates of 1.5% and 2% (v/v) HC (3% and 4% formulated product) when applied to run-off. However, ‘Misty’ ripening date was advanced and mean berry weight increased with little to no flower bud injury at 0.75% and 1.0% (v/v) HC. Similarly, vegetative budbreak was increased and fruit ripening date advanced for ‘Climax’ rabbiteye blueberry with 0.75% (v/v) HC. Later work showed that 1.25% (v/v) HC sprays caused significant flower bud injury on ‘Emerald’ which is also considered a HC-tolerant cultivar (J.G. Williamson, unpublished data). Research and grower experience in Florida suggests that 0.75 – 0.88% (v/v) HC [1.5 - 1.75% (v/v) of formulated product] sprays applied with sufficient spray volume to achieve thorough coverage have generally been effective on HC-tolerant cultivars when applied at stage 2 or less of flower bud development to plants that have received sufficient chilling (Krewer et al., 2012; Williamson et al., 2013). However, tolerance to HC varies significantly among cultivars. For the major Florida SHB cultivars, 'Emerald' is considered one of the most tolerant cultivars and 'Primadonna' one of the least tolerant, with most other cultivars between these two extremes. Within a cultivar, HC tolerance can be influenced by dormancy level and the amount of chilling before treatment. 'Jewel' is an example of a cultivar that has responded well to HC treatments in north-central Florida when fully dormant and exposed to adequate chilling temperatures before treatment. However, in central Florida, where full dormancy may not be achieved and/or chilling is limited, 'Jewel' has shown significant flower bud injury from HC treatments (B. Braswell, personal communication). Product labels caution that HC may be ineffective or phytotoxicity may occur with negative chill-hour accumulation and climatologically-induced incomplete plant dormancy. Negative chill-hour accumulation and incomplete dormancy are likely to occur in subtropical climates such as central and south-central Florida and may be partially responsible for the problems associated with HC use in those regions, especially during mild winters. From observations, HC rates as low as 1.0 to 1.25% (v/v) of HC without surfactants and day-time applications tend to reduce HC injury (G. Krewer, unpublished data). More research and field tests are needed to elucidate HC tolerance among SHB cultivars and determine the effects of environmental and climatic factors on HC efficacy and phytotoxicity in Florida's variable subtropical climate.

In conclusion, HC is commonly used in SHB production in Florida and parts of southeast Georgia because of its potential to increase vegetative growth in the spring and advance berry ripening date. Advanced ripening of this early-season crop can significantly increase profitability. Increased uniformity of budbreak and shortened fruit development period may also reduce plant stress and simplify some cultural practices. However, treatment results vary with cultivar, climatic conditions, plant dormancy, and chill accumulation. Response to HC has been more problematic in central and south-central Florida where winters are mild and chill accumulation is sometimes extremely low. Research and field experience has demonstrated the importance of attaining dormancy and chill accumulation before HC treatment and the complexities of using HC during warm winters in central and south-central Florida.

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