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TIMING AND CONCENTRATION OF HYDROGEN CYANAMIDE SPRAYS AFFECT BUD DEVELOPMENT, FLOWER MORTALITY, AND HASTEN FRUIT MATURITY OF BLUEBERRY

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Abstract. **The effects of hydrogen cyanamide (H_2CN_2) sprays on vegetative and reproductive bud growth and development were evaluated for 'Misty' southern highbush blueberry (*V. corymbosum* L. hybrid) and 'Climax' rabbiteye blueberry (*Vaccinium ashei* Reade). 'Climax' plants were sprayed with 0 or 1% H_2CN_2 (v/v) at each of several time intervals or flower bud growth stages following either 270 or 600 hours of continuous artificial chilling. 'Misty' plants were sprayed with 0, 1 or 2% H_2CN_2 (v/v) immediately after exposure to 0, 150 or 300 hours of continuous artificial chilling. H_2CN_2 application to 'Climax' plants at 3 days after forcing (DAF) and at 10-30% stage 3 flower bud development dramatically accelerated leafing with only minimal flower bud injury. For 'Misty', vegetative budbreak was increased and advanced by both H_2CN_2 spray concentrations, regardless of pre-treatment chilling levels; the number of vegetative budbreaks per plant increased with increased spray concentration. Timing of anthesis did not appear to be affected by H_2CN_2, but fruit maturity was hastened. Increased pre-treatment chilling alone also hastened fruit development. Enhanced fruit maturity date appears to be due primarily to increased and accelerated vegetative budbreak, which probably increased leaf:fruit ratios during fruit development. Greater flower bud mortality from H_2CN_2 occurred in non-chilled plants than in those chilled for 150 or 300 hours, especially at 2% H_2CN_2. These results indicate that H_2CN_2 has potential value in stimulating vegetative bud development, which potentially hastens maturity in blueberries grown under the mild winter conditions of the southeast United States. However, spray concentration and timing will be critical to successful use of this compound.**

Rabbiteye and southern highbush blueberries grown in the lower southeastern United States often experience mild winters with limited chilling hours. Under these conditions, flowering can be erratic, depending on cultivar and chilling requirement (NeSmith and Bridges, 1992). An equally serious problem caused by lack of chilling is poor leafing (Lyrene and Williamson, 1997). Leaf buds of most blueberry cultivars have a higher chilling requirement than do flower buds. Following low to moderate chilling, many blueberry cultivars such as 'Misty' will flower but have greatly delayed vegetative bud break and leaf canopy development. Delayed spring foliation can reduce fruit size and delay fruit maturity, both of which are critical to the early-season blueberry crop in the lower southeastern United States (Williamson and Lyrene, 1995). Therefore, a method of accelerating spring foliation of certain blueberry cultivars is needed to improve overall crop production following mild winters.

Dormex® (50% hydrogen cyanamide = H_2CN_2) has been tested for several years for increasing bud break of various deciduous fruit crops, especially when chilling is inadequate (Dokoozlian and Williams, 1995; Erez, 1987; Shulman et al., 1986). To date research on H_2CN_2 in blueberry has been limited, although some field trials have shown increased and accelerated spring foliation and increased fruit size and earliness (Williamson and Krewer, Univ. of Florida and Univ. of Georgia, respectively, unpublished). The objective of this research was to determine the effect of timing and concentration of H_2CN_2 applications with respect to accumulated chilling on leaf bud development, flower bud mortality, and fruit growth and development of blueberry.

Materials and Methods

Expt. 1. This experiment was conducted with 1-year-old, container-grown, 'Climax' rabbiteye blueberry plants in a greenhouse at Griffin Ga. during 1996 and 1997. 'Climax' has a reported chilling requirement between 400-500 h below 45°F. Two chilling treatments were established for 270 h (low chill) and 600 h (high chill) in a cold room at 41 to 45°F. Dormant blueberry plants were sequentially placed in the cooler so that all could be removed on the same date. After chilling, all plants were moved to a greenhouse (75°F day/64°F night) under natural daylight for forcing bud break and for application of H_2CN_2 (Dormex®, Dormex Co., Fresno, Calif.) treatments. H_2CN_2 (1%) treatments were as follows: 1) control; 2) H_2CN_2 applied 1 d after forcing (DAF); 3) H_2CN_2 applied 3 DAF; 4) H_2CN_2 applied when 10-30% of the flower buds were at stage 3 (Spiers, 1978); and 5) H_2CN_2 applied when 30-50% of the flower buds were at stage 3. There were six single-plant replicates per treatment in a randomized complete block design. H_2CN_2 sprays were applied with 0.25% (v/v) X-77® surfactant (Loveland Ind., Inc., Greeley, Colo.) to the point of drip using a backpack sprayer.

All flower buds on each plant were counted and evaluated for stage of development at weekly intervals and flower bud mortality was noted. Leaf bud development was assessed weekly for 10 vegetative buds per plant. A stem was randomly selected for each plant and a tag designated the position of the leaf buds to be observed. Leaf bud stages were classified according to the scale of NeSmith et al. (1998). Fruit and yield data were not taken since pollination was not possible in the greenhouse. All data were subjected to ANOVA and means were separated by least significant difference (LSD) procedures at $P \leq 0.05$.

Expt. 2. Sixty-three, 2-year-old, container-grown, 'Misty' southern highbush blueberry plants were grown outdoors on a gravel bed at Gainesville, Fla. during 1996 prior to the initiation

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of chilling treatments. Three chilling treatments were established by moving two-thirds of the plants into a cold room for either 150 or 300 h of continuous chilling at 41 to 43°F. The remaining 21 control plants were never placed in the cold room but were moved into a greenhouse prior to accumulating any chilling outside. H_2CN_2 was applied to run off with a backpack sprayer at concentrations of 0, 1 or 2% (v/v) H_2CN_2. A nonionic surfactant at 0.25% v/v was included in each spray treatment. Sprays were applied immediately after plants were removed from the cold room. After treatment, all plants were placed in a greenhouse where the maximum and minimum temperatures ranged from approximately 86 ± 3°F and 64 ± 3°F, respectively. The plants remained in the greenhouse for several weeks after treatment and were later moved permanently outdoors during flowering for cross-pollination and fruit set.

Flower and vegetative budbreak were measured weekly between 8 Jan. and 5 Feb. by counting all buds which had begun to grow on each plant. A final measurement of vegetative budbreak was determined on 15 Mar. At each measurement date, all flower buds were assessed for development using a modification of the developmental scale reported by Spiers (1978) for rabbiteye blueberry. The number of dead flower buds was determined for each plant. All fruit were harvested at 3 to 4-d intervals beginning at first fruit ripening. A randomized complete block design with seven single-plant replications per treatment was used. ANOVA and regression analysis were used to determine treatment effects.

Results and Discussion

Expt. 1. The control 'Climax' plants had no stage 6 leaf buds at 30 DAF (Table 1). H_2CN_2 applications at 1 DAF, 3 DAF and at 10-30% stage 3 flower buds increased stage 6 leaf bud numbers at 30 DAF of plants chilled for 270 h. Only the treatment applied 3 DAF increased stage 6 leaf bud numbers at 30 DAF in plants chilled for 600 h. By 60 DAF, only 10-12% of the control leaf buds had progressed to stage 6 of leaf bud development. From 22-80% of the leaf buds on plants treated with H_2CN_2 were at stage 6, depending on application timing. The greatest vegetative bud break for both the low and high chill plants occurred for H_2CN_2 applied when 30-50% of the flowers were at stage 3 of development. For the low chill plants, all H_2CN_2 treatments applied 3 DAF, or later, increased percentage of leaf buds that were at, or past, stage 6 of development. A similar trend was observed for the 600 h plants.

The high degree of stage 6 leaf bud numbers for H_2CN_2 treatments applied at 30-50% stage 3 for flower buds was coupled with substantial flower bud mortality (Table 2). Flower bud removal tends to accelerate leafing; thus the direct "effect" of H_2CN_2 on promoting vegetative bud break was confounded by injury to flower buds when applied at this later stage of flower bud development. However, H_2CN_2 application at 3 DAF and at 10-30% stage 3 flower buds resulted in a dramatic acceleration of leafing with only minimal flower bud damage.

Expt. 2. Vegetative budbreak of 'Misty' was increased and advanced by both H_2CN_2 spray concentrations at 5, 7 and 15 weeks after application regardless of pre-treatment chilling levels (Table 3). Significant H_2CN_2 × pre-treatment chilling interactions were found; therefore all treatment combinations are reported. The number of vegetative budbreaks per plant increased with H_2CN_2 concentration regardless of pre-treatment chilling level. For plants receiving pre-treatment chilling, vegetative budbreak increased linearly as H_2CN_2 concentration increased. For control 'Misty' plants, most vegetative budbreak occurred between weeks 7 and 15 regardless of pre-treatment chilling. However, most vegetative budbreak for H_2CN_2-treated 'Misty' plants began prior to week 5. The number of vegetative budbreaks per plant at 5 weeks after treatment application ranged from 62 to 81 for the 1% H_2CN_2 treatment vs. 0 to 2 for the control plants. By 15 weeks after treatment application, both H_2CN_2 treatments dramatically increased the number of vegetative budbreaks per plant. Pre-treatment chilling had an influence on H_2CN_2-induced vegetative budbreak. At 5 and 7 weeks after treatment, vegetative budbreak increased as pretreatment chilling level increased for 0 and 2% H_2CN_2, but not for 1% H_2CN_2. Moreover, with no pre-treatment chilling, the additional increase in vegetative budbreak that occurred with the 2% H_2CN_2 treatment was less than when plants were chilled for 150 or 300 h.

Time of flowering of 'Misty' was not greatly affected by H_2CN_2 treatment (data not reported). However, both H_2CN_2 treatment and pre-treatment chilling advanced fruit development and ripening (Table 4). Significant spray concentration × pre-treatment chilling interactions were noted at most harvest dates for percent of total fruit harvested. For example, by 16 weeks after treatment, there was no effect of pre-treatment chilling on the percentage of total fruit harvested for the 0%

Table 1. Percentage of stage-6 leaf buds 30 and 60 days after forcing (DAF) in response to H_2CN_2 sprays (1%) applied at different times or stages of development to greenhouse-grown 'Climax' blueberry following 270 or 600 h of chilling.

	Chilling (h below 45°F)	
Time of treatment	270	600
	30 days after forcing	
Control	0 b[z]	0 b
1 DAF	25 a	18 ab
3 DAF	40 a	38 a
10-30% Stage 3[y]	37 a	3 b
30-50% Stage 3	2 b	0 b
	60 days after forcing	
Control	12 d	10 c
1 DAF	27 cd	22 bc
3 DAF	40 bc	43 b
10-30% Stage 3	53 b	28 bc
30-50% Stage 3	80 a	67 a

[z]Means separation within columns and forcing time by LSD, $P \leq 0.05$.
[y]Refers to floral development stage.

Table 2. Blueberry flower bud mortality in response to H_2CN_2 applications (1%) at different stages of development.

	Chilling (h below 45°F)	
Timing of treatment	270	600
	Flower buds killed (%)	
Control	0 c[z]	0 c
1 DAF	0 c	0 c
3 DAF	16 b	1 c
10-30% Stage 3[y]	12 bc	26 b
30-50% Stage 3	34 a	72 a

[z]Means separation within columns by LSD, $P \leq 0.05$.
[y]Refers to floral development stage.

Table 3. H_2CN_2 spray concentration and pre-treatment chilling effects on the number of vegetative buds growing per plant of 'Misty' blueberry 5, 7, and 15 weeks after H_2CN_2 application.

H_2CN_2 spray conc. (%)	Pre-treatment chilling (h)			Significance	
	0	150	300	L	Q
	----- 5 weeks after treatment -----				
0	0.1	0	2.0	**	**
1	62	81	69	NS	NS
2	71	152	180	***	NS
Significance					
L	***	*	***		
Q	*	NS	NS		
	----- 7 weeks after treatment -----				
0	1.4	0.7	3.0	NS	*
1	68	76	79	NS	NS
2	94	146	183	**	NS
Significance					
L	***	***	***		
Q	*	NS	NS		
	---- 15 weeks after treatment ----				
0	15	11	23	NS	NS
1	68	94	72	NS	NS
2	82	161	178	*	NS
Significance					
L	**	***	***		
Q	NS	NS	NS		

NS, *, **, *** = nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 4. H_2CN_2 spray concentration and pre-treatment chilling effects on the percentage of total fruit harvested for 'Misty' blueberry by 16, 17 and 18 weeks after treatment application.

H_2CN_2 spray conc. (%)	Pre-treatment chilling (h)			Significance	
	0	150	300	L	Q
	---- 16 weeks after treatment ----				
0	5.5	1.4	1.6	NS	NS
1	24	31	21	NS	NS
2	32	33	71	***	**
Significance					
L	***	***	***		
Q	NS	***	*		
	---- 17 weeks after treatment ----				
0	8.7	11	21	*	NS
1	33	33	55	**	NS
2	40	42	92	***	***
Significance					
L	***	***	***		
Q	NS	***	NS		
	---- 18 weeks after treatment ----				
0	25	19	47	*	*
1	42	44	74	***	*
2	45	49	98	***	***
Significance					
L	**	***	***		
Q	NS	***	NS		

NS, *, **, *** = nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

and 1% H_2CN_2 treatments. However, for 2% H_2CN_2, the percentage of ripe fruit increased as pre-treatment chilling increased. Similarly, at 17 weeks after treatment, the percentage of ripe fruit increased more as pre-treatment chilling increased from 150 h to 300 h for the 2% H_2CN_2 treatment than for the other treatments. By 17 and 18 weeks after treatment, chilling had resulted in advanced ripening of fruit on both H_2CN_2-treated and control plants. Overall, H_2CN_2 treatments increased the percentage of ripe fruit on all harvest dates regardless of pre-chilling treatment. The advanced fruit ripening appeared to be primarily related to the effect of H_2CN_2 in stimulating earlier and greater spring leaf development. Both the number of vegetative bud breaks per plant and the percentage of ripe fruit increased as H_2CN_2 concentration increased. Within each pre-treatment chilling level, the H_2CN_2 treatments that stimulated the greatest vegetative bud break also hastened fruit ripening most.

The blueberry fruit development period is known to be inversely related to crop load (Maust et al., 1999). Although leaf:fruit ratios were not measured in this experiment, the H_2CN_2 treatments applied to 'Misty' provided earlier and more extensive leaf bud break, which probably resulted in higher leaf:fruit ratios during the major period of fruit development, thus hastening fruit development and ripening. However, flower bud mortality and subsequent fruit thinning could have played a secondary role in influencing fruit maturity date. Flower bud mortality was low for the plants that received some pre-treatment chilling prior to treatment with 1% H_2CN_2, which suggests that flower thinning was not a factor in earlier fruit ripening for those treatments (Table 5). However, treatments with 2% H_2CN_2 thinned (killed) flower buds and reduced both total fruit number per plant and total fruit fresh weights compared to other treatments (Table 6). Earlier fruit ripening at this concentration of H_2CN_2 may be partially due to reduced fruit numbers as a result of flower bud thinning.

For plants receiving some pre-treatment chilling, there was a compromise between total fruit yield and earliness of fruit ripening from H_2CN_2 treatments. Across all pre-treatment chilling levels, 1% H_2CN_2 sprays resulted in the greatest fruit numbers per plant and the highest fruit fresh weights (Table 6). However, fruit ripening was more advanced for the 2% H_2CN_2 treatments for plants receiving 150 or 300 h of pre-treatment chilling. Overall, the effectiveness of H_2CN_2 at providing early and high fruit yields of southern highbush blueberry appears to be strongly related to both pre-treatment chilling and spray concentration. Both H_2CN_2 treatments increased total fruit yield. However, 1% H_2CN_2 increased fruit number and fruit fresh weight per plant more than the 2%

Table 5. Effect of H_2CN_2 spray concentration and pre-treatment chilling on the percentage of flower bud mortality of 'Misty' blueberry.

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

NS, *, **, *** = nonsignificant, or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 6. Effects of H_2CN_2 spray concentration on fruit number and yield of 'Misty' blueberry.

H_2CN_2 spray conc. (%)	Fruit fresh weight (g)	Total fruit no./plant
0	324	232
1	579	345
2	465	261
Significance		
L	NS	NS
Q	**	**

NS, ** = nonsignificant, or significant at $P \leq 0.01$, respectively.

treatment, where considerable flower bud thinning occurred. Flower bud mortality for both the 1% and 2% H_2CN_2 concentrations was inversely related to pre-treatment chilling. This suggests that some accumulated chilling is needed by blueberry plants to minimize flower bud injury from H_2CN_2.

Results from our experiments indicate that H_2CN_2 can promote vegetative bud development and hasten fruit development for blueberries grown under the mild winter conditions of the lower southeastern United States. However, spray concentration and timing will be critical to its successful use. H_2CN_2 applications made before any chilling occurred stimulated less vegetative growth, resulted in higher flower bud mortality, and reduced total yields compared with plants receiving a pre-chilling treatment. H_2CN_2 applied to plants with more than 30% stage 3 flower buds caused excessive flower bud injury regardless of chilling treatment. Thus, H_2CN_2 should not be applied before significant chilling has occurred, or at advanced stages of floral development (>30% stage 3 buds).

Additional research is needed to determine how best to use H_2CN_2 to improve blueberry leafing and hasten fruit development. Timing under field conditions needs to be assessed and cultivar responses need to be compared. Our results indicate that the timing of H_2CN_2 applications will need to be based on plant development rather than calendar date. If application timing is monitored carefully, both high- and low-chill plants can benefit in terms of accelerated leaf development. In some cases (i.e., southern highbush cultivars with heavy flower bud set) some degree of flower bud injury would be acceptable to achieve earlier harvests of higher quality fruit.

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CHARACTERISTICS OF PLUMS FROM THE UNIVERSITY OF FLORIDA BREEDING PROGRAM

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Abstract. **'Gulfruby', 'Gulfbeauty', 'Gulfblaze', and 'Gulfrose' Japanese-type plums (*Prunus salicina* Lindl.) arose from the University of Florida plum breeding program. They are adapted from southern through northern Florida because they appear to require low amounts of winter chilling, but high heat units to force flowers and foliation following winter. They also are resistant to Plum Leaf Scald [*Xylella fastidiosa* Wells et al.] and Bacterial Spot [*Xanthomonas campestris* pv. *pruni* (Smith) Dye], the two main diseases of plums in the eastern United States. They require cross-pollination and appear to be cross-fruitful in all combinations. Tree and fruit characteristics for these varieties are presented and compared for identification and for general knowledge of their advantages and characteristics. These cultivars are recommended for the home garden and for grower trial because they ripen in late April to late May when few plums are available in the markets from other United States sources and prices are likely to be high.**

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