Surfactants Improve the Response of Grapevines to Hydrogen Cyanamide

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Abstract. The effects of surfactants on the efficacy of hydrogen cyanamide (H_2CN_2) applied to 'Perlette' grapevines (*Vitis vinifera* L.) grown in the Coachella Valley of California were examined in 1994 and 1995. Vines were pruned in mid-December in both years and treatments applied at 1000 L·ha⁻¹ the following day to dormant spurs and cordons using a hand-held spray wand. In 1994, H_2CN_2 was applied at 0.5%, 1%, or 2% by volume in combination with 0%, 0.5%, 1%, 2%, or 3% by volume of the amine-based surfactant Armobreak. In 1995, H_2CN_2 was applied at 0.5%, 1%, or 2% by volume in combination with Armobreak at 0% or 2% by volume. In 1994, budbreak rate was highly dependent upon H_2CN_2 concentration when 0% to 1% Armobreak was used; budbreak was generally most rapid for vines treated with 2% H_2CN_2 and slowest for vines treated with 0.5% H_2CN_2 . When 2% or 3% Armobreak was used, however, little effect of H_2CN_2 concentration was observed. Results were similar in 1995, but the budbreak of vines treated with 2% H_2CN_2 + 2% Armobreak lagged behind that of vines treated with 1% H_2CN_2 + 2% Armobreak. The number of days after treatment required for 70% budbreak generally declined as the concentrations of H_2CN_2 and Armobreak were increased. A separate experiment conducted in 1995 revealed that several surfactants varying in chemical composition, Armobreak, Activator 90 and Agridex, had similar effects on H_2CN_2 efficacy. The results indicate that the addition of surfactants to H_2CN_2 solutions can significantly reduce the amount of active ingredient necessary for maximum efficacy on grapevines. Chemical names used: hydroxypolyoxyethylene polyoxypropylene ethyl alkylamine (Armobreak); alkyl polyoxyethylene ether (Activator 90); paraffin petroleum oil (Agridex).

Hydrogen cyanamide (H_2CN_2) is commonly applied to advance the growth and improve the uniformity of budbreak of grapevines grown in low-chill regions (Lavee et al., 1984; McColl, 1986; Wicks et al., 1984). In the Coachella Valley, the principal desert table grape growing region of California, H_2CN_2 is typically applied as a 2% (v/v) solution immediately after pruning. The cost of H_2CN_2 for this application is approximately U.S. \$370/ha. Methods to improve treatment efficacy, thereby reducing the amount of active ingredient applied and treatment cost, are desirable. Surfactants improve the uptake and penetration of plant growth regulators applied to horticultural crops (Greenberg et al., 1987; Knoche and Bukovac, 1992; Tan and Crabtree, 1992). The surfactant Armobreak (AKZO-Noble

Chemicals, Dobbs Ferry, N.Y.) improved the efficacy of dormancy-breaking agents applied to deciduous fruit trees (Erez, 1995). The purpose of this study was to examine the effects of surfactants on the efficacy of H_2CN_2 applied to improve the budbreak of 'Perlette' table grapes grown in a low-chill region.

Materials and Methods

The experiments were conducted in a mature, drip-irrigated 'Perlette' table grape vineyard located near Thermal, Calif. The own-rooted vines were spaced 3.6 m (between rows) × 1.8 m (between vines), trellised to a standard "T" system, and bilateral cordon-trained and spur-pruned. The vines were pruned to 40, two-bud spurs on 15 and 14 Dec., respectively, in 1993 and 1994. Treatments were applied to cordons and spurs the day after pruning using a hand-held spray wand at 1000 L·ha⁻¹. Treated surfaces dried completely 35 to 45 min after application. In both seasons, temperatures at the time of application ranged between 16 and 18 °C, and no precipitation occurred for at least 3 weeks after treatment.

The effects of the surfactant Armobreak on H_2CN_2 efficacy were examined in both years. In 1994, H_2CN_2 was applied at 0.5%, 1%, or 2% by volume in combination with 0%, 0.5%, 1%, 2%, or 3% by volume Armobreak. In

1995, H_2CN_2 was applied at 0.5%, 1%, or 2% by volume in combination with Armobreak at 0% or 2% by volume. Treatments in both experiments were replicated eight times using single-vine plots arranged in a split-plot design (H_2CN_2 = main plots, Armobreak = subplots). In 1995, a separate experiment compared the performance of three surfactants differing in chemical composition, Armobreak, Activator 90 (alkyl polyoxyethylene ether) (Loveland Industries, Greeley, Colo.), and Agridex (paraffin petroleum oil; Helena Chemical Co., Memphis, Tenn.), on H_2CN_2 efficacy. The surfactants were applied at 2% by volume with 0.5% by volume H_2CN_2 . Vines treated with 0.5% H_2CN_2 alone served as the control. The treatments were replicated eight times using single-vine plots arranged in a randomized complete-block design. A single-vine buffer was retained between plots in all experiments. Ten spurs were randomly selected and numbered on each data vine prior to budbreak. The spurs were monitored two to three times per week beginning in early January for budbreak, which was designated as the initial emergence of green tissue from beneath the bud scale. The date of budbreak for the distal and proximal bud on each spur was recorded. The number of days after treatment required for 70% budbreak, an indication of budbreak rate and uniformity, was calculated for each replicate. The total number of chill hours (total hours ≤ 7 °C) and potential chill-negating hours (hours ≥ 20 °C) during the dormant period (1 Nov. to 31 Dec.) in each year was obtained from the CIMIS Weather Station in Thermal, Calif. Data from each year were analyzed separately using general linear model curve fitting and analysis of variance procedures of SAS (SAS Institute, Cary, N.C.).

Results and Discussion

The slope of the budbreak curves became more steep as H_2CN_2 concentration increased in both years, indicating more rapid and uniform budbreak (Figs. 1 and 2). In 1994, when Armobreak was added at 0.5% or 1%, vines treated with 1% and 2% H_2CN_2 exhibited superior budbreak compared to vines treated with 0.5% H_2CN_2 (Fig. 1). When 2% or 3% Armobreak was added, little difference among H_2CN_2 concentrations was observed. When Armobreak was not used, maximum observed budbreak was greater for vines treated with 1% and 2% H_2CN_2 than for vines treated with 0.5% H_2CN_2 . In contrast, maximum observed budbreak did not differ among H_2CN_2 concentrations when Armobreak was added to the solutions. In 1995, when 2% Armobreak was added, budbreak in vines treated with 0.5% and 1% H_2CN_2 was more rapid than that in vines treated with 2% H_2CN_2 (Fig. 2). Maximum observed budbreak was similar among the treatments in 1995 (Fig. 2).

Interaction between H_2CN_2 and Armobreak was significant ($P < 0.0001$) for the number of days to 70% budbreak in both seasons (Table 1). In 1994, vines treated with 0.5% H_2CN_2 required 54 d to reach 70% budbreak, compared to 48 and 42 d, respectively, for vines

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Fig. 1. Influence of H_2CN_2 and the surfactant Armobreak applied on 15 Dec. 1993, on the budbreak of 'Perlette' grapevines in 1994. Data points are the means of eight, single-vine replications per treatment and were plotted to the following equations: 0.5% H_2CN_2 : $y = 92.956/(1 + e^{-0.132(x-28.701)}) - 6.072$; 1% H_2CN_2 : $y = 150.847/(1 + e^{-0.096(x-15.647)}) - 50.157$; 2% H_2CN_2 : $y = 128.412/(1 + e^{-0.151(x-16.344)}) - 29.379$; 0.5% H_2CN_2 + 0.5% Armobreak: $y = 126.694/(1 + e^{-0.121(x-20.156)}) - 25.684$; 1% H_2CN_2 + 0.5% Armobreak: $y = 109.301/(1 + e^{-0.294(x-15.904)}) - 11.835$; 2% H_2CN_2 + 0.5% Armobreak: $y = 112.756/(1 + e^{-0.314(x-14.328)}) - 14.089$; 0.5% H_2CN_2 + 1% Armobreak: $y = 112.910/(1 + e^{-0.177(x-17.859)}) - 17.722$; 1% H_2CN_2 + 1% Armobreak: $y = 104.271/(1 + e^{-0.443(x-14.681)}) - 5.298$; 2% H_2CN_2 + 1% Armobreak: $y = 105.436/(1 + e^{-0.350(x-15.889)}) - 7.786$; 0.5% H_2CN_2 + 2% Armobreak: $y = 102.462/(1 + e^{-0.352(x-17.298)}) - 4.912$; 1% H_2CN_2 + 2% Armobreak: $y = 104.109/(1 + e^{-0.432(x-14.130)}) - 5.746$; 2% H_2CN_2 + 2% Armobreak: $y = 106.091/(1 + e^{-0.358(x-15.126)}) - 9.101$; 0.5% H_2CN_2 + 3% Armobreak: $y = 105.732/(1 + e^{-0.367(x-16.151)}) - 5.903$; 1% H_2CN_2 + 3% Armobreak: $y = 106.608/(1 + e^{-0.472(x-13.931)}) - 6.805$; 2% H_2CN_2 + 3% Armobreak: $y = 101.468/(1 + e^{-0.559(x-14.329)}) - 1.828$.

treated with 1% and 2% H_2CN_2 . The number of days to 70% budbreak declined for vines treated with 0.5% H_2CN_2 as Armobreak concentration increased, while budbreak was similar among vines treated with 1% or 2% H_2CN_2 and 0.5% to 3% Armobreak. In 1995, vines treated with 0.5%, 1%, and 2% H_2CN_2 required 47, 40, and 36 d, respectively, to reach 70% budbreak. The addition of 2% Armobreak reduced the time to 70% budbreak for vines treated with 0.5 and 1% H_2CN_2 , but had no effect on vines treated with 2% H_2CN_2 . Note that in both years vines treated with 0.5% H_2CN_2 + 2% Armobreak reached 70% budbreak significantly ahead of vines treated with 2% H_2CN_2 alone, the standard commercial treatment in California.

In 1995, several surfactants varying in chemical composition were equally effective in improving H_2CN_2 efficacy (Fig. 3). The budbreak of vines treated with 0.5% H_2CN_2 +

2% Armobreak, 2% Activator 90, or 2% Agridex was similar, and more rapid than that of vines treated with 0.5% H_2CN_2 alone. Maximum observed budbreak was similar for all treatments (Fig. 3).

Bud scales, which protect the bud from desiccation and environmental extremes (Esau, 1977), provide a significant barrier to H_2CN_2 and other agrichemicals. Surfactants appear to increase H_2CN_2 penetration into the bud, reducing the amount of active ingredient necessary for optimum budbreak. Relatively high surfactant concentrations appear to be necessary to enhance chemical penetration into dormant buds. Surfactant concentrations that improved H_2CN_2 efficacy in this study were at least 10-fold greater than those typically used for foliar applications of plant growth regulators (Greenberg et al., 1992; Tan and Crabtree, 1992).

A wide range of H_2CN_2 + surfactant com-

Fig. 2. Influence of H_2CN_2 and the surfactant Armobreak applied 14 Dec. 1994, on the budbreak of 'Perlette' grapevines in 1995. Data points are the means of eight, single-vine replications per treatment and were plotted to the following equations: 0.5% H_2CN_2 : $y = 11.917 - 4.264x + 0.341x^2 - 0.004x^3$; 1% H_2CN_2 : $y = 348.867/(1 + e^{-0.107x}) - 245.991$; 2% H_2CN_2 : $y = 843.251(1 + e^{-0.186x}) - 745.348$; 0.5% H_2CN_2 + 2% Armobreak: $y = 23009.655(1 + e^{-0.461x}) - 22909.803$; 1% H_2CN_2 + 2% Armobreak: $y = 2770.186(1 + e^{-0.283x}) - 2669.451$; 2% H_2CN_2 + 2% Armobreak: $y = 602.588(1 + e^{-0.149x}) - 500.825$.

binations had similar effects on budbreak in this study (Table 1). The optimum treatment from an economic standpoint will therefore vary based on the cost and availability of each chemical. At present, the comparatively high cost of H_2CN_2 favors increased surfactant concentration. Yearly variations in environmental conditions and various endogenous factors that regulate plant responses to dormancy-breaking treatments must also be considered when selecting chemical concentrations. In 1994, H_2CN_2 concentrations of 0.5%, 1%, and 2%, combined with 2% Armobreak, produced similar results, and significantly advanced budbreak compared with 2% H_2CN_2 applied alone (Table 1). In 1995, however, only 0.5% H_2CN_2 + 2% Armobreak was more effective than 2% H_2CN_2 applied alone. This variability in vine response was probably related to plant dormancy status at the time of treatment. Total hours $\leq 7^\circ\text{C}$ during the dormant period were similar, 320 and 340, respectively, in 1993 (1994 growing year) and 1994 (1995 growing year). However, vines were exposed to 270 h $\geq 20^\circ\text{C}$ during the 1993 dormant period compared to only 140 h in 1994. Thus the potential chilling negation was greater, and the net chilling exposure lower, for 1994 than for

Fig. 3. Influence of 0.5% H_2CN_2 , applied with and without surfactants on 14 Dec. 1994, on the budbreak of 'Perlette' grapevines in 1995. Data points are the means of eight, single-vine replications per treatment and were plotted to the following equations: 0.5% H_2CN_2 : $y = 2346.789(1 - e^{-0.129x}) - 2238.836$; 0.5% H_2CN_2 + 2% Armobreak: $y = 63896.310(1 - e^{-0.280x}) - 63798.998$; 0.5% H_2CN_2 + 2% Agridex: $y = 73509.289(1 - e^{-0.282x}) - 73410.10$; 2% H_2CN_2 = 2% Activator 90: $y = 67459.117(1 - e^{-0.279x}) - 67360.998$.

1995 (Erez et al., 1979). Previous studies have shown that while >2% H_2CN_2 may be required for optimum budbreak in warm winters, such rates may inhibit budbreak under more favorable chilling conditions (Lavee and May, 1997).

The optimum H_2CN_2 concentration for improving the total budbreak and budbreak uniformity of grapevines grown in low chill regions ranges between 2% and 2.5% (Lavee et al., 1984; McColl, 1986; Wicks et al., 1984). At present, 2% H_2CN_2 is the standard commercial treatment for grapevines in the Coachella Valley (Neja et al., 1994). Our results indicate that this concentration may be reduced up to 75%, and treatment efficacy maintained or even improved, when 2% surfactant is added to the solution. Depending upon the H_2CN_2 + surfactant combination selected, the addition of surfactants can reduce chemical costs 25% to 50% compared with the use of 2% H_2CN_2 alone. Additional studies are needed to determine the effect of chilling exposure on H_2CN_2

× surfactant rate interactions, as well as to further examine the effects of surfactant composition on the performance of H_2CN_2 and other dormancy-breaking agents.

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Table 1. Influence of H_2CN_2 and Armobreak concentrations on the number of days required for 'Perlette' grapevines to reach 70% budbreak after treatment in 1994 and 1995.

H_2CN_2 (%)	Armobreak (%)	No. days to reach 70% budbreak	
		1994	1995
0.5	0	54 a ²	47 a
	0.5	47 bc	---
	1	43 cd	---
	2	38 e	32 d
	3	36 e	---
1	0	48 b	40 b
	0.5	37 e	---
	1	35 e	---
	2	34 e	34 cd
	3	34 e	---
2	0	42 d	36 c
	0.5	36 e	---
	1	37 e	---
	2	37 e	38 c
	3	34 e	---

²Mean separation within years using Duncan's multiple range test at $P < 0.001$.

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