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Improving Grapevine Budbreak and Yields by Evaporative Cooling

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Abstract. **The effect of evaporative cooling on budbreak and yield of *Vitis vinifera* L. ('Perlette' and 'Thompson Seedless') vines grown in the southern Jordan Valley in Israel was investigated. Overhead microsprinklers were operated from 0600 to 1800 HR daily during the autumn and winter months, either alone or in combination with cyanamide sprays after pruning. Evaporative cooling decreased the temperature of buds exposed to direct sunlight from 30° to 16°C and that of shaded buds from 25° to 13°. Evaporative cooling induced an early uniform budbreak. However, when evaporative cooling was combined with cyanamide spray, its effect was evident only during the initial phase of bud emergence. In 1985 cyanamide spray and evaporative cooling alone increased yield of 'Perlette' by 6% and 6% to 24%, respectively, and by 17% to 46% when both treatments were combined. In 1986 prolonged evaporative cooling increased the yield of 'Perlette' by 25% but, in combination with cyanamide, by only 11.6% over the unwetted cyanamide-treated control. In both years, evaporative cooling with or without cyanamide advanced fruit maturation.**

In many warm areas, grapevines suffer from insufficient chilling needed to induce full and uniform budbreak (9, 10). The problem is most severe in early maturing cultivars grown in regions where sunny and clear days prevail during autumn and winter. In these regions, the days are hot and temperatures of the buds exposed to the sun exceed considerably those of the air. The detrimental effect of high day temperatures during autumn and winter on budbreak has been demonstrated in peaches (2–4). A negation by high day temperatures of the chilling acquired during the colder night period was shown.

In recent years, cyanamide has been used to improve budbreak of grapevines and of some other deciduous species (2, 9, 11). This chemical sometimes can substitute for chilling, although in extreme cases it is only partly effective. In situations where early maturation is forced by means of very early pruning and polyethylene covers (9), or complete budbreak of cane-pruned cultivars is desired, the effect of cyanamide is not satisfactory.

The objective of this study was to evaluate evaporative cooling to counteract the effect of high day temperatures for improved budbreak of grapes. Aspects of early and uniform budbreak were studied using evaporative cooling alone and in combination with cyanamide treatments.

Materials and Methods

'Perlette' and 'Thompson Seedless' grapevines were used in this study. 'Perlette' vines were spur-pruned and 'Thompson Seedless' cane-pruned. The experiment was conducted at Gilgal in the southern Jordan Valley of Israel, 270 m below sea level. Vine and row spacings were 1.5 and 3.0 m, respectively (2200 vines/ha) with "factory roof" trelissing.

Evaporative cooling was attained using overhead microsprinklers with Dan-7755 microjets (Dan Sprinklers, Kibbutz Dan, Israel). The nozzles were spaced 3 m apart along the rows, nominally discharging 120 liters of water per hr, in very small droplets. A water gauge recorded total cumulative water application. The sprinklers were operated daily from 0600 to 1800 HR for 1.5 min at 15- to 20-min intervals. This interval and duration ensured complete wetting of canes just before they dried off completely. Single lines of elevated sprinklers were positioned over each of two adjacent rows with pairs of non-treated guard rows in between. The experiment was designed as a complete randomized block with three replicates of eight vines in 1984–85 and 13 to 15 vines in 1985–86.

In 1984, treatments were initiated in the 'Perlette' vineyard on 12 Nov. and continued until pruning on 6 Jan. 1985 or until 19 days later. Treatments in the 'Thompson Seedless' vineyard were initiated on 4 Dec. 1984 and terminated on 25 Jan. 1985.

In 1985–86, a time–duration study was conducted on both grape cultivars. The date and duration of each cooling treatment in the 'Perlette' vineyard were as follows: early, 15 Oct.–28 Nov.; late, 28 Nov.–5 Jan.; and early + late, 15 Oct.–5 Jan. In the 'Thompson Seedless' vineyard the dates of evaporative cooling were: early, 3 Nov.–12 Dec.; late, 12 Dec.–25 Jan.; and early + late, 3 Nov.–25 Jan.

When cyanamide treatment was combined with evaporative cooling, it was applied as a canopy spray (5% to 7% Alzodef, SKW, F.R.G., containing 500 g·liter^{-1} hydrogen cyanamide), immediately after pruning.

Air temperature and relative humidity were recorded continuously with a thermohygrograph situated within the plot at vine height. Bud temperatures were measured once each season in mid-December using thermistors situated within the buds and recorded by a multi-channel recorder. Only the data from 1984–

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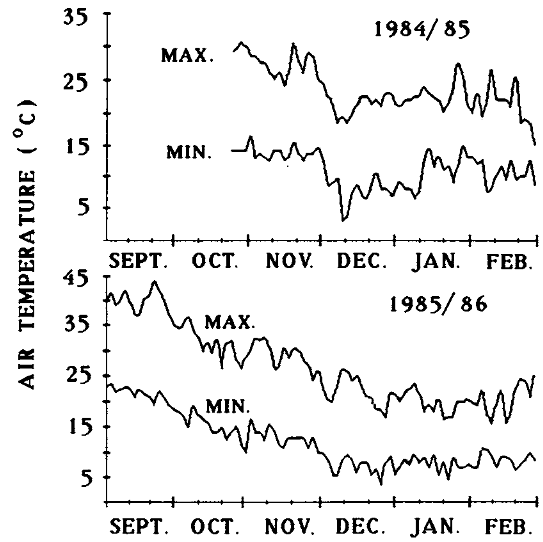

Fig. 1. Daily minimum and maximum air temperatures at Gilgal during the autumn and winter, 1984–1985 and 1985–1986.

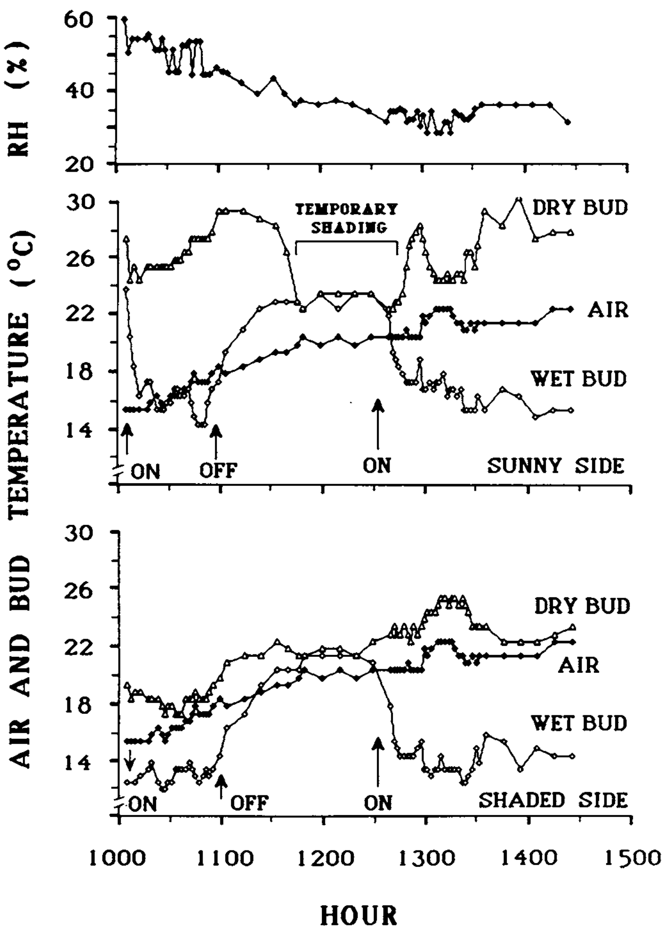

Fig. 2. The effect of evaporative cooling on the temperatures of buds of shaded and exposed grapevine canes at the southern Jordan Valley. Measurements were taken with thermistor sensors on 19 Dec. 1984. Arrows indicate time of manually turning the system on or off.

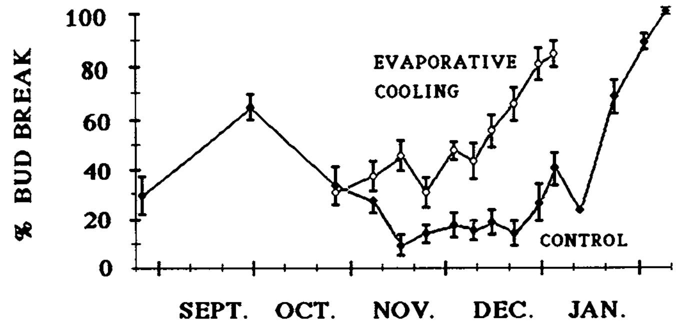

Fig. 3. Percent budbreak of single-node cuttings prepared from 'Perlette' canes during evaporative cooling treatment (budbreak was recorded after 20 days).

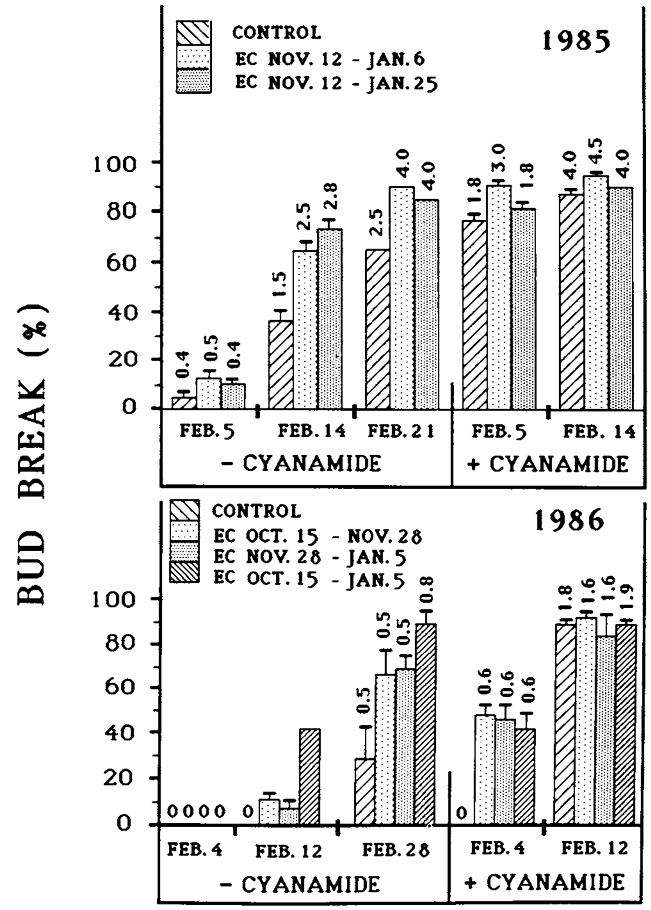

Fig. 4. The effect of evaporative cooling (EC) and cyanamide (5% to 7% Alzodef) sprays on budbreak of 'Perlette' grapevines in the southern Jordan Valley, 1985 and 1986. Numbers above columns represent the mean stage of shoot development: 1.0 = one leaf stage, 2.0 = two leaf stage, etc. Bars represent ± SE.

1985 are presented, since the results of both seasons were similar.

Canes from the different treatments were collected and sectioned into single-node cuttings. Five to 10 replicates of 10 cuttings for each treatment were placed with their bases immersed in water in an illuminated growth chamber at 23°C. The degree of dormancy was deduced from percent budbreak after 20 days.

The time, percent, and uniformity of budbreak, stage of shoot development, and the time of flowering were recorded in both vineyards on four to eight vines per replicate. The yield of each replicate was weighed and a sample was taken for tests of maturity (acidity and titratable soluble solids) for determining optimal harvest date. For each treatment, the mean ± SE was

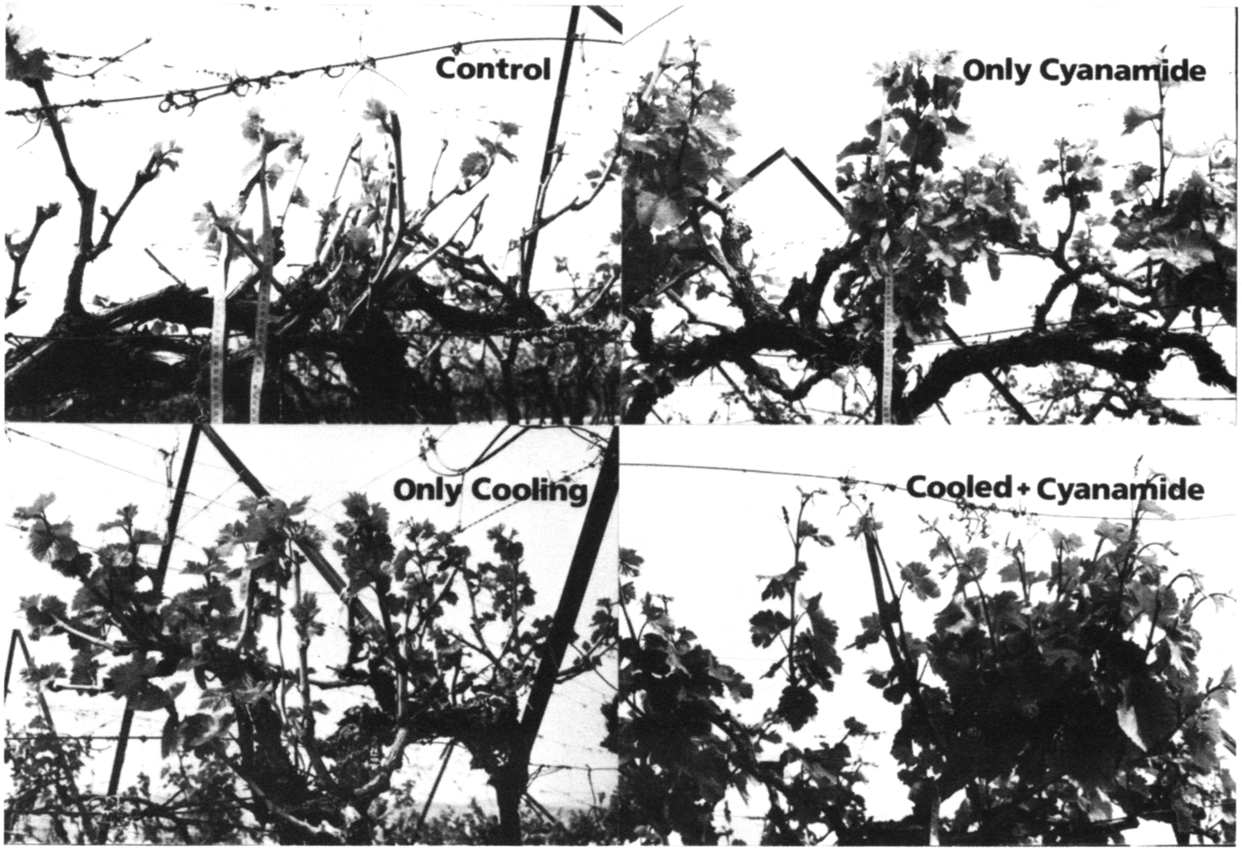

Fig. 5. Budbreak and shoot development of 'Perlette' grapevines after different combinations of evaporative cooling and cyanamide sprays (5% Alzodef). Photograph taken on 5 Feb. 1985.

calculated. Statistical differences were considered significant at the level of $P = 0.05$.

Results

The minimum and maximum air temperatures were recorded in the autumn and winter of 1984–85 and 1985–86 (Fig. 1). In 1984–85, during November, the minimum was close to 15°C and the maximum was above 25° (Fig. 1). In December, the daily minimum temperature decreased to 5° to 10° and the maximum to 20° to 25°. During January and February, the minimum temperature fluctuated around 10°. In 1985–86, maximum and minimum temperatures decreased gradually until they leveled off at the end of November, ≈15° and 5°, respectively.

Until the end of November, leaves usually persist on the vines, mostly at the tip of the shoots. Evaporative cooling enhanced the shedding of these leaves. The effect of evaporative cooling on bud temperatures was measured on 19 Dec. between 1000 and 1500 HR, when air temperatures rose from 16° to 23°C and the relative humidity declined from 55% to 30% (Fig. 2). The evaporative cooling system on the day of bud temperature measurement was operated manually, and turned on, off, and on again to trace closely the response of cooling and the duration of temperature equilibration of the buds.

When air temperature was 16°C, the temperature of buds exposed to the sun was 25°. The temperature of exposed wetted buds dropped to 14° and that of shaded wetted buds to 12°. At mid-day, the exposed bud became shaded and its temperature decreased considerably, but remained 1° to 2° higher than the air temperature, until it was exposed to the sun again. In the early afternoon, the temperature within the exposed unwetted buds reached 30°, whereas that in the exposed wetted buds was only 16°. Complete temperature equilibration between dry and wetted buds occurred within 30 to 60 min after turning off the sprinklers.

Percent budbreak of single node cuttings prepared from canes sampled from the experimental plot and maintained at 23°C increased at the end of September before decreasing gradually until mid-November (Fig. 3). Similar changes in bud dormancy were observed during 1982–86 (G.N., unpublished data). In January, bud dormancy decreased again gradually and, by mid-February, budbreak of the cuttings was essentially 100%. Evaporative cooling decreased the dormancy of buds of these cuttings as early as mid November, or ≈1 month after the treatment was imposed. The increase in percent budbreak and the final decrease in dormancy of the buds wetted throughout the winter season preceded that of the controls by ≈1 month.

The effect of evaporative cooling on budbreak. In 1984–85, evaporative cooling significantly enhanced budbreak of 'Perlette' vines, particularly when applied without cyanamide. One month after pruning (5 Feb.), 4.9% of the buds of unwetted control buds emerged, as compared with 12.5% and 10.3% in the wetted and prolonged wetted treatments, respectively (Fig. 4). The young leaves emerging from buds of the prolonged wetted treatment had a reddish color, indicating some stress. The effect of evaporative cooling still persisted on 21 Feb., 16 days after initial budbreak. Application of cyanamide as a budbreaking agent caused 76.5% budbreak on 5 Feb. The addition of evaporative cooling to the vines increased bud opening to

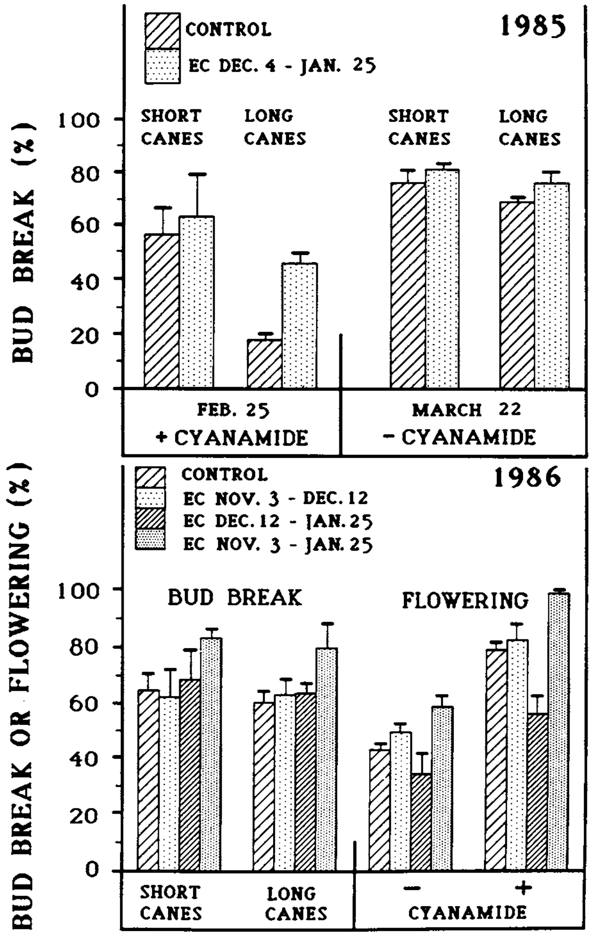

Fig. 6. The effect of evaporative cooling (EC) and cyanamide treatment on percent budbreak and flowering of 'Thompson Seedless' grapevines in the southern Jordan Valley. Percent budbreak in 1986 on cyanamide-treated vines was recorded on 13 Mar. and flowering on all treatments on 10 Apr. Bars represent ± SE.

90.3% and 81.6% in the wetted and prolonged wetted treatments, respectively. In addition, shoots on wetted vines were more developed than those on the control. Evaporative cooling increased the uniformity of budbreak, both in cyanamide-treated and in control vines (Fig. 5).

In the second year of the experiment, wetting treatments in 'Perlette' started earlier (15 Oct.), and their effect on budbreak was evident with or without a cyanamide spray (Fig. 4, 1986). Once again, evaporative cooling without cyanamide advanced budbreak significantly. On 28 Feb., more than 16 days after initial emergence of buds in the wetted treatments, budbreak of the control was only one-third that of the continuously wetted treatment. The effect of evaporative cooling combined with cyanamide spray was evident only on 4 Feb., at the very onset of budbreak. On 12 Feb., cyanamide was as effective alone as in combination with evaporative cooling.

Budbreak of 'Thompson Seedless' grapevines was recorded separately on short (up to six buds) and long pruned canes. In 1985, budbreak on the cyanamide-treated vines was evident on 25 Feb., whereas buds on untreated vines started to open only on 22 Mar. (Fig. 6). The effect of evaporative cooling was evident mainly on cyanamide-treated, long, pruned canes, causing doubling of the percent budbreak as early as 25 Feb.

In 1986 (13 Mar.), percent budbreak was recorded only on cyanamide-treated vines. Budbreak of cyanamide-treated short and long pruned canes of the prolonged wetted treatment (early + late) was 83.1% and 79.9%, respectively, whereas that of all the other treatments ranged from 60.1% to 68.6% (Fig. 6). As in 'Perlette', budbreak of 'Thompson Seedless' was more uniform on wetted vines than on the control, and the shoots that developed from those buds were more advanced (Fig. 7).

Percent flowering was recorded on 10 Apr. in all the treatments. The percent of inflorescences in full bloom in the early wetted treatment and the control was very similar. This similarity included both cyanamide-treated and untreated vines. The late short wetted treatment delayed flowering significantly. On the other hand, prolonged wetting (early + late) markedly enhanced flowering as compared with the other treatments.

The effect of evaporative cooling on yield. In 1985, evaporative cooling without cyanamide increased the yield of 'Perlette' vines in accordance with the duration of the wetting treatment (Table 1), but the increase over the control was not significant. Evaporative cooling combined with cyanamide treatment increased the yield from 20.3 $t\cdot ha^{-1}$ in the control to 29.6 and 23.7 $t\cdot ha^{-1}$ in the short and prolonged wetted treatments, respectively.

In 1986, the yield of cyanamide-treated vines was higher than the respective untreated vines (Table 2), except for the prolonged wetted treatment, which had similar yields with or without cyanamide. There were no significant differences between the early or late short-term wetted treatment and the control, but the prolonged wetting (early + late) treatment without cyanamide spray had a significantly greater yield ($P = 0.05$) than the control.

Cyanamide treatments advanced fruit maturation in both seasons. In 1985, the first picking of fruit in the cyanamide treatments was on 21 May. At this time, 47.6% of the fruit was picked in the wetted treatment and only 30.3% in the unwetted control (Table 1). In the prolonged wetted treatment, 15.8% of the fruit was picked at that date. The second and final harvest took place on 30 May. Treatments without cyanamide were harvested on 5 June, regardless of treatment. In 1986, 12.2% to 20.7% of the fruit was picked in the first harvest of the evaporative-cooled and cyanamide-treated vines, as compared with only 7.8% in vines with cyanamide and without cooling (Table 2). In the treatments without cyanamide, evaporative cooling increased the proportion of fruit picked at the first harvest from 12.3% in the control to 34.7%, 23.2%, and 33.4% in the early, late, and prolonged (early + late) wetted treatments, respectively.

Discussion

It was demonstrated previously that evaporative cooling decreased peach and nectarine bud temperatures by 3° to 5°C (3, 6). The low humidity prevailing in the southern Jordan Valley was conducive to high rates of evaporation, which explains the marked effect of wetting on bud temperatures in this study. The large differences in temperature between shaded and exposed buds may explain the uneven budbreak in such a warm region. Evaporative cooling reduces these differences, thus improving synchronization of budbreak. The pronounced effect of evaporative cooling operating only during the warmer daytime hours is in agreement with the previous studies showing the adverse effect of high day temperatures on the accumulation of chilling units needed to overcome dormancy (2, 4).

The wetting of the vines advanced the time of budbreak, as determined by the rate of bud opening following pruning. The

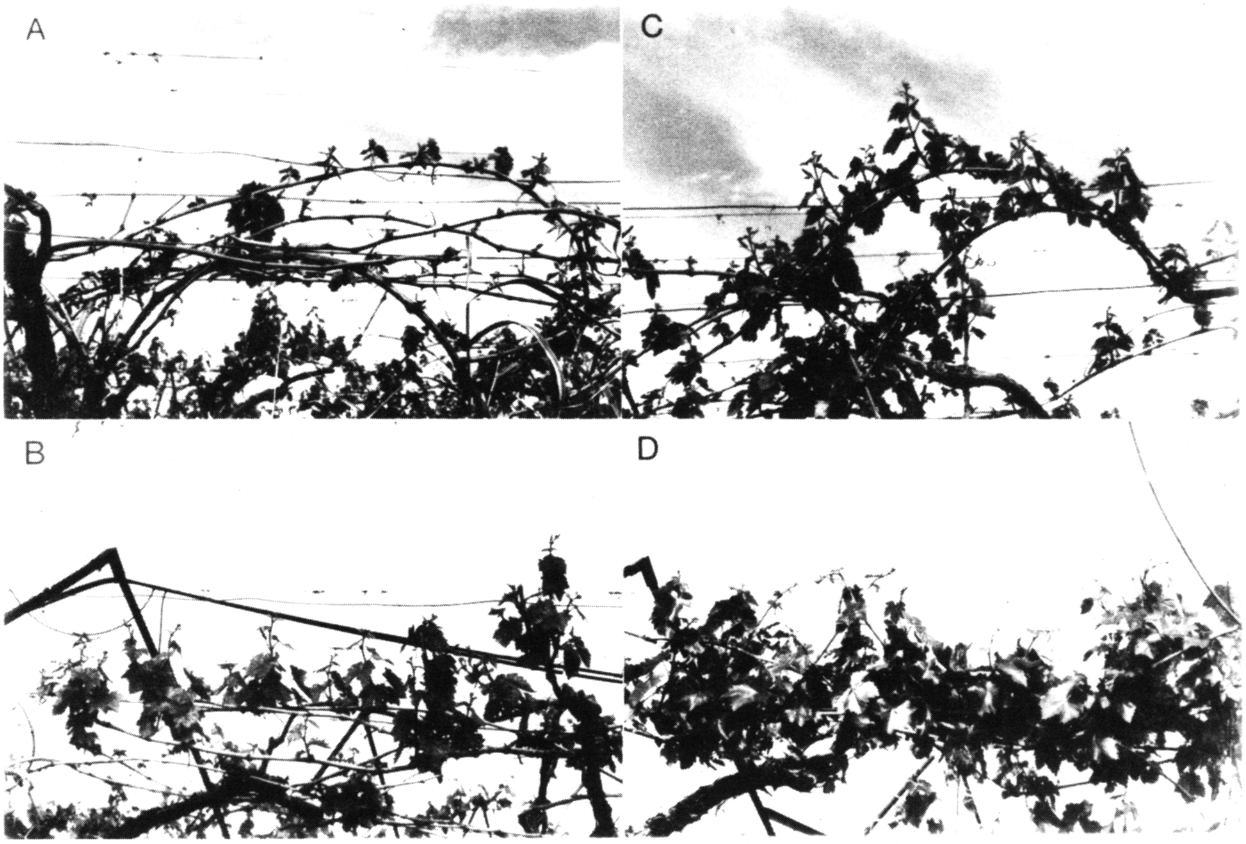

Fig. 7. 'Thompson Seedless' budbreak and shoot development after treatment with prolonged evaporative cooling and cyanamide spray. Photographs were taken on 13 Mar. 1986. (**A**) Untreated control. (**B**) Evaporative cooling alone. (**C**) Cyanamide (5% Alzodef) alone. (**D**) Evaporative cooling + cyanamide.

Table 1. The effect of evaporative cooling on the date of harvest and yield of 'Perlette' grapes in the southern Jordan Valley in 1985.

Period of evaporative cooling	Without cyanamide		With cyanamide	
	Harvested 5 June		Harvested 21 May + 30 May	
	$t \cdot ha^{-1}$	Percent of total	$t \cdot ha^{-1}$	First picking (%)
Control	19.1 ± 1.7[z]	100	20.3 ± 3.2	30.3
12 Nov.–5 Jan.	20.3 ± 1.6	100	29.6 ± 4.6	47.6
12 Nov.–25 Jan.[y]	23.7 ± 3.1	100	23.7 ± 12.4	15.8

[z] Mean ± SE.
[y] Evaporative cooling in this treatment was continued after pruning (6 Jan.).

Table 2. The effect of evaporative cooling on the date of harvest and yield of 'Perlette' grapes in the southern Jordan Valley in 1986.

Period of evaporative cooling	Without cyanamide		With cyanamide	
	Harvested 19 May + 27 May		Harvested 12 May + 25 May	
	$t \cdot ha^{-1}$	First picking (%)	$t \cdot ha^{-1}$	First picking (%)
Control	21.0 ± 1.4[z]	12.3	27.4 ± 2.3	7.8
15 Oct.–28 Nov.	17.1 ± 2.2	34.7	26.3 ± 3.4	13.1
28 Nov.–5 Jan.	20.6 ± 2.8	23.2	30.6 ± 4.4	12.2
15 Oct.–5 Jan.	26.2 ± 2.8	33.4	27.7 ± 0.5	20.7

[z] Mean ± SE.

difference in the rate of budbreak between wetting and control was more pronounced and lasted longer when cyanamide was not applied than when it was. When evaporative cooling was combined with cyanamide spray, budbreak also occurred early, but the differences persisted for only ≈1 week at the initial phase of bud emergence. During that stage, the effects of evaporative cooling and cyanamide appeared to be additive. About 1 week after initial budbreak, the effect of cyanamide was fully expressed and evaporative cooling did not contribute any more to percent budbreak, which then was essentially complete. Early pruning (in December), combined with cyanamide spray, has been found to advance budbreak, but the final percentage of open buds is low and bud growth is non-uniform (9). Early opening of a few buds increases the polarity and competition between shoots on the vine. The early effect of evaporative cooling on budbreak when used alone or in combination with cyanamide resulted in highly uniform budbreak and shoot growth.

When evaporative cooling was continued after pruning on 'Perlette' vines, budbreak was slightly delayed and the young leaves that emerged were somewhat stressed. This effect of evaporative cooling has been used to delay bud opening of peaches (1) and plums in the Golan Heights, (A. Peleg, unpublished data) where the bloom is usually damaged by spring frosts.

Prolonged wetting, which did not extend past the time of pruning, was most effective in breaking the dormancy of grapevine buds, but, when cyanamide was sprayed on vines of this treatment, there was a slight decrease and delay of budbreak. These results indicate that buds on vines of the prolonged wetted treatment were already nondormant at the time of the cyanamide spray, thus becoming very susceptible to phytotoxicity of cyanamide. Cyanamide also is a herbicide (9), which is probably the reason for the ineffectiveness of cyanamide treatments or even damage occurring sometimes in cool areas, where natural chilling is sufficient to break dormancy (7, 13). Thus, it may be necessary to reduce concentrations of cyanamide when the material is applied after prolonged wetting to avoid phytotoxicity. The evaporative cooling improved percent and uniformity of budbreak also in long, pruned 'Thompson-Seedless', although in 1986 only the prolonged wetted treatment was effective.

In spite of an improvement in budbreak of 'Thompson Seedless', evaporative cooling did not increase yields in this cultivar. The reason for this is unclear.

Complete budbreak of the grapevine is a prerequisite for achieving maximum yield, whereas advancing the time of budbreak is essential for early maturation. Attempts to achieve both objectives by use of a cyanamide spray and early pruning were rarely successful, since earliness is associated with incomplete budbreak and vice versa (9). The use of evaporative cooling in combination with cyanamide enabled the achievement of both objectives (Figs. 4–7). Evaporative cooling alone improved yield and earliness of 'Perlette' only in 1986 in the prolonged wetted treatment, whereas cyanamide alone (which caused earliness in both years) failed to increase yield in 1985. The combination of the two treatments, however, successfully advanced harvest date and increased yield of 'Perlette' in both seasons.

Evaporative cooling consumed large volumes of water (91 $m^3 \cdot ha^{-1} \cdot day^{-1}$). The water applied evaporated from the grape canopy and from the top 2 to 5 cm of the soil without contributing to the water reservoir in the soil. Shutting off the system (using the thermostats) whenever air or bud temperatures are low during autumn and winter could improve efficiency in terms of water consumption.

The economic value of evaporative cooling is yet to be established, but a well-designed system may be used with slight modifications also for irrigating the vineyard, using the same microjets but lowered to ground level. The overhead microjets also can be used to overcome frost hazards and for improving fruit quality (e.g., size, sugar content, and color) by reducing supra-optimal temperatures (35°C) during fruit development, provided that the water contains only small amounts of salts (5, 8, 12).

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