# Response of Grapevines to Soybean Oil Application

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**Abstract:** Chancellor, Chambourcin, and Chardonel grapevines were treated with soybean oil-based adjuvants and then compared to untreated (control) vines for phytotoxicity, date of budbreak, yield components, and fruit composition. The purpose of dormant oil application was to delay budbreak without affecting date of fruit ripening, yield, or fruit composition. In the first year, Prime Oil and Amigo were applied at a 10% concentration (v/v) to runoff with a backpack sprayer on three different dates during the dormant season. Prime Oil but not Amigo was phytotoxic to dormant buds in all three cultivars. Both oil treatments led to a significant budbreak delay in all cultivars ranging from 1 to 20 days as compared to control vines. A reduced carbon dioxide exchange from oil-treated buds was associated with a delay in bud development. At harvest, cultivars that sustained bud injury from Prime Oil treatment had reduced yields and delayed fruit maturity; conversely, Amigo did not affect yield components or fruit composition. In the second year, six rates (0%, 2%, 4%, 6%, 8%, and 10%) of Amigo oil were applied to Chambourcin and Chardonel grapevines and none was phytotoxic to either cultivar. Rates of 8% and 10% (v/v) delayed budbreak in Chardonel, but not in Chambourcin. None of the rates resulted in any deleterious effects on fruit set, yield components, or fruit composition in either cultivar. Grapegrowers may consider soybean oil application as an efficient and affordable practice that may protect early cultivars against spring frost injury by delaying the date of budbreak.

**Key words:** delayed budbreak, phytotoxic, spring frost

Winter freeze and spring frost are common events in continental climates. Consequently, commercial grape production under those conditions is risky and may occasionally suffer substantial economical losses due to cold-induced injury (Howell 2000, USDA 1986, Wolfe 2000). While appropriate site selection is the best method for avoiding cold injury (Bartholic and Martsolf 1979, Evans 2000, Stergios and Howell 1977, Wolf and Boyer 2000), many vineyards are established in less than ideal sites. Different methods of frost protection have been used commercially, with varying effectiveness and cost (Dami 1997, Evans 2000, Howell 1988, Rieger 1989, Wample and Wolf 1996). One of the low-cost methods consists of applying chemicals, including growth regulators, antitranspirants, cryoprotectants, and dormant oils (Call and Seely 1989, Dami et al. 1996, 2000, Myers et al. 1996, Rieger 1989). Dormant oils have been used for insect control in fruit trees (Pless 1995); however, bloom and shoot growth delays have been observed as side effects (Call and Seely 1989, Deyton et al 1992, Myers et al. 1996). Myers et al. (1996) found that the application of soybean oil to peach trees resulted in a six-day delay in bloom. Although not as severe as petroleum-based oils, soybean oil application caused significant phytotoxicity. Dormant oil application on grapevines was first reported in Virginia using petroleum- and vegetable-based oils (Dami et al. 2000). Petroleum-based oils were more phytotoxic than soybean oil when used at the same rate.

In this study, soybean oils were used with the purpose of delaying budbreak of important grape cultivars in the Midwest. Our specific objectives were (1) to compare commercially available and vegetable oil-based adjuvants and evaluate their phytotoxicity in three hybrid cultivars, (2) to determine the optimum time of application for maximum effectiveness of oils, (3) to determine the effects of oil application on time of budbreak, yield, and fruit composition, and (4) to attempt to elucidate possible mechanisms of budbreak delay by oil application.

## Materials and Methods

**Experiment 1: 1999 to 2000.** The first experiment was conducted at Alto Vineyards in Alto Pass, Illinois. It had a 3 x 3 factorial, completely randomized design with three oil treatments and three application dates. Four replications were used with three-vine plot units. The treated *Vitis* spp. cultivars were 15-year-old Chambourcin, 17-year-old Chancellor, and 4-year-old Chardonel. Vines were spaced 2.4 m x 2.7 m (vine x row). Chambourcin and Chardonel were trained to a high bilateral cordon system. Chancellor was trained to a vertical shoot positioned system. Vines were balance-pruned during the dormant season and subjected to standard vineyard management practices during the growing

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season (I.E. Dami 1999, unpublished data). Two soybean oil-based adjuvants, Amigo (Loveland Industries, Greeley, CO) and Prime Oil (Riverside/Terra Corp., Sioux City, IA), were applied at a 10% concentration (v/v). The 10% concentration consists of 9.3% oil and 0.7% emulsifier in Amigo, and 9.0% oil and 1% emulsifier in Prime Oil. Prime Oil solutions were applied on dormant canes to runoff (~0.7 L/vine) using a backpack sprayer. Applications were made to each of the three unpruned cultivars on three dates: 29 November 1999 (date 1), 28 December 1999 (date 2), and 3 February 2000 (date 3).

**Oil phytotoxicity to dormant buds.** Bud injury was evaluated on 27 February 2000 after all oil applications were completed. Twelve to 24 canes were collected from each treatment for the phytotoxicity study. On each cane, only the 15 basal buds were visually examined for signs of tissue injury. Bud injury was indicated by necrosis or by water-soaked and brown appearance within the bud scales on the primary, secondary, or tertiary bud. Most of the injury observed was located in the primary bud. The 15 buds were analyzed collectively, then divided in three groups (or positions) of five buds each as follows: position 1: buds 1 to 5; position 2: buds 6 to 10; and position 3: buds 11 to 15. Bud position was investigated to determine whether phytotoxicity was different between basal and apical buds. Mixed model procedure was used to conduct tests for fixed effects of application date, oil treatments, bud position and their interactions (SAS statistical software; SAS Institute, Cary, NC).

**Carbon dioxide exchange in dormant buds.** Canes were collected from all treatments in Chardonel and Chancellor on 22 and 23 March, respectively, approximately 5 weeks before budbreak. The canes were excised into one-node sections about 2.5 cm in length. Forty sections were collected from each treatment, collectively weighed, and then placed in an airtight plastic bag. Carbon dioxide ($CO_2$) concentration inside the bag was measured with an ADC 2250 series gas analyzer (ADC Gas Analyzers Ltd., UK) according to Miller et al. (1996). Carbon dioxide concentration was then analyzed for oil, date and interactions using the general linear model of SAS statistical software.

**Budbreak.** In the spring and following pruning, vines were visually evaluated for budbreak. Total bud counts for each vine were recorded prior to budbreak initiation. Budbreak was determined as stage five of the Eichhorn and Lorenz (1977) scale of grapevine development. Stage five indicates that the bud scales have expanded to the point at which the green shoot is visible. Budbreak was evaluated twice a week throughout the spring until each treatment reached ≥80%. Budbreak response was analyzed using the generalized model procedure of SAS statistical software, with date and oil type treated as categorical variables, while day of observation was treated as a continuous variable.

**Yield components.** At harvest, yield components and fruit composition were measured to determine whether oil applications affected harvest parameters. Harvest time was chosen according to the fruit composition of the control, and all treatments were harvested on the same date. Chancellor was harvested on 29 August 2000, Chardonel on 1 September 2000, and Chambourcin on 15 September 2000. Clusters were counted and crop weights were measured for each vine. Cluster weight was computed by dividing crop weight by cluster number per vine; 100-berry weight was also measured.

**Fruit composition.** Fruit composition included soluble solid concentration (Brix), pH, and titratable acidity (g/100 mL). Fruit composition was measured for each treatment using 100-berry samples. The samples were frozen at -20°C at harvest and then thawed to ambient room temperature on the day of measurement. All data for yield components and fruit composition were analyzed with SAS statistical software using ANOVA and Duncan's multiple range test for mean separation.

**Experiment 2: 2000 to 2001.** The second experiment was also conducted at Alto Vineyards. The objectives were to determine the phytotoxic effect of various oil rates on bud viability, inflorescence count, and fruit set and to determine the effect of each oil rate on time of budbreak, yield, and fruit composition. The experiment was set up as a completely randomized design, with a single factor (oil concentration) and six replications. Amigo oil was applied on 23 January 2001 to runoff (~0.7 L/vine) at six concentrations: 0%, 2%, 4%, 6%, 8%, and 10% (v/v), using a backpack sprayer. Two cultivars were used, Chambourcin and Chardonel. In year 2, parameters were measured and data collected in a manner consistent with year 1 (described above). Regression analyses were performed to test the effects of oil concentrations on phytotoxicity, fruit set, budbreak, yield components, and fruit composition using the general linear model (SAS statistical software).

## Results and Discussion

**Oil phytotoxicity to dormant buds.** Oils caused various levels of injury depending on the adjuvant type and cultivar. Prime Oil caused the most injury in all three cultivars when compared to Amigo and controls (Table 1). Bud injury in vines treated with Prime Oil ranged from 6% to 10%, while vines treated with Amigo sustained 4% to 5% injury (Table 1). However, injury in Amigo-treated vines was not different from that of control vines (Table 1), indicating that at a 10% rate, Prime Oil but not Amigo is phytotoxic to all three cultivars. There was a date effect in Chancellor, with date 1 showing the most injury (12%) (Table 1). Most injury occurred with Prime Oil-treated vines on 29 November 1999 (date 1), corresponding to the first use of the oil. We speculate that perhaps the oils were not thoroughly mixed before and during application, which led to uneven application of higher rates than desired. There was also a bud position effect in Chambourcin, with the basal buds showing more injury than apical buds (Table 1). This response is not desirable, as basal buds are usually retained after pruning. The other cultivars did not show this response. Overall,

**Table 1** Bud injury of Chancellor, Chambourcin, and Chardonel grapevines in response to oil type, date of application, and bud position in 2000.

| | Injury (%) | | |
|---|---|---|---|
| **Variable** | **Chancellor** | **Chambourcin** | **Chardonel** |
| Amigo | 5 b[a] | 4 ab | 5 b |
| Prime | 10 a | 6 a | 10 a |
| Control | 4 b | 2 b | 4 b |
| Date 1[b] | 12 a | 4 | 7 |
| Date 2 | 5 ab | 4 | 5 |
| Date 3 | 3 b | 3 | 8 |
| Position 1[c] | 6 | 5 a | 6 |
| Position 2 | 6 | 5 a | 8 |
| Position 3 | 7 | 2 b | 6 |
| ANOVA[d] | | | |
| Oil | ** | * | * |
| Date | * | ns | ns |
| Position | ns | * | ns |

[a]Means with same letters, for a given variable, are not significantly different at $p \leq 0.05$.

[b]Date 1: 29 Nov 1999; date 2: 28 Dec 1999; date 3: 3 Feb 2000.

[c]Position 1: buds 1-5; position 2: buds 6-10; position 3: buds 11-15.

[d]*, **, and ns indicate significance at $p \leq 0.05$, 0.01, and not significant, respectively, according to the F test. All interactions were not significant.

there were no interactions among oil, date, and bud position in all cultivars. Oil phytotoxicity has been reported in fruit trees (Myers et al. 1996). Dami et al. (2000) indicated that rates above 10% of soybean oil are phytotoxic to dormant grape buds. This study corroborates those findings even though different grape cultivars were used. It should also be noted that these oil adjuvants are premixed with emulsifiers. Emulsifiers may also cause a phytotoxic response. The higher phytotoxicity of Prime Oil as compared to Amigo may be caused by the higher emulsifier concentration in the former rather than the soybean oil effect per se.

In the second year, rates of 0%, 2%, 4%, 6%, 8%, and 10% (v/v) Amigo had no effect on bud injury in Chambourcin and Chardonel (data not shown). Rates of 10% Amigo (9.3% soybean oil + 0.7% emulsifier) or lower do not appear to be phytotoxic in the cultivars studied.

**Carbon dioxide exchange in dormant buds.** The emission of carbon dioxide in Chardonel nodal sections was greater in the control than in oil-treated vines (Table 2). Although not significant for Prime Oil, Amigo-treated nodal sections had 41% less $CO_2$ emitted than that of the controls (Table 2). Chancellor showed a similar trend; however, $CO_2$ concentrations were not different among oil treatments. Application date had no effect on $CO_2$ exchange for either cultivar. Oil coating of dormant buds may have hindered $CO_2$ escape from treated samples, which resulted in a decrease rather than an increase in respiration. Normally, respiratory activities in grapevines steadily increase from the

**Table 2** Carbon dioxide concentration (μmoles [$CO_2$]/g tissue/sec) (x $10^{-3}$) emitted from the nodal sections of Chardonel and Chancellor in response to oil application.

| **Oil type** | **Chardonel** | **Chancellor** |
|---|---|---|
| Amigo | 7 b[a] | 19 |
| Prime | 9 ab | 21 |
| Control | 12 a | 32 |
| Significance[b] | *** | ns |

[a]Means with the same letters, in columns of cultivars, are not significantly different at $p \leq 0.05$.

[b]*** and ns indicate significance at $p \leq 0.001$ and not significant, respectively, according to the F test. Date and oil x date interaction were not significant.

ecodormant to budbreak stage (Gardea et al. 1994). This finding agrees with previous work on peach flower buds (Deyton et al. 1992, Myers et al. 1996). Myers et al. (1996) reported that soybean oil interferes with the escape of respiratory $CO_2$, which results in an increase of internal $CO_2$ concentrations. This leads to a decrease in respiratory activity as a result of a feedback inhibition (Isenberg 1979).

When both cultivars were compared, $CO_2$ levels in Chancellor were much higher than those in Chardonel (Table 2), which indicates higher respiratory activities in Chancellor. This may explain the relative earlier budburst for Chancellor than for Chardonel (data not shown). The lack of significant response of $CO_2$ exchange between treatments in Chancellor may be associated with the time of measurement, which was closest to budburst in Chancellor than in the other two cultivars.

**Budbreak.** Amigo and Prime Oil delayed budbreak in all cultivars (Table 3). In Chancellor, budbreak delay of 9 to 20 days was observed in oil-treated vines as compared to controls. Budbreak delay in Chambourcin ranged from 3 to 8 days, while in Chardonel it ranged from 3 to 6 days. Both oils caused the most budbreak delay in Chancellor, with a delay of 20 days. A budbreak delay of this extent is likely indicative of oil phytotoxicity on Chancellor vines treated with Prime Oil (Tables 1 and 3). Similarly, budbreak delay in Chambourcin and Chardonel treated with Prime Oil is likely the result of bud injury caused by phytotoxicity. However, this is not the case for Amigo-treated vines. Amigo caused significant budbreak delay in all cultivars without being phytotoxic (Tables 1 and 3). In addition to the oil-treatment effect, there was a date effect in Chambourcin and a date by oil interaction in Chancellor and Chambourcin (Table 3). Date of application was not significant except for Chambourcin, with date 1 and date 3 causing the most budbreak delay (Figure 1, Table 3). The delay in date 1 but not date 3 is associated with phytotoxicity caused by Prime Oil treatment. It is suggested that Chambourcin benefited the most from the latest spray application (date 3) because it is a late cultivar to budbreak as compared to Chancellor (earliest) and Chardonel (middle) (data not shown).

**Table 3** Number of days of 50% and 75% budbreak delay relative to control treatment of Chancellor, Chambourcin, and Chardonel grapevines in response to oil type and date of application in 2000.

| | Chancellor | | Chambourcin | | Chardonel | |
|---|---|---|---|---|---|---|
| **Variable** | **50%** | **75%** | **50%** | **75%** | **50%** | **75%** |
| Amigo | 20 a[a] | 9 a | 8 a | 3 a | 5 a | 3 a |
| Prime | 20 a | 9 a | 8 a | 4 a | 6 a | 5 a |
| Control | 0 b | 0 b | 0 b | 0 b | 0 b | 0 b |
| Date 1[b] | 20 | 9 | 9 a | 5 a | 4 | 5 |
| Date 2 | 21 | 11 | 5 b | 1 b | 3 | 4 |
| Date 3 | 19 | 8 | 11 a | 6 a | 5 | 6 |
| ANOVA[c] | | | | | | |
| Oil | *** | | *** | | *** | |
| Date | ns | | * | | ns | |
| Oil x date | * | | ** | | ns | |

[a]Means with same letters, for a given variable, are not significantly different at $p \leq 0.05$.

[b]Date 1: 29 Nov 1999; date 2: 28 Dec 1999; date 3: 3 Feb 2000.

[c]*, **, ***, and ns indicate significance at $p \leq 0.05$, 0.01, 0.001, and not significant, respectively, according to the F test.

In the second experiment, Chardonel but not Chambourcin showed significant budbreak delay at 8% and 10% (Figure 2, Table 4). Amigo consistently delayed budbreak in Chardonel at a 10% rate in 2000 and 2001, and at 8% in 2001 (Table 4). The effectiveness of the 8% rate is significant since it would be less phytotoxic and less costly to apply than the 10% rate. The lack of response in Chambourcin was not expected, but may be explained by the nature of Chambourcin to break bud later (75% budbreak on 30 April) than Chardonel (75% budbreak on 15 April). The effectiveness of Amigo may have been diminished from the time it was applied on 23 January 2001 until the occurrence of budburst. In the first year, it was found that a late application (date 3) was effective in delaying budbreak of Chambourcin. In the second year, only one application was used in January, which may be too early for Chambourcin to be effective in the spring. The lack of response may also be due to the warmer than average early spring in 2001 (data not shown). A rapid accumulation of heat units may lead to sudden budburst and thus minimize the effectiveness of oil treatment. A similar observation has been reported in Virginia (Dami et al. 2000).

Our findings of budbreak delay with soybean oil are similar to those reported with Cabernet franc, Chardonnay, Concord, Norton, and Seyval blanc (Dami et al. 2000). The delay in budbreak and development may be a result of reduced respiratory activities as demonstrated with the $CO_2$ exchange experiment (Table 2). Myers et al. (1996) found that application of soybean oil to dormant peach trees delayed the date of bloom. The delay was caused by increasing levels of internal $CO_2$ in flower buds that resulted in reduced respiration activities. Oil treatment may have induced the so-called atmospheric ecodormancy (Lang et al. 1987), which means that the dormancy of buds is controlled by environmental factors, specifically oxygen and/or carbon dioxide levels.

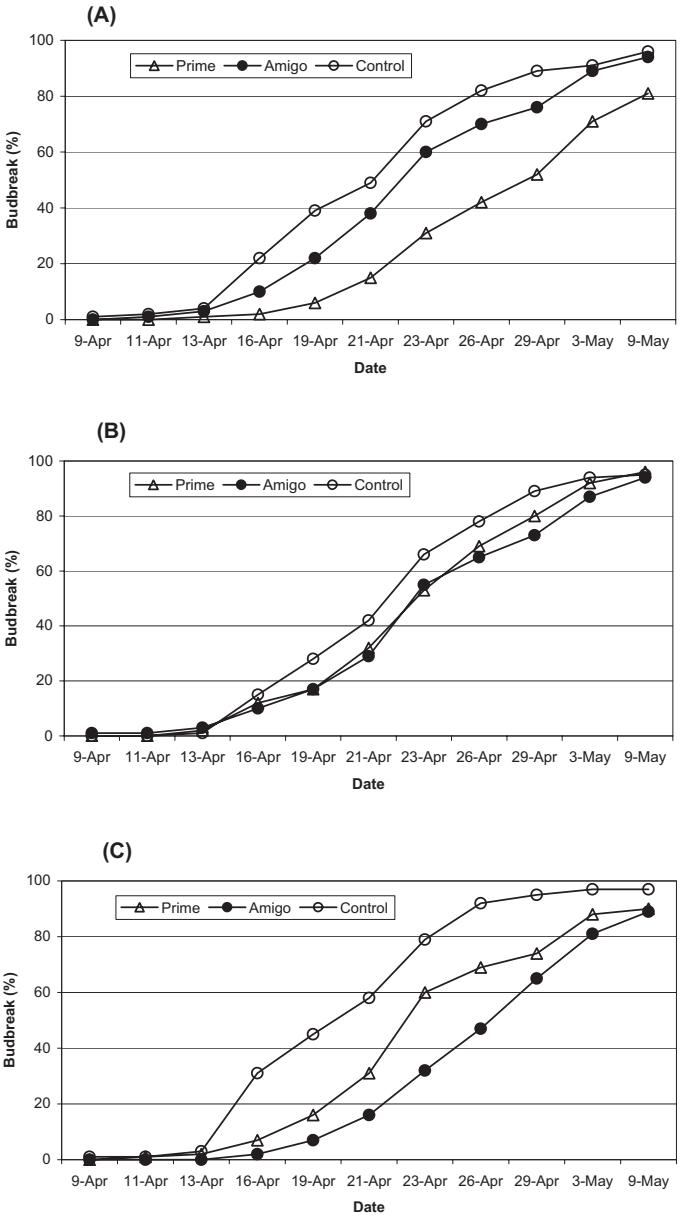


**Figure 1** Budbreak development of Chambourcin in response to oil treatment by date of application in 2000. (**A**) Date 1: 29 Nov 1999; (**B**) date 2: 28 Dec 1999; (**C**) date 3: 3 Feb 2000. Each data point corresponds to the mean of budbreak percent on that date (n = 12). Percent budbreak of oil-treated vines was statistically different than that of controls on date 1 and 3 but not date 2 (see also Table 3).

**Yield components.** In the first experiment, yield components were negatively affected in the cultivars studied except in Chancellor (Table 5). The main effect was a result from the oil treatment, but not the date of application (Table 5). In Chambourcin and Chardonel, there was a reduction in cluster number and crop weight with the Prime Oil treatment as compared with the control treatment (Table 5), again indicating that Prime Oil was phytotoxic at the10% rate and that the negative impact carried through harvest. The lower crop

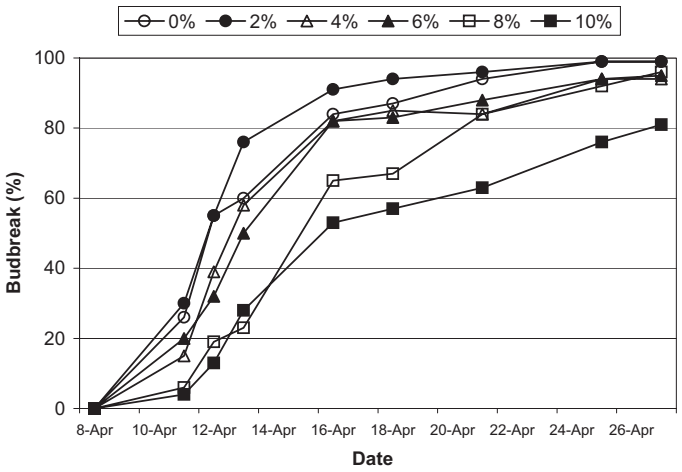


**Figure 2** Budbreak development of Chardonel in response to Amigo oil rates in 2001. Each data point corresponds to the mean of budbreak percent on that date (n = 6). Percent budbreak of 8% and 10% oil-treated vines was statistically different than that of controls (0%) (see also Table 4).

**Table 4** Number of days of 50% and 75% budbreak delay relative to control treatment of Chambourcin, and Chardonel grapevines in response to Amigo oil rate in 2001.

| | Chambourcin | | Chardonel | |
|---|---|---|---|---|
| **Treatment (%)** | **50%** | **75%** | **50%** | **75%** |
| 10 | 0 | -1[a] | 5 a[b] | 3 a |
| 8 | 0 | -1 | 3 a | 1 b |
| 6 | 0 | -1 | 1 b | 1 b |
| 4 | -1 | 0 | 1 b | 1 b |
| 2 | 0 | 0 | -1 b | -1 b |
| 0 (control) | 0 | 0 | 0 b | 0 b |
| ANOVA[c] | ns | ns | ** | ** |

[a]Negative number indicates number of days of budbreak advancement rather than a delay in comparison to the control.

[b]Means with the same letters, in columns of cultivars, are not significantly different at $p \leq 0.05$.

[c]** and ns indicate significance at $p \leq 0.01$ and not significant, respectively, according to the F test.

weight is likely a result of a lower cluster number in both cultivars. Cluster number is an indicator of bud fruitfulness of a given cultivar (Mullins et al. 1992). The reduced cluster number in Chambourcin and Chardonel vines treated with Prime Oil indicates reduced bud fruitfulness. Although it is unclear how Prime Oil led to reduced fruitfulness, we have identified three explanations. First, the damage on bud fruitfulness may have occurred well before budbreak and it is likely that Prime Oil interfered with the normal development of flower primordia while inside the dormant buds. Second, Prime Oil may have caused injury in primary buds, leading to the development of less fruitful secondary shoots. Third, a combination of the previous two scenarios may have occurred.

Amigo treatment of Chardonel resulted in a significant reduction of crop weight (Table 5). Field observations indicated that some Chardonel vines treated with Amigo exhibited viral symptoms and cluster number and that yields in those vines were significantly reduced (data not shown). Therefore, a reduction in yield components from Amigo-treated vines is likely a result of diseased vines rather than a phytotoxicity effect. This assumption was justified in the second year, during which vines with no virus symptoms and with similar oil treatment showed no yield reduction (data not shown).

Another inexplicable observation is the lack of yield reduction in Chancellor even though this cultivar exhibited the most phytotoxic injury. Our field observations indicated that a significant portion of the clusters in Prime Oil-treated vines was borne on secondary shoots that originated from base buds (data not shown). Chancellor may have compensated for crop loss because of primary bud injury by producing a full crop from the fruitful base buds (Pool et al. 1978). In Chambourcin, cluster weight was only significantly lower (150 g) in Amigo-treated vines than in the control (190 g) (Table 5). Since berry weight was not affected by any treatments, we speculated that oil application might have reduced berries per cluster by disrupting fruit set. This hypothesis was tested in the second year in both Chambourcin and Chardonel by counting flowers per inflorescence prior to bloom, then berries per cluster after fruit set, and computing fruit set. We found no significant effect of different oil rates of Amigo on fruit set in either cultivar (data not shown). Furthermore, when the experiment was repeated in the second year using different rates of Amigo, neither cultivar was affected by any oil rate on any yield component (data not shown).

**Fruit composition.** In the first year, oil treatments had no effect on soluble solids in all cultivars. Soluble solids among all treatments ranged from 18.7 to 19.2 Brix in Chancellor, from 22.5 to 22.9 Brix in Chambourcin, and from 23.4 to 23.9 Brix in Chardonel. However, pH and titratable acidity were affected by oil treatment in Chancellor (Table 6). Juice from Prime Oil-treated vines had lower pH (3.71) than that from Amigo-treated and control vines (pH 3.78 and 3.84, respectively) (Table 6). The titratable acidity from the Prime Oil treatment was higher (0.56%) than the Amigo (0.49%) and the control (0.47%) treatments (Table 6). Prime Oil seems to have caused a delay in fruit ripening. The delayed fruit ripening may be explained by the later development of clusters from secondary shoots in Prime Oil-treated vines, as described in the previous section.

Fruit composition among all oil treatments and date of application were not different in Chardonel (data not shown). However, Chambourcin showed some differences of pH and titratable acidity; the differences were not consistent and thus difficult to interpret (Table 6). There were no differences in fruit composition in either cultivar in the second year (data not shown). It is also worth noting the unusual high pH and low acidity of fruit samples from the

**Table 5** Yield components of Chancellor, Chambourcin, and Chardonel grapevines in response to oil type application in 2000.

| Cultivar | Parameter | Cluster number/ vine | Crop wt/vine (kg) | Cluster wt (g) | Berry wt (g) |
|---|---|---|---|---|---|
| Chancellor | Amigo | 24 | 4.68 | 189 | 1.59 |
| | Prime | 25 | 4.79 | 180 | 1.63 |
| | Control | 27 | 5.14 | 190 | 1.71 |
| | Significance[a] | ns | ns | ns | ns |
| Chambourcin | Amigo | 37 a[b] | 5.70 ab | 150 b | 2.24 |
| | Prime | 28 b | 4.70 b | 168 ab | 2.27 |
| | Control | 38 a | 7.05 a | 190 a | 2.30 |
| | Significance | * | ** | * | ns |
| Chardonel | Amigo | 37 a | 5.89 b | 155 | 2.21 a |
| | Prime | 28 b | 4.36 c | 157 | 2.04 b |
| | Control | 44 a | 7.45 a | 172 | 1.98 b |
| | Significance | ** | ** | ns | * |

[a]*, **, and ns indicate significance at $p \leq 0.05$, 0.01, and not significant, respectively, according to the F test. Date and date x oil interaction were not significant.

[b]Means with the same letters are not significantly different at $p \leq 0.05$.

**Table 6** Fruit composition of Chancellor and Chambourcin grapevines in response to oil type and date of application in 2000.

| Cultivar | Treatment/ treatment effect | pH | TA (g/100 mL) |
|---|---|---|---|
| Chancellor | Amigo | 3.78a[a] | 0.49b |
| | Prime | 3.71b | 0.56a |
| | Control | 3.84a | 0.47b |
| | Date 1[b] | 3.74 | 0.54a |
| | Date 2 | 3.81 | 0.48b |
| | Date 3 | 3.82 | 0.47b |
| | ANOVA[c] | | |
| | Oil | ** | * |
| | Date | ns | ** |
| | Oil x date | ** | ns |
| Chambourcin | Amigo | 3.66b | 0.48a |
| | Prime | 3.73a | 0.50a |
| | Control | 3.66b | 0.44b |
| | Date 1[b] | 3.63b | 0.49 |
| | Date 2 | 3.72a | 0.48 |
| | Date 3 | 3.70a | 0.47 |
| | ANOVA[c] | | |
| | Oil | *** | *** |
| | Date | *** | ns |
| | Oil x date | ns | ns |

[a]Means with the same letters in columns are not significantly different at $p \leq 0.05$.

[b]Date 1: 29 Nov 1999; date 2: 28 Dec 1999; date 3: 3 Feb 2000.

[c]*, **, ***, and ns indicate significance at $p \leq 0.05$, 0.01, 0.001, and not significant, respectively, according to the F test.

year 1 experiment (Table 6). The samples from year 1 (and not year 2) were frozen as described in Materials and Methods. It has been demonstrated that freezing may increase the must pH and reduce its titratable acidity (Mattick 1983, Spayd et al. 1987).

## Conclusions

Soybean oil from commercially available adjuvants successfully delayed budbreak of Chancellor and Chambourcin in the first year and of Chardonel in both years when nonphytotoxic rates were used. Optimum rates were either 8% or 10%; these rates were effective in delaying budbreak but not fruit ripening and did not affect fruit set, yield components, or fruit composition. The effectiveness of oil used may depend on the intrinsic phenological characteristics of the cultivar sprayed. In other words, cultivars with late budbreak may require a later oil application than cultivars with early budbreak. Furthermore, the response of a given cultivar to oil application may vary according to the climatic conditions during the period between the date of oil application and date of budburst. Oil effectiveness may vary from one season to another according to the degree of oil "weathering." Finally, the extent of budbreak delay may be enhanced by cooler (rather than warmer) periods preceding budburst. Soybean oil application to dormant grapevines has potentially multifold benefits: it is easy and affordable to apply; it does not negatively affect the yield or the fruit quality; and it may protect early grape cultivars from spring frost injury.

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