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Communication

Net CO_2 Assimilation Rate of Grapevine Leaves in Response to Trunk Girdling and Gibberellic Acid Application[1]

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ABSTRACT

Net CO_2 assimilation rate (A), stomatal conductance (g_s), and weight per unit leaf area (W) were determined on Thompson Seedless grapevines grown in the field. Treatments included fruit set applications of gibberellic acid (40 milligrams gibberellic acid (GA_3) per liter) to vines, shoots and clusters, alone and in combination with trunk girdling. Leaf A and g_s were measured prior to and 3, 6, and 13 days after fruit set. Weight per unit leaf area was determined on leaves collected subsequent to gas exchange measurements. Leaf A of girdled vines was reduced approximately 30% when compared to the control 13 days after treatment. The reduction in A due to girdling was not as great when vines were sprayed with GA_3. GA_3 sprays alone had no significant effect on A. Stomatal conductance was reduced by girdling 13 days after treatment. Weight per unit leaf area was 17% greater for trunk girdled vines when compared to the controls. Results indicate GA_3 affected net CO_2 assimilation rate only on girdled vines, a treatment which increased weight per unit leaf area.

Trunk girdling and GA_3 applications long have been used commercially to increase the weight of seedless grapes (4, 17). Presently both practices are used in conjunction with one another as their effects have been shown to be synergistic on increasing berry weight (17). It also has been shown these cultural practices affect net CO_2 assimilation rate (3, 5, 8, 16), stomatal conductance (2, 3), and carbohydrate distribution (7, 20) in various plant species including *Vitis vinifera*. Girdling and GA_3 application alters grapevine leaf (2, 8), shoot (15) and berry (19) hormone concentrations. Girdled grapevines have higher ABA concentrations in leaves (2, 8), and may or may not have higher GA_3 concentrations in fruit above the girdle (19) when compared to control vines. High concentrations of ABA in leaves have been shown to reduce stomatal conductance and leaf net CO_2 assimilation rate (2, 8, 14). The accumulation of carbohydrates above the girdle (5, 18) also has been implicated in reducing leaf net CO_2 assimilation rate of grapevines (5). The association between A[2] and carbohydrate level is not unique to grapevines, and has been shown in numerous plants when girdled (5, 15). GA_3 sprays have been shown to increase A of several species (7, 16, 20), however, conflicting reports have been published on the effect of GA_3 on A of bean plants (1, 9). GA_3 application has been shown to change assimilate distribution in kikuyu grass (7). Cluster or vine GA_3 sprays also increased the amount of assimilates directed into the fruit of Black Corinth grapevines, from the leaf above the cluster (20).

There is no information as to the effect of a combination of GA_3 and girdling on grapevine leaf net CO_2 assimilation despite their combined use to increase berry weight. The objectives of this study were to determine the effects of girdling, GA_3 application, and a combination of both practices on leaf A, stomatal conductance (g_s), and weight per unit leaf area of Thompson Seedless grapevines in a field situation. This grape cultivar was chosen since its berry weight consistently has been increased by GA_3 applications and girdling (4, 17).

MATERIALS AND METHODS

Vitis vinifera L. (cv Thompson Seedless) grapevines used in this study were 16-year-old vines grown at the University of California, Kearney Agricultural Center near Fresno, CA. Pretreatment cultural practices consisted of an application of GA_3 (Pro-Gibb 2%, containing 16 g GA_3/L, Abbott Laboratories, Fresno, CA) at a rate of 18.6 g/ha during bloom. Cluster number was reduced to 18 per vine by hand thinning. Treatments at fruit set (average berry diameter 5.4 mm) included GA_3 sprayed vines (GA_3-vine), shoots only (GA_3-shoot), clusters only (GA_3-cluster), and unsprayed controls. Additional treatments were imposed by trunk girdling alone, and in conjunction with GA_3 sprayed vines (Gird+GA_3-vine), shoots only (Gird+GA_3-shoot), and clusters only (Gird+GA_3-cluster). The eight treatments were replicated six times in a randomized complete block design. The GA_3 solution (40 mg/L) was applied at the rate of 74.2 g/ha. For the shoot only sprayed treatments, clusters were shielded from the spray by covering with plastic bags and promptly removed after the application. A 40 mg/L GA_3 solution was sprayed on cluster treatments to the point of runoff. Vines were trunk girdled with a double-bladed 4.8 mm knife and rechecked for completeness.

Vines in each block were designated for either gas exchange or W measurements. Gas exchange measurements were made 2 d before, and 3, 6, and 13 d after fruit set. Leaf A and g_s were determined in three of six blocks. The most recent, fully expanded leaves with exposure to solar radiation throughout the day were selected on each 'gas exchange' vine. Four leaves per vine were chosen on separate fruiting shoots and used repeatedly for the remainder of the study. Measurements commenced at 1000 h and were completed by approximately 1500 h. The photosynthetic photon fluence rate at the leaf surface exceeded 1.5 mmol m^{-2} s^{-1} during all measurements. Leaf temperatures averaged 35°C throughout the study. Daily maximum ambient

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[2] Abbreviations: DAT, days after treatment; A, net CO_2 assimilation rate; W, weight per unit leaf area.

temperatures during the experimental period, May 24 to June 9, 1984, were in excess of 40°C. Leaf CO_2 and water vapor exchange were measured in blocks. Net CO_2 assimilation rate, stomatal conductance and intercellular CO_2 concentration were determined in an open system and calculated similar to that described by Williams and Smith (21).

Weight per unit leaf area was determined on leaves at two shoot positions. The positions were located opposite the cluster and on the shoot at a position analogous to where A was measured. Leaves were collected from one shoot in the six blocks, on each sampling date. Each shoot was sampled once. Leaf samples for W were collected from 1900 to 2100 h. Leaf area was measured with a LiCor 3100 area meter, and leaves subsequently were dried in a forced air oven at 75°C and dry weights taken. Analyses of variance were conducted and comparisons among treatment means were made using least significant difference.

RESULTS

Pretreatment A averaged 20 μmol m^{-2} s^{-1}. Net CO_2 assimilation rates of these vines were unaffected by trunk girdling 3 d after fruit set, however, 6 and 13 DAT, girdled vines had significantly ($P < 0.05$) lower rates of A than did ungirdled vines (Table I). Net CO_2 assimiliation rates of most girdled treatments decreased each day measurements were taken after fruit set, but the greatest decrease was for girdled vines without GA_3 spray (Table I). Leaf A was not significantly affected by GA_3 treatments.

There were no significant treatment effects on g_s, 3 and 6 d after the treatments were imposed. Stomatal conductance was reduced on unsprayed, and GA_3 shoot and cluster sprayed vines that were girdled, however, it increased for GA_3 sprayed vines that were girdled, 13 DAT. This resulted in a significant interaction between girdling and GA. There were no significant differences in the intercellular CO_2 concentration among treatments throughout the study.

The weight per unit leaf area of all vines averaged 5.2 mg cm^{-2} 2 d prior to fruit set. Weight per unit leaf area from girdled and ungirdled vines averaged 5.8 and 5.3 mg cm^{-2}, 13 DAT, respectively. GA_3 alone did not directly affect W, however, it reduced W of girdled vines (Table I).

Table I. *Net CO_2 Assimilation rate and Weight per Unit Leaf Area of Field Grown Thompson Seedless Vines as Influenced by Girdling and GA_3 Application at Fruit Set (Day 0)*

Leaves selected for net CO_2 assimilation rate measurements were fully expanded and exposed to solar radiation throughout the day. Readings were taken in blocks on the same set of leaves each measurement day.

Treatment		Days from Treatment		
		CO_2 assimilation rate		Weight
		6	13	13
		$\mu mol\ m^{-2}\ s^{-1}$		$mg\ cm^{-2}$
1. Control		18.9	19.4	5.2
2. GA_3-vine		19.6	17.9	5.2
3. GA_3-shoot		20.2	21.2	5.4
4. GA_3-cluster		21.0	20.3	5.4
5. Girdled		15.0	13.0	6.1
6. Gird + GA_3-vine		18.2	15.2	5.6
7. Gird + GA_3-shoot		18.2	15.1	5.8
8. Gird + GA_3-cluster		18.0	15.8	5.6
LSD = 0.05	Girdled	1.3[a]	1.7[a]	0.2[a]
	GA_3	NS[b]	NS	NS
	Interaction	NS	NS	NS

[a] Also significant at the 1% level. [b] NS, not significant.

DISCUSSION

Leaves of girdled Thompson Seedless grapevines grown in the field had lower net CO_2 assimilation rates when compared to ungirdled vines by 6 DAT (Table I). These results are similar to what occurred when potted grapevines were girdled (5, 8). GA_3, when used as the sole treatment had no effect on leaf CO_2 assimilation rate. Previously it had been demonstrated that A of several crop species (1, 16) was increased due to GA_3 application. GA_3 applications, however, reduced the depressing effect of girdling on A in this study. The relative effect of each GA treatment in conjunction with girdling, depended in part on areas of the vine sprayed with this phytohormone (Table I).

The reduction of A by girdling may be due to either ABA of feedback inhibition. ABA accumulation in leaf tissue can reduce the stomatal aperture of girdled plants (2), thus lowering the rates of net CO_2 assimilation (8, 14). Alternatively, feedback inhibition (10) may result from a buildup of carbohydrates in the leaves of girdled vines. Carbohydrate levels have been shown to increase above the girdle in several grape cultivars (5, 8, 18) as did weight per unit leaf area in this study (Table I). Leaf A may be reduced by an accumulation of photosynthetic products (6, 10). ABA accumulation and feedback inhibition appear to be distinct from one another, as carbohydrate accumulation is not a prerequisite for reduced stomatal aperature and ABA accumulation (14).

It has been shown that GA_3 may enhance the export of leaf carbohydrates in grape (20). The greatest increase of W in this study was due to girdling, with smaller increases when girdled vines were sprayed with GA_3. The difference in W between girdled and girdled+Ga_3 sprayed vines provides indirect evidence that GA_3 may have facilitated the export of carbohydrates from the leaves in this study. It previously has been shown that short-term increases in W are due to an accumulation of nonstructural carbohydrates and starch (11). Thus, the intermediate value of A measured on girdled vines when sprayed with GA_3 compared to the control and girdled only vines, suggest that feedback inhibition may have played an important role in regulating A of vines on which these cultural practices were performed. These results also may explain differences among studies with regard to the effect of GA_3 on leaf CO_2 assimilation rate (1, 7, 9, 16). GA_3 may enhance A only under conditions in which feedback inhibition may be regulating photosynthesis. At present, we know of no antagonistic effects of GA on ABA that also would explain the above results.

There was a significant reduction in stomatal conductance of the girdled vines 13 DAT. If A had been reduced without a concomitant decrease in g_s, intercellular CO_2 concentration (c_i) would have increased. The lack of a significant difference in c_i among treatments 13 DAT, is consistent with the view that C_3 plants maintain constant c_i under various conditions (12). The stomatal response of these vines most likely was to maintain a constant c_i when the leaf's mesophyll capacity was reduced from girdling.

Results from this study demonstrated that A of field grown Thompson Seedless grapevines was reduced due to trunk girdling. The effect of girdling on A and W was altered by GA_3 applications. Additional studies are in progress to determine whether the alterations in leaf CO_2 assimilation and weight per unit leaf area shortly after girdling and GA_3 applications, are related to the rapid increase in berry size that previously has been shown during the same time measurements were made in this experiment (13).

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