Necrosis in grapevine buds (Vitis vinifera cv. Queen of Vineyard)

II. Effect of gibberellic acid (GA$_3$) application

by

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Knospennekrosen bei der Rebsorte Queen of Vineyard (Vitis vinifera)

II. Einfluß der Gibberellinsäure- (GA$_3$)Behandlung


Introduction

The use of gibberellins (GA) in horticulture has often been found to be associated with delayed bud sprouting (11), a decrease in the number of developing buds, bud necrosis, and a decrease in productivity (13, 15, 16, 17). GA application to several fruit species was found to affect the number of flowering buds (2, 6, 7, 9) in many stone fruits (almond, plum, peaches) and bud necrosis and death have also been observed (4, 5).

In the grapevine, GA$_3$ application has become common practice for fruit improvement. However, adverse effects, such as bud necrosis, delayed sprouting and a decrease in inflorescence number in the seeded varieties have limited its use to a few cultivars not sensitive to GA$_3$ (12, 13, 15, 18). In order to prevent bud necrosis, it was recommended that, particularly in seeded cultivars, only inflorescences should be treated. In varieties such as Queen of Vineyard, Alphonse Lavallee and Early Panse, GA$_3$ application often caused necrosis of the central bud and elongation of the axillary ones, resulting in many cases in a “split bud” (13, 14). When GA$_3$ was


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applied before flowering, bud necrosis was found in the lower part of the cane, while spraying after flowering caused necrosis in higher buds. In vigorous plants of Queen of Vineyard, naturally occurring necrotic buds were noted (1). Bud necrosis was found to be related to the position on the cane and stage of development of the buds and to shoot vigor (10).

The possibility that the applied GA$_3$ is involved in bud necrosis and its relation to natural bud necrosis and drying were the subjects of the present study.

Materials and methods

Plant material, growth and pruning practices were as described in the first part of this study (10).

Gibberellin solutions (ICI Berlex, 10% active GA$_3$) including Tween 20 (0.03%) as a surfactant were either sprayed on the leaves or fed to the petioles through a rubber tube. The leaf lamina was removed just prior to attachment of the rubber tube and an open syringe cylinder of 2 ml was connected to the rubber tubing. 1 ml of GA$_3$ solution was introduced, taking care to remove all air bubbles from the tube (Fig. 1). An amount of 1 ml was also left on the leaf blade after spray application.

Direct application to buds was done by painting a measured volume of GA$_3$ on the bud, using a camel hair brush.

Radioactive $^3$H-GA$_3$ (Amersham, England; non-specifically labelled, specific activity 6.12 mCi/m mole) was either applied on the upper and lower epidermis of the 6th leaf lamina or fed through the petiole. Radioactivity was measured by a
Necrosis in grapevine buds. II.

Fig. 2: The effect of various GA$_3$ concentrations applied at the end of bloom to the leaf blade or petiole at node no. 6 on the occurrence of necrosis in buds above and below the application site.

liquid scintillation counter (Packard model 3255) after buds oxidation in a Tri Carb sample oxidizer (Packard model 306). $^3$H-GA$_3$ was absorbed as tritiated water by 10 ml monophase. 7 buds were used for each $^3$H-GA$_3$ treatment; results were analyzed statistically by the Multiple Range Test.

Results

Exogenous GA$_3$ application (20 mg/l) to leaves and buds showed that the degree of bud necrosis was determined by the time and mode of GA$_3$ application (Table 1). The highest rate of bud necrosis occurred when GA$_3$ was applied to the leaves as a spray at flowering time. 3 weeks later, even 5 times the concentration (100 mg/l) was ineffective in causing bud necrosis. GA$_3$ given directly to the buds had a considerably smaller and insignificant effect.

Table 1

The effect of time and concentration of GA$_3$ applications on bud necrosis of grape shoots of cv. Queen of Vineyard

<table>
<thead>
<tr>
<th>Time of application</th>
<th>GA$_3$ concentration (mg/l)</th>
<th>Organ treated</th>
<th>Necrotic buds (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Control)</td>
<td>-</td>
<td>-</td>
<td>7.0 bc</td>
</tr>
<tr>
<td>Full bloom</td>
<td>20</td>
<td>leaf</td>
<td>43.0 a</td>
</tr>
<tr>
<td>&quot;</td>
<td>20</td>
<td>bud</td>
<td>20 b</td>
</tr>
<tr>
<td>21 d after full bloom</td>
<td>20</td>
<td>leaf</td>
<td>2.2 bc</td>
</tr>
<tr>
<td>&quot;</td>
<td>20</td>
<td>bud</td>
<td>3.0 bc</td>
</tr>
<tr>
<td>&quot; &quot; &quot; &quot; &quot; &quot;</td>
<td>100</td>
<td>leaf</td>
<td>3.7 bc</td>
</tr>
<tr>
<td>&quot; &quot; &quot; &quot; &quot; &quot;</td>
<td>100</td>
<td>bud</td>
<td>1.5 c</td>
</tr>
</tbody>
</table>

$^1$) Leaves sprayed or buds painted at nodes no. 5—10.

$^2$) Results are pooled values for buds at nodes no. 5—10.

$^3$) Numbers followed by different letters differ significantly at $P = 0.05$.

Increasing the GA$_3$ concentration given at flowering time resulted in a higher level of necrosis when applied by petiole feeding than by laminar spray. 1 ml of a 1 mg/l GA$_4$ solution fed to the petiole caused a similar degree of bud necrosis as the same amount of a 40 mg/l GA$_3$ solution applied as a laminar spray (Table 2).

The distribution of necrosis in the buds below (nodes 3—5) and above (nodes 7—12) the point of GA$_3$ application (node 6) is shown in Fig. 2. GA$_2$ sprays to leaf blades had only a slight effect in inducing bud necrosis below the 6th node while the buds above it showed necrosis similar to that in the axil of the 6th leaf itself. This was noticeable at a GA$_3$ concentration of 40 mg/l and higher. The same amounts of GA$_3$ applied by petiole feeding affected also the buds below the 6th node when given at the high concentration of 100 mg/l, while buds at nodes 6—12 were necrotic even when 1 mg/l GA$_3$ was applied.

The effect of time of GA$_3$ application (40 mg/l) on bud necrosis is shown in Table 3. From full bloom and up to 2 weeks thereafter, GA$_3$ sprays caused 80—90% of the
Fig. 3: The effect of GA₃ application time on bud necrosis at different positions along the shoots of Queen of Vineyard grapevines. GA₃, 40 mg/l, was sprayed on leaves at nodes 5–10, buds were analyzed in September.

buds to become necrotic. At later applications the sensitivity of the buds to GA₃ dropped considerably, reaching the same levels as the control.

The data presented in Table 3 were analyzed further, to establish the effect of GA₃ application on bud necrosis in relation to bud position on the shoot. The buds in the axil of the treated leaves (5—10th nodes) and those above them (1—12th node) showed a high degree of necrosis when sprayed before or 2 weeks after full bloom (Fig. 3). Buds at the 3—4th nodes showed a slightly higher but insignificant level of necrosis than the equivalent control buds.

The topmost 6 leaves of growing shoots were sprayed with 40 mg/l GA₃ 1 week before full bloom or 1 month thereafter, when the shoots already had 25 leaves. Fig. 4 shows the relation between vine vigor and bud sensitivity to GA 3. In young shoots, a high percentage of bud necrosis was found in the treated area and above it (nodes I—VI and +1 to +6), as compared with those below the treated zone. When GA₃ was given after flowering to older but still growing shoots, buds above the zone of application were found to be more sensitive than those at or below the GA₃ treated area.

The time needed for the development of necrotic areas in the bud after GA₃ treatments was determined after a spray application of 40 mg/l GA₃ to the 5—10th

### Table 2

<table>
<thead>
<tr>
<th>Organ treated</th>
<th>GA₃ concentration (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Leaf blade (spray)</td>
<td>23 bc</td>
</tr>
<tr>
<td>Petiole (feeding)</td>
<td>14 c</td>
</tr>
</tbody>
</table>

1) Numbers followed by different letters differ significantly at \( P = 0.05 \).

### Table 3

The effect of date of GA₃ application on the percentage necrosis in buds of cv. Queen of Vineyard grapevine shoots (GA₃ concentration 40 mg/l; spray application starting at full bloom on leaf blades at nodes 5—10; necrosis recorded in buds at nodes 3—12; numbers followed by different letters differ significantly at \( P = 0.05 \))

<table>
<thead>
<tr>
<th>April</th>
<th>10 c</th>
<th>88 a</th>
<th>91 a</th>
<th>82 a</th>
<th>33 b</th>
<th>9 c</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
leaves at the end of the bloom period. 10 d after the application, no necrotic buds could be seen; 10 d later, 21.7% of the buds had a necrotic layer, and 37 d after the GA$_3$ treatment, 70% of the buds had a necrotic center. In a later analysis, in September, necrosis was found in 90% of the GA$_3$-treated buds.

The extent and type of damage caused by GA$_3$ was found to depend on the stage of bud development. Mature, fully differentiated buds are insensitive to GA$_3$. In mature buds which continue to differentiate, GA$_3$ damage was manifested by central bud necrosis without any external malformation. In young buds, GA$_3$ caused elongation of the lower internodes, development of a necrotic layer below the apex, and eventual death of the central bud (Fig. 5).

![Graph](image)

Fig. 4: The effect on bud necrosis of GA$_3$ application before and after full bloom to the top 6 leaves of growing shoots. Queen of Vineyard shoots were sprayed with 40 mg/l GA$_3$ 1 week before or 1 month after full bloom (FB), which was on April 12.

Einfluß der GA$_3$-Behandlung der oberen 6 Blätter wachsender Triebe von Queen of Vineyard vor und nach der Vollblüte. Die Triebe wurden 1 Woche vor oder 1 Monat nach der Vollblüte (FB), die auf den 12. April fiel, mit 40 mg GA$_3$/l besprüht.

![Diagram](image)

Fig. 5: Necrosis development in control and GA$_3$ treated Queen of Vineyard buds. — A: Control with necrotic central bud. GA$_3$-treated with elongating active central bud. C: GA$_3$-treated with elongated necrotic central bud. — a = scales, b = hairs, c = central bud, d = axillary bud, e = necrotic layer, f = bud base.

The axillary buds elongated rapidly after the necrotic decline of the central bud. In a longitudinal cut of such buds, the actively developing axillary buds near the hollow necrotic center are seen (Fig. 6). This rapid development of the axillary buds pushes the scale leaves covering the whole bud to open, resulting in a "split bud" formation (Figs. 7 and 8).

Translocation of GA₃ into the different buds along the vine was followed by use of tritiated GA₃, which was introduced by petiole feeding (10 mg/l) or smeared

![Fig. 6: Longitudinal cut through a GA₃-treated bud with necrotic center and developing axillary bud.](image1)

![Figs. 7 and 8: General view of a normal bud (7) and a "split bud" (8) induced by Ga₃ treatments to cv. Queen of Vineyard grapevine.](image2)

Translocation of ³H-GA₃ in cv. Queen of Vineyard grapevine shoots and per cent bud necrosis along the shoot after petiole feeding (10 mg/l) or leaf blade application (40 mg/l) to the leaf at the 6th node (radioactivity in buds measured after 9 h; necrosis determined on parallel shoots; 1 ml of solution was applied in both methods)

<table>
<thead>
<tr>
<th>Bud position</th>
<th>Petiole feeding</th>
<th>Leaf blade application</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>³H (cpm/bud)</td>
<td>GA₃ (mg/bud)</td>
</tr>
<tr>
<td>9</td>
<td>3972</td>
<td>6.7 X 10⁻⁶</td>
</tr>
<tr>
<td>8</td>
<td>3746</td>
<td>6.3 X 10⁻⁶</td>
</tr>
<tr>
<td>7</td>
<td>3576</td>
<td>6.0 X 10⁻⁶</td>
</tr>
<tr>
<td>6</td>
<td>5561</td>
<td>9.4 X 10⁻⁶</td>
</tr>
<tr>
<td>5</td>
<td>186</td>
<td>0.3 X 10⁻⁶</td>
</tr>
<tr>
<td>4</td>
<td>679</td>
<td>1.2 X 10⁻⁶</td>
</tr>
<tr>
<td>3</td>
<td>101</td>
<td>0.2 X 10⁻⁶</td>
</tr>
</tbody>
</table>

Abb. 6: Längsschnitt durch eine GA₃-behandelte Knospe mit nekrotischem Zentrum und sich entwickelnder Axillarknospe.

Abb. 7 und 8: Gesamtansicht einer normalen Knospe (7) und einer "gespaltenen" Knospe (8), ausgelöst durch GA₃-Behandlung von Queen of Vineyard.

Tabelle 4

Translokation von ³H-GA₃ in den Trieben der Rebsorte Queen of Vineyard und Knospennekrosen (%) längs der Triebe nach Aufnahme über den Stiel (10 mg/l) oder über die Spreite (40 mg/l) des Blattes am 6. Knoten (Radioaktivität in den Knospen nach 9 h gemessen; Nekrosen an parallelen Trieben bestimmt; bei beiden Methoden wurde 1 ml Lösung appliziert)
on the leaf blade (40 mg/l) of the leaf at the 6th node. Buds from the 3—9th nodes were sampled 9 h after treatment. On shoots with petiole feeding of $^{3}$H-GA$_{3}$, the axillary bud of the fed petiole (6th bud) contained as much as $9.4 \times 10^{-6}$ mg $^{3}$H-GA$_{3}$. A slightly lower level of $^{3}$H-GA$_{3}$ was found in each of the three buds above it (Table 4). The buds below the application site contained lower levels of $^{3}$H-GA$_{3}$. Laminar application of $^{3}$H-GA$_{3}$ was found to be ineffective and the amounts detected were insignificant.

Discussion

The application of gibberellic acid to the leaves of cv. Queen of Vineyard grapevine caused more bud necrosis than when applied directly to the buds. As shown previously with cv. Barlinka grapevines (15), the leaves having a larger exposed area and a smaller penetration barrier apparently allow a better penetration and translocation of GA$_{3}$ to the buds. Petiole feeding of GA$_{3}$ caused a higher degree of bud necrosis at lower GA$_{3}$ concentration than either spraying or smearing the GA$_{3}$ on the lamina. The degree of bud necrosis depended to a large extent on the stage of development of the buds. Upper, young still differentiating buds and mature canes were affected by GA$_{3}$ to the same extent as those on young, still growing shoots. It is obvious, then, that bud damage was determined by the bud's stage of development and to a lesser extent by the shoot's age. Further support for this idea comes from the observation that the number of necrotic buds found at or above the GA$_{3}$ treated zone was greater than that found below the zone of GA$_{3}$ application. GA$_{3}$ has been found to cause bud internode elongation, and in young buds to affect dormancy (3). Since the GA$_{3}$ applied to the leaves must be translocated to the buds, the direction of GA$_{3}$ translocation will affect the position of necrotic buds on the shoot. HALE and WEAVER (8) found that GA$_{3}$ moved downward, along with leaf metabolites. Our results show that the small degree of bud necrosis below the zone of application correlated with low levels of labelled $^{3}$H-GA$_{3}$ in the lower buds (below the $^{3}$H-GA$_{3}$-treated area). This may indicate that the lower bud did not constitute a strong metabolic sink for GA$_{3}$ at the time the experiment was conducted. However, it is also possible that the lower buds were not affected by GA$_{3}$, since they were already fully differentiated and had ceased to grow.

Generally, the naturally occurring necrosis in the central bud on a Queen of Vineyard grapevine was similar to that induced by exogenous treatments of GA$_{3}$. Exogenous application of GA$_{3}$ (18) also enhances the rate of shoot growth in most grapevine cultivars. As the natural necrosis is induced only during active shoot growth, and mainly in vigorous vineyards, it is suggested that high levels of endogenous gibberellins are involved in the development of necrosis in the central buds of vigorously growing shoots. This would need verification by direct analysis for endogenous gibberellins in buds at various stages of development and different degrees of shoot vigor.

Summary

The effect of gibberellic acid application on the development of necrosis in cv. Queen of Vineyard grapevine buds was studied. GA$_{3}$ caused the development of a necrotic layer at the base of the central bud and promoted the development of the
axillary buds. GA₃ application to leaves caused necrosis in the buds more readily than direct application to the buds. GA₃ fed to the petiole was 100 times more active in inducing necrosis than leaf application. Only developing and relatively young buds were sensitive to GA₃. A minimum of 6 × 10⁻⁶ mg GA₃ in the bud was needed to cause bud necrosis. During the period from 1 week before to 3 weeks after bloom, the movement of GA₃ in the grape shoot was acropetal. The possible involvement of gibberellins in the natural necrosis of buds on vigorous grapevines is discussed.

**Literature cited**


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