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EFFECTS OF GIBBERELLIC ACID ON RIPENING AND RIND PUFFING IN 'SUNBURST' MANDARIN

L. POZO, W. J. KENDER, J. K. BURNS, U. HARTMOND AND A. GRANT
University of Florida, IFAS
Citrus Research and Education Center
700 Experiment Station Road
Lake Alfred, FL 33850

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Abstract. **Foliar sprays of gibberellic acid (GA_3) were used to control puffing of 'Sunburst' mandarin and to delay the harvest season under central Florida conditions. The application of 25 mg·L^{-1} GA_3 to trees of 'Sunburst' mandarin prior to color break, 6-8 weeks before the normal harvest season, delayed color change in the flavedo and prevented peel puffing. Peel thickness and weight were reduced and fruit firmness was higher in GA_3- treated fruits. The treatment also retarded the loss of juice in mature fruits. Based on these results, the harvest season could be extended from November-December into early January. GA_3 application reduced the frequency of both plugging and small fissures around the calyx. No significant effects on internal quality were found as a result of the GA_3 application.**

Mandarins are prone to rind damage during harvesting. This is closely related to puffiness, a weakening and disintegration of the albedo tissues (Kuraoka et al., 1966) which is characteristic of mature mandarins. At the time of fruit maturation, the peel continues to grow, and small fissures in the deeper layers of the albedo increase in size and number. This results in the separation of the peel and segments and finally in the disintegration of the axial structure of the segments. During the harvesting season, peel firmness decreases rapidly. Rind damages such as plugs and fissures around the calyx can cause severe harvest and postharvest losses. As a result, the acceptable harvest period is relatively short and delay of harvest because of labor shortages or temporarily low prices can greatly compromise crop value.

Gibberellic acid (GA_3) is known to delay chlorophyll-degradation in citrus when applied at or prior to color break. In both Mediterranean and tropical climates GA_3 was found to be effective in delaying the picking season and allowing on-tree storage of mandarins (Garcia-Luis et al., 1985; Greenberg et al., 1992: Pozo et al., 1986). In tropical conditions, GA_3 applied to mandarins slows peel growth and its separation from the segments, reduced plugging during harvest, and reduced postharvest losses (Pozo et al., 1986; Perez et al., 1992).

The present research was initiated to explore the potential of GA_3-treatments for reducing harvesting losses and improving the harvesting management of mandarins under central Florida's subtropical conditions.

Materials and Methods

Healthy, uniform 10-year old 'Sunburst' mandarin trees [*Citrus reticulata* Blanco × (*C. paradisi* Macf. × *C. reticulata*] grafted on 'Cleopatra' mandarin (*Citrus reticulata* Blanco) were used. The trees were grown in a Candler fine sand soil at 4.5× 6.0 m (15 ×20 ft) spacing at the Citrus Research and Education Center in Lake Alfred, FL, in the 1999-2000 harvest season. Foliar sprays of 25 mg·L^{-1} GA_3 (ProGibb®, Valent BioSciences Corp., Libertyville, IL) and 0.1% of the adjuvant Tween-20 (ICI, Wilmington, DE) were applied to three full trees on 29 Sept. 1999, at a rate of 5 L (1.3 gal) per tree using an electric 50 L (15 gal) field sprayer (Chemical Containers, Lake Wales, FL) equipped with a hand-held 2.4 m (8 ft) spray boom with flat-fan nozzles (R&D Sprayers, Opelousas, LA). Three control trees were sprayed with a solution containing only the adjuvant, in a randomized complete block design.

Observations and measurements were taken monthly from Sept. 1999 to Jan. 2000. Fruit detachment force (FDF) and degree of plugging were determined on 10 fruits per tree randomly harvested at each sampling date. Fruits were clipped with 2 cm of stem, inserted into a digital force gauge (Force Five™, Wagner Instruments, Greenwich, CT), and the stem pulled parallel to the fruit axis until it separated from the fruit. The number of stems detached with portions of the peel (plugs) and the number of fruit with only small rind damage (fissures) around the abscission zone were recorded.

The fruits were then used to evaluate firmness as peel puncture force (PPF), color and peel puffing. The Wagner force gauge was used as a penetrometer with a 10 mm^2 flat-tip probe to measure PPF on four locations around the shoulder of each fruit. Peel color (chroma and hue angle) was measured on three positions along the equator of each fruit using a chromameter (CR200, Minolta Co., Osaka, Japan). Fruits were cut vertically and rated on a scale of "unpuffed", "minor" (moderated puffing) and "major" (complete separation of peel from the segments). Peel thickness at the fruit equator was measured with a caliper.

The juice of five fruits from each sample was extracted with an electric juice extractor (Sunkist, Overland Park, KS), weighed, and analyzed for citric acid content by NaOH titration and sugar content (°Brix) using a hand refractometer (Wardowski et al., 1991). The remaining peel and solid pulp were separated and weighed. Total pulp included both solid pulp and juice.

All data were tested for treatment effects by analysis of variance using SAS statistical software (SAS Institute, Cary, NC).

Results

Effects on fruit color, peel firmness, peel growth and peel/pulp ratio. The rate of degreening of GA_3-treated fruits was significantly slower than that of control fruits. Gradual changes were observed for chroma and hue angle values in GA_3-treated fruits during Oct., Nov., and Dec. (Fig. 1A, B). In contrast, a complete peel degreening was reached in the control 50 days after spray (mid-Nov.).

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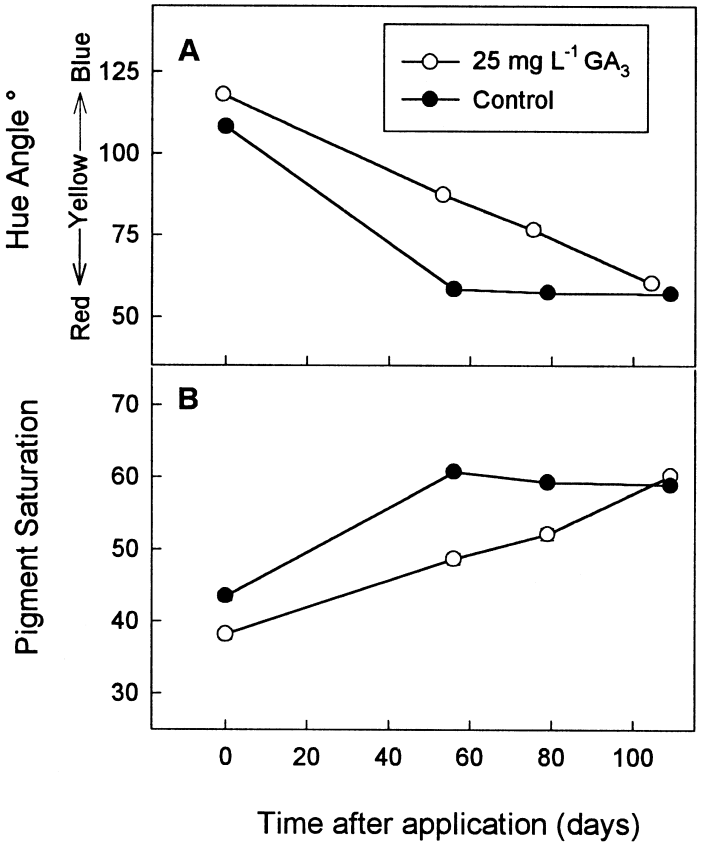

Figure 1. Effect of 25 ppm GA_3 spray applied 29 Sep. 1999, on fruit peel color expressed as (A) hue angle and (B) chroma. Standard error bars are smaller than symbol size.

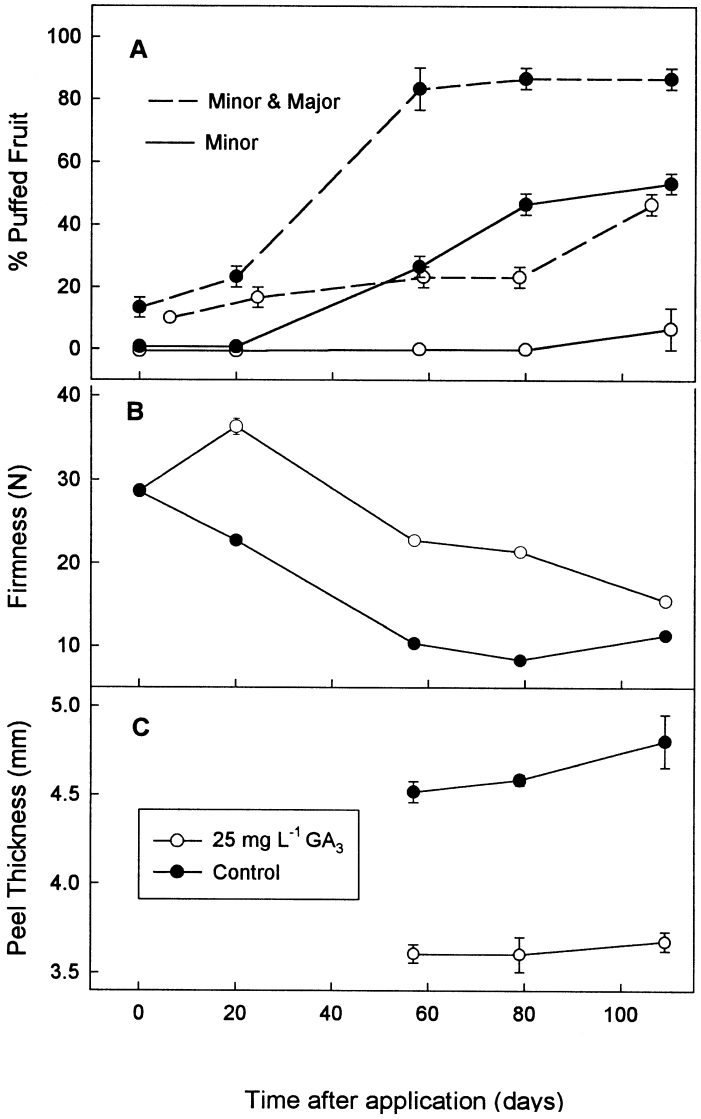

Figure 2. Effect of 25 ppm GA_3 spray applied 29 Sep. 1999, on (A) fruit puffiness, (B) fruit firmness, and (C) peel thickness. Bars indicate S.E.

The effects on rind color were associated with a significant delay in peel puffing (Fig. 2A). A rapid increase of fruit puffiness occurred in untreated fruits from Oct. to Nov., whereas puffiness remained low in GA_3-treated fruit until Dec. Afterward, a moderate increase in the number of puffed fruit was found in GA_3-treated fruits, but significantly lower than in the control ones. Reduced puffing was associated with higher PPF and reduced peel thickness in GA_3-treated fruits (Fig. 2B, C). Total peel fresh weight increased during fruit maturation (Fig. 3A). However, GA_3 slowed and reduced the increase in peel weight during maturation. GA_3 treatment significantly increased the pulp weight when compared to the control and thus, significantly delayed the naturally occurring decrease of pulp/peel ratio (Fig. 3B, C).

Effects on fruit harvest and fruit quality. GA_3 sprays increased and delayed the normal decline of fruit detachment force (FDF) over the fruit harvest season (Fig. 4A). The incidence of plugging or rind fissures remained low in treated fruits, (Fig. 4B). Juice content—like total pulp weight—was higher in GA_3-sprayed fruits (Fig. 5A). No significant differences in citric acid content were found in treated fruits, but sugar content, and subsequently sugar/acid ratio were slightly reduced during Nov. and Dec. (Fig. 5B, C, D).

Discussion

During the 3 month observation period, GA_3 treated fruits showed higher chroma values indicating retarded chlorophyll loss in the flavedo (Agusti et al., 1981; Kawase et al., 1981; Garcia-Luis et al., 1985; El-Otmani and Coggins, 1991). GA_3 is not limited to the regulation of rind color, but may instead play a role in delaying the more general process of peel aging (Baez-Sañudo et al., 1992). The close association found in our study between the retardation of flavedo degreening and the reduction of peel growth has already been reported for satsumas and clementines (Garcia-Luis et al., 1985, 1992).

In our experiment, we measured significantly lower peel thickness and peel weight in treated 'Sunburst' fruits demonstrating that GA_3 delayed fruit aging and the associated puffiness through slower fruit peel growth. Late growth of the peel is a characteristic of the puffy mandarin fruits (Kawase and Hirai, 1983). In satsuma, the inhibition of peel growth by GA_3 application is directly related to the prevention of puffiness (Garcia-Luis et al., 1985).

Irrespective of the reduced peel thickness, we measured increased PPF as an indication of higher peel firmness. These effects have previously been reported for satsumas, clementines, navels and

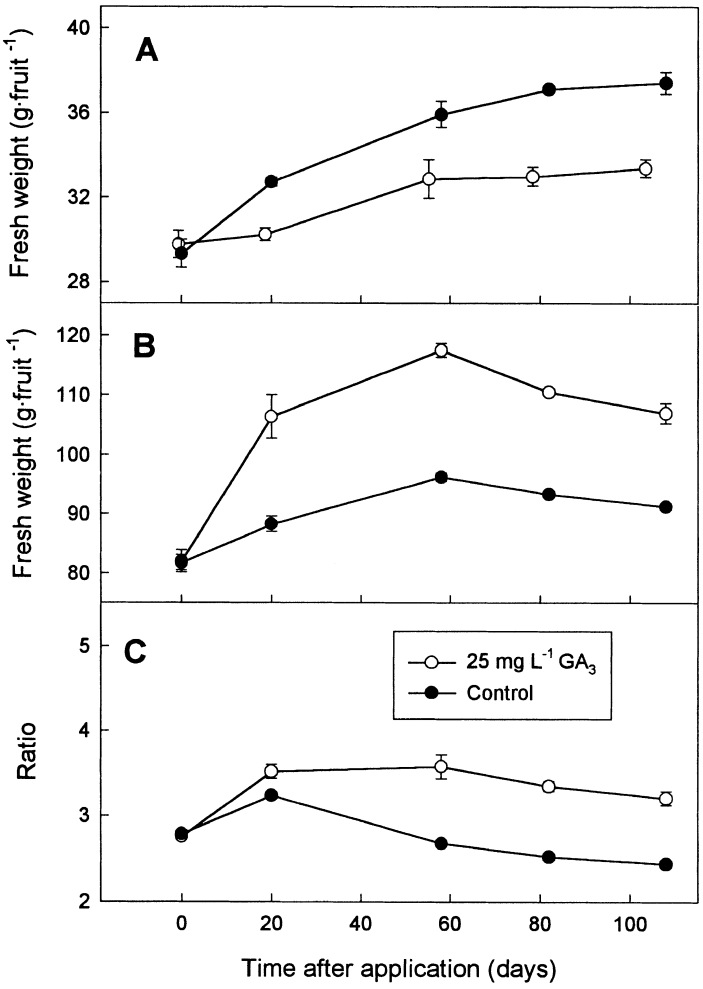

Figure 3. Effect of 25 ppm GA_3 spray applied 29 Sep. 1999, on (A) peel weight, (B) pulp weight including juice content and (C) pulp/peel ratio. Bars indicate S.E.

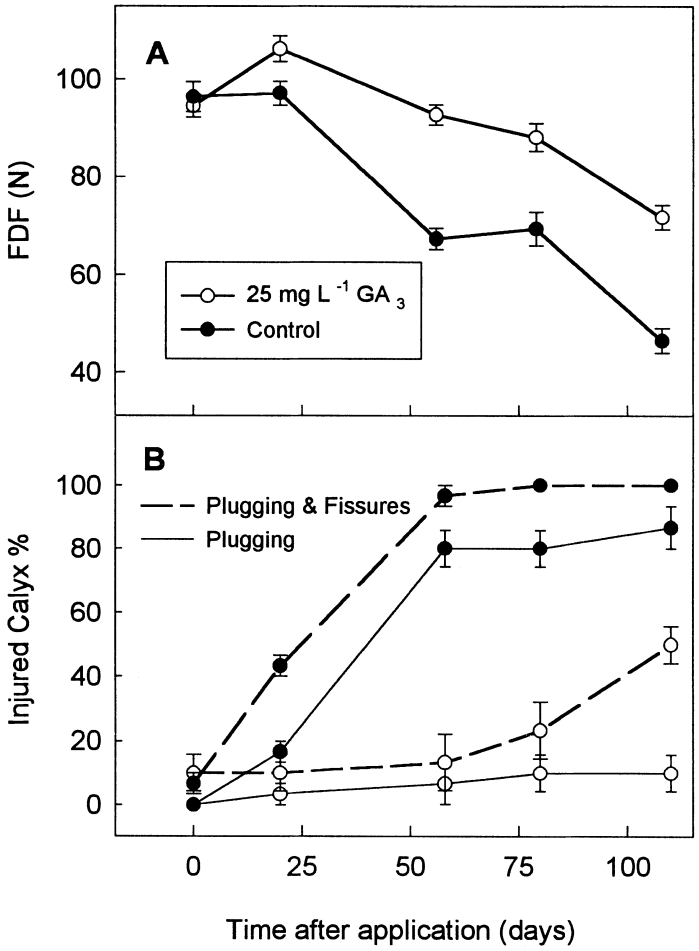

Figure 4. Effect of 25 ppm GA_3 spray applied 29 Sep. 1999, on (A) fruit detachment force (FDF) and (B) rind damage during harvest. Plugging represents a small portion of the rind that detaches with the pedicel. A fissure is a small lesion around the calyx.

'Hamlin' (Garcia-Luis et al., 1985; Garcia-Luis et al., 1992; Coggins, 1981; Monselise et al., 1976; Davies et al., 1999). The reduction of rind damage in GA_3 treated fruits during manual harvest despite an increase in FDF (Fig. 4A) indicates that plugging in mandarins is due to the separation between peel and the segments (puffiness) rather than high FDF.

Effects of GA_3 treatments on peel quality are depending on variety and climatic conditions (El-Otmani and Coggings, 1991). Foliar sprays have been found to reduce creasing, a disorder of the albedo considered to be an initial step toward puffiness (Monselise et al. 1976; Gilfillan and Cutting, 1992). As we found for 'Sunburst', fall applications of GA_3 on 'Minneola' tangelo in Israel (Greenberg et al., 1992) and 'Hamlin', 'Pineapple,' and 'Valencia' oranges in Florida (Davies et al., 1997) increased peel firmness and delayed color development. However, when applied early, GA_3 sprays can control creasing without affecting chlorophyll retention in the peel or delaying harvest in some citrus varieties (Monselise et al., 1976; Coggins, 1981; Greenberg et al., 1992).

Fruit quality parameters were generally not affected by GA_3 treatments. However, due to reduced peel growth, pulp/peel ratio was higher in treated fruit. GA_3 application has been shown to increase juice content of satsuma mandarins (Garcia-Luis et al., 1985).

The improvements we measured in some fruit characteristics, such as peel/pulp ratio, juice content, and fruit firmness (puncture resistance), as well as the reduction of rind damage during harvest, indicate that GA_3 enables 'on-tree' storage and later harvest of 'Sunburst' mandarin. However, effects of GA_3 sprays on mandarin fruit puffing is closely linked to chlorophyll retention, and manipulation of application timing cannot separate the two effects (Garcia-Luis et al., 1985). Thus, the use of GA_3 to prevent rind puffiness is impractical when fruits are intended to be harvested early due to the retarded color development (Kawase et al., 1981; Agustí et al., 1981).

Our results agree with those obtained for 'Dancy' mandarin under tropical conditions (Pozo et al., 1986; Pozo et al., 1990; Perez et al., 1992). GA_3 foliar treatments in the fall seem to be suitable for delaying the harvest season of mandarin fruit with low losses due to plugging and other rind damages. The low incidence of rind fissures in treated fruit would result in lower postharvest losses and longer shelf-life (Pozo et al., 1990). Nevertheless, further research is needed to verify that these results are reproducible in different growing seasons.

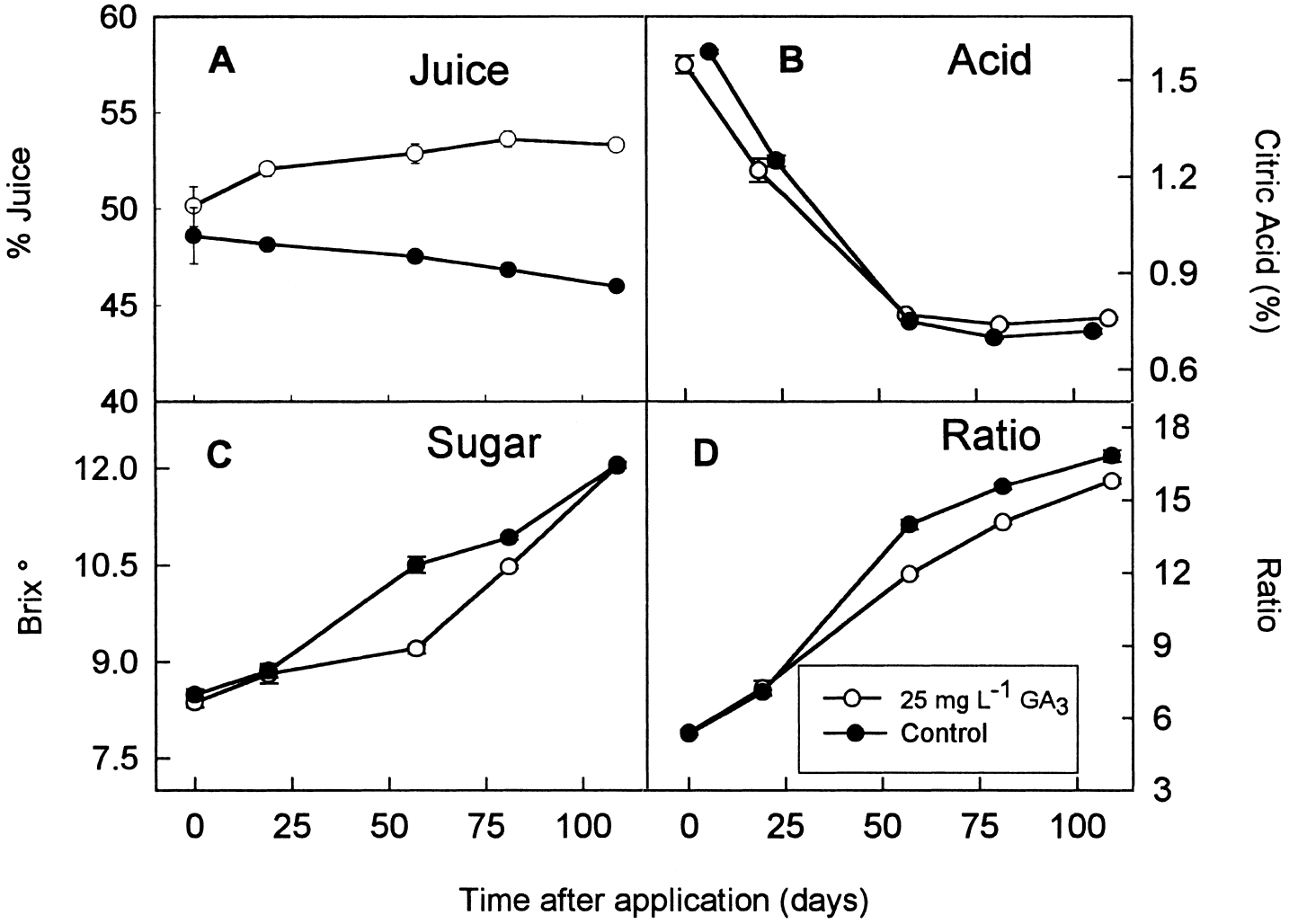

Figure 5. Effect of 25 ppm GA_3 spray applied 29 Sep. 1999, on juice quality.

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