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IMPROVING THE EFFICACY OF GIBBERELLIC ACID BERRY SIZING TREATMENTS

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Summary

The effects of solution pH and acidifying agents, the influence of GA treatment timing, and the time course of GA uptake in grape berries were investigated to determine their effects on the efficacy of GA berry sizing treatments.

Acidifying GA solution pH with citrate buffer, phosphoric acid or urea phosphate had no effect on the physiological efficacy of GA berry sizing treatments. The addition of urea in both buffered (pH 3.0) and non-buffered GA solutions also had no effect on treatment efficacy.

The relationship between berry size and GA treatment response was examined for Perlette and Flame Seedless. The response of Perlette to GA was greatly dependent upon berry size, with maximum response obtained for berries approximately 4 mm in diameter. The response of Flame Seedless berries to GA treatment was less dependent upon berry size than in Perlette. Response to GA treatment was similar among Flame Seedless berries 4 to 9 mm in diameter.

The results of this study suggest that berries continue to take up GA more than 24 hours after their treatment. Up to 30 minutes may be required for berries to absorb sufficient quantities of GA to elicit a growth response.

Introduction

Recent studies have reported that solution acidification and acidifying agents, such as urea phosphate, increase the uptake of exogenous gibberellic acid (GA) applied to plant tissues. The results of these studies indicated that improved GA uptake led to enhanced physiological efficacy of GA applications on grape berries and citrus fruits. The improved efficacy of GA applications would have obvious benefits to table grape growers. Improved efficacy would enhance the action of current GA application rates and, perhaps more importantly, allow lower rates of GA to have the same treatment efficacy as the higher rates currently in use. The latter would reduce production costs and decrease vine exposure to the potentially detrimental effects of GA on bud fruitfulness.

Application timing also influences the efficacy of GA berry sizing applications. The optimum timing for Thompson Seedless berry sizing sprays are well established, however, more information is needed to establish optimum timings for Perlette and Flame Seedless berry sizing applications.

Additional information regarding the mechanisms influencing GA uptake into grape berries is also needed to improve GA treatment efficacy. Little is known regarding the kinetics of GA uptake in grape berries under field conditions.

The purpose of this study was to investigate methods to improve the efficacy of GA berry sizing applications on table grapes. Several experiments were conducted to determine the influence of solution pH and the effectiveness of acidifying agents on the efficacy of GA berry sizing applications. The influence of berry size on the response of Perlette and Flame Seedless to GA sizing treatments was studied. The effect of uptake period on the efficacy of GA berry sizing applications was also examined.

Materials and Methods

Five separate experiments were conducted in 1990 at the University of California Kearney Agricultural Center in Parlier, CA. Five year-old, own-rooted Thompson Seedless grapevines (U.C. Clone 2A) were used in Experiments 1, 2, 3 and 5. The vines were cane pruned (5 to 6 canes retained per vine) and trained to a "T" trellis (7' stakes and 42" cross-arms with 3 foliage support wires). The vines received two berry thinning sprays of 9 (6 May) and 7 (9 May) grams of GA_3 per acre during flower cluster bloom. The vines were thinned to 24 clusters following bloom. The vines used in Experiments 1, 2 and 3 were trunk girdled on 24 May using 3/16" girdling knives. Mean berry diameter at girdling was approximately 6 mm. Vines used in experiment 5 were not girdled.

Six-year old, own-rooted Perlette and Flame Seedless grapevines were used in Experiment 4. The vines were cordon trained and spur pruned (14 to 18 two-bud spurs retained per vine). A "T" trellis system (7' stakes and 36" cross-arms with 2 foliage support wires) was used for both varieties. The Flame Seedless vines received one GA berry thinning spray (4 grams of GA_3 per acre) during flower cluster bloom (7 May). The Perlette vines were berry thinned by hand (approximately 50% of the berries removed) at the initiation of berry shatter (12 May). The vines used in Experiment 4 were not girdled.

Experimental treatments were applied as single cluster dip by immersing entire clusters for 10 seconds. The specific details of each experiment are discussed below.

Experiment 1: Influence of solution pH on the efficacy of GA berry sizing treatments on Thompson Seedless

Investigated in the 3 x 5 factorial experiment were the interactive effects of buffer (citrate buffer, solution pH = 3.0; phosphoric acid, solution pH = 3.0; unbuffered solution) and GA (0, 20, 40, 60, and 80 mg GA_3/l) on the efficacy of GA berry sizing treatments. Buffered solutions were prepared by adding granular citrate buffer or concentrated phosphoric acid to 3 l of GA solution until the desired pH (3.0 $\pm$ 0.05 pH units) was obtained. An Orion model SA 720 pH meter and combination electrode were used to determine solution pH. A magnetic stir plate was used for solution preparation and pH determinations. The meter was calibrated immediately prior to use with commercially standardized pH 4.0 and pH 7.0 buffers. Unbuffered solutions were prepared using tap water. Triton B-1956 was added to all solutions (0.02%) as a wetting agent. The influence of GA concentration on the pH of unbuffered solutions is presented in Figure 1.

The treatments were randomly assigned to twenty clusters on each vine. Experimental clusters were tipped (5 to 6 rachis laterals retained per cluster) immediately prior to treatment on 25 May. Each treatment was replicated 20 times using single cluster plots. All treatments within a replication were placed on the same vine (i.e. 20 vines were used in the experiment).

Clusters were harvested over a 10 day period at the beginning of August (August 1 to August 10). All experimental clusters on a vine were harvested on the same date. All berries were removed from the cluster, counted and weighed. Berry diameter, length and soluble solids content (^{0}Brix) were determined from a randomly selected 50 berry subsample of each cluster.

Experiment 2: Effect of urea phosphate on the efficacy of GA berry sizing treatments on Thompson Seedless.

The 4 x 5 factorial experiment investigated the influence of urea phosphate (0, 500, 1000 and 2000 mg/l) and GA (0, 20, 40, 60, and 80 mg/l GA_3) on the efficacy of GA berry sizing treatments. The solutions were prepared by adding the appropriate amount of granular urea phosphate to 3 l of GA solution. Triton B-1956 was added as a wetting agent (0.02%) to all solutions. Solution pH was determined as previously described. The final pH of each solution is presented in Figure 2.

The treatments were assigned to twenty randomly selected clusters per vine. Experimental clusters were tipped (5 to 6 rachis laterals retained per cluster) on 23 May. The treatments were applied on 24 May. Each treatment was replicated 20 times using single cluster plots. All treatments within a replication were placed on the same vine (i.e. a total of 20 vines were used in the experiment).

Clusters were harvested over a 7 day period from August 14 to August 20. All experimental clusters on a vine were harvested on the same date. All berries were removed from the cluster, counted and weighed. Berry diameter, length and soluble solids content (^{0}Brix) were determined on a randomly selected 50 berry subsample of each cluster.

Experiment 3: Effect of urea and solution pH on the efficacy of GA berry sizing treatments on Thompson Seedless.

The effects of urea (0, 200, 400 and 600 mg/l) and solution pH (solution pH adjusted to 3.0 using phosphoric acid or solution pH unbuffered) on the efficacy of GA berry sizing treatments was measured in this 4 x 2 factorial experiment. Buffered solutions were prepared by adding concentrated phosphoric acid to 3 l of urea solution until the desired pH (3.0 $\pm$ 0.05 pH units) was obtained. Solution pH was determined as described previously. All solutions contained 40 mg/l of GA_3. Unbuffered solutions were prepared using tap water. Triton B-1956 was added as a wetting agent (0.02%) to all solutions. Urea had no effect on solution pH (data not presented). The pH of the unbuffered solution was approximately 7.0.

Clusters were tipped (5 to 6 rachis laterals retained per cluster) on May 24. The treatments were randomly assigned to 15 clusters per vine and applied on 27 May. Each treatment was replicated 14 times using single cluster plots (i.e. a total of 14 vines were used in the experiment). All treatments within a replication were placed on the same vine.

Clusters were harvested over a 4 day period from 21 August to 24 August. All experimental clusters on a vine were harvested on the same date. All berries were removed from the cluster, counted and weighed. Berry diameter, length and soluble solids content (^{0}Brix) were determined on a randomly selected 50 berry subsample of each cluster.

Experiment 4: Influence of berry size on the response of Perlette and Flame Seedless to GA sizing treatments.

Twelve vines of each variety were used in the experiment. At the initiation of berry shatter, six representative clusters on each vine were tipped to 5-6 rachis laterals and randomly assigned a GA treatment date. Perlette clusters were treated 4, 10, 15, 26, or 35 days after full bloom. Flame Seedless clusters were treated 2, 8, 12, 23 or 32 days after full bloom. Clusters received a single cluster dip application of 60 mg GA_3/l. A randomly selected, 20 berry sample was removed from each cluster immediately prior to treatment to determine berry diameter. An untreated control was included in each variety. All treatments within a replication were placed on the same vine (12 replications were used in each variety).

Perlette and Flame Seedless clusters were harvested on 16 July and 23 July, respectively. All berries were removed from the cluster, counted and weighed. Berry diameter, length and soluble solids content (^{0}Brix) were determined on a randomly selected 50 berry subsample of each cluster.

Experiment 5: Influence of uptake period on the efficacy of berry sizing applications on Thompson seedless.

Experimental clusters were tipped (5 to 6 rachis laterals retained per cluster) and treated with a single application of GA (60 mg GA_3/l) on 6 June. Average berry diameter at the time of treatment was approximately 7 mm. Clusters were washed with 1 gallon of clean water either immediately after GA treatment, or 0.5, 1, 4 and 24 hours later. The clusters were washed with a hand-held spray wand. Both a treated, unwashed control and an untreated, washed control were included in the experiment. Unwashed clusters remained visibly damp for approximately 30 minutes after treatment. Each treatment was replicated 12 times, with all treatments of a single replicate placed on the same vine. Clusters were harvested on 31 July. All berries were removed from the cluster, counted and weighed.

Results

Experiment 1

Significant interactions between buffer x GA were not found for any of the experimental parameters (P = 0.681, 0.643, and 0.276 for berry fresh weight, berry diameter and soluble solids content, respectively) (Figure 2). Buffer had no significant influence on any of the experimental parameters (P = 0.299, 0.515, and 0.213 for berry fresh weight, berry diameter and soluble solids content, respectively). GA concentration was highly significant (P = .0001) for all parameters. Berry fresh weight and berry diameter were significantly increased, and berry soluble solids content significantly decreased, with increasing GA concentration.

Experiment 2

Significant interactions between urea phosphate and gibberellin concentration were not observed for any of the experimental parameters (P = 0.5923, 0.2347, 0.5341 and 0.7989 for berry fresh weight, berry diameter, berry length, and soluble solids content, respectively) (Fig. 3). Berry soluble solids decreased as urea phosphate concentration was increased (P = 0.002). GA concentration was highly significant (P = 0.0001) for all experimental parameters; berry fresh weight and berry diameter were increased, and berry soluble solids content decreased, as GA concentration was elevated.

Experiment 3

Urea x solution pH had no interactive effects on the experimental parameters (Fig. 4). Urea had no influence on any of the experimental parameters. Acidifying solution pH to 3.0 significantly increased berry diameter ($P = 0.0366$) and berry length ($P = 0.0382$). Berry diameter and length were 17.1 and 26.6 mm, respectively, for berries treated with the buffered GA solution compared to 16.9 and 26.0 mm for berries treated with the unbuffered solution.

Experiment 4

Perlette berries exhibited their maximum response to GA sizing treatments at a diameter of 4 mm. The response of Perlette to GA fell rapidly as berry diameter exceeded 4 mm, and dropped to nearly zero as berry diameter approached 7 mm. The length:diameter ratio of Perlette berries was most sensitive to GA applied immediately after bloom; the response of this parameter to GA decreased rapidly with subsequent berry development.

The maximum responsiveness of Flame Seedless berries to GA treatment occurred over a much broader range of berry size compared to Perlette berries. Response to GA was similar among berries 4 to 9 mm in diameter. Response to GA fell rapidly, however, when berry diameter fell out of this range.

Experiment 5

The berry weight of clusters washed immediately after GA treatment were similar to those of the untreated control. The berry weight of clusters washed 30 minutes after treatment were greater than that of the untreated control, but less than those from clusters washed 1, 4 or 24 hours after treatment. Berry weights of the latter treatments were significantly less than those of the treated control. The berry weight of clusters washed 24 hours after treatment was approximately 90% of that of unwashed clusters.

Discussion

The acidification of GA solutions causes the formation of the nonpolar, undissociated form of GA. This form of GA is believed to be more permeable to plant membranes than the polar, dissociated form of GA present in solutions of neutral pH. Previous reports indicated that solution acidification improved the uptake and physiological activity of exogenous GA in citrus fruits and grape berries. With the exception of Experiment 3, in which slight increases in berry diameter and length as a result of solution acidification were observed, solution pH had no effect on the physiological efficacy of GA applications in this study. Previous studies also reported that urea phosphate improved the efficacy of

GA berry sizing treatments. Berry growth parameters were unaffected by urea phosphate in the current study.

Urea has been shown to increase the uptake of low-soluble nutrients, and is believed to influence the permeability of plant membranes. The presence of urea in either buffered or unbuffered GA solutions in this study had no effect on the efficacy of GA berry sizing applications.

Berry size has a significant influence on the responsiveness of grapes to GA treatment. Cell division in the berry is most rapid during the initial stages of berry growth (i.e. early phase I). It has been suggested that GA berry sizing applications should be applied at this time for maximum effectiveness. GA applied during this period stimulates pericarp cell division, increasing cell number per berry and eventual cell size. This period of rapid cell division is believed to last approximately 16 days after berry set in Thompson Seedless, but has not been extensively studied for other grape cultivars. Varietal differences in the relationship between berry size and response to GA may reflect differences in the length of the rapid cell division phase among berries of different cultivars.

The results of this study suggest that GA is taken up into berries 24 hours or more after its application. It is unclear if berries must be re-moistened (perhaps by early morning dew) for this uptake to occur. Further work is needed to determine the time course and mechanism of GA uptake in grape berries.

Conclusions

1. Solution pH had little effect on the physiological efficacy of GA berry sizing treatments.

2. Urea phosphate did not improve the physiological activity of GA berry sizing treatments.

3. The addition of urea to buffered and unbuffered GA solutions had no effect on the physiological activity of GA berry sizing treatments.

4. The relationship between berry size and physiological responsiveness to GA sizing applications varies due to cultivar. Perlette berries were most responsive to GA when approximately 4 mm in diameter, while Flame Seedless berries 4 to 9 mm in diameter were equal in their response to GA.

5. GA continues to be absorbed by berries for more than 24 hours after treatment. Up to 30 minutes may be required for berries to take up sufficient quantities of GA to elicit a partial increase in berry growth. No difference in the physiological activity of GA treatments was observed when the uptake period varied between 1 and 24 hours.

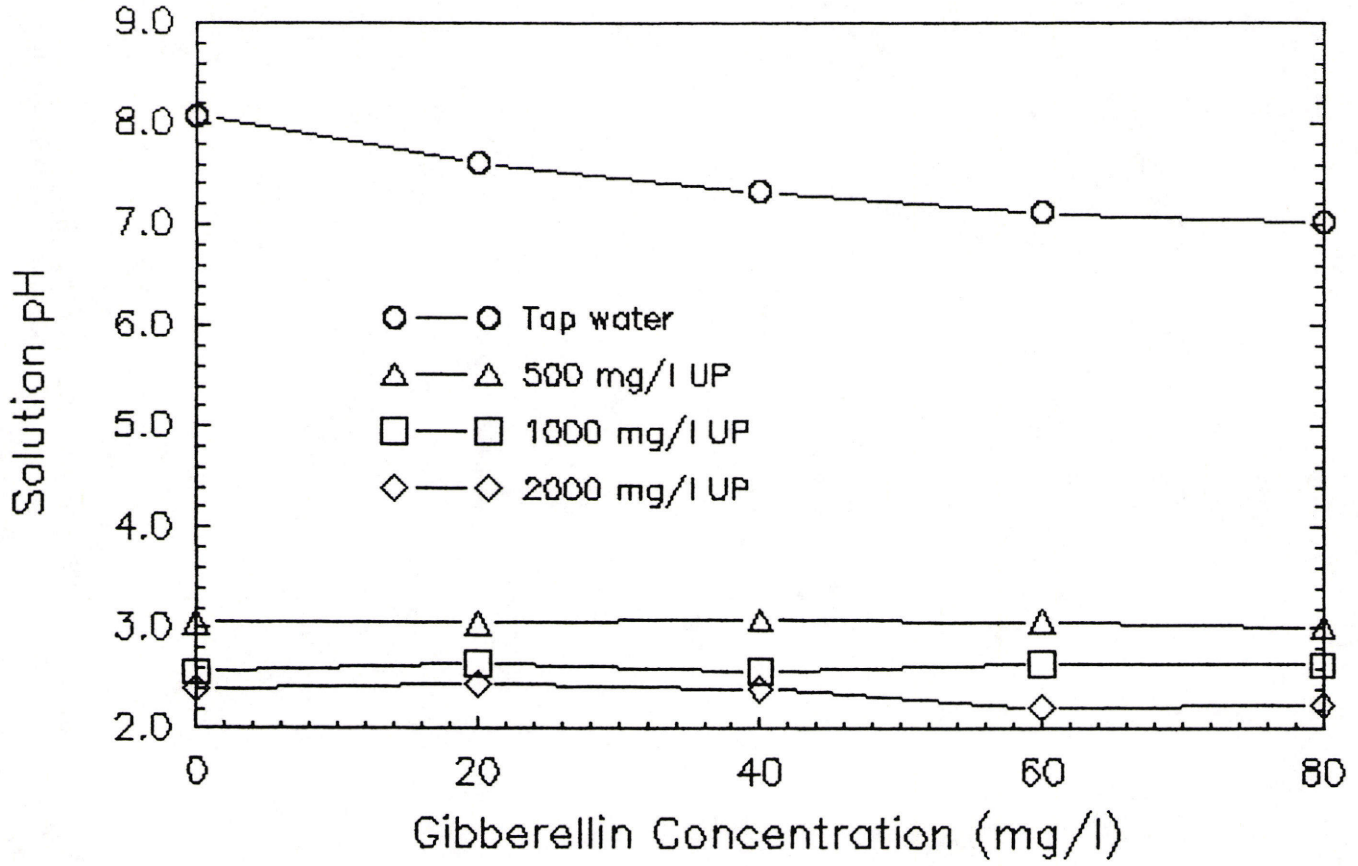


Figure 1. Influence of urea phosphate and GA_3 on solution pH.

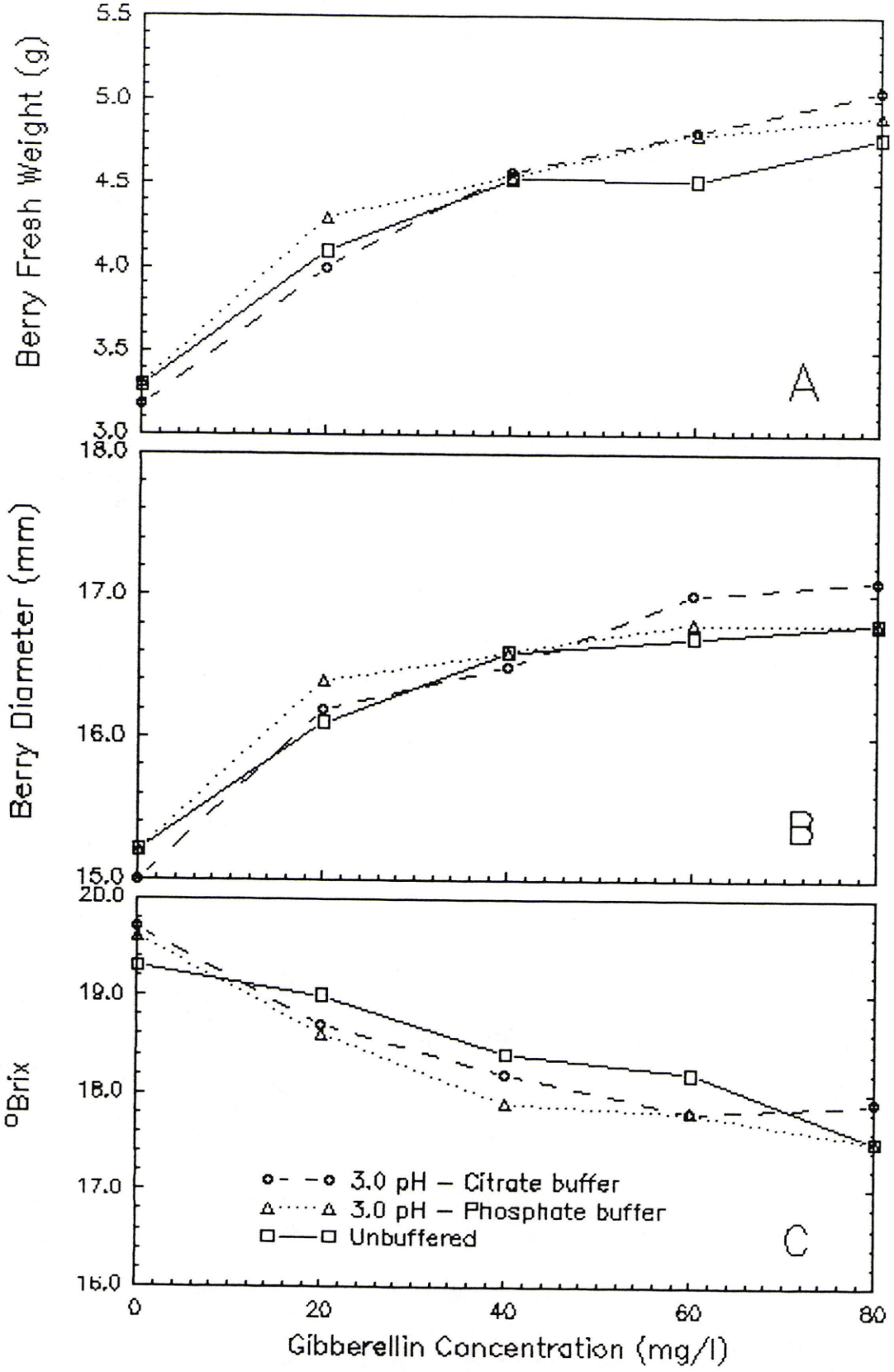


Figure 2. Influence of buffer and GA_3 on the fresh weight (A), diameter (B), and soluble solids content (C) of Thompson Seedless grape berries. Main effect equations for GA conc. represent the average of the 3 buffers.

Berry fresh wt. = $4.9904 - 1.7244e^{(-0.0338 \times \text{GA conc.})}$, $R^2 = 0.969$.

Berry diameter = $16.9421 - 1.8016e^{(-0.0439 \times \text{GA conc.})}$, $R^2 = 0.968$.

°Brix = $19.5190 - 0.0417$ GA conc. $+ 0.000232$ GA conc.^{2}, $R^2 = 0.926$.

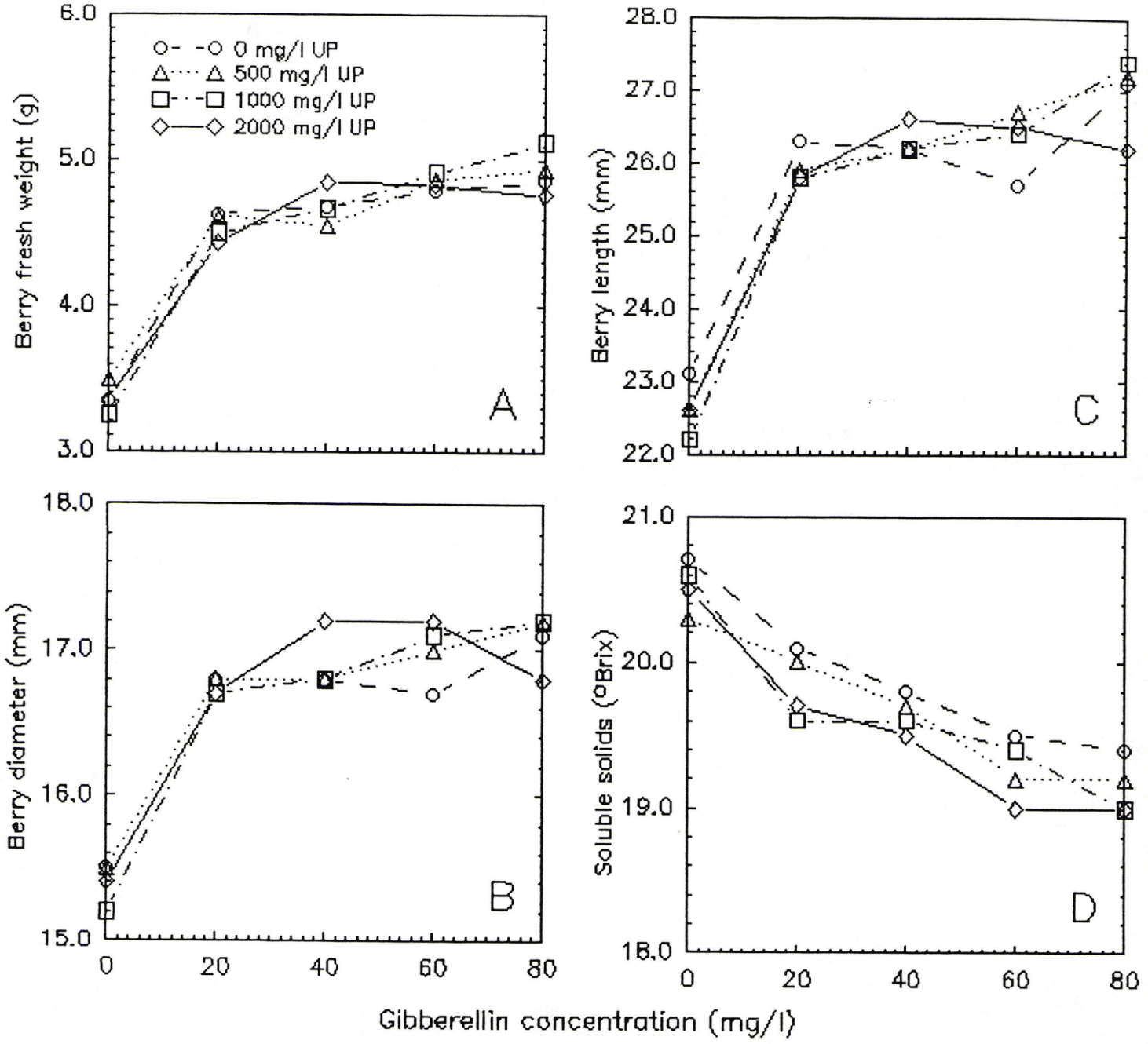


Figure 3. Influence of urea phosphate and GA_3 on fresh weight (A), diameter (B), length (C), and soluble solids content (D) of Thompson Seedless grape berries. Main effect equations for GA conc. represent the average of the 4 urea phosphate concentrations.

Berry fresh wt. = $4.8695 - 1.5122e^{(-0.0706 \times \text{GA conc.})}$, $R^2 = 0.996$.

Berry diameter = $17.0307 - 1.6282e^{(-0.0818 \times \text{GA conc.})}$, $R^2 = 0.946$.

Berry length = $26.6 - 3.9778e^{(-0.0852 \times \text{GA conc.})}$, $R^2 = 0.940$.

Soluble solids = $20.4871 - 0.0298 \text{ GA conc.} + 0.000165 \text{ GA conc.}^2$, $R^2 = 0.877$.

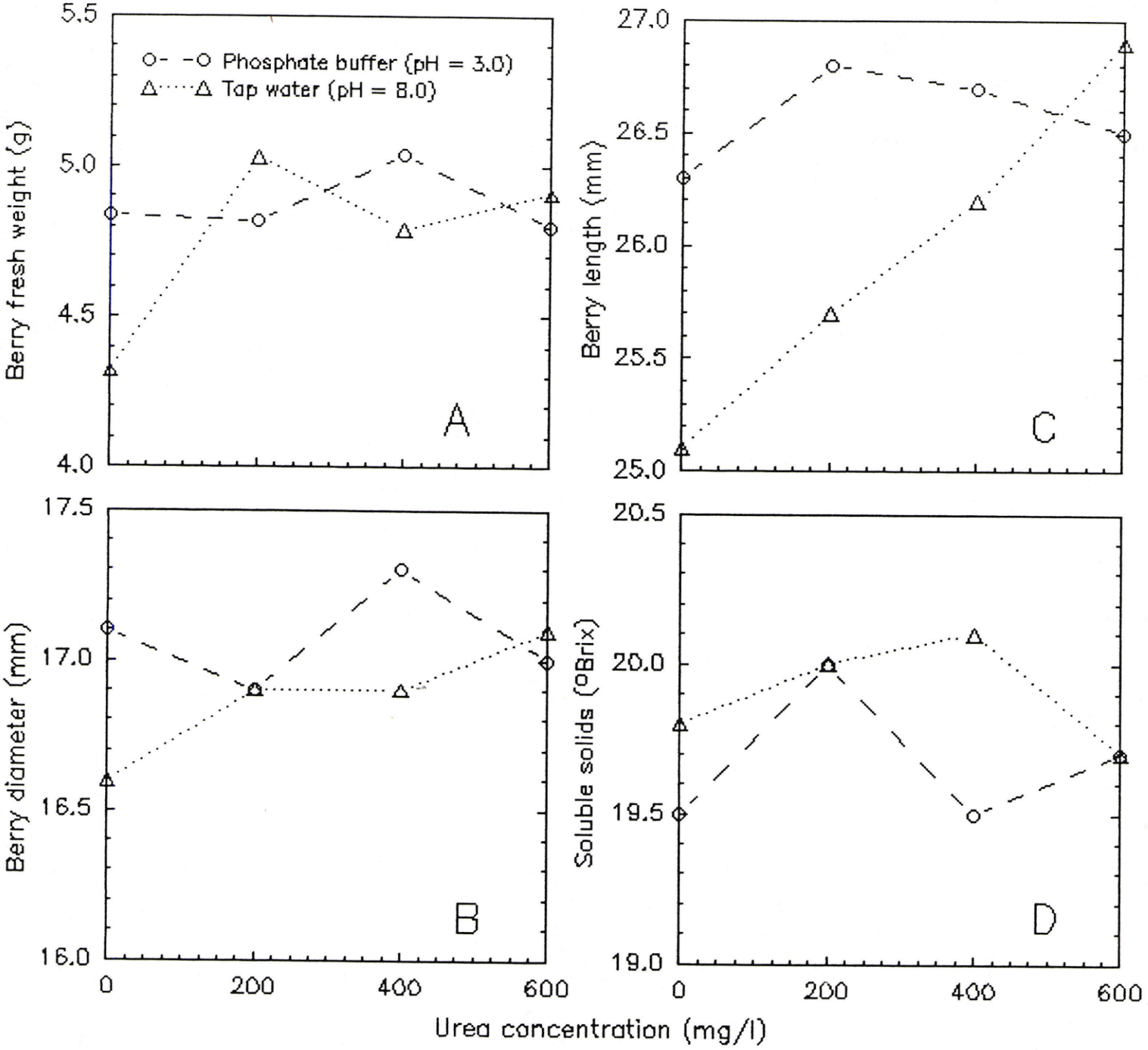


Figure 4. Influence of solution pH and urea on fresh weight (A), diameter (B), length (C), and soluble solids (D) of Thompson Seedless grape berries.

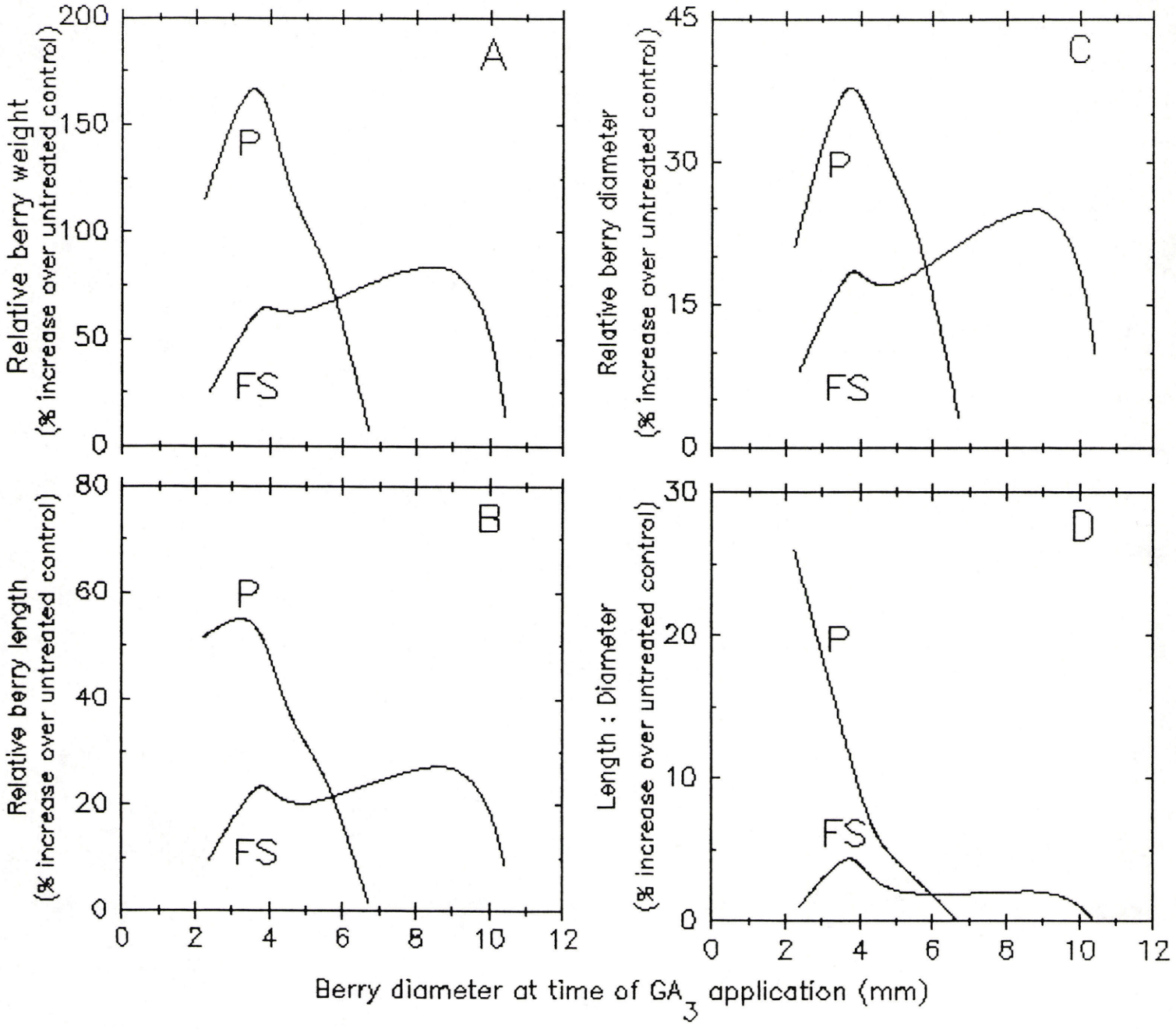


Figure 5. Influence of berry diameter at the time of GA_3 treatment on the relative weight (A), relative length (B), relative diameter (C), and length:diameter ratio (D) of Perlette (P) and Flame Seedless (FS) grape berries. Results are expressed as the percent increase over the untreated control.

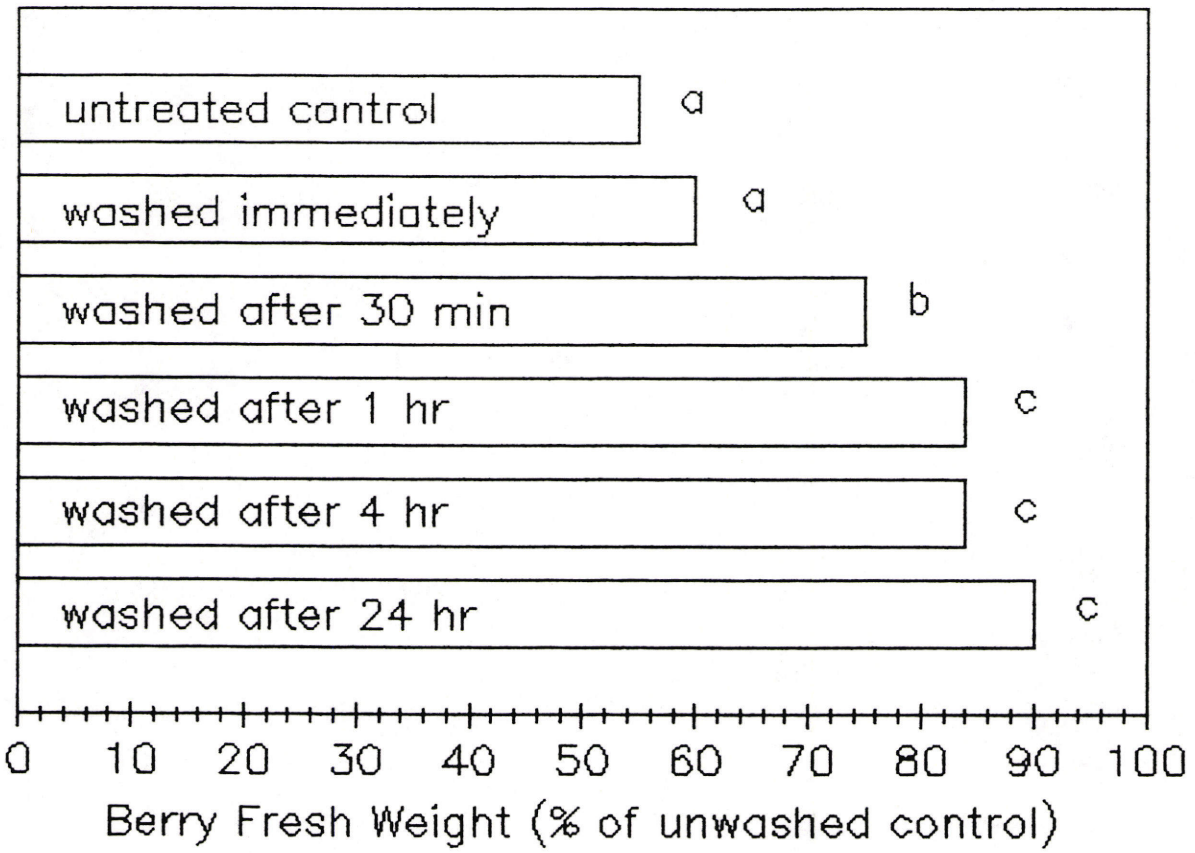


Figure 6. Influence of GA_3 uptake period on fresh weight of Thompson Seedless grape berries. Treatment means are expressed as a percentage of the unwashed control. Means followed by the same letter are not significantly different at the 5% confidence level (DMRT).