Evaluation of GA$_{4+7}$ plus 6-Benzyladenine as a Frost-rescue Treatment for Apple

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Additional Index Words. cytokinins, fruit set, gibberellins, *Malus × domestica*, parthenocarpy

Summary. Freeze events during bloom can be a relatively frequent occurrence in many apple (*Malus × domestica*) production areas in the United States that significantly reduce orchard productivity and profitability. This study investigated the potential for a proprietary mixture of gibberellin A$_4$ + A$_7$ and 6-benzyladenine (GA$_{4+7}$ plus 6-BA) to increase fruit set and cropping of apple following freeze events at three locations across the United States during bloom in 2012. GA$_{4+7}$ plus 6-BA increased fruit set in two of five experiments, and increased fruit number and yield per tree in three of five experiments. GA$_{4+7}$ plus 6-BA increased fruit set and yield of ‘Taylor Spur Rome’ following freezes on two consecutive days during bloom when the minimum temperature reached 23.9 and 28.4 °F. Fruit set was increased due to a stimulation of parthenocarpic fruit growth. Using locally obtained market prices, GA$_{4+7}$ plus 6-BA treatments increased the crop value of ‘Taylor Spur Rome’, ‘Ginger Gold’, and ‘Jonagold’ by $3842, $977, and $6218, respectively. Although GA$_{4+7}$ plus 6-BA application(s) after a freeze increased fruit set and cropping in some instances, tree yields were well below the average yields previously obtained in the test orchards.

Foliar gibberellin (GA) sprays during bloom increase fruit set in pear (*Pyrus communis*) by stimulating parthenocarpic fruit development (Deckers and Schoofs, 2002; Dreyer, 2013; Luckwill, 1960; Zhang et al., 2008). This strategy is used in commercial practice to increase fruit set and cropping in pear cultivars that naturally have poor fruit set (Lafer, 2008; Vilardell et al., 2008), and to increase fruit set of pear after frost damage during bloom (Ouma, 2008, Yarushnykov and Blanke, 2005). Deckers and Schoofs (2002) suggested that GAs need to be applied to pear within 4 d after a frost event to alleviate damage, and that gibberellic acid (GA$_3$) increased fruit set more effectively than GA$_{4+7}$. Gibberellins, and in particular GA$_4$, induce and sustain parthenocarpic growth of apple fruit (Bukovac, 1963; Davison, 1960; Luckwill, 1960). Bukovac (1963) reported that gibberellins “induced parthenocarpic fruit growth and promoted fruit development to maturity at growth rates and with final size, color, and general quality comparable to seeded fruits” in the cultivars Sops-of-Wine, Wealthy, and Delicious. However, Wertheim (1973) showed that GA$_{4+7}$ only temporarily increased fruit set of ‘Cox’s Orange Pippin’ apple flowers after effemination. Thus, the efficacy of GA$_{4+7}$ to promote parthenocarpy may vary between apple cultivars. Application of gibberellins together with the synthetic cytokinin N-(2-chloro-4-pyridyl)-N-phenylurea (CPPU) had a positive synergistic effect on set of parthenocarpic fruit and fruit size in apple (Bangerth and Schröder, 1994; Watanabe et al., 2008).

While GA sprays are commonly used to increase fruit set and cropping of pear following a freeze, there is no information describing the efficacy of this treatment in apple. The objectives of the current studies were to investigate the potential for a proprietary formulation of GA$_{4+7}$ plus 6-BA (Promalin®, Valent BioSciences Corp., Libertyville, IL) to increase fruit set and cropping of apple following freeze events during bloom. A series of spring freezes throughout major apple production regions in the eastern United States in 2012 provided the opportunity to evaluate GA$_{4+7}$ plus 6-BA applications as a frost-rescue treatment.

Materials and methods

Henderson County, NC. A commercial formulation of 1.8% w/w each of GA$_{4+7}$ and 6-BA (Promalin®) was applied at a rate of 25 or 50 mg L$^{-1}$ to mature ‘Taylor Spur Rome’/‘Malling 7’ (‘M.7’) apple trees in a commercial orchard in Henderson County, NC. There was minimal elevation change across the orchard. There were a total of three treatments in the study: an unsprayed control, and GA$_{4+7}$ plus 6-BA applied at 25 or 50 mg L$^{-1}$. Each treatment was assigned to fully guarded

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### Units

| To convert U.S. to SI, multiply by | U.S. unit | SI unit | To convert SI to U.S., multiply by |
|-----------------------------------|-----------|---------|-----------------------------------|
| 0.4047                            | acre(s)   | m       | 2.4711                           |
| 0.0304                            | ft        | m       | 3.2808                           |
| 9.3540                            | gal/acre  | L ha$^{-1}$ | 0.1069                           |
| 25.4                              | inch(es)  | mm      | 0.0394                           |
| 6.4516                            | inch$^2$  | cm$^2$  | 0.1550                           |
| 0.4536                            | lb        | kg      | 2.2046                           |
| 28.3495                           | oz        | g       | 0.0353                           |
| 1                                 | ppm       | mg L$^{-1}$ | 1                               |
| 1°F – 32                          | °F        | °C      | 1°C (× 1.8) + 32                 |
The number of blossom clusters on each limb was counted and expressed as blossom cluster density (clusters per square centimeter limb cross-sectional area). Trees were separated into eight groups (blocks) of three trees each based upon the calculated blossom cluster density. Within each group, trees were randomly assigned to receive one of the following three treatments: Control (no treatment), GA$_4$ plus 6-BA at 25 or 50 mg L$^{-1}$. Thus, the study was a randomized complete block design with eight replications. The phenological development in this orchard was tight cluster (9 Apr.), pink bud stage (16 Apr.), early petal fall (23 Apr.), and petal fall (30 Apr.). GA$_4$ plus 6-BA was applied in a water volume of 100 gal/acre using an airblast sprayer on 18 Apr., 5 d after a frost of 31.8 °F recorded at early pink (13 Apr.). This location also recorded frosts on three consecutive days during petal fall (31.6, 30.1, and 30.4 °F on 28, 29, and 30 Apr., respectively). The number of fruit on each sample limb was counted at the end of June drop and final fruit set expressed as fruit/100 blossom clusters. No additional fruit drop was observed between June drop and harvest. The fruit from each tree were counted and weighed when normal commercial maturity was reached, and yields (kilograms per tree, bushels per acre) were calculated from this data. The number of misshapen fruit and those with frost rings were determined and the seed count was taken on a 25-apple subsample from each tree. Crop value was calculated on a per acre basis assuming misshapen and frost ring–damaged fruit would be sold as culls at a value of $0.15/lb and the remaining marketable fruit were sold for $0.55/lb.

Results
Henderson County, NC. The test orchard experienced freezing temperatures on two consecutive nights during full bloom in 2012, the first on 12 Apr. when the minimum air temperature reached 23.9 °F and the second on 13 Apr. when the minimum air temperature was 28.4 °F. Air temperatures were below 32 °F for ~5 h each night (Fig. 1). GA$_4$ plus 6-BA significantly increased fruit set, yield, and fruit number per tree at harvest compared with the untreated control (Table 1). In addition, the marketable yield per tree and the percent of
fruit with frost russet at harvest were higher on the GA4+7 plus 6-BA treated trees compared with the control (Table 2). Fewer than 5% of fruit on control trees exhibited parthenocarpy, compared with \( \approx 70\% \) of the fruit on trees sprayed with GA4+7 plus 6-BA. Thus, GA4+7 plus 6-BA increased fruit set and yield after the two freeze events by stimulating production of parthenocarpic fruit (Table 3). Parthenocarpic ‘Taylor Spur Rome’ fruit had similar weight (Table 1) and shape as measured by L:D ratio (Table 3) compared with control fruit. The crop value in the GA4+7 plus 6-BA treatments was \( \approx 4000/\)acre higher than the crop value of the untreated control.

**Geneva, NY.** GA4+7 plus 6-BA significantly increased fruit set of ‘Jonagold’, but did not significantly improve fruit set of ‘Ginger Gold’ or ‘Gala’ although there was a numeric increase in set for all three cultivars (Table 4). Fruit number per tree, yield, and crop value of ‘Ginger Gold’ and ‘Jonagold’ were increased by GA4+7 plus 6-BA, but not significantly in ‘Gala’ (Table 4). GA4+7 plus 6-BA increased the crop value of ‘Ginger Gold’ and ‘Jonagold’ by \( $977 \) and \( $6218/\)acre, respectively, but the increase in crop value of ‘Gala’ (\( $941/\)acre) was not significant. There was no effect of treatment on mean fruit weight of any of the cultivars. GA4+7 plus 6-BA resulted in a significant reduction in average seed number per fruit in ‘Ginger Gold’ due to a (nonsignificant) increase in the number of parthenocarpic fruit. About 20% of the control fruit were parthenocarpic compared with 70% of fruit from the GA4+7 plus 6-BA treatment. Seed number was not measured in ‘Gala’ or ‘Jonagold’. The yield of untreated ‘Ginger Gold’ was estimated to be \( \approx 4\% \) of a full crop while the yield of untreated ‘Jonagold’ and ‘Gala’ was estimated to be \( \approx 11\% \) and 55% of a full crop, respectively. Applications of GA4+7 plus 6-BA increased the percentage of a full crop to \( \approx 12\%, 39\% \), and 66% of a full crop for ‘Ginger Gold’, ‘Jonagold’, and ‘Gala’, respectively.

**Empire’ in Amherst, MA.** There was no effect of GA4+7 plus 6-BA application on fruit set or yield of ‘Empire’ (Table 5). There was no effect of GA4+7 plus 6-BA on the percent of misshapen fruit, the percent of fruit with frost rings (data not shown), or seed number per fruit at harvest. Total yield in the control plots (580 bushels/acre) was \( \approx 70\% \) of the normal expected crop for trees in this orchard.

### Table 1. Effects of gibberellin A4 + A7 and 6-benzyladeneine (GA4+7 plus 6-BA) treatments after freezes during full bloom on 12 and 13 Apr. 2012 on fruit set, total yield, fruit number per tree, and mean fruit weight of ‘Taylor Spur Rome’/‘M.9’ apple in Henderson County, NC.

| Treatment* | Fruit set (fruit/100 clusters) | Yield (kg/tree) | Crop value (bu/acre) | Fruit (no./tree) | Mean fruit wt (g) | Crop value ($/acre)* |
|------------|-------------------------------|-----------------|----------------------|-----------------|-----------------|---------------------|
| Untreated control | 2.6 a* | 11.7 a | 94 a | 58 a | 198 | 1965 |
| GA4+7 plus 6-BA (25 mg L\(-1\)) | 17.7 b | 36.8 b | 296 b | 195 b | 185 | 5807 |
| GA4+7 plus 6-BA (50 mg L\(-1\)) | 14.9 b | 33.9 b | 273 b | 185 b | 182 | 5328 |

*1 mg L\(-1\) = 1 ppm, 1 kg = 2.2046 lb, 1 gal = 19.1 kg bushel (bu) per acre = 47.0757 kg ha\(^{-1}\), 1 g = 0.0353 oz.

*Calculated assuming cull fruit had a value of $0.20/lb ($0.441/kg) and fresh fruit had a value of $0.57/lb ($1.257/kg); $1/acre = $2.4711/ha.

*Values in a column with different letters are statistically different by Duncan’s multiple range test at \( P \leq 0.05 \).

*NS, **, ***Nonsignificant or significant at \( P \leq 0.01 \) or 0.001, respectively, based on analysis of variance.

### Discussion

These results demonstrate the potential for GA4+7 plus 6-BA to increase fruit set, yield, and crop value of apple following freeze events during bloom. Although production following GA4+7 plus 6-BA treatments was only a fraction of the expected normal yields, they did increase yields to make the treatments economically worthwhile under some conditions. For ‘Taylor Spur Rome’ and ‘Ginger Gold’, the positive effect of GA4+7 plus 6-BA on fruit set was due to stimulation of parthenocarpic fruit development. This result was in agreement with previous findings that GA4 stimulated parthenocarpic fruit development of several apple cultivars (Bukovac, 1963). GA4+7 plus 6-BA spray(s) were without effect on fruit set of ‘Gala’/‘M.9’ in Geneva, NY or ‘Empire’/‘M.9’ in Amherst, MA. The relatively
high yield of untreated ‘Gala’ (55% of a full crop) was largely due to the excessive production and set of lateral flower clusters on 1-year-old wood. The delayed bloom of flower clusters on 1-year-old wood resulted in improved survival compared with earlier blooming flower clusters on spurs or terminal buds. These late blossoms on 1-year-old wood (lateral flower clusters) went on to set fruit. However, fruit size of ‘Gala’ was quite small because of the high percentage of the fruits originating from these late blooms. ‘Jonagold’ also had some lateral flower clusters, but less than ‘Gala’, while ‘Ginger Gold’ had few lateral flower clusters.

Apple cultivars differ in their response to a parthenocarpic stimulus provided by GA₄ (Bukovac, 1963). Fruit growth rates, final size, color, and general quality were comparable in parthenocarpic and seeded fruits of ‘Sops-of-Wine’ and ‘Wealthy’, whereas parthenocarpic ‘Delicious’ were smaller than seeded fruits at maturity, and parthenocarpic ‘Jonathan’ and ‘Rhode Island Greening’ fruit abscised before reaching maturity. It was suggested that gibberellins present in the receptacle and/or ovary before flowering may be important for inducing parthenocarpic, whereas cytokinins may be responsible for continued growth of parthenocarpic fruit (Watanabe et al., 2008). If this suggestion is valid, the combination of GA₄ plus 6-BA might be a more effective frost-rescue treatment compared with GA₄ alone since presumably the 6-BA could provide a stimulus for normal growth and expansion of the parthenocarpic fruit. Additional research is needed to establish the separate roles of gibberellin and cytokinin on parthenocarpic fruit development in apple.

In this study, seeded and parthenocarpic fruit of ‘Taylor Spur Rome’ were not different in either size, L:D ratio, or the incidence of misshapen fruit at harvest. The effects of GAs on apple fruit shape are not consistent between cultivars. Bukovac (1963) reported that parthenocarpic fruit of the cultivars Sops-of-Wine and Wealthy induced by GA₄ had significantly lower transverse diameter, smaller core

Table 2. Effects of gibberellin A₄ + A₇ and 6-benzyladenine (GA₄+7 plus 6-BA) treatments after freezes during full bloom on 12 and 13 Apr. 2012 on marketable yield and cull fruit of ‘Taylor Spur Rome’/‘M.7’ apple in Henderson County, NC.

| Treatment          | Marketable yield (kg/tree) | Cull fruit (kg/tree) | Cull fruit (% total fruit no.) | Significance |
|--------------------|-----------------------------|----------------------|--------------------------------|--------------|
| Untreated control  | 10.3 a                      | 1.4 a                | 3.1 a                          | NS           |
| GA₄+7 plus 6-BA   | 29.3 b                      | 7.5 b                | 9.4 b                          | ***          |
| GA₄+7 plus 6-BA   | 26.8 b                      | 7.0 b                | 7.2 b                          | ***          |
| Significance       | ***                         | ***                  | *                              | NS           |

Table 3. Effects of gibberellin A₄ + A₇ and 6-benzyladenine (GA₄+7 plus 6-BA) treatments after freezes during full bloom on 12 and 13 Apr. 2012 on the number of fully developed seeds per fruit, the percent of parthenocarpic fruit, and fruit length:diameter (L:D) ratio of ‘Taylor Spur Rome’/‘M.7’ apple in Henderson County, NC.

| Treatment          | Seeds (no./fruit) | Parthenocarpic fruit (%) | Fruit shape (L:D ratio) | Significance |
|--------------------|-------------------|--------------------------|-------------------------|--------------|
| Untreated control  | 4.1 a             | 4.3 a                    | 0.87                    | NS           |
| GA₄+7 plus 6-BA   | 1.1 b             | 69.4 b                   | 0.87                    | ***          |
| GA₄+7 plus 6-BA   | 0.8 b             | 71.5 b                   | 0.85                    | ***          |

Table 4. Effect of 50 mg L⁻¹ (ppm) gibberellin A₄ + A₇ and 6-benzyladenine (GA₄+7 plus 6-BA) sprays after a series of frost/freeze events during pink bud and full bloom on fruit set, yield, crop load, mean fruit weight, seed number per fruit, and crop value of ‘Ginger Gold’, ‘Gala’, and ‘Jonagold’ apple trees on ‘M.9’ rootstock in Geneva, NY.

| Cultivar    | Treatment          | Fruit set (fruit/100 clusters) | Fruit (no./tree) | Yield (kg/tree) | Crop load (% full crop) | Mean fruit wt (g) | Seeds (no./fruit) | Crop value ($/acre) |
|-------------|--------------------|--------------------------------|-----------------|-----------------|------------------------|------------------|------------------|-------------------|
| Ginger      | Control            | 8.5                            | 9               | 1.6             | 50                     | 12               | 207              | 5.5               | 967               |
|             | GA₄+7 plus 6-BA    | 25.4                           | 24              | 4.6             | 141                    | 66               | 133              | 1.6               | 1944              |
| Significance| NS                 | **                            | **              | **              | **                     | NS               | NS               | **                |
| Gala        | Control            | 39.9                           | 168             | 21.6            | 664                    | 55               | 133              | 1.6               | 5057              |
|             | GA₄+7 plus 6-BA    | 49.4                           | 200             | 25.9            | 797                    | 66               | 132              | 1.6               | 5988              |
| Significance| NS                 | NS                            | NS              | NS              | NS                     | NS               | NS               | **                |
| Jonagold    | Control            | 18.3                           | 20              | 4.8             | 148                    | 11               | 268              | 1.6               | 2238              |
|             | GA₄+7 plus 6-BA    | 45.6                           | 71              | 17.9            | 550                    | 39               | 257              | 1.6               | 8456              |
| Significance| **                 | **                            | **              | **              | **                     | NS               | NS               | **                |

1 mg L⁻¹ = 1 ppm. 
Values in a column with different letters are statistically different by Duncan’s multiple range test at P ≤ 0.05. 
NS, ** Non-significant or significant at P ≤ 0.05 or 0.001, respectively, based on analysis of variance.
Table 5. Effect of a gibberellin A4 + A7 and 6-benzyladenine (GA4+7 plus 6-BA) application on 18 Apr. 2012 following frost on 13 Apr. on fruit set, yield, and mean fruit weight of ‘Empire’/‘M.9’ apple at harvest in Amherst, MA.

| Treatment* | Fruit set (fruit/100 clusters) | Crop density (fruit/cm² LCSA) | Fruit (no./tree) | Yield (kg/tree) | Crop value ($) | Mean fruit wt (g) | Crop value ($) |
|------------|--------------------------------|-------------------------------|----------------|----------------|--------------|----------------|--------------|
| Control    | 25                             | 2.8                           | 143            | 28.4           | $200         | 12,181         |              |
| GA4+7 plus 6-BA (25 mg L⁻¹) | 18                             | 2.0                           | 146            | 27.8           | $197         | 12,042         |              |
| GA4+7 plus 6-BA (50 mg L⁻¹) | 21                             | 2.2                           | 171            | 30.9           | $182         | 13,535         |              |

Significance*: NS = Non-significant based on analysis of variance.

*1 mg L⁻¹ = 1 ppm, 1 kg = 2.2046 lb, 1.42 lb (19.1 kg) bushel (bu) per acre = 47.0757 kg ha⁻¹, 1 g = 0.0353 oz.

1 LCSA = limb cross sectional area; 1 fruit/cm² = 6.4516 fruit/inch².

1m g

1/79870 1/245 175 x

Fruit

Yield Mean fruit

Crop value

$($/acre)x(kg/tree)z (bu/acre)z

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1m g

1/79870 1/245 175 x

Fruit

Yield Mean fruit

Crop value

$($/acre)x(kg/tree)z (bu/acre)z

Literature cited

Ballard, J.K., E.L. Proebsting, and R.B. Tukey. 1998. Critical temperatures for blossom buds: Apples. Washington State Univ. Bul. 0913. 5 Apr. 2013. <treefruit.yakima.wsu.edu/weatherbuds/budhardiness/BudCharts/Apple%20Bud%20Chart%20EB0913.pdf>.

Bangerth, F. and M. Schroeder. 1994. Strong synergistic effects of gibberellins with the synthetic cytokinin N-(2-chloro-4-pyridal0-N-phenylurea on parthenocarpic fruit set and some other fruit characteristics of apple. Plant Growth Regulat. 15:293–302.

Blanpied, G.D. and K.J. Silsby. 1992. Predicting harvest date windows for apples. Cornell Coop. Ext. Bul. 221.

Bramlage, W.J., S.A. Weis, and D.W. Greene. 1990. Observations on the relationships among seed number, fruit calcium, and senescent breakdown in apples. HortScience 25:351–353.

Bukovac, M.J. 1963. Induction of parthenocarpic growth of apple fruits with gibberrellins A3 and A4. Bot. Gaz. 124:191–195.

Davidson, R.M. 1960. Fruit setting of apples using gibberellic acid. Nature 4751:681–682.

Decker, T. and H. Schoofs. 2002. Improvement of fruit set on young pear trees cultivar Conference with gibberellins. Acta Hort. 596:735–743.

Drazeta, L., A. Lang, A.J. Hall, R.K. Volz, and P.E. Jameson. 2004. Modeling the influence of seed set on fruit shape in apple. J. Hort. Sci. Biotechnol. 79:241–245.

Dreyer, C. 2013. Fruit set and fruit size studies on ‘Forelle’ and ‘Abate Fetel’ pear (Pyrus communis L.). Stellenbosch Univ., South Africa, M.Sc. Thesis. 13 Dec. 2013. <http://scholar.sun.ac.za/handle/10019.1/79870>.
Greene, D.W. 1984. Microdroplet application of GA$_4$ + BA: Sites of absorption and effect on fruit set, size, and shape of ‘Delicious’ apples. J. Amer. Soc. Hort. Sci. 109:28–30.

Lafer, G. 2008. Effects of different bio-regulator applications on fruit set, yield and fruit quality of ‘Williams’ pears. Acta Hort. 800:183–188.

Luckwill, L.C. 1960. The effect of gibberellic acid on fruit set in apples and pears. Long Ashton Res. Stn. Annu. Rpt. 1959:59–64.

Ouma, G. 2008. Use of gibberellins to improve fruit set in pears after frost damage. J. Biol. Sci. 8:213–216.

Rufato, L., A.A. Kretzschmar, A.F. Brighenti, B.D. Machado, A.R. Luz, and J.L. Marcon Filho. 2011. Plant growth regulators increase productivity of ‘Packham’s Triumph’ pear in southern Brazil. Acta Hort. 909:429–434.

Vilardell, P., J.M. Pages, and L. Asin. 2008. Effect of bioregulator applications on fruit set in ‘Abate Fetel’ pear trees. Acta Hort. 800:169–174.

Watanabe, M., H. Segawa, M. Murakami, S. Sagawa, and S. Komori. 2008. Effects of plant growth regulators on fruit set and fruit shape of parthenocarpic apple fruits. J. Jpn. Soc. Hort. Sci. 77:350–357.

Wertheim, S.J. 1973. Fruit set and June drop in Cox’s Orange Pippin apples as affected by pollination and treatment with a mixture of gibberellins A$_4$ and A$_7$. Sci. Hort. 1:85–105.

Yarushnykov, V.V. and M.M. Blanke. 2005. Alleviation of frost damage to pear flowers by application of gibberellin. Plant Growth Regulat. 45:21–27.

Zhang, C., U. Lee, and K. Tanabe. 2008. Hormonal regulation of fruit set, parthenogenesis induction, and fruit expansion in Japanese pear. Plant Growth Regulat. 55:231–240.