Selective Inhibition of Flowering on 'Braeburn' Apple Trees with Gibberellins

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Abstract. 'Braeburn' apple trees were treated with GA₃ or GA₇ at either 100, 200, or 400 mg·L⁻¹, 2 years after being grafted onto 4-year-old 'Royal Gala'/MM.106 trees in order to evaluate their effects on flower bud formation. Inhibition of flowering was observed on 1-year wood only and not on spurs in response to GA treatments applied later than 6 weeks after bloom. GA₇ was a more potent inhibitor of flowering than GA₃. These results indicate that GA treatments may provide a useful technology for the selective removal of flowers from 1-year wood in apple and may also provide a useful tool for overcoming biennial bearing in apple by inhibiting flower bud formation when applied in the light-cropping year of the biennial cycle.

Economic returns for export quality 'Braeburn' apples (*Malus ×domestica* Borkh.) can be much higher than for other cultivars, such as 'Gala' or 'Royal Gala' in New Zealand. Consequently, this situation has led to some growers topworking more profitable cultivars, such as 'Braeburn' onto 'Gala' or 'Royal Gala' trees, commonly growing on MM. 106 rootstock. 'Braeburn' trees, particularly when topworked can be prone to biennial bearing (McArtney, 1994) because few or no flowering spurs develop on the very vigorous shoots arising from scions in the first year after grafting. The excessive shoot vigor in the first and subsequent seasons can trigger a biennial bearing cycle.

Using inhibitors of flower bud formation to overcome biennial bearing in apple trees is not widely documented in the literature. This technology was used in tart cherries where continuous applications of GA₃ maintained a desired ratio of vegetative to flower bud formation and increased cumulative yield by 22% over a 5-year period (Bukovac et al., 1987). GA₃ and a mixture of GA₄₊₇ inhibited flower bud formation in 'Early McIntosh' (Marino and Greene, 1981) and 'Golden Delicious' (Meador and Taylor, 1987) apple trees, respectively. GA₄₊₇ inhibited flowering more effectively in apple than did GA₃ (Dennis and

Edgerton, 1966; Tromp, 1973). GA₃ and especially GA₇ and GA₄₊₇ markedly reduced flowering on apple spur buds, but GA₄ had little effect (Tromp, 1982). Application of GA₃ compared favorably with fruit and leaf removal as a means of determining the critical period of flower bud induction in 'Red Fuji' and 'Ralls Janet' apple trees (Li et al., 1995). When GA₃ or GA₄₊₇ was applied to 'Braeburn' apple trees in the light-cropping year of a biennial bearing cycle, the proportion of vegetative spurs was not only increased in the year after treatment but was also reduced 2 years after treatment compared with a nonsprayed control (McArtney, 1994).

The objective of the present study was to compare the effect of GA₃ and GA₇ on flower bud formation when applied to vegetative apple trees.

Materials and Methods

GA₃ (BDH Limited, Poole, England) or GA₇ (ABG 3069, Abbott Laboratories, Long Grove, Ill.) was applied to individual 'Braeburn'/'Royal Gala'/MM.106 apple trees at either 100, 200, or 400 mg·L⁻¹ together with Regulaid at 1 mg·L⁻¹ (Kalo, Overland Park, Kans.) as a wetting agent. Each GA was applied either 6, 9, or 12 weeks after the normal bloom date for this cultivar, corresponding to 16 Dec. 1993, 6 Jan. 1994, and 27 Jan. 1994, respectively. In addition, a wetting agent control was applied either 6, 9, or 12 weeks after bloom, and there was also a single, nonsprayed control treatment. Treatments were arranged as a 2 × 3 × 3 factorial in a randomized block design with four replicates, with a total of 22 treatments (trees) per replicate. Each spray treatment was applied with a motorized air-

blast sprayer to the point of leaf wetness. In the season after treatment the numbers of flowering and vegetative buds on spurs and on 1-year wood (including both terminal and axillary buds) was recorded on one grafted limb per tree. From these data the proportion of buds flowering on spurs and on 1-year wood was calculated. Arcsin transformation of percent data were analyzed using the general linear models procedure in the SAS statistical package. A single-degree-of-freedom contrast was used to test the effect of the wetting agent against the nonsprayed control.

Results and Discussion

All trees were totally vegetative in the year of treatment. The wetting agent inhibited flowering in the year after treatment compared with the nonsprayed controls (Table 1). Eighty-six percent of all buds on nonsprayed trees were floral in the year after treatment vs. 76% of all buds on trees treated with Regulaid. This inhibition of flowering was evident on 1-year wood only. The percentage of spur buds that flowered was not affected by any of the treatments, although the effect of time of application almost achieved statistical significance. Because the wetting agent significantly inhibited flowering, all effects will be discussed in relation to the wetting agent controls. There were no significant interactions between form of GA, concentration, or time of treatment (data not shown).

GA₇ reduced flowering more effectively than did GA₃ (Table 1). The percentage of flowering buds on one-year wood was reduced from 70% for the wetting agent control to 55% and 45% for GA₃ and GA₇, respectively. Delaying the time of treatment enhanced this inhibitory effect. When treatments were applied 6, 9, and 12 weeks after bloom the percentage of floral buds on 1-year wood was reduced to 58%, 53%, and 39%, respectively. These findings are similar to those of Tromp (1982), who reported that early GA sprays had little or no effect on flower bud formation on the current-year shoots, whereas late sprays reduced flowering considerably. There was a linear effect of GA concentration on flowering; the highest rate reduced the flowering of buds on 1-year wood in the year after treatment to 38%. The effects of concentration and time of treatment were additive, so each GA reduced flowering in the following year most effectively when applied 12 weeks after bloom at 400 mg·L⁻¹. At this concentration and timing GA₃ and GA₇ reduced the percentage of buds that flowered on 1-year wood to 29% and 14%, respectively.

Gibberellins were effective only on 1-year wood and not on spurs (Table 1). This result may be explained by differences in the time of application in relation to the critical period of flower bud formation on wood of different ages. In previous studies, GA treatments applied at bloom inhibited flowering on spurs only (McArtney, 1994; Tromp, 1982), whereas later GA applications reduced flower bud formation on current-year shoots (Tromp, 1982). These results led Tromp (1982) to conclude

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Table 1. Main effects² of concentration and time of application (Dec.–Jan. 1993–94) of GA₃ or GA₇ on return flowering of 'Braeburn'/'Royal Gala'/MM.106 apples. Christchurch, New Zealand.

Treatment	Flowering buds in the year after treatment (%)		
	Total	On spurs	On 1-year wood
Control	86	97	83
Wetting agent	76	92	70
Gibberellins			
GA ₃	65	93	55
GA ₇	59	91	45
Concentration (mg·L ⁻¹)			
100	69	91	59
200	65	93	53
400	53	92	38
Time of application (weeks after full bloom)			
6	69	93	58
9	66	95	53
12	52	89	39
Contrasts ³			
Control vs. wetting agent	0.043	0.44	0.018
Significance			
Gibberellin	0.041	0.44	0.005
Concentration	L ^{0.0002}	NS ^{0.61}	L ^{0.0001}
Time of application	L ^{0.0001}	NS (L ^{0.06} , Q ^{0.06})	L ^{0.0005}

²None of the interactions between main effects were significant at $P \leq 0.05$.

³Values represent $P < F$; L = linear; Q = quadratic. Figure in superscript is $P < F$.

^{NS}Nonsignificant.

that GAs affect flower bud formation at an early stage of bud development, long before the actual initiation of flowers, which usually occurs much later in buds on current-year shoots than in spur buds. Treatments applied after the critical period of spur flower bud initiation should have little or no effect on formation of spur flowers but should still inhibit formation of flowers on 1-year wood, as they did in the present study. Because later treatments inhibited flowering on 1-year wood most effectively, we can assume that flowers were still being initiated on current year shoots 12 weeks after bloom under the conditions of this study, and that most critical period of response to GA may have been later still. However, this hypothesis is not supported by

the data of Marino and Greene (1981) who found that application of GAs 10 d after full bloom inhibited flowering on both spurs and 1-year wood, with the latter appearing to be more sensitive. These conflicting results may be explained by differences in environmental conditions. Under a temperate climate such as that in New Zealand termination of shoot growth occurs later than under a more continental climate, and the initiation of flower buds on current-season shoots presumably continues later into the growing season.

These results provide further evidence that GA treatments are capable of severely inhibiting flower bud formation in apple, and suggest that the time of treatment may be important for inhibition of flower bud formation on wood of

different ages. As well as offering the potential to restore biennial bearing trees to regular cropping by regulating the ratio of vegetative to fruiting spurs, this technology may also be useful in confining the inhibition of flowering to 1-year wood, which typically produces inferior fruit (Volz et al., 1994). The significant effect of Regulaid in the present study also reinforces the need for caution in designing experiments where wetting agents are used.

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