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Early Gibberellic Acid Sprays Increase Firmness and Fruit Size of 'Sweetheart' Sweet Cherry

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Abstract

Growers in British Columbia, the U.S. Pacific Northwest and increasingly in other regions of the world apply gibberellic acid (GA) to increase fruit size, improve fruit firmness and delay maturity of sweet cherries (*Prunus avium* L.). The recommendation in BC has been to apply a single spray of 20 ppm GA at the straw-yellow stage of fruit development. The objective of this trial was to determine if the timing of the gibberellic acid spray has an effect on 'Sweetheart' sweet cherry fruit yield and quality. Treatments consisted of four timings of 20 ppm GA beginning in mid-June. There were two applications before the straw-yellow stage, the third spray coincided with the straw-yellow stage, and the fourth timing was about one week later. Fruit were harvested when non-treated control fruit were mature, and again one week later. Yield per tree, average fruit weight, rain-induced cracking, fruit firmness, total soluble solids, pH, and titratable acidity were determined for a sub-sample of fruit. Yield was not affected by the GA treatment. Fruit size was increased by about 1 g per fruit and fruit firmness increased by 15% when treated with GA. Fruit size and fruit firmness responded linearly to the GA applications with earlier sprays having the largest and firmest fruit.

A gibberellic acid (GA) spray at the straw-yellow stage of fruit development is a standard practice of sweet cherry (*Prunus avium* L.) growers in British Columbia (BC), Canada, and the Pacific Northwest of the United States. The use of GA is also becoming an important practice in other parts of the world. GA sprays delay maturity by 5 to 7 days and improve fruit quality by increasing fruit firmness and size. The delay in maturity from late season cultivars and the use of GA sprays has allowed late-season producers in BC to market fruit at the end of the marketing season with resultant increase in prices. Any improvement in fruit size and firmness from GA application may also improve grower returns.

First reports for delay in maturity of sweet cherries were for 'Rainier' cherries treated with GA, which resulted in fruit with reduced amounts of anthocyanin (12). Looney and Lidster (10) reported a delay in maturity of about one week for 'Van' and 'Lambert'. 'Bing' and 'Lambert' had delayed fruit color development (6), and 'Sweetheart' fruits treated with 10 or 30 ppm GA were harvested five days later than the control (7).

Growers have long received a premium price for larger sweet cherry fruit (13); therefore treatments that increase fruit size are extremely important. 'Rainier' cherries in Washington were more than 1 g heavier than controls in 3 of 4 years of GA applications (12). A 20 ppm application of GA increased average fruit weight of Washington 'Bing' cherries (3). 'Lambert' cherries in Oregon were 1 g heavier than controls when treated with 10 ppm GA (4). 'Sweetheart' cherries in Argentina treated with 10 or 30 ppm were 1 g heavier and 1 mm larger in diameter than controls (7) and 1 g heavier in BC when treated with 10, 20 or 30 ppm GA (9).

Sensory panels have shown that firm fruit are more acceptable than soft fruit (8). Applications of GA increased the firmness of cherries in different locations and in different varieties: 'Rainier' in Washington (12);

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'Lambert' in BC (10); 'Bing' and 'Lambert' in Oregon (4, 6); 'Napoleon' in Oregon (5); 'Sweetheart' in BC (9) and Argentina (7); 'Bing' in California (2); and 'Aksehir Napolyon' in Turkey (11).

The effect of GA treatment on soluble solids concentration (SSC) and titratable acidity (TA) varies with variety, location and year. GA did not affect SSC of 'Rainier' (12) and 'Bing' cherries in Washington (3) or California (2), 'Sweetheart' cherries in BC (9) or Argentina (7). Results by Facteau and co-workers in various experiments were not consistent. SSC was affected in some years and not in others (4, 5). However Özkaya et al. (11) reported that 'Aksehir Napolyon' in Turkey treated with GA had lower SSC at harvest. In BC, 'Sweetheart' cherries had higher TA after GA treatments (9); however, 'Bing' cherries in California had no response (2) and 'Aksehir Napolyon' in Turkey had lower TA levels due to GA treatment (11).

The recommended timing for GA is at the straw color stage which is usually 21 days before harvest for mid-season cherries. This timing usually coincides with late Stage II of cherry development. However for late and very late maturing cherries such as 'Sweetheart' the Stage II period is longer than it is for mid-season cherries (1). Therefore the timing established for mid-season cherries may not be appropriate for late maturing cultivars. The purpose of this work was to determine the response of 'Sweetheart' cherries (a late maturing cultivar) to various timings of GA sprays.

Materials and Methods

Whole 'Sweetheart' cherry trees (planted in 1988) were sprayed to run-off using a hand-gun applicator in 2002 and 2004. Treatments consisted of 4 timings of 20 ppm GA_3 (Activol; Norac Concepts Inc., Burlington, Ont.) beginning in mid-June each year (Table 1). The third spray, T_3, was timed to coincide with the straw-yellow stage in both years which is the currently recommended time of application. Two trees per replicate were sprayed with each treatment. This allowed for two harvests, with the first tree harvested when the unsprayed controls were considered to be mature, and the second tree 7 days later. The same trees received the same treatments each year.

For each replicate, a 100 fruit sample was randomly selected, and the number of fruit with rain splits and the average fruit weight were determined. Fruit firmness was deter-

Table 1. Dates of GA_3 application to 'Sweetheart' sweet cherry trees, harvest dates, average fruit weight, and diameter of fruit on date of application in 2002 and 2004.

	2002			2004		
	Date of application	Average fruit weight (g)	Average fruit diameter (mm)	Date of application	Average fruit weight (g)	Average fruit diameter (mm)
T_1	June 14	2.24	14.65	June 8	2.98	17.07
T_2	June 20	3.14	16.41	June 14	4.17	18.88
T_3^z	June 24	3.77	18.14	June 21	6.04	22.47
T_4	July 2	-	-	June 28	8.69	25.72
Harvest dates						
Tree 1	August 12			July 27		
Tree 2	August 19			August 3		

^{z} T_3 coincides with the straw-yellow stage of fruit development mined using a FirmTech fruit firmness measuring device (BioWorks, Wamego, Kansas) on 25 fruit per replicate. After the firmness measurements, the stems were removed and the juice was expressed by crushing the fruits in a plastic bag. Total SSC of the juice was measured using an ABBE Mark II digital refractometer (AO Scientific Instruments, Keene, N.H.). The pH was measured and the TA of a 10-mL sample of juice was measured using a 719 S Titrino autotitrator (Metrohm, Herisau, Switzerland). The number of milliliters of 0.1 N NaOH required to bring the pH to 8.1 was determined and TA was expressed as % malic acid.

The experiment was designed as a completely randomized design with 5 replicates (2 trees per replicate). The data were analyzed as a split plot with GA_3 treatments, harvest time, and year as main effects. Data were analyzed by the general linear model procedure and planned contrasts were used to compare means of the main effects (SAS Institute, Cary, N.C.).

Results and Discussion

The first application in 2004 was 6 days before the treatment in 2002, even though fruit were larger in 2004 than 2002 (Table 1). Fruit were harvested more than 2 weeks earlier in 2004 than in 2002 (at the same apparent maturity). The application at T3 coincides with the straw-yellow stage of development. Normally some fruit are beginning to turn pink at this stage. We attempted to time sprays at weekly intervals and time the T3 spray with the straw-yellow stage. In 2002 there was only a 4 day interval between T2 and T3. The timing of the sprays in 2004 more closely fit our predetermined schedule.

Yield was not affected by the GA treatments, time of harvest or any of the interactions (Table 2). The year by treatment interaction was significant for average fruit weight. There was a greater response in fruit size in 2002 than in 2004 (Table 3). However for both years the contrast of GA treated fruit versus control indicated that all treated fruit were 1.5 and 0.5 g (2002 and 2004, respectively) larger. The effect of spray timing on average fruit weight was linear; that is, the earlier the application of the GA, the larger the fruit. As the treatment date approached the harvest date, the response decreased. This is reasonable considering that the size of fruit in 2004 at the T4 date was already 83% of the final size. This suggests that earlier applications during Stage II of fruit development should result in the most favourable response for fruit size. The increase in fruit size previously reported has been fairly consistent, with most workers reporting increased fruit size regardless of variety or location (3, 4, 7, 9, 12). Fruit size increase is likely due to the delayed maturity of GA treated fruit and thus a longer growing period (1, 7).

The year by treatment interaction for rain-induced cracking was significant (Table 2). In 2002 there was no response to any treatment (Table 3). In 2004 there was a significant response to the GA treatment with the T1 treated fruit having more than twice the percent cracked fruit as the control. Within two days of the T1 application 17.6 mm of rain fell. This result supports anecdotal reports from growers that cherry fruits are more susceptible to rain-induced cracking shortly after a GA application.

GA treated fruit were significantly firmer than the control fruit (Table 2). There was also a positive linear response ($P = 0.0071$) to the timing of the sprays, that is the earlier the GA spray the firmer the fruit. An increase in fruit firmness is one of the most consistent responses to GA application. The mode of action of GA on fruit firmness has not been elucidated. Increase in alcohol-insoluble substances has been implicated by Looney and Lidster (10) and Facteau (4). Facteau (4) further suggested that increased firmness may be related to pectinase-soluble pectin, and lower concentrations of water soluble pectins.

Table 2. Yields, average fruit weights, rain-induced cracking levels, firmness, total soluble solids, pH, and titratable acidity of 'Sweetheart' sweet cherry treated with gibberellic acid on different treatment dates in response to main effect (GA_3 treatments, harvest date, and year of trial).

Main effects	Yield (kg/tree)	Average fruit weight (g)	Rain cracking (%)	Fruit firmness (g/mm)	Total soluble solids (%)	pH	Titratable acidity (% malic acid)
GA Treatment							
Control	8.0	9.7	17.8	273	20.9	3.92	1.0
T1	8.5	10.9	30.2	324	21.8	3.74	1.17
T2	8.0	10.6	23.1	318	21.6	3.81	1.16
T3	10.0	10.7	23.0	314	22.6	3.80	1.21
T4	8.6	10.4	19.6	295	22.0	3.79	1.18
Significance	0.8063	<0.0001	0.1189	<0.0001	0.0567	0.0010	<0.0001
Harvest							
First	8.6	10.7	23.5	340	21.1	3.77	1.13
Second	8.7	10.2	22.0	269	22.5	3.86	1.15
Significance	0.9491	0.0002	0.6091	<0.0001	0.0003	0.0007	0.2658
Year							
2002	9.6	10.3	20.6	297	21.9	3.84	1.17
2004	7.6	10.7	24.8	312	21.7	3.79	1.12
Significance	0.0967	0.0018	0.1702	0.0150	0.5302	0.0259	0.0139
Interactions							
Harvest X Treatment	0.9872	0.2123	0.6277	0.3386	0.8832	0.1905	0.0052
Year X Treatment	0.7311	0.0173	0.0151	0.0688	0.8544	0.4635	0.0333
Treatment X harvest X year	0.9323	0.3926	0.9671	0.2019	0.0043	0.4678	0.0053
Contrast							
Control vs GA trt.	0.5028	0.0002	0.0284	0.0005	0.0163	0.0012	<0.0001
Linear	0.3075	0.0062	0.6387	0.0071	0.0148	0.0708	<0.0001

Choi et al. (1) showed that treatment with GA delayed the initiation of polygalacturonase activity in late ripening cherries without a significant effect on activity levels of the enzyme at harvest. None of the other enzymes that have been implicated in fruit softening were affected by GA treatment.

GA treated fruit had higher TSS than control fruit in both years (Table 2). The linear response was also significant ($P = 0.0148$) with TSS increasing with the later applications of GA. TA increased due to GA applications. All the interaction terms (harvest by treatment, year by treatment, and treatment by harvest by year) were significant. TA increased as the GA applications were delayed. In previous work in BC, soluble solids content of 'Sweetheart' was not increased by GA sprays (9). The response of TSS and TA is not consistent and varies depending on cultivar and location.

'Sweetheart' cherries treated with GA exhibited increased firmness and fruit size

Table 3. Annual yield, average fruit weight, rain-induced cracking, firmness, total soluble solids, pH, and titratable acidity of 'Sweetheart' sweet cherry treated with gibberellic acid on different treatment dates in 2002 and 2004.

Main effects	Yield (kg/tree)	Average fruit weight (g)	Rain cracking (%)	Fruit firmness (g/mm)	Total soluble solids (%)	pH	Titratable acidity (% malic acid)
GA Treatment							
Control	7.6	9.1	17.8	261	20.8	3.92	1.07
T1	10.7	10.8	18.5	322	21.9	3.78	1.22
T2	9.1	10.6	17.8	295	22.0	3.86	1.17
T3	11.1	10.4	28.5	318	23.0	3.86	1.20
T4	9.5	10.4	20.5	290	21.9	3.80	1.17
Significance	0.5406	<0.0001	0.1270	0.0013	0.0651	0.3515	0.0583
Harvest							
First	10.6	10.5	21.3	326	21.1	3.76	1.19
Second	8.7	10.0	19.9	268	22.7	3.92	1.15
Significance	0.1835	0.0027	0.6227	<0.0001	0.0013	0.0026	0.2596
Interaction							
Trt X Harvest	0.8815	0.6391	0.8735	0.2978	0.0081	0.4476	0.0048
Contrast							
Cont. vs GA trt	0.1696	<0.0001	0.3306	0.0003	0.0183	0.0825	0.0069
Linear	0.9496	0.0565	0.1834	0.1982	0.4943	0.4447	0.4605
2004							
GA Treatment							
Control	8.4	10.3	17.7	285	21.0	3.92	0.93
T1	6.3	11.0	42.0	327	21.8	3.70	1.12
T2	6.8	10.6	28.3	340	21.3	3.79	1.14
T3	8.8	10.9	17.5	310	22.3	3.74	1.22
T4	7.7	10.5	18.7	299	22.1	3.78	1.19
Significance	0.3766	0.0213	0.0127	0.0006	0.2574	0.0149	<0.0001
Harvest							
First	6.6	10.9	25.7	353	21.0	3.77	1.08
Second	8.7	10.4	24.0	271	22.4	3.80	1.16
Significance	0.0286	0.0027	0.7146	<0.0001	0.0042	0.5628	<0.0001
Interaction							
Trt X Harvest	0.8927	0.1236	0.6854	0.1283	0.0709	0.6986	0.1066
Contrast							
Cont. vs GA trt	0.3915	0.0149	0.1290	0.0008	0.0939	0.0018	<0.0001
Linear	0.1660	0.1707	0.0047	0.0032	0.3794	0.3931	0.0001

regardless of the timing. The earlier the GA application, the greater the response in fruit size and firmness. This would suggest that the application "window" for GA on 'Sweetheart' is quite large; that is, during the pit hardening stage through until the straw-yellow stage. Whether other late maturing cultivars would respond similarly is not known.

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Global Warming Predicted to Affect Japanese Apple Production

Most apple trees are cultivated in the northern part of the temperate zone in Japan. Crops produced in a cold area may be greatly influenced by warming. This study was undertaken to assess the impact of global warming on the production of apple in Japan. The temperature ranges assumed to be appropriate for the cultivation of apple were 6-14ºC for mean annual temperature and 13-21ºC for mean temperature from April to October, respectively. The database "Climate Change Mesh Data (Japan)" was used to simulate possible changes in favorable regions for the cultivation of apple with approximately 10 by 10 km resolution. It was predicted that regions favorable for apple cultivation will gradually move northward. All the plains of southern Tohoku in the 2040s and central Tohoku in the 2060s will be unfavorable for apple cultivation, while most of the regions in Hokkaido will be suitable by the 2060s. Many of the current apple producing districts in Japan will be possibly unfavorable by the 2060s. From: T. Sugiura et al. 2005. Phyton-Annales Rei Botanicae (Horn, Austria) 45(4):419-422.