Project Title: **Reduction of stem loss in 'Bing' sweet cherry, 2003**

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Summary 2003:

We evaluated the effects of plant growth regulator and calcium sprays on stem retention or stem pull force (PF) in 'Bing' sweet cherry at two locations (Linden and Lodi). The trials were exploratory and only limbs were treated. The major contributor to PF reduction in untreated fruit was maturity change. Time spent on the tree may contribute to PF reduction as it is affected by maturity, but may not inherently reduce pull force (i.e. as 'time spent on the tree'). Pull force at harvest in both locations ranged from the 300's to 500's g, across all marketable colors and treatments. These values are generally lower than noted in the Northwestern US. We expect that spray treatments designed to retain stems should be applied well before the stages of maturity that exhibit a PF range close to these values. Based on our study of PF change over time and maturation in untreated fruit, we would suggest that treatments to enhance fruit/stem attachment should be applied prior to color break/pink.

Those treatments which improved PF included chemicals with cytokinin-like activity: Maxel (25 ppm) and Promalin (75 ppm) showed the highest increase in PF compared with the untreated. CPPU (20 ppm) and ReTain, an ethylene biosynthesis inhibitor, appeared to have some positive effect on stem pull force. Fruit Fix (NAA) and select calcium products appeared to reduce stem pull force in some cases. While results were not entirely consistent, the observed trends suggest that cytokinins and ReTain may contribute to improved stem retention and their use in this study should be the basis for ongoing work. Further studies are required on whole trees to validate these preliminary results where chemical concentration, timing of applications based on fruit color and pull force, as well as split applications, should be incorporated into future studies.

Problem and its significance:

Sweet cherry packers and shippers have been noticing significant stem loss in cherries prior to packing. Some packers presumed that the increasing stem loss was from the increase of gibberellin (GA; gibberellin A_3) use and the tendency for delayed harvest. But concrete evidence for this GA effect has been lacking. California cherry growers have been routinely using GA in orchards for more than 10 years. GA is used primarily to improve the quality of the fruit. Sometimes the maturity of the fruit is delayed with GA as well. In recent years, the use of GA has increased as the export markets have favored cherries treated with GA. With the increased use growers, packers and buyers have noted that GA-treated cherries have stems that are loose or have become detached from the fruit. Customers generally prefer cherries with the stem attached and fruit without stems may be more susceptible to decay with shipment and storage.

Introduction:

We began to address the issue of stem loss in 2002 through a survey of orchards where GA was being used in an effort to assess GA treatment(s) and conditions that lend themselves to the production of fruit without stems. We conducted a survey of 23 'Bing' cherry orchards in the Lodi/Stockton area in 2002 to gain information about stem loss of 'Bing' cherries through the season. We interviewed packer/shipper and growers about stem loss from their orchards and in the packing shed and as a result we devised an elaborate survey form that each of the 23 orchard cooperators filled out and was used in our assessment of data. We sampled fruit from GA-treated orchards where the range of GA used varied from 10 to 40 oz or grams per acre with volumes of water used to deliver the GA ranging from 100 to 350 gallons per acre. Orchards varied in production practices including rest-breaking treatments, irrigation types and amounts, soils, climate and general production practices.

We found in a general sense that the stem loss varied by orchard with some high loss and some low loss. Some orchards had 15 to 20% stem loss, while others had only a ~1%. All orchards had some stem loss. We found that, in a very general sense, the later in the season harvest occurred, the greater the stem loss, but there were some orchards with high stem loss relatively early in the season. Our survey also suggested that cooling the fruit through reducing temperature in cold storage or hydrocooling after picking and prior to packing helped to reduce stem loss. It appears that the stem attachment of 'Bing' cherries in California may be lower than those in Oregon and Washington because of some condition specific to California.

To continue our efforts to better understand and reduce stem loss in 'Bing' sweet cherry we proposed investigating chemical sprays that reduce ethylene production, have potential for fruit retention through regulation by auxins, or have cytokinin-like activity. Stem loss in cherries has been shown to be modulated by ethylene and the use of ReTain, an ethylene biosynthesis inhibitor, may help reduce stem loss in 'Bing'. Cytokinins are generally thought to be able to help to delay senescence. Several products are currently available (i.e. Accel, Promalin, CPPU and various seaweed products) that contain cytokinin-like compounds and/or possess cytokinin-like activity. Auxins may have senescence-delaying activity as well and have reduced pre-harvest drop of pome fruits, an abscission phenomenon akin to cherry stem loss. Additionally, we proposed testing gibberellins (GA_{4+7} and GA_3), used both to enhance fruit development (especially some grapes and apples) and fruit set. Both gibberellins and calcium products are routinely used in cherry and other stone fruit production for improving firmness; we proposed testing some of these products to elucidate a role in stem loss/retention.

Objectives:

1. Determine dynamics of stem pull force (PF) change and maturity index (color) for predicting PF reduction timing.

2. Determine if pre-harvest sprays might reduce stem loss in 'Bing' cherry.

3. Identify improved technology of measuring stem retention.

Plans and Procedures:

Plant materials, experimental design, fruit sampling and statistical analyses:

Two experimental sites were established in commercial orchards of mature 'Bing' trees. <u>Location 1</u> on Turner Road near Lodi is on sandy soil and is irrigated by harrowing and flooding. Trees are 'Bing' on mahaleb, spaced 20' x 20' and pollenizers are 'Vista', 'Rainier' and 'Black Tartarian'. Irrigation water was tested in 1994 and proved to be high in calcium. Nitrogen has not been applied as a fertilizer for several years. Grower-applied chemicals included 7% calcium as ActaGro (5 qt per acre), applied with Cabrio on April 9, shortly before bloom. Zinc was applied at 5 lb per acre on April 30 and gibberellin was applied May 11 at varying concentrations from 30 oz to 34 oz per 150 gallons per acre in blocks of several rows each.

<u>Location 2</u> on Comstock Road near Stockton is impact sprinkler-irrigated turf. Grower-applied chemicals included Metalosate® Calcium as four applications at 1 qt per 100 gallons per acre, timed at full bloom, small fruit stage, 10 days later and slightly before harvest. Soluble potash for potassium fertilization was applied with Metalosate® Calcium. Zinc, Sevin and Cabrio were also applied. Gibberellin was applied on May 18 at a concentration of 20 oz per acre (12.5 ppm) with 5 lb per acre of Muracal.

Experimental plots were laid out as complete random block designs with four single-limb replicates per treatment. Limbs selected for treatment had a range of fruit maturity at the time of treatment, with some green fruit. All spray treatments were applied by hand sprayers to wetness. Trees with treated limbs had no more than four limb replicates per tree; limbs were located at tree quadrants and were 1 to 3 meters from the ground surface. Each block of replicates was located within a single row with guard rows between treatment rows to reduce spray drift. All treatments (Tables 1 and 2) with the exception of ReTain were applied in combination with 0.1% Regulaid and 2.5% RNA-85 as adjuvants. Water used to prepare solutions was within pH 6-7 and solutions were made at the date of usage. As calcium had been applied to trees at Location 2, this location received only sprays of plant growth regulators; Location 1 received sprays of various forms of calcium as well (Table 2). Fruits were sampled at each of two commercial harvest dates, taking an random subsample from each treated limb of approximately 50 fruit. Fruit were kept cool during transportation and evaluated within 2 to 3 hours of picking. Fruit were graded by colors and stem removal force (pull force) measured.

Coincidental with spray trials, we conducted a time course of sampling untreated fruits of all color classes found on trees at Locations 1 and 2 to determine the dynamics of stem PF change and a maturity index (color) for predicting PF reduction timing. Beginning on May 15 and occurring at regular intervals through commercial harvests, we sampled fruits from each orchard, graded them into seven color classes (green, straw, color break/pink, light red, dark red, mahogany and dark mahogany; light red, dark red or mahogany = CTIFL color chips 3, 4 and 6, respectively), and measured stem PF. In order to improve our technology for determining stem removal force, we investigated a variety of force gauges available and tested the University of California-Ametek penetrometer with an attachment clip made on campus for cherry stem removal versus an Imada DPS11-R digital force gauge with a cam-type attachment to hold cherry stems. We determined that the Imada gauge, with a capacity to measure up to 11 lb pressure/tension (5 kg, 49 newtons), with a resolution of 0.01 lb (1 g, 0.01 newtons), was superior to the Ametek gauge.

Statistical Analysis Systems software (SAS Institute, Cary, NC) was used to perform the analysis of variance (PROC GLM). Mean separation was by LS Means and by Duncan's Multiple Range Test, 5% level of significance.

Results:

Pull force change over time in untreated fruit; relationship to maturity (color development; Table 3):

Location 1: PF for untreated cherries at Location 1 was equivalent in green and straw cherries when fruit from all sampling dates were combined (Table 3). Stems from fruit that were color break/pink exhibited a 20% drop in PF compared to green/straw fruit, and light and dark red fruit had PF's 37% less than color break/pink fruit. Mahogany and dark mahogany fruit had equal PF's; these were 26% less than those of light and dark red fruit.

Location 2: PF for straw-colored fruit had 18% lower PF than green fruit; color break/pink fruit, although statistically equivalent to straw fruit with respect to PF, had 24% lower PF than did green fruit. Light red fruit had 22% lower PF than straw and color break/pink fruit. Mahogany fruit had PF's statistically equal to dark red fruit; these had PF's 12% lower than light red fruit.

At both locations, PF's decreased substantially with change in color. PF's did not change significantly over time, when fruit color class differences were accounted for (data not shown). Thus, it appears that fruit stem removal force was a function of fruit maturation, rather than time, for untreated fruit sampled from May 15 through June 12. The degree to which PF's changed from one color class to the next tended to be approximately 20%, regardless of color or location, with the exception of light and dark red fruit at Location 1. The reduction in PF for these fruit compared to the color grade immediately prior in maturity (color break/pink) was approximately double that of all other comparisons. It appears that reduction in stem removal force is a gradual process over the maturation period of 'Bing' cherries, rather than an abrupt change with physiological maturity. At time of commercial harvests at both Locations, fruit of all marketable color classes (light red to mahogany) had PF's that were generally half or less than half that of green/straw fruit. Gibberellin was applied at the two locations in mid-May, when fruit color ranged from green to red (light red at Location 1, dark red at Location 2). All fruit sampled in this study received gibberellin treatment by the growers, and while the concentrations and timings of application were different between the two locations, the trends in stem removal force vs fruit color were quite similar.

Pull force relationship to type, concentration and timing of chemical treatments:

When results from treated fruit at both locations and harvests were combined, we found that results varied by location, treatment, harvest date and color (analysis of variance, Table 4). When fruit pull forces were combined across orchards, harvest dates and colors, we found that fruit treated with Maxel at 25 ppm had the greatest PF and fruit treated with Fruit Fix at 20 ppm had PF lower than any other treated fruit, as well as the control (Table 4).

When PF's were compared by treatment at Harvest 1, Location 1 (Table 5), only fruit treated with Maxel at 25 ppm had PF's greater than that of the untreated control, and PF was reduced by Fruit Fix at 20 ppm and CPPU at 10 ppm, compared with the control. At Harvest 2, Location 1, CPPU at 20 ppm, Maxel at 25 ppm and Promalin at

75 ppm resulted in improved PF. Foli-Cal (applied May 22), Kelpak (5 ppm), CPPU (10 ppm) and Fruit Fix (20 ppm) reduced PF; all other treatments were equivalent to the control (data not shown). When fruit from both harvests were combined, improved PF was found overall in fruit treated with CPPU (20 ppm), Maxel (25 and 75 ppm) and Promalin (75 ppm). Fruit Fix, CPPU (10 ppm)and May 16 Foli-Cal-treated fruit reduced PF compared to the control.

When fruit were evaluated for effects of location, treatment, and color at Location 1, we found that color was not a contributor to PF differences at this location, either as a single factor or in an interaction with treatment (data not shown). Fruit maturity was relatively uniform at this location, primarily light red to dark red at the June 6 harvest date, and primarily dark red to mahogany at the June 11 harvest date. Al Location 2, treatment and color contributed to differences in PF (data not shown).

At Location 2, PF was improved by Maxcel applied at 25 ppm compared to the control when fruit of different colors were combined (Table 5); in both harvests Fruit Fix reduced PF and in the second harvest Promalin and ReTain (25 g a.i. per acre) reduced PF. When treatment effect was examined by different color classes (data not shown), light red fruit, dark red fruit and mahogany fruit exhibited a reduced PF when treated with Fruit Fix at 20 ppm and at 10 ppm in mahogany fruit. Maxel (75 ppm) reduced PF in mahogany fruit and Promalin (25 ppm) in dark red fruit (Harvest 2) and mahogany fruit. PF was reduced by ReTain (25 g) in mahogany fruit.

Conclusions:

$ PF in untreated fruit remained more or less consistent within a color grade across time. The major contributor to PF reduction in untreated fruit was maturity change. Time spent on the tree may contribute to PF reduction as it is affected by maturity, but may not inherently reduce pull force (i.e. as 'time spent on the tree').

$ Pull force at harvest in both locations ranged from the 300's to 500's g, across all marketable colors and treatments. Most stem loss occurs at harvest and packing, not prior (i.e. there is not a significant preharvest fruit drop), thus we might conclude that these PF's represent a range in which stem loss would tend to occur. Treatment, then, should occur well before the stages of maturity that exhibit a PF range close to these values. Based on our study of PF change over time and maturation in untreated fruit, we would surmise that treatments to enhance fruit/stem attachment should be applied prior to color break/pink.

$ Since maturity appears to be a major factor affecting stem removal force, when maturity is variable on a tree, treatments to improve stem retention may be more efficacious if used as split applications.

$ Those treatments which improved PF included chemicals with cytokinin activity: Maxcel (25 ppm), CPPU (20 ppm), and Promalin (75 ppm) showed the highest PF's. ReTain showed improvement, but not at the same degree as those chemicals aforementioned. These trends suggest that cytokinins may contribute to improved stem retention and their use in this study should be the basis for ongoing work.

Table 1. Product information for trials, 2003.

Chemical	Active	Manufacturer
Metalosate® Calcium	6% amino acid-chelated calcium	Albion Laboratories, Inc
Foli-Gro® Calcium 6%	6% calcium from calcium citric acid	Wilbur-Ellis
Foli-Cal®	10% mannitol-chelated calcium	Brandt Consolidated
Nutrical®	8% calcium from calcium nitrate + 6.5% calcium + polyhydroxy-carboxylic acids and carbohydrates	CSI Corporation
Kelpak®	11 ppm auxins (high naturally-occurring auxins) and 0.03 ppm cytokinins (very low activity)	(Kelp Products Pty Ltd). Caltec Agri Marketing Services
CPPU (N-(2-chloro-4-pyridyl)-N'-phenylurea; forchlorfenuron	synthetic cytokinin @ 0.8%	(SKW Corp.) Valent Biosciences, distributor

ReTain®	[S]-trans-2-amino-4-(2-aminoethoxy)-3-butenoic acid hydrochloride 15%	Valent Biosciences
Fruit Fix™	NAA, ammonium salt 21.4%; equivalent to 19.6% acid form	AMVAC Chemical Corp.
Maxel (replaces Accel)	0.18% GA_{4+7}, 1.8% cytokinin	Valent Biosciences
Promalin®	1.8% GA_{4+7}, 1.8% cytokinin	Valent Biosciences

Table 2. Treatments, concentrations and timings, 2003. All treatments except ReTain were applied with 0.1% Regulaid + 2.5% RNA-85.

Location 1				Location 2	
	Chemical	Timing	Concentration		
1	Untreated control			1	Untreated control
2	Metalosate® Calcium	5/16	2 qt/100 gal/acre (5 ppm)		
3		5/22			
4	Foli-Cal®	5/16	2 qt/100 gal/acre (5 ppm)		
5		5/22			
6	Nutrical®	5/16	4 qt/100 gal/acre (10 ppm)		

7		5/22			
8	Foli-Gro® Calcium 6%	5/16	4 qt/100 gal/acre (10 ppm)		
9		5/22			
Treatments 10-22 applied on 5/22				all treatments applied on 5/22	
10	Fruit Fix™	10 ppm (0.6 fl oz/100 gal/acre		2	Fruit Fix™; 10, 20 ppm
11		20 ppm (25 g a.i./acre)		3	
12	Kelpak®	2 pt/100 gal/acre (2.5 ppm)		4	Kelpak®; 2.5, 5 ppm
13		5 ppm		5	
14	CPPU	10 ppm		6	CPPU; 10, 20 ppm

15		20 ppm	7	
16	Maxel	25 ppm	8	Maxel; 25, 75, 150 ppm
17		75 ppm	9	
18		150 ppm	10	
19	Promalin®	25 ppm	11	Promalin®, 25, 75 ppm
20		75 ppm	12	
21	ReTain®	25 g a.i./100 gal/acre	13	ReTain®; 25, 50 g a.i./100 gal/acre
22		50 g a.i./100 gal/acre	14	

Table 3. Pull force vs time, by color, dates of sampling combined. Each number is a mean of all fruit sampled within a color grade.

Color grade	Location 1		Location 2	
	#Samples	Pull force (g)	#Samples	Pull force (g)
green	79	1127.5 a [x]	79	1209.3 a
straw	18	1149.8 a	58	991.4 b
color break\pink	66	909.9 b	102	923.7 b
light red	63	581.7 c	68	746.8 c
dark red	66	591.4 c	81	615.8 d
mahogany	32	434.4 d	46	545.2 d

dark mahogany	16		424.4 d			
[x] Means separation by Duncan’s Multiple Range Test, *P* = 0.05%.						

Table 4. Analysis of variance for combined harvests, locations, and colors [y]. Pull force for fruit, colors [y], harvests and locations combined. Treatments include only those applied at both locations.

Source	df	MSIII	Treatment, concentration		Pull force (g)
Model	80	156879.5***	Control		458.7 bc [x]
Orchard	1	1896228.3***	Fruit Fix	10 ppm	439.6 bc

Treatment		13		126448.1***		20 ppm		360.1 d
Trt*orchard		13		55008.2***	Kelpak	2.5 ppm		464.5 bc
Color		3		67817.8***		5 ppm		443.6 bc
Trt*color		39		19463.5****	CPPU	10 ppm		398.2 cd
Orchard*color		3		30885.9*		20 ppm		497.3 ab
Harvest date(orchard)		2		325023.3***	Maxel	25 ppm		521.8 a
Block(orchard)		6		131199.0***		75 ppm		461.4 bc
Error		1617		11811.3		150 ppm		444.8 bc
					Promalin	25 ppm		419.2 c
						75 ppm		478.5 abc
					ReTain	25 g		471.5 abc
						50 g		472.2 abc

[x] Means separation by Duncan's Multiple Range Test, P = 0.05%; **,***, ns = P = 0.01, 0.001, non significant, respectively.

[y] Fruit maturity was evaluated visually by assigning fruit to color stages as follows: on a scale of 1-7 where 1 = green, 2 = straw, 3 = color break/pink, 4 = light red, 5 = dark red, 6 = mahogany, 7 = dark mahogany. Colors light red, dark red, mahogany and dark mahogany correspond to CTIFL color chips 1, 3, 6 and 7, respectively.

Table 5. Pull force for fruit, colors [y] combined.; harvests at Location 1 on June 6 and 11, at Location 2 on June 6 and 12. At Location 2 all treatments were applied May 22.

Loc 1; date, concentration			Harvests 1 & 2	Location 2			Harvests 1 & 2
1	Control		390.9 c-h	1	Control		529.3 a-d
2	Metalosate calcium	5/16	430.9 abc				
3		5/22	419.6 b-f				
4	Foli-Cal	5/16	335.2 ij				
5		5/22	406.0 b-g				
6	Nutrical	5/16	386.9 d-h				
7		5/22	421.6 b-e				
8	Foli-Gro	5/16	427.2 bcd				
9		5/22	410.3 b-g				
10	Fruit Fix	10 ppm	380.6 fgh	2	Fruit Fix	10 ppm	488.0 cd
11		20 ppm	295.5 k	3		20 ppm	399.0 e
12	Kelpak	2.5 ppm	424.9 b-e	4	Kelpak	2.5 ppm	525.5 a-d
13		5 ppm	359.0 hi	5		5 ppm	503.8 bcd
14	CPPU	10 ppm	315.8 jk	6	CPPU	10 ppm	519.7 a-d
15		20 ppm	442.0 ab	7		20 ppm	536.5 abc
16	Maxel	25 ppm	467.3 a	8	Maxel	25 ppm	587.3 a
17		75 ppm	433.9 ab	9		75 ppm	467.6 cd
18		150 ppm	414.9 b-g	10		150 ppm	513.8 bcd
19	Promalin	25 ppm	385.3 e-h	11	Promalin	25 ppm	459.8 d
20		75 ppm	435.3 ab	12		75 ppm	528.9 a-d
21	ReTain	25 g	416.5 b-g	13	ReTain	25 g	507.7 bcd
22		50 g	379.2 gh	14		50 g	562.0 ab

[x] Means separation by Duncan's Multiple Range Test, $P = 0.05\%$.

[y] Fruit maturity was evaluated visually by assigning fruit to color stages as follows: on a scale of 1-7 where 1 = green, 2 = straw, 3 = color break/pink, 4 = light red, 5 = dark red, 6 = mahogany, 7 = dark mahogany. Colors light red, dark red, mahogany and dark mahogany correspond to CTIFL color chips 1, 3, 6 and 7, respectively.