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IDENTIFICATION OF STONE FRUIT CULTIVARS RESISTANT TO INFESTATION BY CODLING MOTH AND ORIENTAL FRUIT MOTH

Project No. 814

Submitted in Two Parts

by

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PART I.

Codling Moth (Lepidoptera: Tortricidae)
Oviposition on California Stone Fruit
In Laboratory Acceptability Tests

PART II.

Acceptability of California Stone Fruit Cultivars to
Oriental Fruit Moth (Lepidoptera: Tortricidae)
in Laboratory Tests

Part I. Codling Moth (Lepidoptera: Tortricidae) Oviposition on California Stone Fruit In Laboratory Acceptability Tests

ABSTRACT Fruit of early, mid-season, and late season cultivars of nectarine and peach, *Prunus persica (L.) Batsch*, and plum, *P. saliciana Lindl.* were studied for acceptability to oviposition by codling moth (CM), *Cydia pomonella* (L.), in laboratory cage tests. CM did not discriminate among fruit maturity stages or skin color for oviposition on nectarines. Stored peaches had more CM eggs than firm/green peaches. Firm/green plums had higher CM egg infestations than later plum maturity stages. The blossom and stem ends of nectarines, peaches, and plums were more acceptable to CM for oviposition than other fruit parts. A packinghouse wash system removed low numbers of CM eggs from the side, suture, blossom, and stem areas of nectarines. No single stone fruit cultivar had significantly lower CM egg infestations. Plums of the 'Queen Ann' cultivar had a significantly higher number of CM eggs. CM oviposition was higher on early to mid-season nectarines and peaches and similar on all late season cultivars.

KEY WORDS codling moth, *Cydia pomonella* (L.), stone fruit, *Prunus persica (L.) Batsch*, *Prunus saliciana Lindl.*, oviposition behavior

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CODLING MOTH (CM), *Cydia pomonella* (L.), is a primary pest of apples (Goonewardene et al. 1984) and pears (Westigard et al. 1976). Resistance to CM has been studied in apple fruit (Goonewardene et al. 1984), apple foliage (Plourde et al. 1985), apple rootstock (Goonewardene & Kwolek 1985) and pears (Westigard et al. (1976). CM oviposition and distribution of eggs in apple orchards was studied by Summerland & Steiner (1943) and Jackson (1979).

CM was reported on California nectarines and peaches, *Prunus persica (L.) Batsch*, and plums, *P. saliciana Lindl.* in 1930 (Mackie 1930). Smith (1929, 1940) discussed the establishment of CM as a stone fruit pest in California. Potential markets for stone fruit are available in countries were CM is not found. However, U.S. and foreign regulatory agency quarantine restrictions require fruit to be pest free prior to shipment (Yokoyama et al. 1987b). Stone fruit cultivars that are not susceptible to CM attack would be ideal selections for quarantine treatment and export. Furthermore, identification of such cultivars would expedite development of resistance to CM in plant breeding programs. Studies of CM/plant interactions in stone fruit have been limited to early field observations by Smith (1929). CM oviposition behavior in fruit has been studied by Roitberg & Prokopy (1982) and was first used by Goonewardene et al. (1979) in choice tests to evaluate resistance in apple fruit.

The objective was to determine acceptablity of nectarine, peach and plum cultivars to CM oviposition and identify those cultivars least susceptible to CM attack for potential export and development of CM resistance in stone fruit.

Materials and Methods

Medium size nectarine, peach, and plum cultivars that were harvested and packed on the same day were obtained from local packinghouses. The postharvest fruit was stored at $0^{o}C$ until used in CM infestation tests. CM was reared by previously described procedures (Yokoyama et al. 1987a). Each fruit was covered with a velour paper or cotton velveteen cloth cap previously described by Yokoyama et al. (1987b). Each cap had an opening (2.5 cm diameter) cut in the top. The napped texture of the cap discouraged females from laying eggs on any surface except the fruit area exposed through the cap opening.

The effect of fruit maturity on CM ovipositional behavior was studied with fruit from both orchards and packinghouses. Orchard fruit was picked in three different stages of maturity. Nectarines and peaches were selected from experimental trees at the Hortic. Crops Res. Lab, ARS, USDA, Fresno, Calif. Plums were selected from a commercial 'Roysum' plum orchard. Each fruit maturity stage was classified by firmness and color and included fruit that was firm and green, firm with $\leq$ 50% color, and soft with 100% color. Fruit in each maturity catagory was compared to packed fruit that complied with California Tree Fruit Agreement (CTFA, Sacramento, Calif.) maturity requirements at harvest. Cultivars included 'Flamekist' nectarines, 'O'Henry' peaches, and 'Roysum' plums that had been stored at $0^{o}C$ for 1-3 wks. One side of each fruit was exposed through the cap opening to CM oviposition for 24 h. Nectarines of the 'Fantasia' cultivar were also tested for differences in acceptability to CM oviposition by color by exposing either a red or yellow skin area on the side of the fruit. CM oviposition on different parts of each fruit was determined by exposing either the blossom end, stem end, suture area, or side area of each fruit through the cap opening to gravid females. Cultivars used for these tests were 'Fantasia' nectarines, 'O'Henry' peaches, and 'Casselman' plums. The eggs were counted at the end of the exposure period. The effect of a packinghouse wash on numbers of CM eggs was determined by washing the infested nectarines for ca. 1 min in a commercial washer consisting of lower roller brushes and overhead water sprayers. Eggs were counted on the fruit after the wash. Only the sides of fruit were exposed through the caps in all other tests. Early, mid-season, and late season nectarine, peach, and plum cultivars (Tables 3 and 4) were compared for acceptability to CM oviposition among and between each stone fruit group.

Capped fruit with exposure openings on the top side were placed in an infestation cage (35 cm wide by 50 cm long by 27 cm high) (Yokoyama et al. 1987b) in a randomized complete block design. An equal number of adult males and gravid females (ca. 150) that were three to 5 days-old were placed in the cage with the fruit. The cage was placed near a west window which provided a natural photoperiod of ca. 16:8 (L:D) at ambient conditions of about 23°C and 55% RH. The exposure period was determined by the number of adults in the infestation cage and the age of the females to provide optimum egg laying. Eggs were counted at the end of the exposure period. The data were analyzed by analysis of variance (ANOVA) using the Duncan option for mean comparisons (SAS Institute 1985).

Results and Discussion

CM is not well adapted to stone fruit (Smith 1929) and reports of nectarines as a host have been limited to field observations. CM females showed no differences in oviposition on nectarines in any maturity stage (Table 1). All nectarines regardless of ripeness were acceptable to CM for oviposition. The number of CM eggs laid on red skin areas of nectarines ($\bar{x}$ = 80.7) did not significantly differ from yellow skin areas ($\bar{x}$ = 91.0) (F = 0.37; df = 1, 6; P > 0.05). CM did not discriminate between ripeness or color for oviposition. These are factors that should affect host specificity (Miller & Strickler 1984). The fruit surface was an acceptable substrate for egg laying in the infestation cage just as wax paper is an acceptable substrate in ovipositional cages (Yokoyama et al. 1987a). Lack of CM host specific behavior on nectarines supports CTFA proposals to export nectarines to CM free countries after quarantine treatment because natural infestations may be extremely low. Nectarines do not apprear to be a primary host and CM is rarely found in packed fruit (Yokoyama et al. 1987b).

Stored peaches had more CM eggs than firm/green peaches (Table 1). Acceptability of peaches in different stages of maturity in laboratory tests (Table 1) was similar to the observation of Smith (1929) that CM larvae were not found in hard, green orchard peaches, but occurred in peaches that had begun to color.

Both firm/green and firm/partially-colored plums had higher CM egg infestations than both soft/full-colored and stored plums (Table 1). The results in Table 1 show CM females can discriminate between unripe and ripe plums. Smith (1929) observed CM larvae in very hard, green 'Santa Rosa' orchard plums. Smith (1940) reported that CM could complete one generation and part of a second generation in green 'Kelsey' plums before the fruit matured and was harvested. Infestation of green plums would be advantageous to CM populations. Green fruit would remain on the tree for the period of time required for CM to complete larval development. Infestation of riper fruit would result in eventual fruit abscission or harvest before the larvae left the fruit to pupate. Apples are a highly suitable CM host because the fruit remains on the trees though a period of time that would allow the pest to complete two generations (Smith 1929).

CM oviposition on nectarine fruit was highest on the blossom end (Table 2). Both the blossom and stem ends of peaches were more heavily infested with CM eggs than the side and suture areas (Table 2). CM oviposited more eggs on the blossom end than the side area of plums (Table 2). The blossom and stem ends of nectarines, peaches, and plums were more acceptable to CM for oviposition than other fruit parts. Inspection for CM eggs in packinghouse procedures should emphasize examination of the fruit in these areas. However, the larvae may enter the fruit and feed in another area. Smith (1929) reported both CM and peach twig borer, *Anarsia lineatella* Zeller, larvae enter the stem and suture areas.

A packinghouse wash system removed the following percent of CM eggs from the side, suture, blossom, and stem areas of nectarines 18.3 ± 7.3, 17.4 ± 5.1, 14.0 ± 3.1, and 8.4 ± 1.6 ($\bar{x} \pm SD$) (Table 2), respectively. Removal of CM eggs from the side area was higher than the stem end. CM eggs in the stem end are located in a depression and mechanical removal with packinghouse brush and spray washers would be difficult. The procedure will have little value as a quarantine disinfestation technique because of the low numbers of CM eggs removed. Newcomer (1930) made similar observations for washed apples and considered the treatment ineffective.

Postharvest stone fruit tests comparing early, mid-season, and late season cultivars of either nectarines, peaches or plums for acceptability for CM oviposition showed no single cultivar with significantly lower CM egg infestations (Table 3). All nectarine cultivars had similar infestations except 'May Grand' nectarines which had slightly higher numbers of CM eggs (Table 3). Results with peaches were similar to nectarines (Table 3). Smith (1929) observed CM larval infestations in 3% of freestone peaches and 0.5% of clingstone peaches. Our studies did not show great differences in CM oviposition among peach cultivars. Plums of the 'Queen Ann' cultivar had a significantly higher number of CM eggs (Table 3). Fruit of this cultivar may attract gravid CM females. Wearing & Hutchins (1973) discussed the role of olfaction in fruit location by CM females. They showed alpha-farnesene in apples was an ovipositional stimulant for gravid CM females and an attractant for hatching larvae. Similar mechanisms for host finding may be used by CM in stone fruits.

Greatest differences in CM oviposition were found among mixed groups of stone fruit in tests with early, mid-season, and late season nectarine, peach, and plum cultivars (Table 4). CM oviposition was higher on early to mid-season cultivars of nectarines and peaches than plums (Table 4). Plums are more acceptable to CM oviposition in earlier maturity (Table 1) which explains the lower egg infestations in these tests. Smith (1929) and List & Yetter (1927) found plums a more suitable CM host than peaches in field observations. CM oviposition was similar on fruit of all late season stone fruit cultivars (Table 4).

Jackson (1979) discussed factors that affect CM oviposition in apples. CM oviposits on leaves near apple fruit and olfactory stimuli from the fruit attracts both females and hatching larvae. Similar insect/plant interactions probably occur in stone fruits. Additional factors of the foliage may affect CM host acceptability. Deleterious foliage compounds such as cyanides (Leather 1985) may be associated with CM resistance. Beneficial plant structures such as extrafloral nectaries of peaches (Putman 1963) and volatile compounds from ripening fruit may attract CM. These are stone fruit characteristics that need further study for affect on CM behavior.

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Table 1. CM oviposition on stone fruit in four stages of fruit maturity

Fruit maturity	$\bar{x}$ no. eggs		
	Nectarine[a]	Peach[b]	Plum[c]
Firm, green	45.4a	4.8b	83.2a
Firm, $\leq$ 50% color	41.1a	11.3ab	79.2ab
Soft, 100% color	51.9a	11.3ab	48.0bc
Postharvest[d]	35.5a	13.2a	44.0c

Means within a column followed by the same letter are not significantly different (*P* > 0.05; Duncan's multiple range test [SAS Institute 1985]).

[a]Eight replicates, 24 h exposure.

[b]Six replicates, 24 h exposure.

[c]Eight replicates, 24 h exposure.

[d]Fruit complied with CTFA maturity requirements at harvest and stored at $0^{\circ}C$ for 1-3 wk.

Table 2. CM oviposition on different parts of stone fruits and eggs retained on nectarines after a packinghouse wash

Area on fruit	$\bar{x}$ no. eggs			
	Nectarine[a]		Peach[b]	Plum[c]
	Pre-wash	Post-wash		
Blossom end	245.8a	211.5a	73.0a	63.3a
Stem end	161.8b	148.8b	74.0a	43.8ab
Side	135.8b	111.5b	51.3b	34.3b
Suture	120.8b	101.5b	49.9b	45.5ab

Means within a column followed by the same letter are not significantly different (*P* > 0.05; Duncan's multiple range test [SAS Institute 1985]).

[a] 32 replicates of 'Fantasia' nectarines, 3 day exposure.

[b] Seven replicates of 'O'Henry' peaches, 2 day exposure.

[c] Eight replicates of 'Casselman' plums, 2 day exposure.

Table 3. CM oviposition on early through late season nectarine, peach, and plum cultivars

Nectarine[a]						Peach[b]			Plum[c]		
Early to mid-season			Mid to late season			Mid to late season			Early, mid to late season		
Harvest date	Cultivar	$\bar{x}$ no. eggs	Harvest date	Cultivar	$\bar{x}$ no. eggs	Harvest date	Cultivar	$\bar{x}$ no. eggs	Harvest date	Cultivar	$\bar{x}$ no. eggs
28 May	'May Grand'	70.7a	25 July	'Late Le Grand'	95.7a	12 June	'Redtop'	26.5a	2 July	'Queen Ann'	105.4a
12 June	'Spring Red'	54.1ab	7 July	'Fantasia'	86.4a	8 July	'Elegant Lady'	16.5ab	8 July	'Laroda'	88.4b
10 June	'Firebrite'	47.6b	30 July	'Flamekist'	83.6a	10 July	'Elberta'	12.0b	12 June	'Santa Rosa'	82.4b
10 June	'Red Diamond'	43.1b				23 July	'O'Henry'	8.5b	24 July	'Casselman'	78.5b
24 June	'Summer Grand'	41.6b									

Means within a column followed by the same letter are not significantly different ($P > 0.05$; Duncan's multiple range test [SAS Institute 1985]).

[a]Seven replicates, 24 h exposure.

[b]Six replicates, 48 h exposure.

[c]Eight replicates, 24 h exposure.

Table 4. CM oviposition on early through late season stone fruit cultivars

Early to Mid-season			Mid-season			Mid to late season			Late season			Late season		
Stone fruit	Cultivar[a]	$\bar{x}$ no. eggs	Stone fruit	Cultivar[b]	$\bar{x}$ no. eggs	Stone fruit	Cultivar[c]	$\bar{x}$ no. eggs	Stone fruit	Cultivar[d]	$\bar{x}$ no. eggs	Stone fruit	Cultivar[e]	$\bar{x}$ no. eggs
Nectarine	'May Grand'	136.3a	Peach	'Redtop'	126.0a	Nectarine	'Fantasia'	158.0a	Nectarine	'Fairlane'	33.0a	Plum	'Angeleno'	34.0a
Nectarine	'Red Diamond'	107.1ab	Nectarine	'Fantasia'	122.8a	Peach	'Late Le Grand'	147.0a	Plum	'Roysum'	25.6ab	Nectarine	'Flamekist'	31.9a
Nectarine	'Firebrite'	89.3ab	Peach	'Elegant Lady'	72.0b	Peach	'Elegant Lady'	139.5a	Nectarine	'September Grand'	18.9ab	Plum	'Roysum'	28.0a
Peach	'Redtop'	64.1bc	Peach	'Elberta'	48.2bc	Plum	'Laroda'	139.2a	Peach	'Fairtime'	7.9b	Peach	'Autumn Lady'	22.9a
Plum	'Santa Rosa'	35.3c	Plum	'Santa Rosa'	20.2c	Peach	'O'Henry'	115.3a	Peach	'Autumn Gem'	6.3b	Peach	'Carnival'	15.0a
						Plum	'Casselman'	88.3a						

Means within a column followed by the same letter are not significantly different ($P > 0.05$; Duncan's multiple range test [SAS Institute 1985]).

[a]Seven replicates, 5 day exposure.

[b]Five replicates, 5 day exposure.

[c]Six replicates, 5 day exposure.

[d]Seven replicates, 2 day exposure.

[e]Seven replicates, 3 day exposure.

Part II. Acceptability of California Stone Fruit Cultivars to Oriental Fruit Moth (Lepidoptera: Tortricidae) in Laboratory Tests

ABSTRACT Oriental fruit moth (OFM), *Grapholita molesta*, ovipositional behavior and first instar survival was studied in laboratory tests on fruit and foliage of nectarine, peach, plum and other stone fruit, *Prunus* spp., cultivars. OFM oviposition on fruit in four different maturity stages was lower on postharvest nectarines and higher on postharvest peaches. More eggs were laid on the stem end than the blossom, side and suture areas of nectarine, peach, and plum fruit. 'Red Diamond' nectarines, 'Redtop' peaches, and 'Laroda' plums were highly acceptable and 'Fantasia' nectarines and 'Roysum' plums were least acceptable to gravid females for oviposition in separate tests of early through late season cultivars of either nectarines, peaches, or plums. Tests with mixed stone fruit groups showed fewer eggs laid on 'Elberta', 'Elegant Lady', 'O'Henry', and 'Fairtime' peaches and higher numbers of eggs laid on 'Late Le Grand' nectarines and 'Laroda' plums. Low oviposition on peaches may be related to pubescense. Vegetative shoots injured by larval feeding produced gum but uninjured shoots and shoots that supported first instars to later larval or pupal stage did not produce gum. Larvae successfully completed normal development to adults on larval diet medium combined with 0-60% v/v aqueous extracts of peach tree gum. Stone fruit gum appears to be an induced host response that creates a mechanical barrier to larval attack.

KEY WORDS *Grapholita molesta* (Busck), stone fruits, *Prunus* spp.

ORIENTAL FRUIT MOTH (OFM), *Grapholita molesta* (Busck), was first found in California on 30 September 1942 and was considered an established pest one year later (Mackie 1944b). Stone fruit, *Prunus* spp., hosts include nectarines, peaches, plums, apricots, and cherries (Mackie 1944a). Summers (1966) previously described the history and biology of OFM in California. OFM does not disperse over great distances from orchards of its hosts (Sziraki 1984). Females oviposit eggs on fully developed leaves toward the top of growing shoots (Phillips & Proctor 1969). In early observations the larvae were reported to primarily feed on succulent twig growth (Armitage 1945). Stone fruit characteristics such as nutritional quality, e. g., extrafloral nectaries (Putman 1963), allelochemics (Leather 1985), and induced plant response to attack, e. g., gum deposition (Karban 1983) may determine the acceptability (Miller & Strickler 1984) and suitability (Scriber 1984) of stone fruits to OFM. Peaches are a primarily OFM host (Summers 1966). Resistance to scales (Kozar 1972), aphids (Massonie & Maison 1980), and peachtree borer, Sanninoidea exitiosa Say (Chaplin & Schneider 1975), has been found in certain peach cultivars. Some peach hybrids have shown resistance to OFM (Roselli et al. 1985). A market for stone fruits is available in countries where OFM is not found (Yokoyama et al. 1987b). Cultivars resistant to OFM would have naturally low pest infestation levels. Such cultivars would be ideal for quarantine treatment and export with minimal risk of possible introduction (Landolt et al. 1984). The objective of this study is to identify stone fruit cultivars that may be both less acceptable and suitable to OFM for oviposition and larval development.

Materials and Methods

Insects and Fruit Tests. OFM was reared by procedures described by Yokoyama et al. (1987a). Fruit of nectarine, peach and plum cultivars used in tests to determine acceptability to OFM for oviposition were obtained and treated by methods described by Yokoyama and Miller (1987). Cultivars used to study the relation of fruit maturity to OFM oviposition included experimental nectarine and peach cultivars from the Horticultural Crops Research Laboratory, ARS, USDA, Fresno, Calif., and plums from a commercial 'Roysum' orchard. 'Flamekist' nectarines and 'O'Henry' peaches, which complied with California Tree Fruit Agreement (CTFA, Sacramento, Calif.) maturity requirements at harvest, were used for postharvest fruit and compared to fruit in three other maturity stages shown in Table 1. 'Flamekist' nectarines were also used to determine acceptability of either red or yellow fruit skin color to OFM for ovipositon. 'Flamekist' nectarines, 'Fairtime' peaches, and 'Casselman' plums were used to determine OFM oviposition on different areas of each fruit shown in Table 2. Infestation cages and techniques used to expose the fruit to OFM (ca. 500 females per cage) have been previously described by Yokoyama and Miller (1987). Early, mid-season, and late season nectarine, peach, and plum cultivars were compared for acceptability to OFM oviposition among each stone fruit group in Table 3 and 4 and among mixed stone fruit groups in Table 5. The data were analyzed by analysis of variance (ANOVA) using the Duncan option for mean comparisons (SAS Institute 1985).

Vegetative Shoot Tests. Vegetative shoots from trees of various stone fruit cultivars in Table 6 were collected from orchards at the Kearney Agricultural Center, University of California, Parlier. Ten shoots (30.5 cm long) were cut from each tree. Ten trees were used for each cultivar. Leaves were removed from each shoot and the base of the shoot was placed in water. One OFM first instar was placed on the terminal of each shoot. The shoots were evaluated 14 d later for feeding injury which was used as evidence of insect attack, and for presence or absence of visible gum and OFM mature larvae or pupae.

Gum Extract Tests. Gum was collected from the trunk and branches of a 'Redtop' peach tree. A gum sample (15 g) was dissolved in water (680 ml) and centrifuged for 30 min at 2,000 x *g*. The supernatant was collected. The sediment was redissolved in water and extracted with equal volumes of hexane, n-butyl alcohol, and chloroform. Both the original supernatant and the aqueous phase that had been extracted with organic solvents were each tested on development of OFM first instar by incorporation into the larval diet at 10, 20, 30, 40, 50 and 60% v/v.

Results and Discussion

Gravid OFM females laid more eggs on nectarines harvested from orchards in three different maturity stages than on postharvest packed fruit (Table 1). The number of OFM eggs laid on red skin areas of nectarines ($\bar{x}$ = 83.4) did not significantly differ from yellow skin areas ($\bar{x}$ = 82.4) (F = 0.01; df = 1,6; $P > 0.05$). Color is not a factor that affects the acceptiblility of nectarines for oviposition. Oviposition was significantly greater on postharvest peaches than on the three other fruit maturity stages tested (Table 1). Summers (1966) made similar observations in cling peach orchards and reported semiripe peaches were less susceptible to OFM than fully ripe peaches. The large number of eggs on postharvest peaches (Table 1) could have resulted from reduced fruit pubescence caused by packinghouse handling procedures which made the fruit more acceptable for oviposition. OFM females can be discouraged from laying eggs on surfaces with the napped texture of velour paper and cloth. OFM females did not discriminate among ripening plums for oviposition and no differences were found in numbers of eggs on plums of any maturity stage (Table 1).

OFM females laid more eggs on the stem end of nectarine, peach, and plum fruit than any other fruit area (Table 2). The stem end has a depression which may be a favorable factor for female ovipositional activities. Summers (1966) showed OFM larval entry holes on the stem end of 'Elberta' peaches. The stem end is probably the most common site of attack on most stone fruits.

Although OFM primarily feeds on foliage, Summers (1966) found that fruit is attacked when pest populations are high or shoots become unfavorable. Mackie (1944b) reported OFM females will oviposit on newly set peaches in the absence of foliage. Furthermore, the presence of fruit suitable for larval entry would reduce intraspecific competition among newly hatched larvae and increase larval survival (Phillips & Proctor 1969). OFM ovipositional behavior on fruit from several common cultivars was fused to determine differences in susceptibility that would help identify potentially resistant cultivars. Fruit with significantly higher numbers of eggs were considered susceptible to attack and fruit with significantly lower numbers of eggs were considered less susceptible. 'Red Diamond' nectarines had higher numbers of eggs than other mid to late season nectarine cultivars (Table 3). However, 'Fantasia' nectarines were less susceptible and had fewer eggs than other mid-season nectarines (Table 3). OFM laid more eggs on 'Redtop' peaches than other mid to late season cultivars (Table 4). Summers (1966) reported canning peaches and peach cultivars that were harvested during August to early September were more susceptible to OFM. OFM laid more eggs on 'Laroda' plums and fewer eggs on 'Roysum' plums than other plum cultivars tested (Table 4).

A comparison of OFM oviposition among nectarine, peach and plum cultivars showed higher numbers of eggs on 'Late Le Grand' nectarines. Lower numbers of eggs were laid on mid through late season 'Elberta', 'Elegant Lady', 'O'Henry' and 'Fairtime' peach cultivars (Table 5). The pubescent surface of peaches may be less favorable to females for oviposition resulting in lower numbers of eggs on peaches in tests with mixed stone fruit groups. However, Weaver and Boyce (1965) reported 'Elberta' peach seedlings were resistant to the peachtree borer. More eggs were laid on 'Laroda' plums in tests with either mixed stone fruit groups (Table 5) or other plum cultivars (Table 4). 'Laroda' plums are highly acceptable to gravid females for oviposition. Differences in infestation among stone fruit groups was not consistent in these tests and most nectarine, peach and plum cultivars had similar numbers of eggs. Summers (1966) reported peaches as the principal host crop with heavy losses caused by OFM in nectarines. Summers (1966) found plums, apricots, and cherries to be less seriously affected hosts.

The relationship of OFM larval feeding injury, plant gum production and successful development of first instar to mature larvae or pupae is shown in Table 6. Most shoots without larval feeding injury did not produce gum but shoots that were attacked produced gum (Table 6). Gum formation at feeding sites forced many larvae to the base of each shoot where many drowned in the water in which the shoots were placed. Most first instars that survived to a later stage were found on shoots that did not produce gum (Table 6). However, there were some exceptions among the stone fruit cultivars to the general observations disscussed above (Table 6). Karban (1983) showed cherry trees responded to periodical cicada oviposition by depositing gum at the egg nest. Similarily, gum deposition in stone fruit appears to be an induced plant response to feeding injury by OFM larvae.

The major behavioral or toxicological barrier to favorable host suitability is determined by the first instar (Scriber 1984). Phillips & Proctor (1969) reported highest OFM mortality occurred during establishment of newly hatched larvae. Gum may function to deter larval insect attack by mechanical means. The water soluble nature of cherry tree gum was described by Karban (1983). OFM larvae successfully completed normal development to the adult stage on larval diet medium that was combined with 0-60% v/v aqueous extracts of peach tree gum. Toxic compounds such as phenolics were extracted with organic solvents. Stone fruit gum appears to function as a mechanical rather than a toxic barrier to insect attack.

Acknowledgment

Special appreciation for assistance in this project is given to Richard E. Rice (Kearney Agricultural Center, University of California, Parlier) and the following California grower-packer-shippers: Ballantine (Sanger), George Brothers (Sultana), Gerawan (Sanger), Giannini (Dinuba), Ito (Reedley), PR Farms (Clovis), Superior (Bakersfield) and Wawona Ranch (Clovis). This study was supported in part by the California Tree Fruit Agreement.

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Table 1. OFM oviposition on stone fruits in four stages of fruit maturity

Fruit maturity	$\bar{x}$ no. eggs		
	Nectarine[a]	Peach[b]	Plum[c]
Firm, green	70.2a	20.7b	99.1a
Firm, $\leq$ 50% color	81.2a	23.3b	84.0a
Soft, 100% color	76.4a	12.3b	98.8a
Postharvest	42.6b[d]	73.3a[d]	82.6a

Means within a column followed by the same letter are not significantly different ($P > 0.05$; Duncan's multiple range test [SAS Institute 1985]).

[a]Eight replicates, 24 h exposure.

[b]Six replicates, 24 h exposure.

[c]Eight replicates, 24 h exposure.

[d]Fruit complied with CTFA maturity requirements at harvest and stored at 0°C for 1-3 wks.

Table 2. OFM oviposition on different parts of stone fruits

Area on fruit	$\bar{x}$ no. eggs		
	Nectarine[a]	Peach[b]	Plum[c]
Stem end	239.7a	53.3a	252.4a
Blossom end	116.9b	10.6b	193.9b
Side	113.4b	11.1b	181.4b
Suture	80.3b	20.1b	173.0b

Means within a column followed by the same letter are not significantly different (*P* > 0.05; Duncan's multiple range test [SAS Institute 1985]).

[a]Seven replicates of 'Flamekist' nectarines, 24 h exposure.

[b]Seven replicates of 'Fairtime' peaches, 24 h exposure.

[c]Eight replicates of 'Casselman' plums, 48 h exposure.

Table 3. OFM oviposition on mid and late season nectarine cultivars

Mid-season[a]			Mid to late season[a]			Late season[b]		
Harvest date	Cultivar	$\bar{x}$ no. eggs	Harvest date	Cultivar	$\bar{x}$ no. eggs	Harvest date	Cultivar	$\bar{x}$ no. eggs
10 June	'Firebrite'	93.5a	10 June	'Red Diamond'	116.5a	25 Aug.	'Fairlane'	81.4a
24 June	'Summer Grand'	84.5a	30 July	'Flamekist'	58.5b	25 July	'Late Le Grand'	77.1ab
12 June	'Spring Red'	81.0a	25 July	'Late Le Grand'	41.0b	22 Aug.	'September Grand'	71.6ab
30 June	'Fantasia'	57.7b	30 June	'Fantasia'	37.8b	2 Sept.	'Flamekist'	62.3b

Means within a column followed by the same letter are not significantly different ($\underline{P} > 0.05$; Duncan's multiple range test [SAS Institute 1985]).

[a]Six replicates, 24 h exposure.

[b]Seven replicates, 24 h exposure.

Table 4. OFM oviposition on early through late season peach and plum cultivars

Peach						Plum					
Mid to late season[a]			Late season[b]			Early, mid to late season[c]			Late season[d]		
Harvest date	Cultivar	$\bar{x}$ no. eggs	Harvest date	Cultivar	$\bar{x}$ no. eggs	Harvest date	Cultivar	$\bar{x}$ no. eggs	Harvest date	Cultivar	$\bar{x}$ no. eggs
12 June	'Redtop'	83.7a	8 Sept	'Autumn Lady'	46.6a	8 July	'Laroda'	314.9a	24 July	'Casselman'	124.1a
10 July	'Elberta'	26.3b	9 Sept	'Carnival'	33.3ab	2 July	'Queen Ann'	210.4b	7 Sept	'Angeleno'	108.0a
8 July	'Elegant Lady'	16.2b	2 Sept	'Autumn Gem'	19.1b	12 June	'Santa Rosa'	187.4bc	2 Sept	'Roysum'	80.0b
23 July	'O'Henry'	15.8b	28 Aug	'Fairtime'	13.7b	24 July	'Casselman'	129.8c			

Means within a column followed by the same letter are not significantly different (*P* > 0.05; Duncan's multiple range test [SAS Institute 1985]).

[a]Six replicates, 24 h exposure.

[b]Seven replicates, 24 h exposure.

[c]Eight replicates, 72 h exposure.

[d]Eight replicates, 24 h exposure.

Table 5. OFM oviposition on mid through late season stone fruit cultivars

Mid-season			Mid to late season						Late season					
Stone fruit	Cultivar[a]	$\bar{x}$ no. eggs	Stone fruit	Cultivar[b]	$\bar{x}$ no. eggs	Stone fruit	Cultivar[c]	$\bar{x}$ no. eggs	Stone fruit	Cultivar[d]	$\bar{x}$ no. eggs	Stone fruit	Cultivar[e]	$\bar{x}$ no. eggs
Nectarine	'Summer Grand'	80.1a	Plum	'Laroda'	472.8a	Nectarine	'Late Le Grand'	136.3a	Peach	'Autumn Lady'	95.3a	Nectarine	'Fairlane'	183.9a
Plum	'Queen Ann'	66.4ab	Nectarine	'Late Le Grand'	362.0b	Peach	'Elberta'	75.0b	Peach	'Carnival'	65.9ab	Nectarine	'Summer Grand'	139.9ab
Nectarine	'Fantasia'	61.0b	Nectarine	'Flamekist'	341.7b	Plum	'Casselman'	73.4b	Nectarine	'Flamekist'	64.0ab	Plum	'Roysum'	81.6bc
Peach	'Elberta'	24.9c	Plum	'Casselman'	275.7c	Peach	'O'Henry'	44.7b	Plum	'Angeleno'	35.9b	Peach	'Autumn Gem'	24.6cd
			Peach	'Elegant Lady'	123.8d							Peach	'Fairtime'	7.9d
			Peach	'O'Henry'	98.2d									

Means within a column followed by the same letter are not significantly different (P > 0.05; Duncan's multiple range test [SAS Institute 1985]).

[a]Seven replicates, 1 d exposure.

[b]Six replicates, 5 d exposure.

[c]Seven replicates, 2 d exposure.

[d]Seven replicates, 3 d exposure.

[e]Seven replicates, 1 d exposure.

Table 6. Relation of OFM first instar (L_1) feeding on stone fruit vegetative shoots to production of plant gum and presence of mature larvae or pupae 14 d later

Stone fruit	Cultivar[a]	Shoots not attacked (%)		Shoots attacked (%): Without larvae or pupae		Shoots attacked (%): With larvae or pupae	
		Without gum	With gum	Without gum	With gum	Without gum	With gum
Nectarine	'Fantasia'	3.0	0	34.0	61.0	3.0	0
	'Flavortop'	6.9	0	62.7	24.5	4.9	0
	'Independence'	2.0	0	38.8	53.1	7.1	0
	'Late Le Grand'	4.0	0	15.0	71.0	10.0	0
	'Le Grand'	2.0	0	31.0	60.0	7.0	0
	'Sun Grand'	6.1	0	57.6	29.3	8.1	0
Peach	'Fay Elberta;	1.0	0	13.0	73.0	13.0	0
	'Redtop'	27.8	1.1	13.3	41.0	16.7	0
Plum	'Casselman'	13.0	0	13.0	65.2	8.7	0
	'Santa Rosa'	3.0	0	27.0	66.0	1.0	3.0
Apricot	'Tilton'	42.0	12.0	12.0	27.0	7.0	0
Cherry	'Bing'	3.4	0	2.6	48.3	45.7	0

[a]Nine-12 trees per cultivar, eight-13 shoots per tree, one OFM L_1 per shoot.

COOPERATIVE EXTENSION
UNIVERSITY OF CALIFORNIA

DAVIS, CALIFORNIA 95616

AUG 13 1986

REPLY TO:

Agricultural Engineering Extension
(916) 752-6167

August 11, 1986

Charlie Sanderson
California Tree Fruit Agreement
P. O. Box 255383
Sacramento, CA 95865

Dear Charlie:

We have finally had a chance to redo the plum sizing study.

The results are basically the same as the last comparison we made, except for the diameter tolerance standard. We found that with "half sizes" it was probably not necessary to increase the diameter tolerance standard above 1/4 inch.

Let me know if you and Gary have any questions about the report.

I hope we will be able to work together in the future.

Sincerely,

Jim

James F. Thompson, P. E.
Extension Agricultural Engineering

JFT:sh

Enclosure

cc: Gordon Mitchell
Jerry Knutson
Gene Mayer

COMPARISON OF THE EXISTING PLUM SIZING SYSTEM WITH A PROPOSED SYSTEM

J. F. Thompson
F. G. Mitchell
J. Knutson
G. Mayer[1]

July 1986

Background: Fresh market plums are currently sized according to a system developed when the fruit was packed in a four basket crate. Fruit was sized primarily by diameter and the geometrical pattern it would form in the basket. For example, large fruit might form a pattern of two fruit across and two fruit down on the top layer. This fruit was designated as size 2x2. This system is less meaningful today because the four basket crate system is seldom used and consumers and retailers think of fruit size primarily in terms of number of fruit per pound.

Objective: Compare packout of seven varieties of fresh market plums under the existing sizing system and a system based on number of fruit per pound.

Procedure:

1. We obtained samples of 200 plums each from field bins at preselected packinghouses. We excluded fruit that was extremely overmature or small enough to be removed by a presizer. Fruit was not sorted for any other grade standard. Eighty one samples were obtained. The following plum varieties were included in the study: Casselman, Laroda, Santa Rosa, Black Beaut, Red Beaut, Friar, and El Dorado.

2. Sampling was repeated for each fruit variety at northern, central, and southern production areas and during early, middle, and late portions of the growing season.

3. We measured maximum equatorial diameter of each fruit to the nearest tenth of a millimeter using a caliper and measured the weight of each fruit to the nearest tenth of a gram using an electronic scale.

4. Fruit was placed into size categories based on the existing and proposed systems using a sorting program written for a microcomputer. The program uses weight data to place fruit in size categories and to calculate the proportion of total fruit weight in each category. The program also evaluates amount of fruit by count that excedes diameter tolerance standards. Size and diameter standards for the existing

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[1]The authors are Extension Agricultural Engineer, Agricultural Engineering Department; Pomologist, Pomology Department; Development Engineer, Agricultural Engineering Department; Staff Research Associate, Pomology Department, respectively at UC Davis. We wish to thank the California Tree Fruit Agreement for supporting this project.

size system are based on 1986 Plum Bulletin No. 1. The proposed size system was developed by CTFA. It is based on a series of sizes from 1 to 9. The sizing system was originally based on a count per pound system. For example, an average size 5 fruit would weigh slightly more than 0.2 lbs. or be equal to a little less than five fruit per pound. Size categories larger than size 6 were found to contain too large a range of fruit weights and were split in half, forming the + and - sizes in size 1 through 5. Table 1 is a description of the proposed system. Figure 1 is a graphic comparison of the existing and proposed sizing systems.

TABLE 1

DESCRIPTION OF PROPOSED PLUM SIZING SYSTEM

Size Designation	1+	1-	2+	2-	3+	3-	4+	4-	5+	5-	6	7	8	9
Minimum Size (No. of Fruit which must weight at least 8 lbs.)	7	11	15	19	23	27	31	35	39	43	51	59	67	75

Results: The packout under the existing and proposed sizing systems for El Dorado, Friar, Black Beaut, Red Beaut, Santa Rosa, Laroda and Casselman varieties is compared in figures 2 through 8 respectively. The comparison is based on equating a fruit size in one system with the closet comparable size or sizes in the other system. All varieties except Laroda, Black Beaut, Friar, and El Dorado had very similar packouts in the existing and proposed systems. The variation in Laroda, Black Beaut, and Friar are due to size boundaries in the two systems which do not correspond well and the actual distribution of fruit sizes in the samples. El Dorado does not have designated sizes above 3 x 4 in the existing system, so all fruit this size and larger was included in the 3 x 4 data point. Overall, the packout in the two systems was fairly similar for each variety we tested.

Differences in packout are only significant if they result in a different return to the grower. We estimated total fruit value under the proposed and existing systems by assuming the fruit value in the existing system was equal to the average of daily values listed in the 1982, 1983, 1984, Federal State Market News reports. Value of fruit in the new size system was assumed to be equal to the value of fruit in closest size category in the existing system. A value index for a variety was calculated as the average value of a fruit size multiplied by the proportion of fruit in that size summed over all fruit sizes. Table 2 shows value indexes for all varieties in the existing and proposed systems. Prices in the Federal State Market News were reported usually to the nearest dollar and because a typical box of plums costs about $10 to $12, we could not say that there is a real difference in price unless the value index changes by about 10% or more. The value index for no variety changes by this much so we could not detect any significant difference in fruit value by using the proposed system compared with using the existing system.

TABLE 2

COMPARISON OF FRUIT VALUE IN
EXISTING AND PROPOSED PLUM SIZE SYSTEMS[2]

	VALUE INDEX		% GREATER VALUE WITH PROPOSED SYSTEM
	EXISTING SYSTEM	PROPOSED SYSTEM	
El Dorado	14.4	14.1	-2
Friar	12.2	12.3	1
Black Beaut	13.9	13.8	-1
Red Beaut	10.7	10.6	-1
Santa Rosa	10.5	10.4	-1
Laroda	8.0	8.7	9
Casselman	9.2	9.8	7

[2] Based on 1982, 1983, 1984 Federal State Market News price data. Both systems have the same undersize limit.

All of the discussion so far has assumed that both systems use the same minimum size cutoff. However, the existing minimum size does not often fall at a size boundary in the proposed system. For example, the minimum size for Casselman is 63 fruit per 8 pounds which is in the middle of the proposed size 8 category. While this is not necessarily a big problem, it does make the proposed system less meaningful.

We evaluated the effect of adjusting the minimum size cutoff to correspond to a size boundary in the proposed sizing system. Table 3 shows the result of this change on quantity of salable fruit. For all varieties, the increase or decrease in fruit quantity is small and there is only a small effect on the value index. The change is very small with varieties such as El Dorado, Black Beaut, and Santa Rosa because little or no change was made in the minimum size. The minimum size was changed as much as 3 to 4 fruit per 8 pounds in varieties such as Friar and Casselman but the change had a small effect on the amount of salable fruit because these varieties had very little small sized fruit in 1985. It is possible that under some cultural and weather conditions, these varieties may produce a large amount of fruit near the minimum size cutoff and the change would have a significant effect on return to the grower.

TABLE 3

COMPARISON OF FRUIT VALUE IN EXISTING AND PROPOSED PLUM SIZE SYSTEMS
EFFECT OF CHANGING THE MINIMUM SIZE TO CORRESPOND TO PROPOSED SIZE CUT-OFF BOUNDARIES

Variety	Current Minimum (fruit/8 lbs	Proposed Minimum (fruit/8 lbs	% Increase Fruit Pool	% Greater Value & Proposed Minimum Size
El Dorado	68	67	-.9	-1
Friar	56	59	.6	0
Black Beaut	69	67	-1	-1
Red Beaut	74	75	.7	1
Santa Rosa	69	67	-1.9	-2
Laroda	58	59	4.6	4
Casselman	63	67	2.3	2

The diameter measurements allowed us to determine if any varieties did not meet the diameter variation standard. All varieties except Friar met the standar. 5.6% of the Friar plums in size 3- were greater than the 1/4" diameter variation limit. However, the standard allows 5% of a sample to be beyond the limit, so even Friar was very close to meeting the standard.

Conclusions:

1. If plums in the proposed system have a value equal to fruit in closest size in the existing system, the proposed sizing system had no detectable effect on fruit value compared with the existing system.

2. Changing the minimum size designation to correspond with the proposed system's size boundaries did not effect fruit value, based on the size fruit harvested in the 1985 season.

3. The 1/4" diameter tolerance standard is large enough for the proposed sizing system.

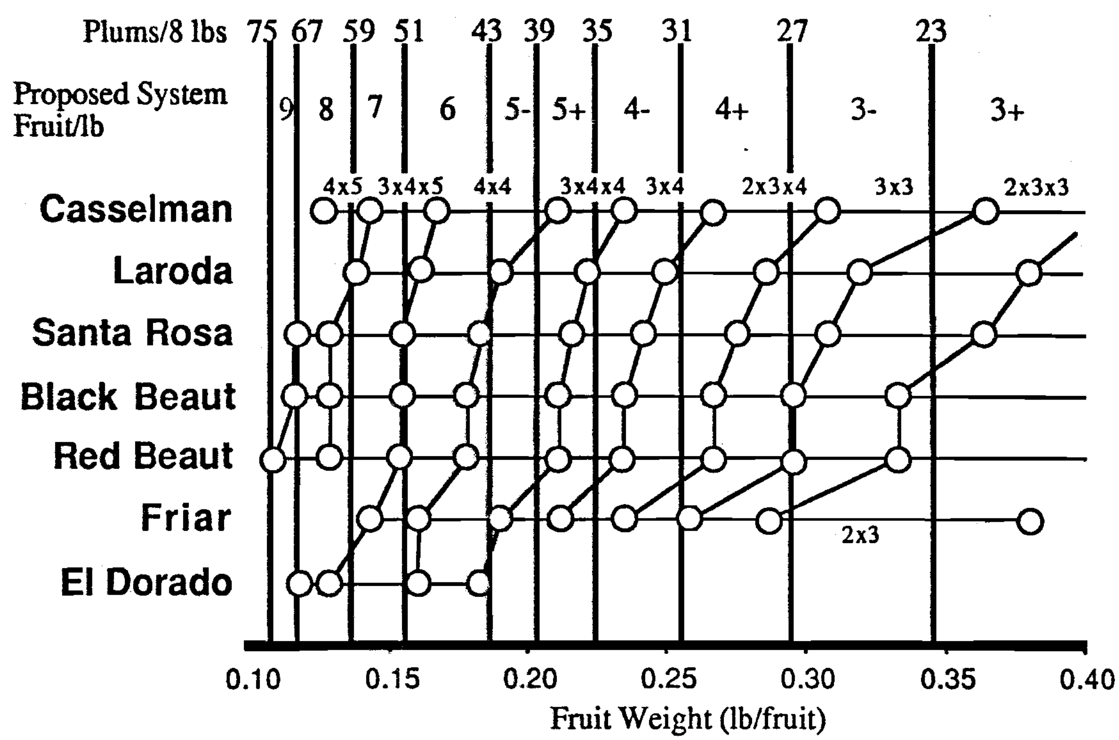

Figure 1. Comparison of existing plum sizing system with proposed system for seven plum varieties.

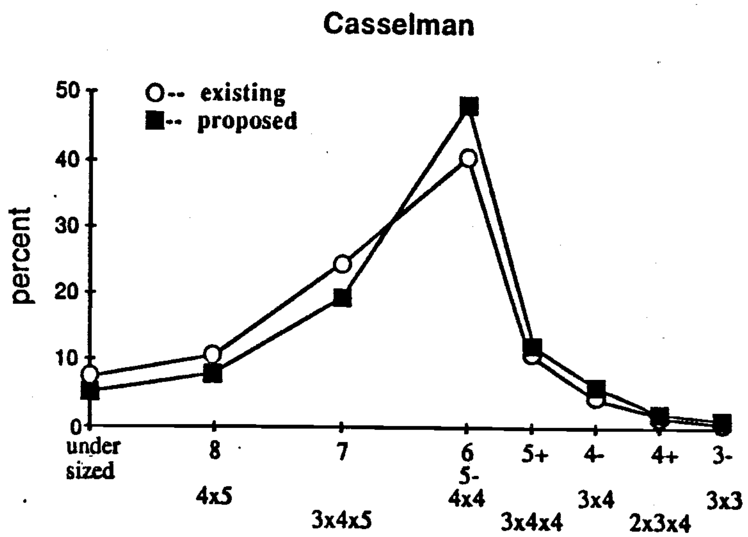

Figure 2. Percent of Casselman Plums by size category in existing & proposed systems

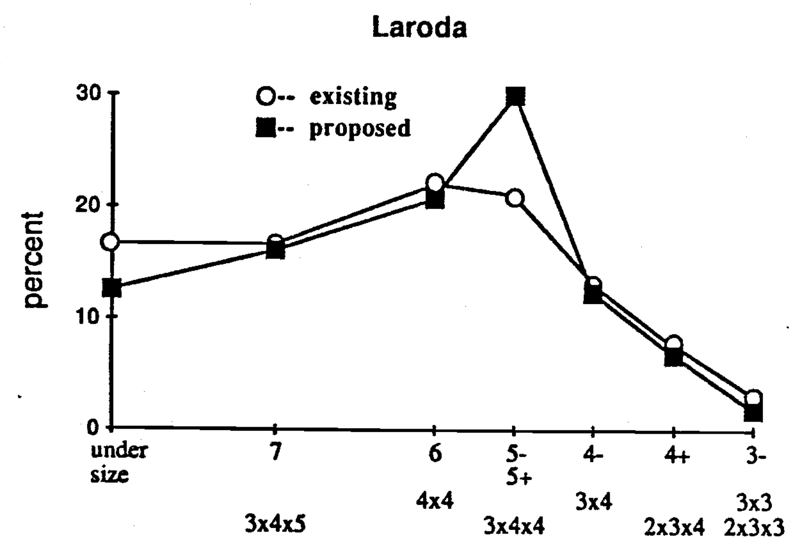

Figure 3. Percent of Laroda Plums by size category in existing & proposed systems

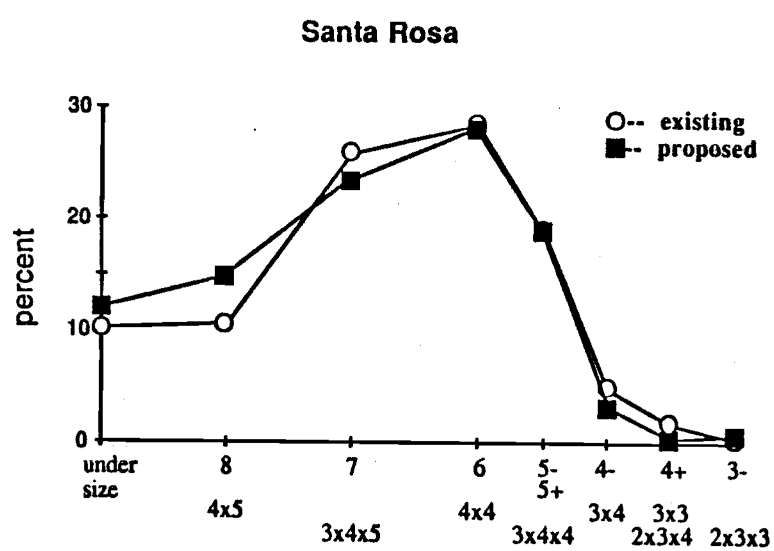

Figure 4. Percent of Santa Rosa Plums by size category in existing & proposed systems

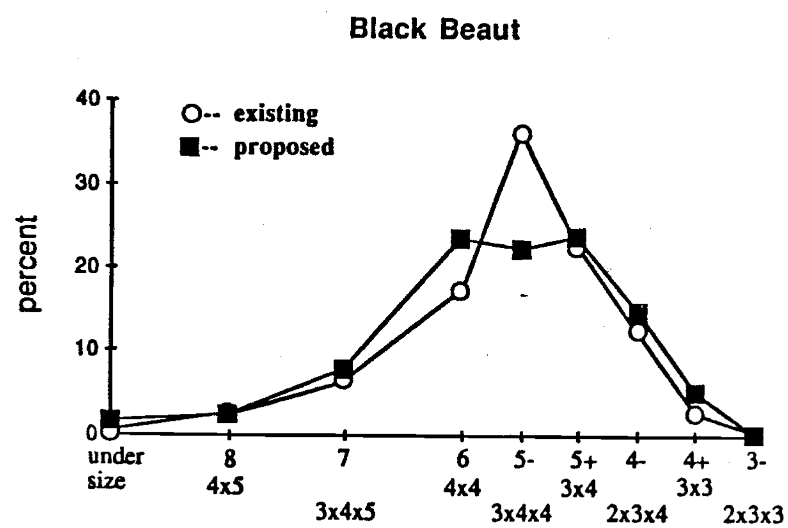

Figure 5. Percent of Black Beaut Plums by size category in existing & proposed systems

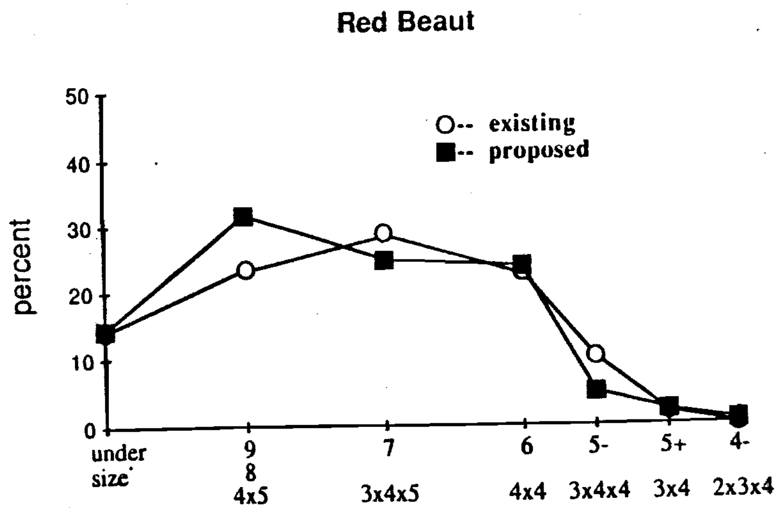

Figure 6. Percent of Red Beaut Plums by size category in existing & proposed systems

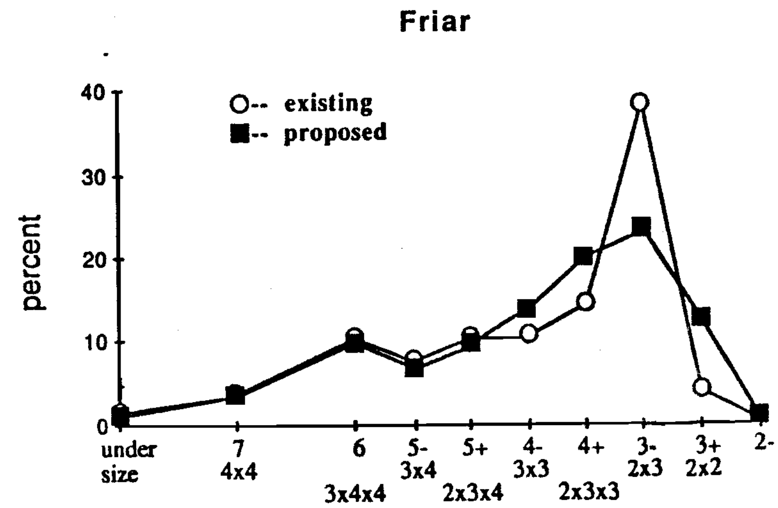

Figure 7. Percent of Friar Plums by size category in existing & proposed systems

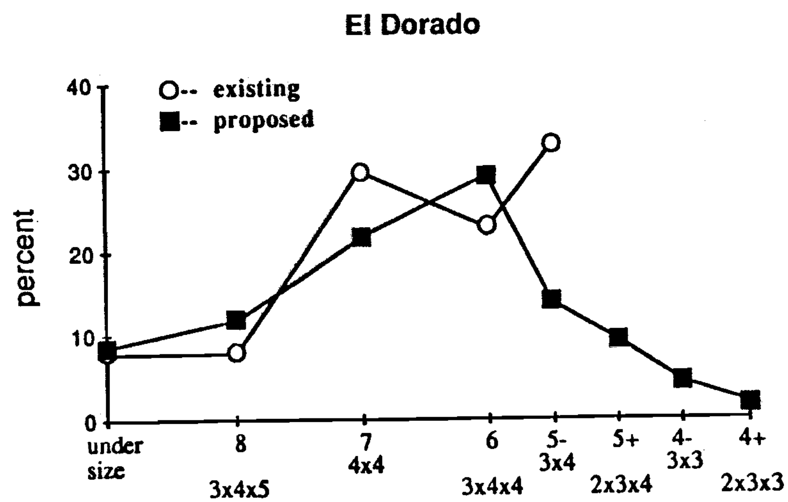

Figure 8. Percent of El Dorado Plums by size category in existing & proposed systems