Strawberry Breeding and Evaluation for Mechanical Harvesting

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Strawberry Breeding and Evaluation for Mechanical Harvesting

F. J. LAWRENCE, L. W. MARTIN, and G. W. VARSEVELD

ABSTRACT

Strawberry seedlings and clones were evaluated in the field for crop concentration, harvest ease, and ease of capping. Laboratory post-harvest studies were made of quality retention in these seedlings and clones. Progress has been made in all these categories toward machine harvest.

Inheritance patterns for crop concentration show that early-season parents, such as 'Sunrise', provided seed'ing populations with crop concentration. Semi-erect fruiting habits could be obtained from parents of the erect habit, such as 'Hood', 'OR-US 2785', and 'OR-US 2993'. A lack of fruit firmness appeared to be related to ease of capping, but a reflexed calyx did not.

Many clones had total yields greater than 'Northwest,' the standard commercial cultivar, and crop concentration measured by the total amount of fruit ripe at any one harvest also was greater than that of 'Northwest.'

Performance of OR-US clones varied widely on a fruit destemming machine called the "OSU stemmer." When fruit was obtained from a once-over harvest, five OR-US selections had distinctly greater amounts of usable fruit after capping than did the commercial cultivars Hood and Northwest. Frozen sliced samples of mechanically harvested ripe fruit of six OR-US selections rated "good" were comparable to hand-harvested 'Northwest' and superior to machine-harvested 'Hood'.

Penetrometer measurements taken on the fresh fruit may be useful for predicting textural breakdown in frozen strawberries.

Key words: strawberry, *Fragaria*, mechanization, harvest, post-harvest, breeding, yield, crop concentration, berry, quality, processing, texture, genetics, capping, calyx.

Introduction

Commercial strawberry (*Fragaria ananassa* Duch.) production in Oregon, Washington, and southwestern British Columbia for 1967-1973, averaged about 53,517,000 kilograms (118 millions lbs.) annually. For the same period, the annual average processed value was about $43.9 million (USDA, 1973; Cusack and Coppedge, 1971). Of this production, Oregon had slightly more than 60%, or an average annual processed value of about $26.5 million. Less than 5% of Oregon's production was sold as fresh fruit.

Some difficulties face the strawberry industry, but none so great as harvesting. How to meet the demand for higher picking wages and other production costs and still remain competitive with other producing areas is the critical problem.

Similar problems in other crops, such as tomatoes and bush beans, have been solved through the breeding of new cultivars and the development of machinery for harvesting and handling. The strawberry is a perishable, delicate fruit requiring gentle handling, yet rapid movement, from the field to the processor. The fruit ripens over a two to three week period in the Northwest and requires three to five pickings. The ripe fruit is located on or near the ground, so machine retrieval is extremely difficult. Existing cultivars have been selected in breeding programs for more than 30 years with little regard for the characteristics necessary for mechanical harvesting.

Pressure to explore the breeding of new cultivars for mechanical harvesting and handling came in 1966-1967 from the Oregon strawberry industry. Also, the Oregon Strawberry Commission, formed in 1967, identified mechanical harvesting as its first major research objective. As a result, a major portion of the long-term cooperative USDA-Oregon Agricultural Experiment Station strawberry breeding program was directed to selection for mechanical harvesting. In the same year, the Department of Agricultural Engineering at Oregon State University developed an experimental harvester and conducted the first mechanical harvesting trials on strawberries in Oregon. Agricultural engineers, horticulturists, and food scientists in the Oregon Agricultural Experiment Station have been cooperatively involved with the USDA strawberry breeding program.

Objectives

Strawberries produced in Oregon and Washington are delivered to the processor to be frozen, made into preserves, or converted to other processed products that supply a year-round consumer demand. An important objective of the breeding program for mechanization has been the origination of new clones with fruit characteristics suited to the requirements of the processing industry, as well as to a mechanical harvesting and handling system.

Strawberry breeders are seeking to originate plant types with attributes which include a simultaneous ripening of fruit, upright fruit habit, easy capping (calyx removal), and bruise resistance needed for mechanical harvesting. Cultivars amenable to mechanical harvesting must be reasonably disease tolerant and must also maintain the quality and potential production of fruit in the industry.

At the North Willamette Experiment Station, Aurora, Oregon, seedlings are propagated after they are screened for resistance to red stele, a root disease caused by *Phytophthora fragariae*, Hickman. They are then grown in the field for evaluation. This station is also initially responsible for keeping virus-free mother plants of all plant entries, thereby providing a source of plants for evaluation.

Post-harvest evaluations are conducted by the Department of Food Science and Technology and include quantitative information on total fruit, ripe fruit, fruit unusable due to damage or attached caps, and fruit usable for processing in the mechanically harvested and stemmed samples of each new clone tested; qualitative information on the sensory attributes of the product processed from the new clones after mechanical harvesting and stemming; and measurements of texural integrity of frozen sliced berries and fresh whole berries of hand-harvested new selections.

The purpose of this report is to present and discuss procedures for and data on breeding, plant selection, and field and laboratory evaluations pertaining to mechanical harvest of the strawberry.

Procedures

Breeding

Materials. Parent types were selected on the basis of previous harvest records and notes for (a) concentration of crop (amount of fruit ripe at one time), (b) easy capping, and (c) erect fruiting habit. Part of the parent material originated from the cooperative USDA-Oregon State Experiment Station breeding program of G. F. Waldo, and are designated 'OR-US.' Other parent clones originated from state programs, such as Iowa (IA), California (CA), Washington (WA), and Canada (BC), and from cooperative USDA state stations in North Carolina (NC-US), Maryland (MD-US), and Southern Illinois (SI-US). A listing of all clones and cultivars reported here appears in the appendix.

Pollination method. All crosses reported here were from controlled pollination. Plants were potted and placed in a greenhouse at 15-21° C during mid-December and early January. As plants flowered, usually during February and March, the flowers were emasculated and pollinated. Achenes were separated from the ripe fruit by a blender and a little water, as suggested by Darrow (1966). The seed was stored dry at room temperature until May 1. To chill the seed, we placed them on moist filter paper in petri dishes, treated them with the fungicide, 75% pentachloronitrobenzene (PCNB), and stored at temperatures of about 2° C for 30 to 45 days, as suggested by Bringhurst and Voth (1957). The chilled seed were planted in June or early July in flats of milled sphagnum moss and placed in the greenhouse at temperatures of about 20 C ± 2° for germination.

Red stele screening. A primary aim of the total strawberry breeding program has been resistance to red stele root rot. In August, all seedlings were transplanted from the seed flats into benches filled with field soils infested with *P. fragariae* from some Oregon strawberry fields. The benches were flooded weekly during the winter and kept cool (10 C ± 2°) to provide for optimum infection. The seedlings were dug during February and March and were rated for red stele resistance on a scale of 1 to 10, where 1 = dead and 10 = no symptoms (Daubeny and Pepin, 1965; Scott et al., 1962). Seedlings rating 7 or greater were saved and planted at the North Willamette Experiment Station.

Propagation and field evaluation

Screenhouse operations. Each year, about 5,000 seedlings tolerant to red stele were transferred to the North Willamette Experiment Station for further propagation and evaluation. Plants were potted in containers of 3.8 l (1 gal.) in February and March and placed in the greenhouse with long-day (16 hr.) light. Runners started to form on most seedlings within six to eight weeks. As the runners formed, they were pegged down in peat pots next to the mother plants. Seedling escapes or plants mildly infected from the screening test always can potentially carry the red stele disease to the next place of the program. Undoubtedly, some of the plants were infected with *P. fragariae*, although occasional checks did not reveal infection. Testing was not extensive at this stage. Three well-rooted runner plants were taken from each mother plant and transferred to the field during late spring. The mother plants were kept in an aphid-free screenhouse and sprayed with diazinon (0, 0-diethyl 0-(2-isopropyl-6-methyl-4-pyrimidinyl) phosphorothioate). Thus, these plants were a source of essentially virus-free material for propagation.

Field plantings and evaluations. The first field evaluation of the seedlings was two years after the original cross. About 3% were selected.

Additional runner plants of the clones selected were propagated from the mother plants kept in the screenhouse. A second planting of 10 plants each of the clones was made in the spring of the third year after the cross. This second planting was evaluated again visually and scored on desirable characteristics in the fourth year. Fifteen to thirty percent of these selections were kept for further evaluation. Other plants of clones chosen in the fourth year were propagated from screenhouse plant sources.

A replicated planting of the clones was then established, and yield of hand-picked fruit was recorded for the first time. Fruit and plant characteristics were evaluated in greater detail in the sixth year. Also, fruit samples were evaluated then by the Departments of Food Science and Technology and Agricultural Engineering for their processing and handling quality.

Fruiting characteristics. Seedlings were rated in the field for ease of capping, fruiting habit, and crop concentration. A scale of 0 to 9 was used: 0 = least desirable, and 9 = most desirable. Seedlings of selected populations were rated once, and first-year clones were rated in the same manner two or more times during each season. Advanced clones were planted in replicated blocks, and yields and fruit size data were taken on hand-harvested fruit.

Ease of capping was rated subjectively, based on hand separation of the fruit from the calyx. The rating scale was a score of 0 to 9; 0 = the calyx could not be separated from the fruit without crushing the berry, and 9 = a clean, easy separation. A rating of 6 or greater was considered an easy-cap (EC) type.

"Cap" refers to a calyx and may include a small portion of the stem. The calyx and stem of fruit of the EC type can be removed readily with little damage to the fruit. Anatomical studies of strawberry fruits at the area of separation between this calyx and receptacle of 27 clones and cultivars did not indicate a visible abscission layer (Garren, unpublished). The calyx separates from the fruit by a rupturing of the receptacular and vascular tissues next to the calyx. Some fruit does not have vascular tissue that separates readily at this junction, but separates near the center of the fruit and leaves a hollow core called a "plug." With a "reflexed cap," the sepals, or lobes, of the calyx are turned away from the fruit. With an "appressed cap," the sepals clasp the fruit closely. These characteristics (fruit firmness and reflexed cap) were measured with the EC character, and the degree of association was calculated by the coefficient of determination. In this work, we chose an r^2 value $\geqq 0.64$ ($r = 0.8$) as the lowest acceptable level for predicting meaningful associations between characters (Kramer and Twigg, 1970).

Seven clones were mechanically capped in 1969 by the Canners' Machinery Ltd. (CML) capper.[1] This machine (Fig. 1), as described by Kirk (1968), consists of ridged steel rollers alternating with smooth rubber rollers of equal diameter 11.1 mm (7/16 in.). The berries enter at right angles to the rollers, and are moved across the rollers by fan jets of water and metal scrapers. The slope of the bed of rollers and the speed of rotation of the rollers can be varied, but not the direction of rotation.

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[1] Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the USDA and does not imply its approval to the exclusion of other products that may also be suitable.

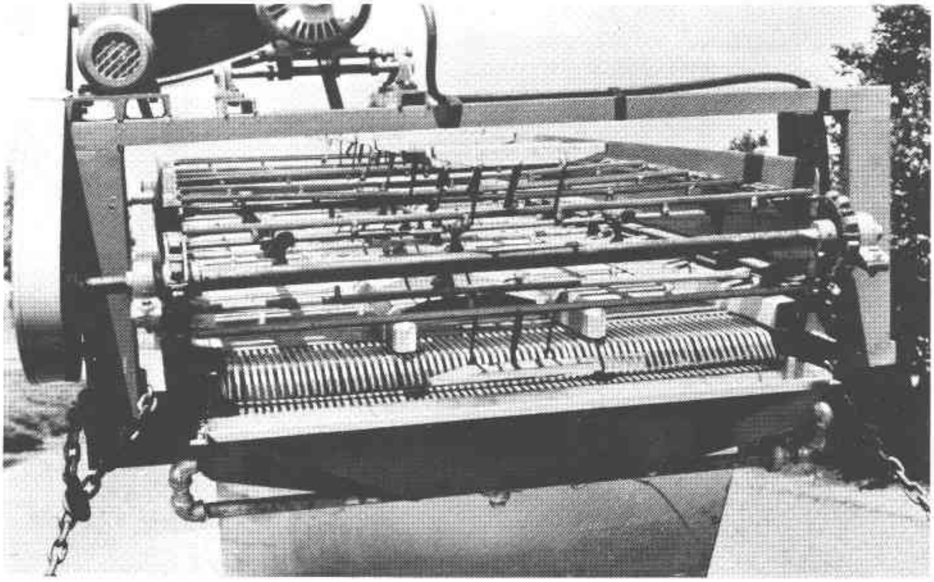

Figure 1. Strawberry-capping machine (Canadian Machinery Limited).

Erect fruiting habit. This characteristic was rated 0 to 9 according to the ability of the main fruit stem or peduncle to support ripe fruit when more than 50% of the berries on the inflorescence were mature. A score of 0 or 1 indicated a very weak or flexible stem that let the ripe fruit lie on the ground, a prostrate fruiting habit. A score of 8 to 9 indicated a strong stem that held mature fruit above the ground (Fig. 2).

Crop concentration. This characteristic, an estimate of the percentage of the crop ripe and usable at once, was assigned a score of 0 to 9: 0 = 0-9%, 5 = 50-59%, and 9 = 90 to 99%. To determine the crop concentration of clones in replicated blocks, we calculated the greatest single hand-harvest yield as a percentage of the total yield. Crop concentration of clones in once-over mechanically harvested 10-plant plots was determined as the ratio of ripe fruit to total fruit yield after mechanical stemming.

Mechanical harvesting evaluation. The machine used in the evaluations was the OSU-developed Clipper harvester (Booster, 1972). This machine cuts the strawberry plants off above the ground, removes the leaves and extraneous material pneumatically, and conveys the fruit attached to the peduncle into containers for handling (Fig. 3). The cutter bar on the Clipper harvester consists of two reciprocating knives. A gathering and lifting reel operates just in front of the knives and helps move

Figure 2. Strawberry clone OR-US 3551 with erect fruiting habit.

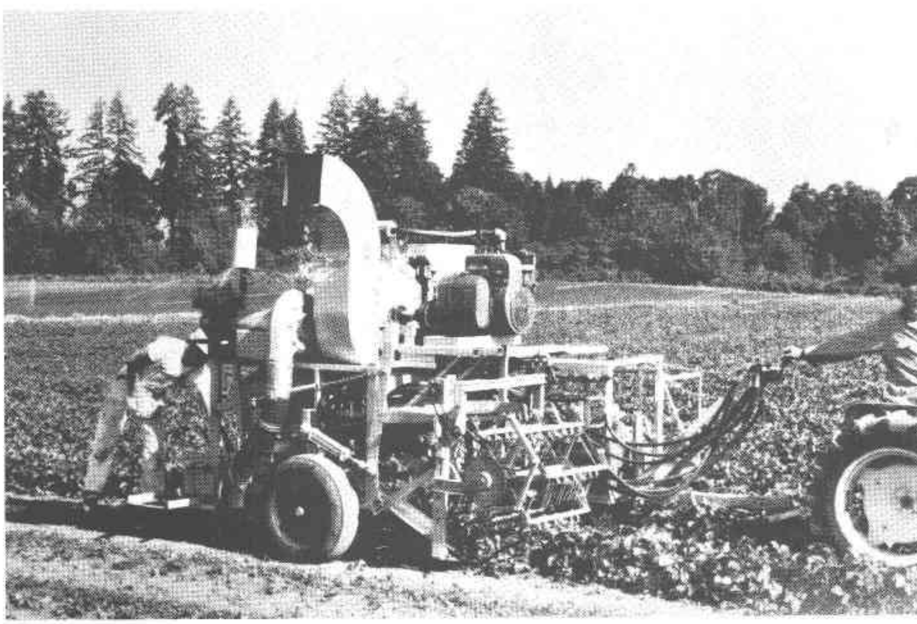

Figure 3. Strawberry "Clipper Harvester," developed by the Agricultural Engineering Department, Oregon State University.

the plant material across the knives and back to the conveying system. Power to operate the harvester is supplied by two 18-hp., air-cooled engines. The various components of the cutting, cleaning, and conveying systems, except for the fan, are driven hydraulically. The harvester is pulled by a tractor at about 1 mph.

Post-harvest fruit evaluation

Components of the harvested lots. Harvest trials conducted in 1971 with the experimental OSU Clipper harvester in several commercial plantings of the 'Northwest' strawberry provided the first sizable lots of mechanically harvested berries which were mechanically declustered and stemmed (capped) before evaluation. Six independent samples, averaging 31.8 kg. (70 lbs.), as received from the field, were mechanically stemmed and capped with a CML strawberry capper. The drained product from the capper, free of most stems and leaves, was weighed and referred to as the "stemmed" lot. The ripe fruit of the stemmed lot was hand sorted from the nonripe by color. The ripe fruit was further segregated into four categories: (a) physically damaged fruit (unusable), (b) biologically damaged fruit (unusable), (c) uncapped fruit (unusable) and (d) fruit usable for processing. The ripe and nonripe fruit categories were determined as a percentage of the stemmed fruit weight in the sample.

In 1972, the first new clones to be selected specifically for mechanical harvest requirements were grown in single 10-plant rows and were harvested with the Clipper. The Clipper also was used to conduct two harvest tests on a planting of 'Hood' strawberries. The harvested samples were mechanically stemmed and capped as were the 'Northwest' lots in 1971, but with an experimental declustering and destemming unit (stemmer) developed at OSU (Fig. 4). The OSU stemmer consisted of a number of pairs of counter-rotating rubberized rollers of 3.5 cm (1-3/8 in.) diameter, which were set at a 7 degree slope and rotated at 300 rpm. The berry trusses were dispersed in a tank of water, from which they were fed onto the rollers in a parallel direction by a flow of water from the tank. A fan-like jet of water was directed onto the rollers from above at an angle sufficient to retard the flow of clusters along the rollers and to force the stems down between the rollers. There they were gripped and pulled through to release the berries, with a minimum of abrasion. The fruit with or without an attached cap moved to the end of the roller bed and into a collecting container. The 23 samples of mechanically harvested fruit, including two mechanically harvested 'Hood' samples, were passed over the stemmer and then hand sorted into stemmed fruit, ripe fruit, and usable fruit categories, as were the 'Northwest' lots in the previous season.

Processing quality. Frozen samples of 18 mechanically harvested clones were prepared for sensory quality evaluation. We combined the

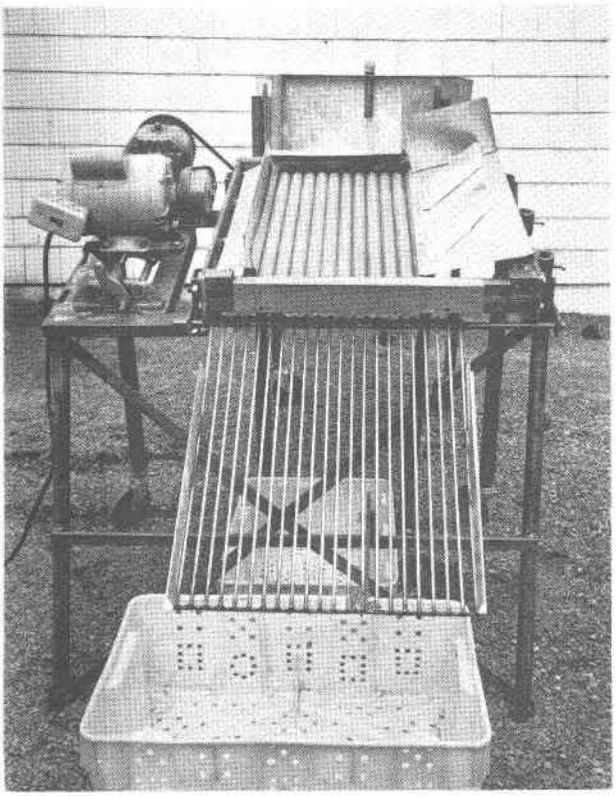

Figure 4. Strawberry stemmer developed by the Agricultural Engineering Department, Oregon State University (water lines removed for photograph).

uncapped ripe fruit after hand capping and the usable ripe fruit. We followed the conventional processing procedure for a frozen sliced strawberry pack of four parts strawberry to one part dry sugar. Hand-picked samples of 'Hood' and 'Northwest' and one machine-harvested sample of 'Hood' were similarly frozen and included in the evaluation for reference. The frozen samples were defrosted after 3 months' storage at –23° C and evaluated for color, slice integrity, texture, and flavor by a panel of 10 experienced judges.

Textural characteristics. The separate and combined effects of flesh firmness and skin strength of the fresh berry on retention of slice wholeness in the frozen sliced product was determined for a number of new strawberry clones and reference cultivars included in the 1972 field trials. Flesh firmness and skin strength were measured on fresh hand-picked whole berry samples by an electrically driven penetrometer designed by

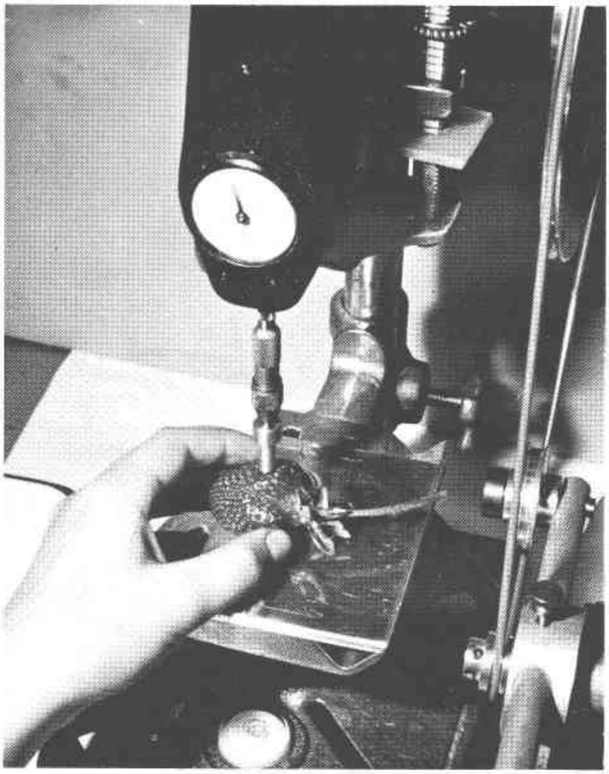

Figure 5. Penetrometer, developed by the Food Science and Technology Department, Oregon State University.

food technologists at Oregon State University (Fig. 5). The penetrometer uses a Hunter Force Gauge of 1,000-g (2.2 lbs.) capacity to measure the force required to penetrate the surface of the strawberry to a depth of 6.4 mm (1/4 in.). It has a 4.8 mm (3/16 in.) diameter flat-tipped plunger moving at a constant speed of 11 cm (4-11/32 in.) per minute.

Test samples consisted of 10 berries drawn randomly from the clone and cultivar samples. Two readings were obtained on each berry with epidermis or skin present (intact berry reading), and two further readings were taken at places on the berry where the skin had been removed with a sharp knife (flesh firmness reading). The mean of 20 readings was calculated for each sample, and the difference between mean readings was considered an estimate of the skin strength for the sample. The penetrometer data were related to panel scores on frozen slice wholeness for each of the samples. The penetrometer data on the fresh samples also were compared with the whole-slice drained weight of the corresponding frozen sliced samples, obtained by a method adapted from the procedure of Sistrunk et al. (1962). We placed the thawed and conventionally drained sample on a 6.35-mm (1/4 in.) mesh screen, immersed the sample in a water bath enough to float the solids, rinsed the sample up and down three times in the bath, drained it for 2 minutes on the screen, and weighed the screen and contents.

The validity of the three measures of fresh strawberry texture (intact fruit firmness, flesh firmness, and skin strength) and the drained weight of frozen whole slices after defrosting was assessed by correlation analysis against the sensory scores for frozen slice wholeness. Degree of correlation was expressed as the coefficient of determination (r^2), and a minimum value of r^2 for satisfactory correlation was set at 0.64 by the practice of Kramer and Twigg (1970).

Results and Discussion

Plant and fruit characteristics

Capping. "Prime" parents were determined as parents used extensively in the breeding program. The prime EC parents were combined with other strawberry types having desirable characteristics such as firm fruit, erect habit, and disease resistance.

The summary of fruit separation ratings for these prime EC parents, when combined with other EC types, shows that seedling ratings exceeded the ratings for prime parents by a range of 18 to 38% (Table 1). Crosses of prime EC by difficult-to-cap types showed a possible partial dominance for difficult fruit separation when 'Hood', 'Siletz', 'OR-US 2905', and 'OR-US 2946' were involved. Very few seedlings from difficult-to-cap crosses (1.6-8.7%) were rated above the prime parent (Table 1). However, when EC 'OR-US 3044' was involved, the percentage of EC types was increased; 18.7% more of its progeny rated easier to cap. (Table 1). This clone may have partial dominance for the EC trait. It is an F_1 of a *F. chiloensis* Duch. clone 'Rockaway #3' crossed with 'OR-US 2475', and is potentially quite different genetically for capping than the other prime parents. It was selected for vigor, disease resistance, and ease of capping.

When both parents were EC types, seedlings' ratings exceeded either parent. As might be expected, the percentage of EC types in the progeny from such crosses was greater than from crosses to EC by difficult-to-cap parents. (Table 1). In the most notable increase, when one parent was 'OR-US 3044', 38.2% of its progeny rated greater than 7.2 for ease of capping.

Table 1. Summary of strawberry fruit separation ratings for prime "easy-cap" (EC) parents and F_1 progeny in combinations with other parents (1967-1969)

		Crosses with difficult-to-cap types					Crosses with other EC types				
Prime EC Parent[1]	Prime parent value[2]	No. of crosses	Mean rating of other parents	Mean rating of F_1	F_1 plants above prime parent	F_1 plants below other diff.-to-cap parent value	No. of crosses	Mean rating of other EC parents	Mean rating of F_1	F_1 plants above prime parent value	F_1 plants below other EC parent value
					%	%				%	%
Hood	7.1	5	5.2	4.8	1.6	14.8	5	6.3	6.2	22.6	10.2
Siletz	6.8	2	5.1	4.7	4.7	10.6	2	6.4	5.7	18.2	13.7
OR-US 2905	7.1	5	4.9	4.5	6.2	15.6	3	6.3	5.8	20.1	12.1
OR-US 2946	6.9	4	4.3	4.5	8.7	11.2	5	6.4	6.1	24.6	9.2
OR-US 3044	7.2	5	4.3	5.8	18.7	7.6	5	6.3	6.3	38.2	6.5

[1] Parent used extensively in the breeding program.
[2] 0 = cap did not separate without crushing fruit; 9 = cap separated cleanly with gentle pressure. Value of 6.0 or greater for any clone was considered EC.

In crosses in which one parent is difficult to cap, many seedlings must be tested because only a small percentage of the progeny equal or exceed the easier capping parent. The other alternatives are to identify parents such as 'OR-US 3044' that appear to carry partial dominance for easy capping or to use EC types for both parents.

The reflexed calyx configuration did not affect ease of capping (Table 2) for the crosses with 'Hood'; 'OR-US No. 2414', '2583', '2893', '2931', '3107'; or 'MD-US No. 2713', or '3184'. The r^2 values were very low, ranging from 0.030 to 0.138. Therefore, selecting for a reflexed calyx in these five crosses failed to provide populations of EC types. A reflexed calyx might be useful in machine capping where the roller mechanism of the capping machine requires an accessible plant part. Regardless of the calyx configuration, the calyx must separate easily from the berry for successful machine capping.

Table 2. Coefficients of determination between "easy-cap" and reflexed calyx for strawberry crosses with progeny showing a reflexed calyx

Cross	Coef. of r^2 determination[1]	Number of comparisons[2]
OR-US 2893 x OR-US 2931	0.077[1]	58
OR-US 3107 x Hood	0.030	62
OR-US 2853 x Hood	0.064	47
MD-US 2713 x Hood	0.138	61
MD-US 3184 x OR-US 2414	0.039	58

[1] r^2 of 0.64 used as minimum base for indicating satisfactory degree of association.
[2] Number of seedlings rated for reflexed caps and for ease of capping.

The relationship between field ratings for fruit firmness and ease of capping (Table 3) from 10 randomly selected populations was shown by the coefficients of determination. The 10 combinations showed that firmness accounted for 47% or more of the variation related to ease of capping. All correlations were negative. Therefore, the highest percentage of EC types had soft fruit. This softness is a serious problem in breeding, because firm fruit with resilient skin is needed for machine handling.

In one of the early mechanical capping trials, seven OR-US clones, rated as EC types in field trials, were harvested with caps and parts of stems intact, transported to the OSU Agricultural Engineering Laboratory, and placed on the CML capping machine. The percentage of berries capped mechanically by this machine ranged from 59.1% to 6.7% (Table 4). The fruits with attached plant parts were separated into partial cap, whole cap, and short stem categories. All clones had some berries in each

Table 3. Coefficients of determination between field ratings for fruit firmness and the "easy-cap" characteristic

Cross	Coeff. of determination[1]	No. of seedlings sampled[2]
OR-US 2635 x OR-US 3596	0.692	62
Earlibelle x OR-US 2931	0.584	53
MD-US 2927 x Shuksan	0.567	47
OR-US 2931 x OR-US 2978	0.523	53
Tioga x Midway	0.684	63
OR-US 2785 x OR-US 2931	0.551	58
OR-US 2785 x OR-US 2981	0.701	48
OR-US 2785 x OR-US 3628	0.530	58
OR-US 2975 x OR-US 3628	0.612	59
OR-US 2975 x OR-US 3596	0.475	52

[1] r^2 of 0.64 used as minimum base for indication of satisfactory degree of association. r values were negative.
[2] Samples of randomly selected strawberry population, 1972.

Table 4. Strawberry-capping trials with CML machine (June 1969, Corvallis)[1]

OR-US clone[2]	Berries (%) with:			
	No cap or stem	Partial cap	Whole cap	Short stem[3]
3666	59.1	7.0	20.0	13.9
2979	33.8	27.1	15.0	24.1
3733	30.0	24.4	34.8	10.8
3734	29.9	29.9	33.3	6.9
3708	18.4	19.6	44.9	17.1
2981	13.7	8.9	27.4	50.0
3706	6.7	11.4	49.0	32.9
Northwest (1968-69)	27-38	25-40	25-40	20–50

[1] Strawberry-capping machine was manufactured by Canners Machinery Limited, Simcoe, Ontario, Canada.
[2] Selected for capping because of potential in field trials; all harvested with caps. Data for Northwest are recorded as a range.
[3] 3.1 mm (1/8 in.) or more in length.

category. The relationship between CML capping performance and field ratings for ease of capping may be influenced by the center of gravity of the berry and the shape of its cap. Because of the center of gravity in a conic or round-conic berry, the berry does not rest on its cap, and the metal guides of the CML machine do not orient these berries with the cap in contact with the rollers. The cap may be appressed, clasping the berry so that the rollers cannot engage it.

However, the best way to determine ease of capping is to sample all promising clones and cultivars and to test them on the capping machines available.

Fruiting habit. The frequency distributions for the fruiting habit of strawberry seedlings (Table 5) show that very few seedlings had erect or even partly erect fruit support when one parent was rated 3 or less. Clones and cultivars, with ratings of 7, such as 'OR-US 2993', 'OR-US 2785', and 'Hood', are needed as parents to obtain even a small number of seedlings with erect or semi-erect fruitings. This character appears to be heritable, and upright types appear to be obtainable. Although the number of fruits per truss was not recorded, field observations have shown it to be important for adequate fruit production. The degree of erect support may vary directly with the number and size of fruit. The positioning of the fruit may be improved by mechanical lifters or other means, such as forced air or specially shaped beds. Also, fruit retrieval can be aided by

Table 5. Mean fruiting habit rating of strawberry seedlings for 17 controlled crosses, (North Willamette Experiment Station, Aurora, 1967-1968)

Cross[1]	Parent ratings[2]	Progeny mean	Number sampled
2988 x Senga Sengana	2;2	1.99	90
2931 x Senga Sengana	2;2	1.02	132
2931 x 2893	2;2	1.62	94
3020 x Earlibelle	2;2	1.86	89
3022 x CA 56.49-1	2;6	4.72	105
2862 x 2993	5;7	5.38	107
2979 x 2862	3;5	3.08	26
2946 x 2862	3;3	1.88	48
Shasta x 2862	2;3	2.45	113
Hood x 2785	7;7	5.43	107
Hood x Senga Sengana	7;2	2.92	70
Hood x 2862	7;5	3.35	69
Hood x 2931	7;2	3.68	91
3044 x Hood	7;7	6.29	74
2853 x Hood	4;7	5.02	58
IA 13-6213 x Hood	6;7	5.03	117
MD-US 3184 x 3044	5;7	4.84	204

[1] Numbered selections are OR-US selections unless otherwise indicated.
[2] On this rating scale, Northwest rated 5 and Hood rated 7.

use of crosses that have parents with strong stems and that support ripe fruit semi-erectly.

Crop concentration. The simultaneous ripening of fruit is important for mechanical, once-over harvest.

Fifty seedlings in each of 14 combinations (i.e., genetic crosses) were visually rated for crop concentration (Table 6). These combinations represent early- and late-season parental types. The early-season parents, 'Earlibelle', 'Sunrise', and 'OR-US 2893', had more than 50% of their fruit maturing at one time. When they were combined with other selections and cultivars, the means of their F_1's were approximately the means of the early-season parent. This result could be interpreted as partial dominance for concentrated croppings by the early-season parent. Progeny of crosses between 'Tioga' and 'Shasta' were rated higher in crop concentration than expected because these parents normally ripen fruit over a long period of time. Both 'Tioga' and 'Shasta' were selected for fresh-fruit-holding qualities. This trait may be transmitted to their progeny, so that ripe fruit may remain on the plant longer without deterioration until other fruits ripen. The ability of ripe fruit to resist rapid breakdown is important when large amounts of ripe fruit are mechanically harvested for processing. Breeders could use early-season cultivars to produce seedling populations that have a high percentage of fruit ripe at one time. But such use increases the possibility of crop loss. Early blooms are subject to frost danger, and the early-maturing fruit are exposed to adverse weather (cloudy, wet days) conducive to fruit rot.

Due to the high heterozygosity of the strawberry clones (Darrow, 1966), some seedlings exceeded the crop-concentration extremes of either parent. Possibly, plants could be selected with more of the crop concentrated later in the season, when late-season parents are crossed.

Clones listed in Table 7 were harvested on five dates during June 1972. Clones with concentrated ripening tended to be earlier than those with less concentrated ripening. Eight of the fifteen clones yielded most heavily at the first picking. Only four clones yielded more than 50% of their total crop on the first picking date. Thus, earliness is possibly related to crop concentration.

The clone with the greatest weight of ripe fruit at one harvest, 10,587 kg/ha (4.7 T/A), was 'OR-US 3554' on June 5. This yield was about three times greater than the greatest single-harvest yield from Northwest, the standard commercial cultivar.

Clone 'OR-US 3774' yielded its greatest harvest, 6,870 kg/ha (3.1 T/A), on June 23, 18 days after the date of the heaviest picking for most of the other clones in the test. Such a late-ripening clone may be of value

Table 6. Crop concentration of F_1 strawberry progenies, 1968-1972

Cross[1]	Crop concentration				
	Ratings[2]			Percentage	
	Parent values	Parent mean	F_1 mean	F_1 above highest parent value	F_1 below lowest parent value
				%	%
Sunrise X	8.0				
OR-US 2931	4.9	6.5	7.1	21.0	6.0
Sunrise X	8.0				
OR-US 2988	4.2	6.1	6.8	26.7	12.2
Sunrise X	8.0				
OR-US 2785	2.5	5.3	6.3	17.6	5.1
Earlibelle X	5.9				
Hood	5.7	5.8	6.0	18.0	17.5
Earlibelle X	5.9				
OR-US 2931	4.9	5.4	5.7	23.0	10.2
OR-US 2893 X	5.8				
OR-US 2931	4.9	5.5	5.7	26.6	18.0
Shasta X	3.2				
OR-US 2893	5.8	4.5	5.6	38.2	6.8
Tioga X	4.2				
OR-US 2893	5.8	5.0	5.2	27.6	12.7
Earlibelle X	5.9				
OR-US 2785	2.5	4.2	5.1	21.2	14.3
Tioga X	4.2				
OR-US 2931	4.9	4.6	4.7	20.2	11.2
Tioga X	4.2				
OR-US 2862	4.0	4.1	4.2	14.3	8.7
Tioga X	4.2				
OR-US 2988	4.2	4.2	4.3	16.2	9.1
OR-US 2988 X	4.2				
OR-US 2862	4.0	4.1	4.0	12.2	9.9
Shasta X	3.2				
OR-US 2862	4.0	3.6	3.7	21.2	6.8

[1] Fifty seedlings from each cross, estimated visually.
[2] Rating scale of 0 to 9, where 9 = 90-100% ripe at one time, and 0 = 0-9% ripe at one time. On this scale, Northwest typically rated 4 and Hood typically rated 5.

in originating cultivars to extend the harvest season and to use harvesting and processing machinery better.

Size and yield of fruit. Size of fruit is considered in the breeding program for several reasons. Large fruit is important to the hand-picker and has greater appeal to the consumer in the fresh market. To the processor, a size range of 1.6-3.2 cm (5/8 - 1 1/4 inches) diameter is normally ac-

Table 7. Yield of hand-picked strawberries (North Willamette Experiment Station, 1972)

	Total yield[2]		Yield by harvest date, T/A[3]				
Cultivar[1]	kg/ha	T/A	June 5	June 9	June 16	June 23	June 30
3824	17,248 a	7.7	3.9	2.0	1.8	------	------
			(50.5)	(26.2)	(23.3)	------	------
3774	15,904 ab	7.1	------	0.0	1.3	3.1	2.7
			------	(0.5)	(17.7)	(43.2)	(38.6)
3554	15,456 ab	6.9	4.7	1.2	1.0	------	------
			(68.5)	(17.5)	(14.0)	------	------
3622	14,366 abc	6.4	2.2	1.9	1.8	0.5	------
			(34.5)	(29.2)	(27.4)	(8.9)	------
3522	14,336 abc	6.4	2.2	2.4	1.8	------	------
			(33.9)	(37.3)	(28.8)	------	------
3604	12,544 bcde	5.6	1.3	1.5	2.0	0.6	0.7
			(24.1)	(27.4)	(35.8)	(11.5)	(1.2)
3624	12,544 bcde	5.6	1.4	1.6	1.9	0.7	------
			(24.3)	(29.8)	(33.5)	(12.4)	------
3769	11,872 cdef	5.3	1.8	1.6	1.7	0.2	------
			(34.8)	(30.1)	(32.5)	(2.6)	------
3605	11,200 defg	5.0	1.3	1.7	1.8	------	0.2
			(25.9)	(34.0)	(36.4)	------	(3.7)
3551	10,752 defgh	4.8	2.6	1.0	1.2	------	------
			(54.0)	(21.3)	(24.7)	------	------
3767	10,528 efgh	4.7	0.3	1.4	2.1	0.9	------
			(6.9)	(30.4)	(44.9)	(17.8)	------
3826	9,856 efgh	4.4	1.3	1.3	1.5	0.3	------
			(28.8)	(29.0)	(35.0)	(7.0)	------
3584	8,736 fgh	3.9	2.0	1.1	0.8	------	------
			(50.0)	(28.5)	(21.5)	------	------
3558	8,736 fgh	3.9	2.8	0.7	0.4	------	------
			(71.2)	(18.9)	(9.9)	------	------
Northwest	8,512 gh	3.8	0.4	1.0	1.5	0.9	------
			(11.5)	(26.4)	(39.6)	(22.5)	------
3608	7,840 h	3.5	1.2	0.8	1.0	------	0.5
			(35.2)	(23.1)	(29.1)	------	(12.6)

[1] Numbered selections are OR-US selections.
[2] Means followed by the same letter do not differ significantly at P = 0.05 according to Duncan's multiple-range test.
[3] Values in parentheses indicate percent of total yield.

ceptable; however, uniformity of size is more important. Size of mechanically harvested fruit is important mainly in relation to the position of fruit on the plant, the distance of fruit off the ground, and accessibility of the fruit to the harvester. The size of fruit for all clones tested was acceptable by current processor standards.

'OR-US 3824' was the highest yielding clone (Table 7); however, it was also the clone with the smallest individual fruit (Table 8). Conversely, 'Northwest' was next to the lowest yielding entry, but it produced the third largest average size fruit. This negative relationship between yield and size of fruit did not hold for all clones. 'OR-US 3604' was a notable exception: it was not significantly different from the second to the highest in yield and also was the largest in average size of fruit. The clone with next to the smallest fruit, 'OR-US 3551', holds most of its fruit off the ground (Fig. 2).

Although yield of 'Northwest', 8,512 kg/ha (3.8 T/A), was low in comparison to clones in the test, its yield approximately equaled the state average for commercial fields in Oregon in 1972 (USDA, 1973).

Post-harvest fruit evaluation

Components of the mechanically harvested lot. The OSU Clipper harvests strawberries by mowing off all parts of the plant just above ground level. In contrast to the hand-picked fruit, which is selected for

Table 8. Size of strawberry fruit at each picking date (North Willamette Experiment Station, 1972)

Clone or cultivar[1]	Average weight (grams per berry)					
	Picking date					Season adjusted[2]
	June 5	June 9	June 16	June 23	June 30	
3604	15.1	12.8	11.1	8.3	5.6	12.14 a
3605	14.9	12.8	10.0	......	5.1	12.04 a
Northwest	15.2	16.7	9.7	6.7	......	11.51 ab
3624	14.1	12.7	8.9	6.3	......	10.97 ab
3558	11.5	8.6	7.2	......	......	10.53 bc
3767	8.0	16.2	8.1	6.4	......	10.25 bc
3554	13.1	11.3	7.2	......	......	9.96 bcd
3608	12.3	9.8	9.0	......	5.8	9.94 bcd
3622	12.1	10.0	7.1	6.2	......	9.59 cde
3774	......	15.0	13.7	8.2	6.6	8.58 def
3522	10.3	8.7	6.0	......	......	8.47 efg
3769	11.5	8.4	5.2	3.2	......	8.30 efg
3584	9.3	7.6	5.2	......	......	8.01 fgh
3826	9.3	7.9	6.0	4.7	......	7.10 gh
3551	8.1	7.2	4.8	......	......	7.09 gh
3824	8.7	6.2	4.2	......	......	6.99 h

[1] Numbered selections are OR-US selections.
[2] Sum of average g (1/28 oz.) per berry at each picking date, multiplied by percent harvested at each date. Means followed by the same letter do not differ significantly at $P = 0.05$ according to Duncan's multiple-range test.

Table 9. Fruit component classification of mechanically harvested strawberries, 1972

Cultivar or clone[1]	Sample weight kg (lbs)		Percentage of sample weight after stemming[4]					
			Ripeness categories (%)		Ripe fruit categories (%)			
	After harvest[2]	After stemming[3]	Nonripe fruit	Ripe fruit	Mech. damage	Other damage	Attached caps	Usable fruit
3358A	——	2.6 (5.7)	7.0	93.0	8.8	14.0	17.6	52.6
4109	——	3.4 (7.5)	6.6	93.4	7.9	9.2	23.7	52.6
4165	4.7 (10.3)	3.8 (8.4)	15.7	84.3	4.8	6.0	31.3	42.4
4125	——	4.1 (9.0)	13.3	86.7	3.3	3.3	37.9	42.2
4177	5.3 (11.7)	4.6 (10.1)	17.8	82.2	3.0	5.0	33.6	40.6
4174	4.6 (10.1)	4.0 (8.8)	32.6	67.4	4.5	11.2	13.5	38.2
3546	——	2.8 (6.2)	1.6	98.4	1.7	11.5	47.5	37.7
3358B	3.9 (8.8)	3.3 (7.3)	12.3	87.7	4.1	5.5	41.1	37.0
Hood #1	10.9 (24.0)	7.9 (17.4)	28.1	71.9	5.2	6.3	29.9	30.5
4153	5.3 (11.7)	4.8 (10.6)	24.5	75.5	2.8	3.8	36.8	30.3
4126	4.5 (9.9)	4.0 (8.8)	25.8	74.2	5.6	0.0	39.4	29.2
4129	2.9 (6.4)	2.5 (5.5)	27.3	72.7	3.6	1.8	38.2	29.1

Table 9. (Cont.) Fruit component classification of mechanically harvested strawberries, 1972

Hood #2	8.0 (17.6)	5.6 (12.3)	33.0	67.0	4.8	7.4	25.8	29.0
3418	4.6 (10.1)	3.4 (7.5)	25.7	74.3	5.4	4.1	37.7	27.1
4150	7.8 (17.2)	6.8 (15.0)	18.1	81.9	1.3	5.4	48.4	26.8
4135	4.2 (9.4)	3.6 (7.9)	26.3	73.7	2.5	3.7	43.7	23.8
3624	——	5.9 (13.0)	22.1	77.9	3.8	3.8	48.1	22.2
4180	4.6 (10.1)	4.1 (9.0)	22.2	77.8	4.4	4.4	46.8	22.2
4123	4.4 (9.7)	3.8 (8.4)	29.8	70.2	3.6	2.4	42.8	21.4
4124	5.9 (13.0)	5.7 (12.5)	11.2	88.8	3.2	4.0	61.6	20.0
3558	——	3.8 (8.4)	8.8	91.2	3.6	16.8	53.1	17.7
4179	5.1 (11.2)	3.0 (6.6)	25.8	74.2	4.5	0.0	53.0	16.7
Northwest	32.3 (71.1)	25.6 (56.3)	35.6	64.4	7.4	4.4	38.0	14.6
4128	7.1 (15.6)	6.0 (13.2)	19.7	80.3	2.3	0.8	66.6	10.6

[1] Numbered selections are OR-US clones.

[2] After-harvest weight includes fruit plus accompanying plant material removed from a single 10-plant row in a once-over harvest (exceptions: Hood, undetermined row length; Northwest, average of four harvest trials made in 1971 on rows of undetermined length).

[3] Drained weight of sample after stemming. In numbered selections only, a stemmed sample weight of 4.6 kg (10.1 lbs.) harvested from a 10-plant row is equivalent to a yield of 11,250 kg/ha (5 T/A).

[4] Nonripe fruit includes underripe and overripe berries. All percent data are based on weight after stemming.

maturity and is free of extraneous material, mechanically harvested strawberries must be further treated before processing to separate the fruit from clusters, stems, leaves, and sepals. The mechanically harvested berries represent all degrees of ripeness, and some may be damaged physically or biologically.

A quantitative classification of the fruit components based on ripeness, damage, and cap retention (Table 9) shows the responses of strawberry clones harvested in 1972 with the Clipper harvester and stemmed with the OSU stemmer. 'Northwest' and 'Hood' were included in the component classification. The new clones varied widely in the component characteristics. For example, yields of stemmed fruit (Table 9) from the clones ranged from 2.5 to 6.8 kg (5.5 to 14.9 lbs.), or an equivalent yield range of 6,048-16,800 kg/ha (2.7 to 7.5 T/A). Six clones yielded at least 0.45 kg (1.0 lb.) per plant, equivalent to 11,200 kg/ha (5 T/A). The percentage of ripe berries in the stemmed samples varied from 67% to 98% among the 21 clones. Thus, progress was made in selecting for crop concentration when compared with an average of 70% for the two samples of 'Hood' from the same trials and an average of 64% for the six samples of 'Northwest' fruit harvested in 1971.

Few of the clones tested in 1972 were superior in ease of capping to 'Northwest' and 'Hood'. Among the 21 clones, ripe berries with attached caps, after passing over the OSU stemmer, varied from 14 to 67% of the stemmed-sample weight. Corresponding average figures of 28% were obtained for the two 'Hood' samples and 38% for the six 'Northwest' samples. Ripe fruit classified as unusable due to severe mechanical damage from the harvesting and stemming operations (Table 9) ranged from a low of 1.3% to a high of 8.8% for all samples in the trials. The percentage of usable fruit for processing that remained after exclusion of the nonripe fruit, damaged fruit, and fruit with attached caps, ranged from 11% to 53% of the stemmed fruit weight. Usable fruit yields for five of the clones from the breeding program ranged between 41% and 53% of the stemmed fruit weight. These figures are distinctly greater than those obtained for the 'Hood' samples (29% and 30%) and the average 'Northwest' sample (15%) for the once-over mechanical harvesting and mechanical stemming system.

Processing quality response. Frozen sliced samples prepared from the mechanically harvested ripe fraction of 18 clones were evaluated for quality (Table 10). Six clones received "good" overall quality scores, as did the hand-picked 'Northwest' reference sample. Four clones were rated "average," as was the hand-picked 'Hood' sample. Seven clones and a machine-harvested 'Hood' sample were rated "fair." One clone was rated "poor."

Table 10. Quality evaluation of frozen strawberry samples processed from machine-harvested and hand-picked clones and cultivars, 1972

Quality category	Clone or cultivar[1]	Overall quality score[2]	Harvest method[3]
Good	Northwest	6.7	HP
	4126	6.7	MH
	4128	6.1	MH
	3358A	5.9	MH
	4123	5.9	MH
	3624	5.6	MH
	4177	5.6	MH
Average	4179	5.2	MH
	Hood	5.1	HP
	4180	5.1	MH
	4125	5.0	MH
	4165	5.0	MH
Fair	Hood	4.2	MH
	3418	4.2	MH
	4150	4.2	MH
	4109	3.9	MH
	4135	3.9	MH
	4153	3.9	MH
	4124	3.2	MH
	4129	3.0	MH
Poor	4174	2.3	MH

[1] Numbered selection is OR-US selection.
[2] Panel of 10 judges; 9-point scale, where 9 = excellent, 1 = very poor. Overall score based on factors of color, slice wholeness, texture, and flavor.
[3] MH = machine harvested; HP = hand picked.

Seven of the more promising strawberry clones in the 1972 tests were evaluated by five criteria of suitability for mechanical harvest and processing (Table 11). These criteria included yield of total fruit, percentage of ripe fruit, percentage of fruit without caps, percentage of usable ripe fruit, and processing quality rating. The minimum acceptable level for each criterion was based on judgment of what would be feasible for a commercial processor to handle. The summary indicates that clones 'OR-US' No. '3358A', '4109', '4128', and '4177' each performed well with regard to three of the five criteria. Three other clones—'OR-US' No. '3624', '4124', '4150'—surpassed the acceptable level for two of the five criteria. This performance record provides a basis for eliminating unsuitable lines, further testing of others, and identifying potential parent material for future crossing.

Table 11. Performance summary for seven promising strawberry clones after mechanical harvesting, mechanical stemming, and processing tests, 1972

	Test response					
	Stemmed fruit[1]					Processed product
OR-US clones	Fruit yield		Total ripe fruit (%)	Ripe fruit without caps (%)	Usable fruit (%)	Panel ratings[2]
	kg/ha	T/A				
3358A	6,500	2.9	93	75	53	4.4
3624	14,750	6.5	78	30	22	5.6
4109	8,500	3.7	93	69	53	3.9
4124	14,250	6.3	89	27	20	3.2
4128	15,000	6.6	80	13	11	6.1
4150	17,000	7.5	82	34	27	4.2
4177	11,500	5.1	82	48	41	5.6
Minimum acceptable level[3]	11,350	5.0	80	60	50	5.5

[1] Percentage figures are based on weight of stemmed fruit from the mechanically harvested lot.
[2] Nine point rating scale for overall quality, where 9.0 to 7.0 = superior; 6.9 to 5.5 = good; 5.4 to 4.5 = average; 4.4 to 3.0 = fair; and 2.9 to 1.0 = poor.
[3] Arbitrarily set as minimum economic units.

Table 12. Textural parameters of fresh and frozen sliced strawberries, 1972

Clones (OR-US) and cultivars	Source[1]	Harvest date	Penetrometer (fresh berry)			Frozen sliced sample	
			Intact berry[2]	Flesh firmness[3]	Skin strength[4]	Whole slice drained wt. (%)	Slice wholeness score[5]
3551	NWS	6- 5	168	96	72	68	4.4
3554	NWS	6- 5	172	104	68	63	4.0
3584	NWS	6- 5	178	118	60	71	5.4
3596	Corv.	6-16	118	84	34	78	5.1
3604	Corv.	6-13	193	148	45	83	6.6
3608	Corv.	6-12	230	173	57	91	7.8
3608	Corv.	6-16	266	198	68	91	7.9
3622	Corv.	6-12	218	151	67	83	6.0
3653	Corv.	6-12	121	81	40	71	3.1
3853	Corv.	6-16	156	101	55	79	5.9
4071	Corv.	6-13	173	155	18	83	6.0
Hood	NWS	6-19	145	112	33	69	4.0
Northwest	NWS	6-12	153	89	64	77	4.5
Northwest	NWS	6-19	137	93	44	72	4.9
Northwest	Corv.	6-12	125	93	32	76	4.5
Northwest	Corv.	6-16	133	82	51	74	5.6
Shuksan	Corv.	6-12	173	125	48	79	5.6
Shuksan	NWS	6-12	183	115	68	83	6.1
Totem	NWS	6-12	203	127	76	79	6.1
Totem	NWS	6-19	197	149	48	72	5.0
Totem	Corv.	6-12	174	120	54	78	6.3
Olympus	NWS	6-12	149	83	66	76	5.5
Olympus	NWS	6-19	145	89	56	71	5.3

[1] Corv. = OSU Horticulture Farm, Corvallis: NWS = North Willamette Experiment Station, Aurora.
[2] Grams (1/28 oz.) of force required, for 4.8 mm (3/16 in.) plunger to penetrate 6.5 mm (1/4 in.) into berry with skin intact.
[3] Grams (1/28 oz.) of force required to penetrate 6.5 mm (1/4 in.) into berry with skin removed.
[4] Difference in grams between "intact berry" and "flesh firmness" readings.
[5] Panel of 10 judges; scale of 9 (like extremely) to 1 (dislike extremely.)

Evaluation of textural characteristics. Texture was evaluated for 10 clones and 4 cultivars hand-harvested at two locations on one or more harvest dates (Table 12). A correlation analysis of these data, summarized in Table 13, indicated that none of the three indices of fresh strawberry texture (intact fruit firmness, flesh firmness, and skin strength) obtained by use of the penetrometer were satisfactorily correlated with panel scores for slice wholeness in the frozen product, according to the criterion selected ($r^2 \geqq 0.64$). By the coefficients of determination obtained, slightly more than half of the variation in the wholeness scores was reflected in the penetrometer measurements of either intact fruit firmness or flesh firmness, whereas skin strength measurements showed no appreciable correlation with the sensory scores. The intact fruit firmness and flesh firmness also did not correlate satisfactorily with direct measurements of percentage of drained whole slices in the frozen product (Table 13). This latter index of texture reflected nearly 75% of the variability in the sensory scores for slice wholeness. Percentage of whole drained slices may be considered a good indicator of textural integrity in frozen strawberries.

Table 13. Coefficients of determination relating slice wholeness ratings and objective measurements of strawberry texture

Comparison[1]	Coef. of determination, r^2
Slice wholeness score versus:	
Intact fruit firmness value	0.563
Flesh firmness value	0.544
Skin strength value	0.058
Percent drained whole slices	0.733
Percent drained whole slices versus:	
Intact fruit firmness value	0.391
Flesh firmness value	0.480

[1] The slice wholeness score and percent drained whole slices were obtained on the frozen sliced product. The other three measurements of texture were made on the fresh whole berries by a special penetrometer. A coefficient of determination $\geqq$ 0.64 indicates a satisfactory correlation.

Thus, further work appears to be needed to ascertain the relationship between fresh berry firmness and the texture of the corresponding frozen slices. A measure of fresh strawberry texture that would correlate satisfactorily with textural quality in the frozen product could be useful in selecting new genetic lines that would retain good texture when mechanically harvested and processed.

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Appendix. Parentage of Strawberry Selections

Clone or Cultivar	Parentage
CA 56.49-1	CA 39.82-19 x CA 51s1-1
IA 13-6213	80-5902 x Midway
MD-US 2713	Redglow x Surecrop
MD-US 2927	Surecrop x US-3919
MD-US 3184	NC 1768 x Surecrop
Olympus	Molalla x Columbia
OR-US Nos.	
2414	OR-US 2136 x OR-US 2242
2475	OR-US 2338 x OR-US 2261
2635	Vale x Puget Beauty
2785	OR-US 2414 x Vale
2853	Molalla x OR-US 2467
2862	OR-US 2433 x Vale
2893	OR-US 2234 x Northwest
2905	OR-US 2312 x OR-US 2467
2931	OR-US 2433 x OR-US 2312
2946	CA 52.16-15 x OR-US 2467
2975	OR-US 2234 x OR-US 2732
2978, 2979, 2981	OR-US 2234 x Earlibelle
2988	OR-US 2433 x OR-US 2467
2993	OR-US 2635 x OR-US 2414
3020, 3022	OR-US 2661 x Hood
3044	OR-US 2475 x Rockaway #3
3107	OR-US 2946 x OR-US 2471
3358A	OR-US 2818 x Tioga
3418	NC-US 2840 x OR-US 2818
3522	Hood x OR-US 2975
3546, 3551, 3554, 3558, 3584	Sunrise x OR-US 2931
3596	Earlibelle x OR-US 2853
3604, 3605, 3608, 3622, 3628	OR-US 2931 x Earlibelle
3653	OR-US 2950 x OR-US 2769
3666	OR-US 2950 x CA 56.49-1
3706, 3708	OR-US 2988 x OR-US 2769
3733	Tioga x OR-US 2853
3734	Tioga x 2853
3767, 3769	OR-US 2975 x OR-US 2785
3774	OR-US 2785 x OR-US 2975
3824, 3826	MD-US 2713 x OR-US 2467
4071	Earlibelle x OR-US 2785
4109	OR-US 2893 x Earlibelle
4123, 4124, 4125, 4126, 4128, 4129, 4135	OR-US 2931 x Tioga
4150, 4153	OR-US 2988 x Sunrise
4165	OR-US 3137 x Tioga
4174, 4177	Shasta x OR-US 2893
4179, 4180	OR-US 3584 x Shasta