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Title: HARVEST MATURITY INDICES OF SWEET CHERRIES (*PRUNUS AVIUM* L.) FOR BRINING

Abstract approved: _______________
Daryl G. Richardson

Oregon's Willamette Valley sweet cherry growers have developed a market for large, high quality, stem-on brining cherries. The maturity indices pull force (PF), percent soluble solids (SS), and weight (Wt) were chosen as being the most probable indicators of maturity.

The rate of change of PF during the harvest period is best described as a logarithmic function, which appears to be consistent between orchards. In contrast the rate of change in SS over time, best described as a quadratic function, was not found to be consistent between orchards. A conversion equation for changing cherry fruit diameter measurements to corresponding Wt was also developed as was a quadratic function to best describe the rate of change in Wt over time during the harvest period. The relationship of Wt and PF was also determined and was best described as a linear function.

The difficulty of removing fruit during the hottest part of the day has resulted in increased fruit damage. Water potentials (ψ) of fruit pedicel, as a measure of pedicel turgor, and leaf petioles were measured to determine the diurnal cycle, which could be used to identify harvest times where fruit damage would be reduced. A procedure to measure fruit ψ using a Scholander-type pressure chamber was used. Fruit pedicel ψ was always lower than leaf ψ at 6 A.M. but leaf ψ was usually lower during the day. There appears to be some varietal difference in ψ but maturity does not appear to have an effect. The magnitude of fruit pedicel and leaf ψ increased under stress conditions. Minimum fruit pedicel and leaf ψ was reached at at about 2 P.M. and then appears to return to the higher ψ during the night.

Harvest Maturity Indices of Sweet Cherries for Brining

by

Paul J. Tvergyak

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HARVEST MATURITY INDICES OF SWEET CHERRIES FOR BRINING

LITERATURE REVIEW

Oregon's Willamette Valley sweet cherry growers have developed a market for lage, high quality-stem-on brining cherries. Cherries which do not meet these standards are marketed along with fruit of similar quality and size which do not receive the premium paid for stem-on fruit. Prior to the mid-1950's brining cherries were hand harvested by predominantly migrant picking crews. The Great Lakes Fruit Growers News in 1968 suggested that sweet cherries could be mechanically harvested like sour cherries, using the same shake and catch equipment (2). Increasing labor costs and stringent housing regulations have encouraged more growers to mechanically harvest their crop, and today, 40-50% of all commercially grown brining cherries in the Willamette Valley are mechanically harvested.

Initial reaction of the cherry briners to mechanical harvesting was not favorable because of several problems; a) less stem-on fruit, b) more grade #3 fruit, c) less packout, and d) more packing plant labor, thus less plant production (50). Based on these drawbacks it was estimated that the grower would receive 30-40% less revenue by mechanical harvesting compared to hand picking. In addition, Tukey (59) foresaw other mechanical harvesting problems such as; a) a cullage rate of 10-20% would reduce the economic feasability, b) differences due to variety and maturity, and c) differences within a growing area, e.g., number and size of grower operations and the markets in which the fruit is being handled. Variations between trees due to different maturity and different harvesting equipment were also noted (44). Fruit quality was the major problem. With mechanical harvest Wittenberger and LaBelle (69) observed more damaged fruit and excessive debris in the brining tanks than was common with hand harvest. The debris problem was solved by skimming the brining tanks and the effects or bruising were minimized by field brining immediately after harvest (35). They concluded that the major difficulty with mechanical harvesting was removal of the fruit from the tree before the fruit was physiologically mature. The fruit was harvested at an earlier maturity to increase the percentage of stem-on fruit (44). However, improved equipment now regularly achieves 90% removal or better.

Part of the maturity problem was solved by changing cultural practices. Trees were pruned to a more upright posture to promote vertical, stiffer growth (51). Stebbins also suggested that trees be kept small and over-cropping be prevented since small trees with moderate fruit set were the easiest to mechanically harvest.

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Development of the fruit abscission zone and its relationship to mechanical harvesting has been studied (30, 38). Abscission layers or zones in fruit have been characterized as has the abscission promoting effect of ethylene and ABA on these tissues (13, 14, 20). The abscission of cherry fruits in particular and the effects of applied growth regulators have also been studied, most notably by Bukovac et al. (10, 11). Bukovac describes two potential abscission sites which pertain to cherry harvest. One occurs between the spur and the pedicel, the other between the pedicel and fruit. Fruits which abscise prematurely usually do so at the spur-pedicel zone while mature fruits abscise at the pedicel-fruit zone. The fruit-pedicel abscission zone of the sour cherry is well defined, whereas it is more diffuse in the sweet cherry (10). The abscission zone in the pedicel-fruit zone initiates near the end of stage II or the beginning of stage III of fruit growth (64, 68). Bukovac et al. (12) experimented with ethephon and its effects on the cherry abscission zones. Results in all cases showed that ethylene promoted abscission at the pedicel-fruit zone in the treated trees which facilitated fruit removal, but at the expense of stem-on fruit. This work is corroborated by Couey et al. (21), Chaplin et al. (18), who used SADH, and Looney (39), who used Alar and Ethrel.

Several researchers determined that the best way to predict how fast peaches (4, 25, 29), apples (7, 8, 23, 40, 41, 60), and pears

(37, 41, 42, 61) move through development and thus predict harvest maturity date was by accumulated heat units. This prediction system works to the extent that it gives the grower a rough estimate of harvest date.

Stebbins et al. (53) and Gaston (26) suggested that since percent soluble solids increased at a constant rate through the season, it may be useful in determining maturity. Norton et al. (43) and Beavers et al. (6) suggested that since percent soluble solids reflects variation in climatic conditions it is not a true index of maturity. Richardson et al. (47, 48) found maturity to be the dominant factor in obtaining a high percentage of stem-on undamaged fruit and that pull force was more highly correlated to maturity than percent soluble solids. It appears that a need in the industry is research directed towards the comparison of the variables pull force and percent soluble solids and how they change as the fruit matures.

An additional observation which may be important with respect to amount of fruit damage is the difficulty of removing fruit during the hottest part of the day. Orchard harvesting operations are often suspended shortly after noon on hot days as the cherries become difficult to remove. Since stem turgidity is likely involved, our attention has been directed towards diurnal changes in plant water relations (24, 33). In plants, where solutes disturb the liquid structure of water, water potential (ψ) is negative (36). Water potential for any part of the plant is the sum of the solute osmotic concentration (S), turgor pressure (P), and matrix effect (τ) in that plant part and roughly describes the equilibrium turgor of the cell. Water potential can be measured using a pressure chamber (49). Water potential is inversely linked to water stress in the plant, i.e. as the water stress in the plant increases due to low relative humidity and/or low soil moisture the ψ of the plant becomes more negative.

Work has been done in the area of moisture stress on apple (27) and peach (1) and how to interpret values with regard to irrigation requirements. Most of this work has been done with shoots and leaves. Since it is the fruit being harvested and damage may be related to moisture stress, we need to determine the relationship of moisture stress in fruit and leaves during stress conditions. Diurnal moisture stress effects on fruit growth have been characterized. Chaney et al. (15) investigated and showed that fruit diameter of the 'English Morello' cherry was positively correlated to the diurnal change in ψ. Kozlowski (34) observed the same results with 'Montmorency' cherries and related them to soil moisture availability, stage of fruit development, weather, and degree of internal moisture stress on the tree. Coccicci et al. (19) observed that under drought conditions normal growth of squash fruit resumed during the night but became more and more reduced with time during the daylight period. Effects of moisture stress on fruit ψ have been studied to a lesser degree. Klepper (33) showed marked diurnal variations in ψ of both leaves and fruit of pear trees with high correlations to evaporative demand of the air. In addition she observed variation in water status during the day between the east and west sides of the tree. Her findings are supported by similar observations in citrus (31). Since maturity is a dominant factor in obtaining a high percent of stem-on undamaged fruit, it appears that a better understanding of one or two maturity indices that are practical and reliable, such as pull force and percent soluble solids, would improve maturity determinations. Also a better description of the reaction of fruit to moisture stress may enable the amount of mechanical damage to be reduced by designating a critical moisture stress beyond which mechanical harvest is inadvisable.

Harvest Maturity Indices of Sweet Cherries (*Prunus avium* L.) for Brining[1]

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Abstract: The rate of change of pull force (PF) over time during the harvest period, is best described by a logarithmic function and appears to be consistent between orchards but not between varieties. In contrast the rate of change in % soluble solids (SS) over time, best described as a quadratic function, was not found to be consistent in orchard or varietal comparison. A conversion equation for changing cherry fruit diameter measurements to corresponding weights (Wt) was also developed as was a quadratic function to best describe the rate of change in Wt over time during the harvest period. The relationship of Wt and PF was also determined and was best described as a linear equation.

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INTRODUCTION

Quality of brined sweet cherries in Oregon is determined by several factors, including a high proportion of stem-on fruit, free of bruises, cuts, and other mechanical injuries. Maturity is a dominant factor in obtaining a high percentage of stem-on, undamaged fruit (4). This is important since a premium price is paid for high quality stem-on fruit. In the past, percent soluble solids has been the chief indicator used to determine maturity. Work by Richardson et al. indicated that pull force, i.e., the amount of force required to remove the stems from the fruit, was more highly correlated to maturity than percent soluble solids (4). Applications of abscission promoters such as ethephon have reduced the amount of shaking required to mechanically harvest cherries, but at the expense of stem-on fruit (1).

The desire to better define conditions leading to a high percentage of stem-on, undamaged fruit requires a better understanding of one or more maturity indices that are practical and reliable.

The objectives of the study were: a) determine the daily changes in fruit size, pull force, and percent soluble solids during the harvest period of sweet cherries in early and mid season orchards; b) assess any differences which might exist between trees, orchards, and varieties with respect to pull force, size, and percent soluble solids.

MATERIALS AND METHODS

Experiment 1: During the spring of 1976 an early and mid season orchard were selected and two eight-year-old trees of the 'Royal Ann', 'Napoleon', variety and one of the 'Corum' variety in the mid season orchard were identified. Trees were selected to minimize differences due to location and size. In the early season orchard three trees of the 'Royal Ann' variety and one of the 'Corum' variety, seven years old, were identified and selected for uniformity. After "June drop," cropping density was determined on a limb count basis for the early season orchard (2). Based on the results, trees were described as having a light, medium, or heavy crop load. The harvest period was specified as the time span wherein pull forces, i.e. the force required to remove the fruit from the pedicel, declined from an initial value of 1200g to the time when they reached 200g or the fruit was damaged by rain cracking. The harvest period for 1976 spanned 26 days beginning 23 June and ending 19 July. On alternate days during the harvest period 25 stem-on fruit from each quadrant of the four cardinal directions were carefully handpicked. Along with daily fruit sampling (conducted at the same hour of each day), temp and relative humidity were continuously recorded by a hygrothermograph as well as at the beginning of each sampling period with a sling psychrometer. Immediately after collecting samples of stem-on fruit, the pull force for each fruit was determined using a 0-1500g Hunter Spring (model LKG-1, Ametek Instruments, Hatfield, Pennsylvania). To minimize errors in measurement, the instrument was held level and the zero setting checked regularly. As the pull force was recorded the fruit samples were placed sequentially in a 2.5 cm diameter irrigation pipe approximately 175 cm long. When filled with fruit of a given quadrant, the pipe was sealed at both ends with rubber stoppers. This sealed container maintained fresh weight and sample order for subsequent wt, diam, and % soluble solids measurements to match with pull force for each fruit. Each fruit was weighed to the nearest 0.1g using an electronic balance, measured to the nearest mm using a vernier caliper, and % soluble solids was measured to the nearest 0.2% with a hand held refractometer. These measurements were recorded with the corresponding pull force measurement. At the end of the harvest period the fruit that remained on each tree was harvested and the total weight for that tree was recorded. The trunk diameter was measured approximately 25-30 cm above ground level. By dividing the cross sectional area of the trunk into the total weight of fruit removed from the tree the crop load of the trees observed was designated to be light, medium, or heavy in terms of kg of fruit per cm^2 of cross sectional trunk area. These data corresponded with earlier fruit counts per cm^2 of limb area. Regression analyses of the variables time, pull force, wt, diam,

% soluble solids, temp, relative humidity, crop load, variety, and orchard were then analyzed by computer.

Experiment 2: In an early and in a mid season orchard fifty fruits were randomly tagged on each of two 'Royal Ann' trees and one 'Corum' tree. Every two days the cheek diam of the tagged fruit was measured and recorded. The average values for each day were obtained. When the average value decreased, due to rain-induced cracking, the measurements were concluded. An equation converting diam to wt was developed for each variety from data collected during experiment 1 (5). Average diam for each day was converted to wt data using the appropriate conversion and plotted against time.

Statistical analyses procedures for each experiment followed the appropriate F or t tests in accordance with Neter and Wasserman (3) and the results were evaluated and discussed at the 0.05 level.

RESULTS

Crop load determination: Results of dividing the total yield in kg per tree by the trunk cross sectional area in cm^2 indicated that in the mid season orchard all the trees had relatively light crop loads compared to trees in the early season orchard. In the early season orchard one 'Corum' tree and one 'Royal Ann' tree had heavy crop loads. The two other 'Royal Ann' trees represented both a light and medium crop load (Table 1). These arbitrary labels designated only the trees in our sample and were used to compare measured parameters.

Weight x diameter: By combining all the wt and diam data from both orchards equations of the following format were developed

$$Y = B_0 + B_1 X$$

where Y = wt

X = diam

for the conversion of diam (mm) to wt (g).

The equations are

for 'Royal Ann': Wt = -10.19 + .746(diam) $r^2 = .86$

for 'Corum': Wt = -7.53 + .609(diam) $r^2 = .89$

There is no significant difference in the slopes of these two equations which suggests a composite equation for all cherries (5). Due to the smaller sample sizes taken for 'Corum', the varietal equations were used to convert diam to wt instead of defining a composite equation for both 'Royal Ann' and 'Corum' cherries.

Pull force x time: Figure 1 shows the decrease in pull force (PF) over time. In all the trees studied a logarithmic relationship of the form

$$Y = B_0 + B_1X_1 + B_2 \mathrm{Log} X_2$$

where Y = PF

X_1 = an indicator variable orchard defined as 1 for early season and 0 for mid season

X_2 = day numbered consecutively from the time PF reaches 1000g.

gave the best fit to the data with r^2 values ranging from .94 to .98 for 'Royal Ann' and .92 to .99 for 'Corum'. Table 2 compares the B_1 coefficients, i.e. slope, between all 'Royal Ann' trees which showed no significant differences. In addition there were no significant differences between the B_1 coefficients of the early season and mid season 'Royal Ann' equations or between the intercept terms of all 'Royal Anns' within an orchard. Pull force on a given day was significantly different for the early and mid season orchard, which suggests that although the rate of change in PF is the same regardless of orchard, the line representing the rate of change may shift by the constant 186.6 when the two orchards are compared. Therefore a composite equation can be determined for the rate of change in PF with an adjustment made for orchard. The equation for this relationship is:

$$PF = 1215.9 - 186.6(\text{orchard}) - 550\ \text{Log}(\text{day}).$$

There was a significant difference in both the intercepts and the B_1 coefficients of the two 'Corum' trees. Therefore a composite equation describing PF over time for 'Corum' was not applicable. However because of the limited number of trees sampled for 'Corum' this may not always be the case.

Soluble solids x time: Figure 2 shows the increase in percent soluble solids (SS) over time. In all the trees studied a quadratic equation of the form

$$Y = B_0 + B_1X_1 + B_2X_1^2$$

where Y = SS

X_1 = day numbered consecutively from the time PF reaches 1000g.

gave the best fit with r^2 values ranging from .81 to .95 for 'Royal Ann' and .91 to .95 for 'Corum'. Table 3 compares the B_1 and B_2 coefficients between 'Royal Ann' fruit from the same orchard and shows no significant differences. There was, however, a significant difference between the B_1 and B_2 coefficients of the composite equations for early and mid season 'Royal Anns'. This implies that the rate of change in SS is different for each orchard. In the early season orchard there was no significant difference between intercepts or the B_1 and B_2 coefficients of the 'Royal Ann' trees, but when the data for the 'Corum' tree in the orchard was added the B_1 and B_2 coefficients changed significantly. This suggests that the rate of change in SS in the same orchard is different for variety. These same conclusions were applicable in the mid season orchard.

A composite equation for 'Royal Ann' in each orchard can be determined for the rate of change in SS. In the early season orchard the equation is:

$$SS = 13.91 - .126(\text{day}) + .061(\text{day}^2)$$

In the mid season orchard the equation is:

$$SS = 12.39 + .098(\text{day}) + .006(\text{day}^2)$$

Since in both orchards the addition of the 'Corum' data significantly changed the B_1 and B_2 coefficients and since sample size for 'Corum' was limited, an equation representing the rate of change in SS for 'Corum' may not be appropriate at this time. However it does appear (Table 3) that the SS rate of change for 'Corum' is significantly different from that of 'Royal Ann'. Further characterization of climate, cropping density and other variables may clarify factors most influential on soluble solids.

Weight x time: Figure 3 shows the increase in individual fruit wt over time. In all the trees studied a quadratic equation of the form

$$Y = B_0 + B_1X_1 + B_2X_1$$

where $Y = wt$

$X_1 = time.$

gave the best fit (Table 4). In the early season orchard there was no significant difference in the B_1 and B_2 coefficients of the 'Royal Ann' trees. However if the 'Corum' datum was added, the intercepts and the B_1 and B_2 coefficients were significantly changed. This implies that the rate of wt change is different for varieties within the same orchard. A similar analysis was performed on data from the mid season orchard but a significant difference was determined between the B_1 and B_2 coefficients comparing the two 'Royal Ann' trees. This may have been due to differences within the trees other than criteria which were used to choose trees for uniformity.

There was a significant difference between both the intercepts and the B_1 and B_2 coefficients of the 'Royal Ann' equations representing the early and mid season orchards. In this case both differences would be expected due to different climatic and environmental conditions in the two orchards. However, a comparison of the intercepts and the B_1 and B_2 coefficients of the two 'Corum' trees demonstrated the expected difference between the intercepts but there were no significant differences between the B_1 and B_2 coefficients. This suggests that the rate of wt change is the same for 'Corum' regardless of orchard. This may be true but considering the sample size of 'Corum', it may not necessarily be representative.

Pull force x weight: The relationship of PF to wt is best characterized by a linear equation of the form

$$Y = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4$$

where Y = wt

X_1 = PF

X_2 = an indicator variable for orchard defined as 1 for early season and 0 for mid season

X_3 = an indicator variable for medium crop load defined as 1 for medium crop and 0 for other

X_4 = an indicator variable for heavy crop load defined as 1 for heavy drop and 0 for other.

with a negative slope (Fig. 4 and 5). Table 5 describes the intercepts and B_1 coefficient values for each orchard and variety combination. In all the tree and orchard combinations studied, this equation gave the best fit with r^2 values from .86 to .98 for 'Royal Ann', and from .83 to .91 for 'Corum'. There were no significant differences in B_1 coefficients, i.e. slope, between 'Royal Ann' trees but there was a significant difference between intercepts for all combinations except for the two light crop load mid season trees. Therefore it was cluded that the rate of change in wt in comparison to the rate of change in PF is the same, but the intercepts of the equations representing these lines shift according to orchard and crop load. The following equation was developed to best explain the wt and PF relationship for 'Royal Ann'.

$$Wt = 12.79 - .0058PF - 2.34X_2 + .34X_3 - .98X_4 \qquad r^2 = .97$$

The relationship of wt and PF in the variety 'Corum' is also of the linear form (Fig. 5). There is a significant difference between both intercept and B_1 coefficients of the two 'Corum' trees. The difference in intercept is probably due to seasonal effects between orchards. The difference in slope could not be explained, but if data for both trees are graphed together and fitted with the above equation plus an indicator variable to identify orchard, it would yield an r^2 of .91. The high r^2 value suggests that the data from both 'Corum' trees can be combined and developed into a composite equation showing the relationship of wt and PF. The model would be of the following form for 'Corum' trees:

$$Wt = 9.23 - .0034PF - 3.07X_2$$

There is a significant difference between both the slopes and B_1 coefficients of the 'Royal Ann' and 'Corum' composite equations. Therefore it appears that an overall equation showing the PF x wt relationship, using indicator variables for crop load, orchard, and variety for all brining cherries is not applicable. However additional observations involving 'Corum' trees are needed.

DISCUSSION

It appears that there is no difference in the equations developed in this study due to crop load. Perhaps the differences in crop load selected for these experiments were not great enough to significantly alter the relationships. PF is a better indicator of maturity of brining sweet cherries than SS. Richardson et al. have shown that PF is more highly correlated to % stem-on fruit than SS (48). The rate of change in PF is consistent regardless of orchard. It could be roughly stated that PF changes at a rate of 25g per day after PF reaches 1000g. Soluble solids, the commonly used maturity measurement, is neither consistent between orchards nor between varieties within an orchard. A model can be developed which predicts the rate of change in PF and % stem-on fruit during maturation. Using SS, a separate model would have to be developed for individual orchards and for each variety within the orchard. This means that if SS is used as a maturity index a more complicated model will be required, contingent upon multiple factors.

The relationship of PF and wt is of interest if we anticipate the development of a revenue prediction model based on pull force as a maturity index. The datum presented here has shown that this relationship is consistent regardless of crop load, orchard, and possibly variety.

Past data indicate that the risk of fruit cracking increases as SS approaches 15.5% to 17% and rain occurs (6). This phenomenon is graphically demonstrated in Figure 6. This figure also shows that at the time of fruit cracking the PF is in the range of 550g to 750g in the early season orchard and about 900g in the mid season orchard. These PF's correspond to about 33% and 56% stem-on fruit in the early and mid season orchards respectively, according to the relationship developed by Richardson et al. (4). Soluble solids measurements at this time ranged between 15% and 17% for both orchards. Assuming that the grower postponed harvest until this point, because he is more interested in obtaining maximum yield instead of maximum stem-on fruit, he must be aware of the increasing risk of losing the entire crop to rain cracking. Therefore it is probably prudent to retain the SS measurement, not as the best indicator of maturity but as a component of maturity which indicates the increasing risk of crop loss due to rain cracking.

Further experimentation is required to better understand differences in the functions presented due to variety, orchard, crop load, and year. However, if these variables are carefully measured and evaluated, a revenue prediction model based largely on PF can be developed for use as a management tool for orchardists.

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Table 1

Crop Load Determination of Sweet Cherries

at Two Orchard Locations

Table 1.

Tree	Orchard	Trunk Diameter (cm)	Trunk Area (cm^2)	Yield (kg)	Crop Density (kg/cm^2)	Crop Load Designation
1 - 'Royal Ann'	Early	15.5	188.7	29.26	0.155	Heavy
2 - 'Royal Ann'	Early	13.8	194.6	29.48	0.152	Medium
3 - 'Royal Ann'	Early	15.3	182.7	22.00	0.120	Light
4 - 'Royal Ann'	Early	19.4	295.6	11.45	0.076	Light
5 - 'Corum'	Early	14.2	158.4	37.20	0.235	Heavy
6 - 'Corum'	Early	15.9	198.6	50.80	0.256	Heavy
7 - 'Corum'	Mid	19.4	295.6	36.29	0.123	Light
8 - 'Royal Ann'	Mid	20.7	337.0	34.25	0.102	Light
9 - 'Royal Ann'	Mid	23.0	415.0	31.07	0.075	Light

Table 2

Regression Coefficients of the Pull Force X Time

Relationship for Sweet Cherries

at Two Orchard Locations

$$PF = B_0 + B_1 \mathrm{Log}(\mathrm{day})$$

where day 1 is June 29

Table 2.

Description		B_0 (g)	B_1	r^2
'Royal Ann'				
Early season, medium	(1)	1071 (31.9)	-552 (44.2)	0.95
Early season, heavy	(2)	979 (29.4)	-519 (40.7)	0.95
Early season, light	(3)	1050 (22.4)	-597 (31.1)	0.98
Mid season, light	(8)	1255 (37.6)	-604 (52.0)	0.94
Mid season, light	(9)	1165 (18.1)	-479 (25.0)	0.98
Early season composite	(E)	1033 (20.6)	-556 (28.5)	0.93
Mid season composite	(M)	1210 (22.5)	-541 (31.1)	0.94
'Corum'				
Early season	(5)	1119 (25.8)	-814 (37.6)	0.96
Mid season	(7)	951 (30.7)	-418 (38.9)	0.92

Statistical analysis in (5) Appendix A.

Values in parentheses are standard errors.

Table 3

Regression Coefficients of the Soluble Solids X Time

Relationship for Sweet Cherries

at Two Orchard Locations

$$SS = B_0 + B_1(\text{day}) + B_2(\text{day})^2$$

where day 1 is June 29

Table 3.

Description		B_0	B_1	B_2	r^2
'Royal Ann'					
Early season, medium	(1)	13.64	0.004	0.05	0.94
		(0.59)	(0.24)	(0.02)	
Early season, heavy	(2)	14.54	-0.490	0.09	0.81
		(1.04)	(0.43)	(0.04)	
Early season, light	(3)	13.60	0.110	0.04	0.96
		(0.48)	(0.20)	(0.02)	
Mid season, light	(8)	12.31	0.330	0.05	0.92
		(1.04)	(0.43)	(0.04)	
Mid season, light	(9)	12.48	-0.130	0.08	0.95
		(0.77)	(0.32)	(0.03)	
Early season composite	(E)	13.91	-0.130	0.06	0.87
		(0.44)	(0.18)	(0.02)	
Mid season composite	(M)	12.39	0.098	0.07	0.88
		(0.80)	(0.33)	(0.03)	
'Corum'					
Early season	(5)	8.45	1.700	-0.10	0.95
		(0.68)	(0.31)	(0.03)	
Mid season	(7)	12.15	0.168	0.04	0.91
		(0.89)	(0.31)	(0.02)	
Early season composite	(1,2, 3, 5)	12.79	0.173	0.04	0.74
		(0.61)	(0.26)	(0.02)	
Mid season composite	(7,8, 9)	14.38	-0.390	0.09	0.46
		(1.20)	(0.52)	(0.05)	

Statistical analysis in (5) Appendix B.

Values in parentheses are standard errors.

Table 4

Regression Coefficients of the Weight X Time

Relationship for Sweet Cherries

at Two Orchard Locations

$$Wt = B_0 + B_1(day) + B_2(day)^2$$

where day 1 is June 29

Table 4.

Description		B_0	B_1	B_2	r^2
'Royal Ann'					
Early season, medium	(1)	2.63 (0.10)	0.80 (0.05)	-0.034 (0.005)	0.99
Early season, light	(3)	2.07 (5.21)	1.07 (0.17)	-0.052 (0.27)	0.97
Mid season, light	(8)	4.97 (1.18)	0.86 (0.03)	-0.045 (0.05)	0.98
Mid season, light	(9)	3.85 (1.39)	0.86 (0.05)	-0.035 (0.07)	0.99
Early season composite	(E)	2.35 (3.78)	0.93 (0.12)	-0.043 (0.20)	0.97
Mid season composite	(M)	4.41 (2.62)	0.86 (0.08)	-0.041 (0.12)	0.89
'Corum'					
Early season	(5)	2.54 (0.96)	0.38 (0.02)	-0.014 (0.05)	0.99
Mid season	(7)	5.48 (1.84)	0.31 (0.03)	-0.004 (0.08)	0.96
Early season composite	(1,3, 5)	3.01 (1.81)	0.71 (0.07)	-0.028 (0.10)	0.93
Mid season composite	(7,8, 9)	5.26 (2.03)	0.52 (0.05)	-0.014 (0.09)	0.86

Statistical analysis in (5) Appendix C.

Values in parentheses are standard errors.

Table 5

Regression Coefficients of the Pull Force X Weight

Relationship for Sweet Cherries

at Two Orchard Locations

$$Wt = B_0 + B_1(PF)$$

Table 5.

Description		B_0	B_1	r^2
'Royal Ann'				
Early season, medium	(1)	11.60 (0.53)	-0.0067 (0.0007)	0.95
Early season, heavy	(2)	8.87 (0.41)	-0.0049 (0.0006)	0.90
Early season, light	(3)	10.40 (0.21)	-0.0058 (0.0003)	0.98
Mid season, light	(8)	12.90 (0.36)	-0.0056 (0.0004)	0.97
Mid season, light	(9)	13.60 (0.40)	-0.0066 (0.0004)	0.97
Early season composite	(E)	9.70 (0.51)	-0.0051 (0.0007)	0.68
Mid season composite	(M)	13.10 (0.30)	-0.0060 (0.0003)	0.96
'Corum'				
Early season	(5)	5.47 (0.18)	-0.0023 (0.0003)	0.91
Mid season	(7)	11.49 (0.75)	-0.0067 (0.0011)	0.83

Statistical analysis in (5) Appendix D.

Values in parentheses are standard errors.

Fig. 1

Pull Force X Time Relationship of

'Royal Ann' Sweet Cherry Fruit in

Two Orchard Locations

Legend

● : Mid season

O : Early season

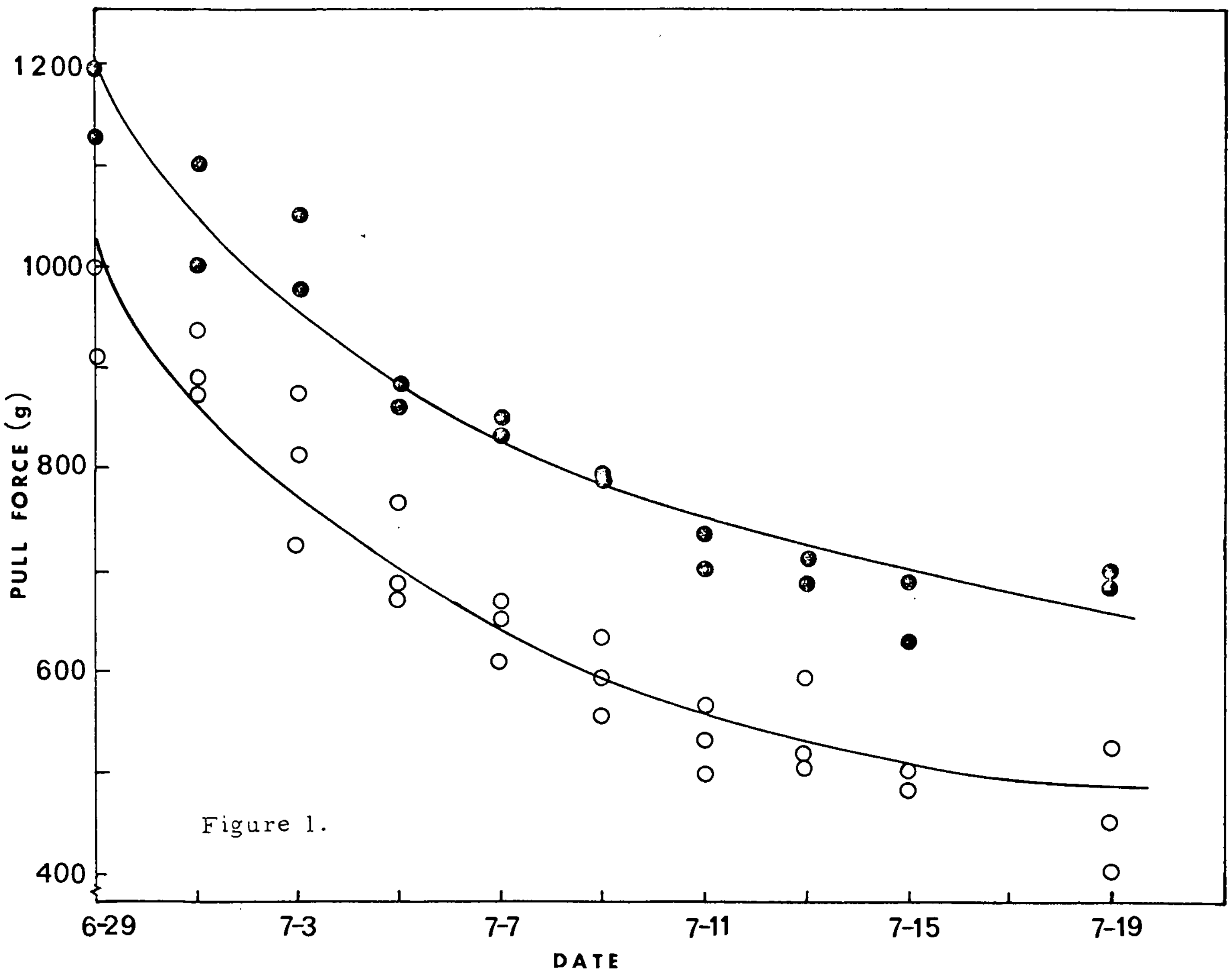


Figure 1.

Fig. 2

Soluble Solids X Time Relationship

of 'Royal Ann' Sweet Cherry Fruit

in Two Orchard Locations

<u>Legend</u>

● : Mid season

○ : Early season

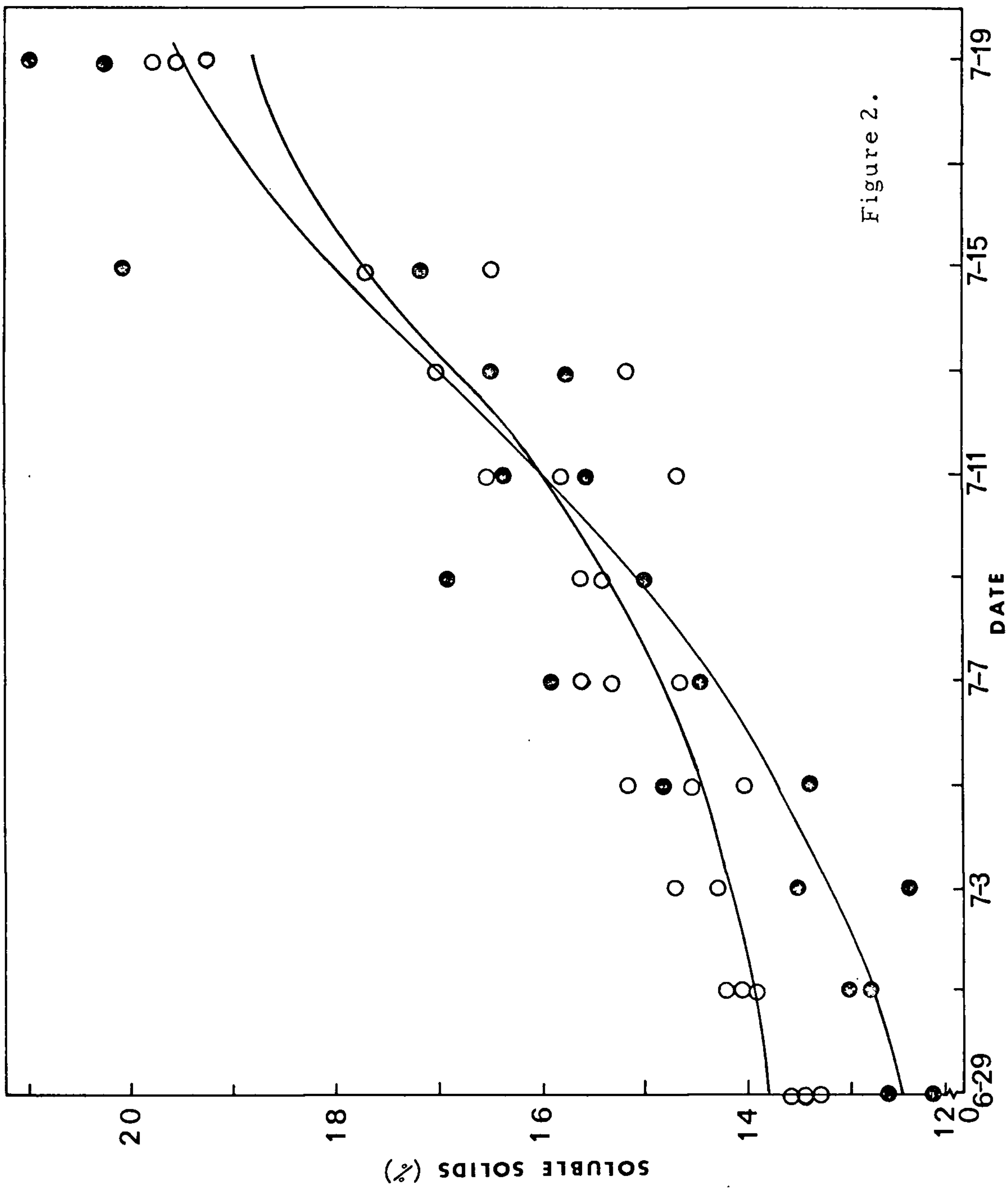


Figure 2.

Fig. 3

Weight X Time Relationship of

'Royal Ann" Sweet Cherry Fruit

in Two Orchard Locations

Legend

○: Mid season, light

+: Mid season, light

△: Early season, medium

●: Early season, medium

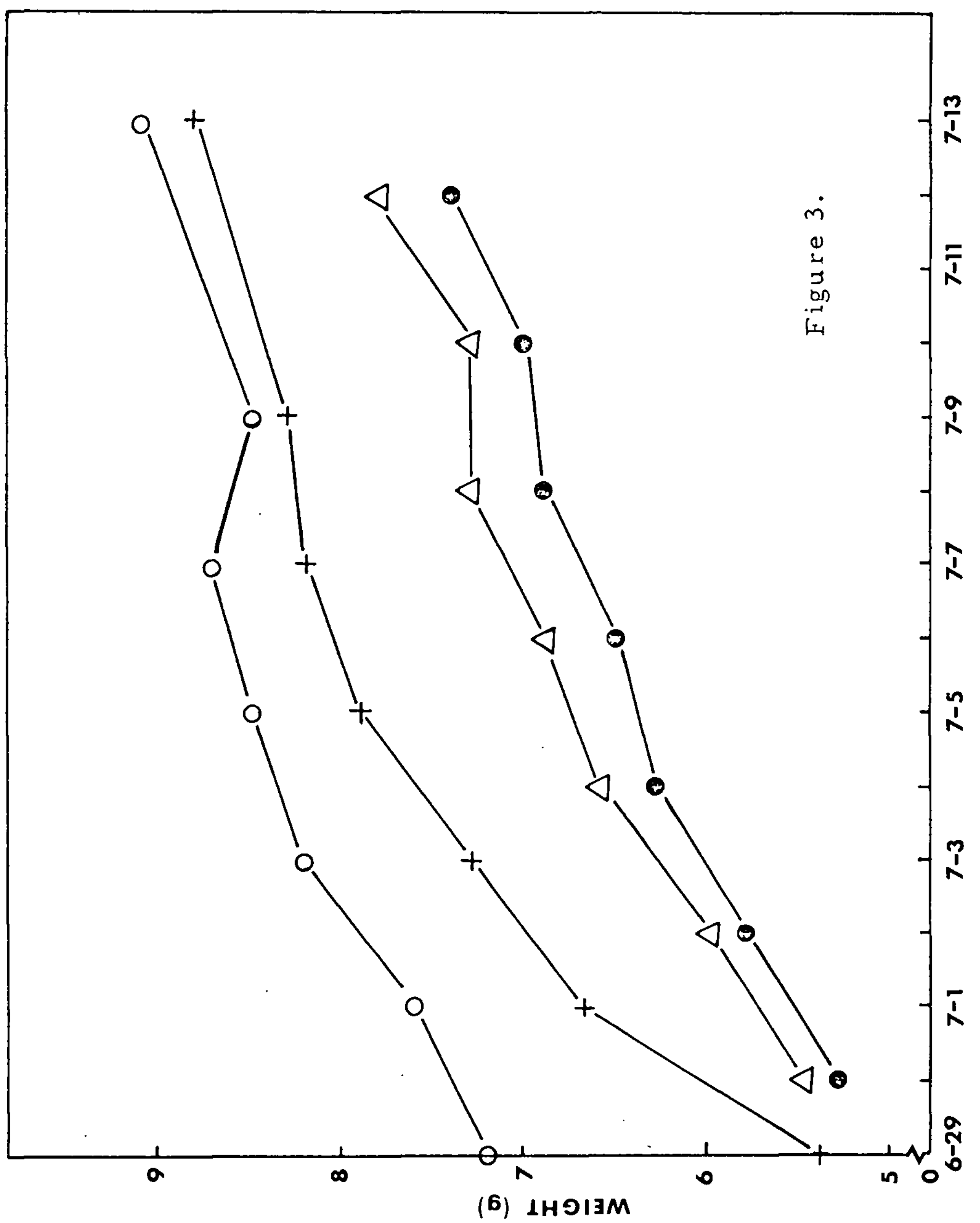


Figure 3.

Fig. 4

Regression Lines through Data Points for

Weight X Pull Force Relationship

for 'Royal Ann'

<u>Legend</u>

+ : Early season, medium

□ : Early season, medium

● : Early season, heavy

○ : Mid season, light

△: Mid season, light

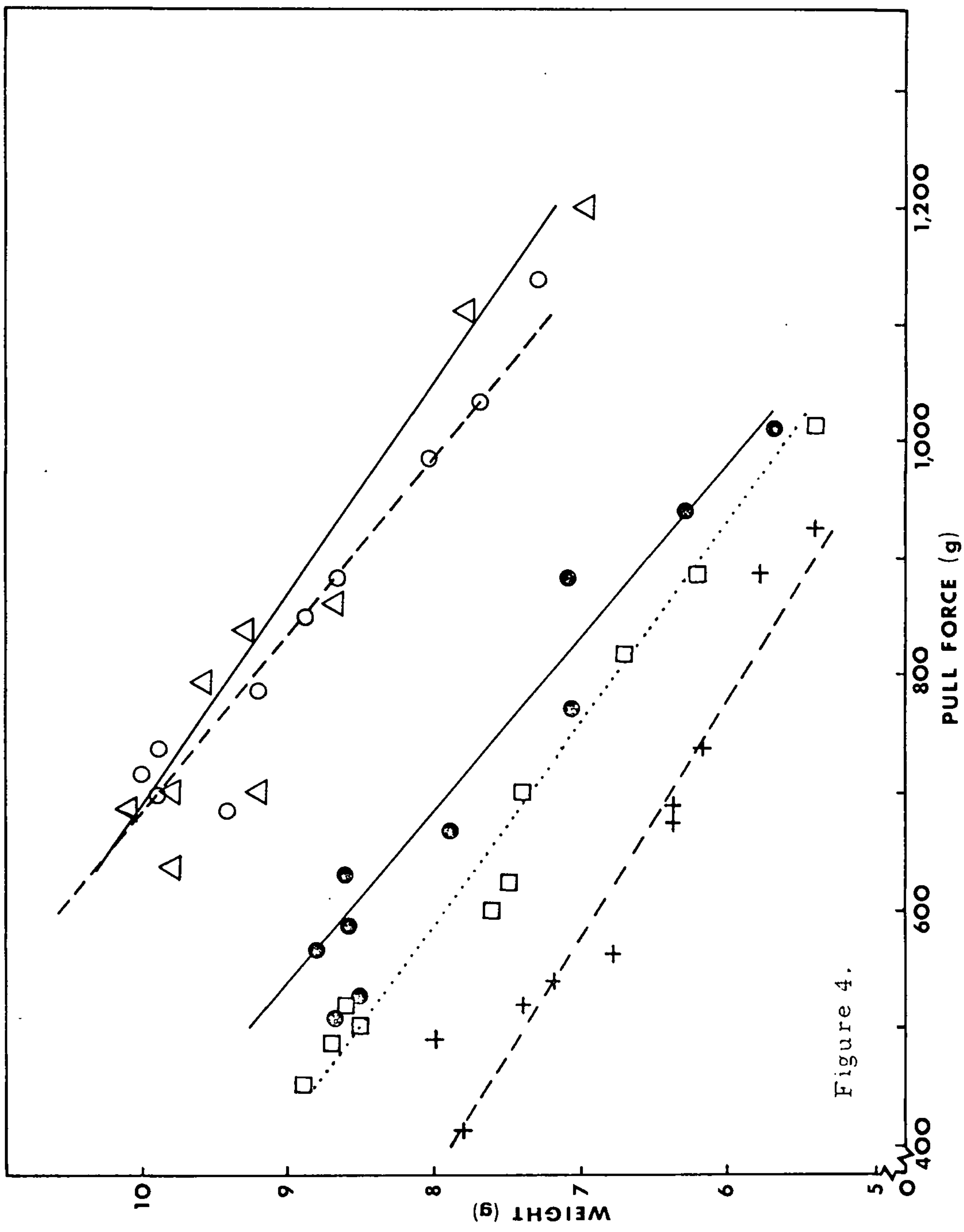


Figure 4.

Fig. 5

Regression Lines through Data Points for

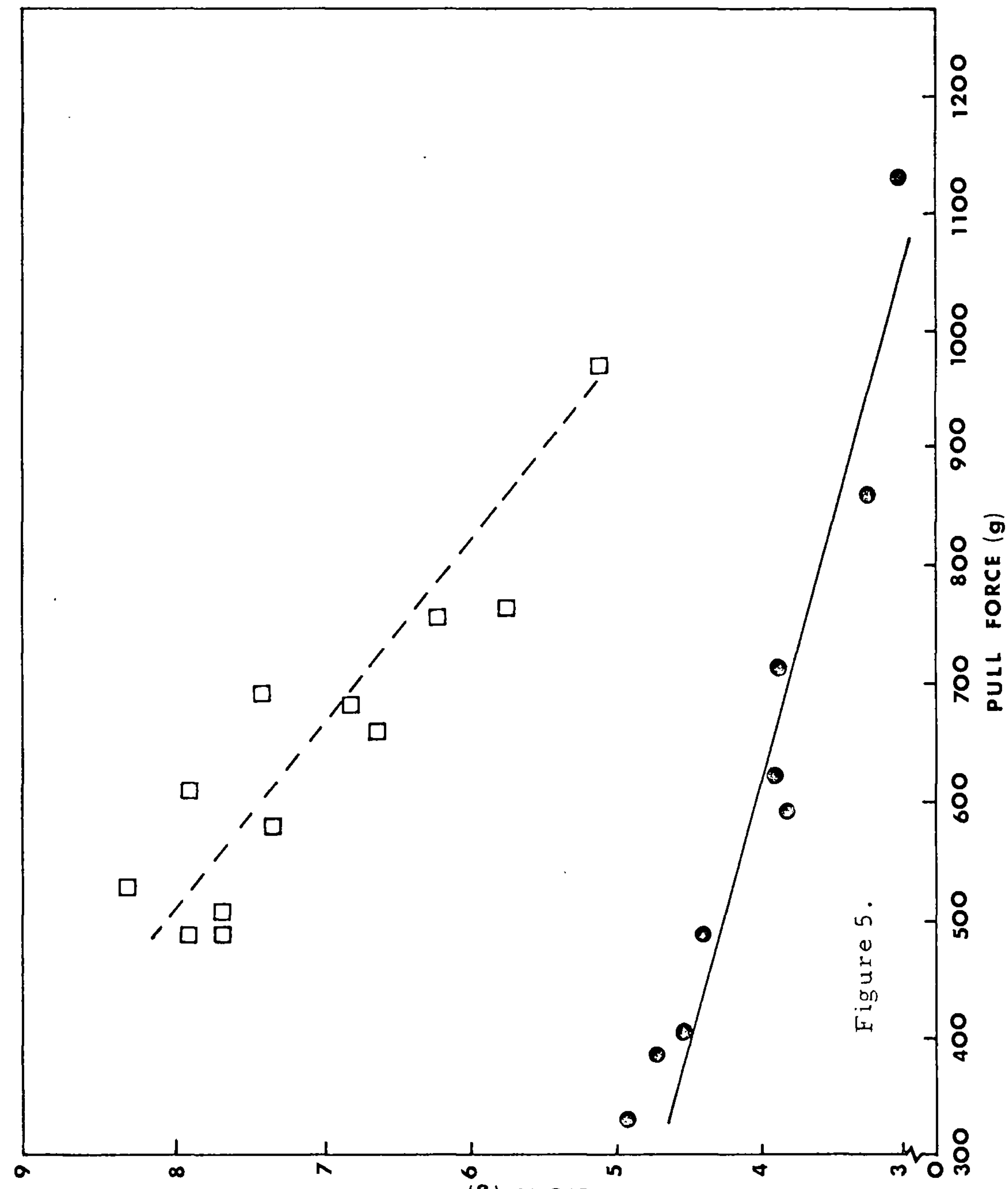
Weight X Pull Force Relationship

for 'Corum'

Legend

● : Early season

□ : Mid season



WEIGHT (g)
9
8
7
6
5
4
3
0
PULL FORCE (g)
300
400
500
600
700
800
900
1000
1100
1200

Figure 5.

Fig. 6

Composite Showing Pull Force X Weight X Soluble

Solids X Time Relationships for Early

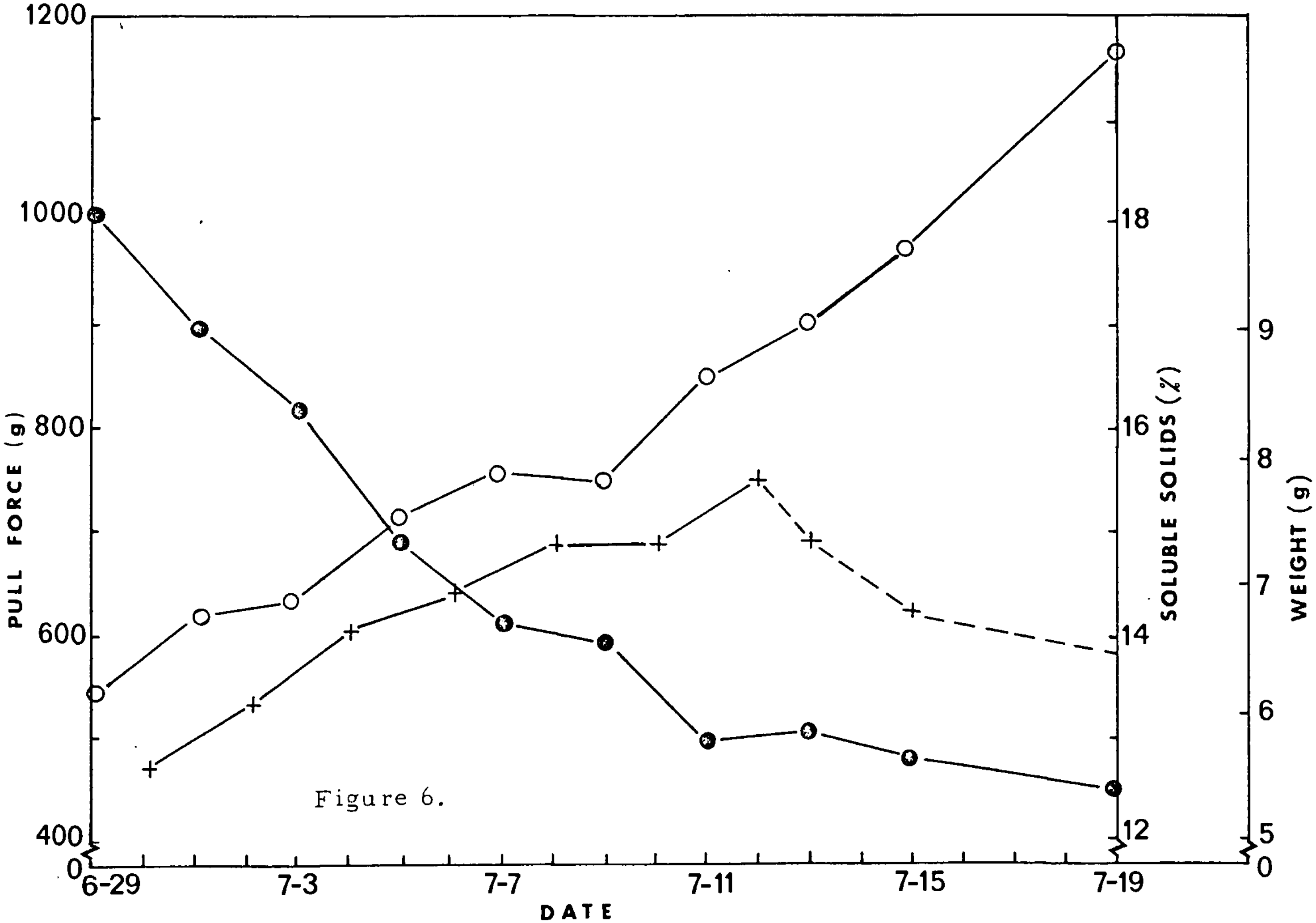
Season 'Royal Ann' Sweet Cherry Fruit

Legend

● : Pull force

○ : % Soluble solids

+ : Weight



PULL FORCE (g)
1200
1000
800
600
400
0
SOLUBLE SOLIDS (%)
18
16
14
12
WEIGHT (g)
9
8
7
6
5
0
6-29
7-3
7-7
7-11
7-15
7-19
DATE

Figure 6.

Diurnal Changes of Leaf and Fruit Water Potentials of Sweet Cherries during the Harvest Period[1]

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Abstract: Diurnal water potential (ψ) of sweet cherry leaves and fruit pedicels was measured using a Scholander-type pressure chamber. Fruit pedicel ψ was always lower at 6 A.M. than leaf ψ but leaf ψ was usually lower during the day. There appears to be some varietal difference in ψ but maturity does not appear to have an effect. The magnitude of fruit pedicel and leaf ψ increased under stress conditions. Minimum fruit pedicel ψ was reached at about 2 P.M. and then appears to recover to the earlier higher ψ as water uptake occurs during the night.

[1]Received for publication ________________. Portions from a thesis presented to the Graduate School of Oregon State University, in partial fulfillment of the requirements for the MS degree.

INTRODUCTION

Mechanical harvest of sweet cherries, Prunus avium L., typically is stopped in early afternoon on hot days as the fruit becomes difficult to remove from the tree. More damage is believed to result from harvest operations when the trees have been under moisture stress. Several researchers have shown a diurnal effect on leaf water potential but little research has been directed toward fruit pedicel water potential and its relationship to leaf water potential (1, 2, 3). Klepper however did show the diurnal change in fruit ψ in pear and related this to the diurnal change in leaf ψ (4). The objectives of this study were to a) develop a procedure to measure fruit pedicel water potential using a pressure chamber, b) observe and record diurnal fluctuations in water potential of leaf petioles and fruit pedicels of sweet cherry, c) determine the time of day when water potential was at a minimum, and d) determine whether or not resumption of harvest might be possible later in the afternoon when turgidity may recover.

MATERIALS AND METHODS

A 'Corum' and 'Royal Ann' tree were selected in an early season orchard and each tree was divided into quadrants; north, south, east, west. Sample numbers of fruit varied from two to five fruit per quadrant and were picked at random. Leaf samples were two per quadrant and were chosen to eliminate variation due to size. During the harvest period, water potential readings were taken every two hours between 6 A.M. and 4 P.M. on alternating days.

By partially filling the pressure chamber with glass beads support was provided for the fruit while the measurement was being taken, the amount of compressed air required to fill the pressure chamber was reduced, and the amount of time required to read each sample was reduced. In addition several rubber stoppers (used to support plant material in the pressure chamber) with different size holes in them, were available. In actual practice only two different size holes, one for 'Royal Ann' fruit and one for 'Corum' fruit and leaves were used.

Other than this modification, the operating procedures were as stated by Scholander et al. (5). Datum was taken as psi and converted to negative bars with means, standard deviation, and variance calculated for each time, quadrant, and tree. Relative humidity and temp were also recorded every two hours.

The water potential of the pedicel alone was statistically different than that of the pedicel with fruit attached (preliminary data). Therefore pull force and fruit pedicel water potential on the same fruit could not be measured. After a pressure chamber reading was obtained and as the chamber pressure was released the pedicel-fruit connection was usually damaged enough so that pull force measurements would be inaccurate.

Prior to performing this experiment the variance between leaves within a quadrant of the same tree was determined to be very small and therefore a sample size of two leaves would be adequate (Dr. Brian Cleary, personal communication). Initial readings of leaf water potential indicated considerable variance; however, choosing leaves of the same size reduced this problem.

RESULTS

The data indicate several relationships between leaf and fruit water potential (Fig. 1 and 2). In all cases the fruit water potential was lower at 6 A.M. than the leaf water potential. However leaves reacted more quickly than fruit to stress and usually attained lower water potentials than fruit during the day. On most days leaves and fruit reached their lowest water potentials at the same time, usually 2 P.M. A comparison of water potential for 'Corum' and 'Royal Ann' on the four days that the readings coincide, shows that the 'Corum' water potentials were always lower. This suggests that there is some varietal difference. This possible varietal difference may partly be explained by the larger leaf size of 'Corum'. 'Corum' generally has larger leaves than 'Royal Ann' and wider variance was observed within 'Royal Ann' leaf water potentials when leaves were chosen randomly regardless of size. Although relative humidity, wind velocity, and temp affect water potential, maturity does not appear to have much of an effect. The last four sets of observations were taken on days with about the same weather conditions yet no trend in water potential was apparent.

Under stress conditions there also appeared to be more variance between fruit and leaf water potential as compared to a less stressful day. This also suggests that there may be wider variance within the tree. At the 6 A.M. reading the variance in both leaves and fruit is relatively small, σ = 2.4 and .98 bars respectively. As the day progresses and the stress increases the variance increases in both leaves and fruit, σ = 10.3 and 4.6 bars respectively.

DISCUSSION

Presently it is common practice for commercial growers to stop harvest operations at about 2 P.M. on a bright, sunny day. This procedure is followed since it becomes difficult to remove fruit and is believed to reduce fruit damage possibly because of loss of turgor of the fruit pedicel. Results of this experiment indicate that the minimum turgor of the fruit pedicel is reached at about 2 P.M. Therefore if low fruit pedicel turgor results in increased fruit damage, growers may be well advised to stop harvest operations prior to 2 P.M. The time could be extended in relation to favorable weather conditions on less stressful days. If after 2 P.M. the fruit pedicel water potential returns toward the early morning values as the late afternoon stress diminishes, as was observed in pears (4), then it might be suggested that harvest operations could resume later in the day when acceptable fruit pedicel water potentials are met. This would be of particular interest to growers who are faced with a threat of rain and potential loss of revenue due to rain cracking. However, we do not yet know if there is a critical water potential value of the fruit pedicel when harvest becomes difficult. Further work under commercial conditions will be needed to ascertain those water potential values.

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Fig. 1

Diurnal Water Potential Fluctuation

of 'Corum' Fruit and Leaves

during the Harvest Period

between 6 A.M. and 4 P.M.

<u>Legend</u>

● : Fruit

▫ : Leaf

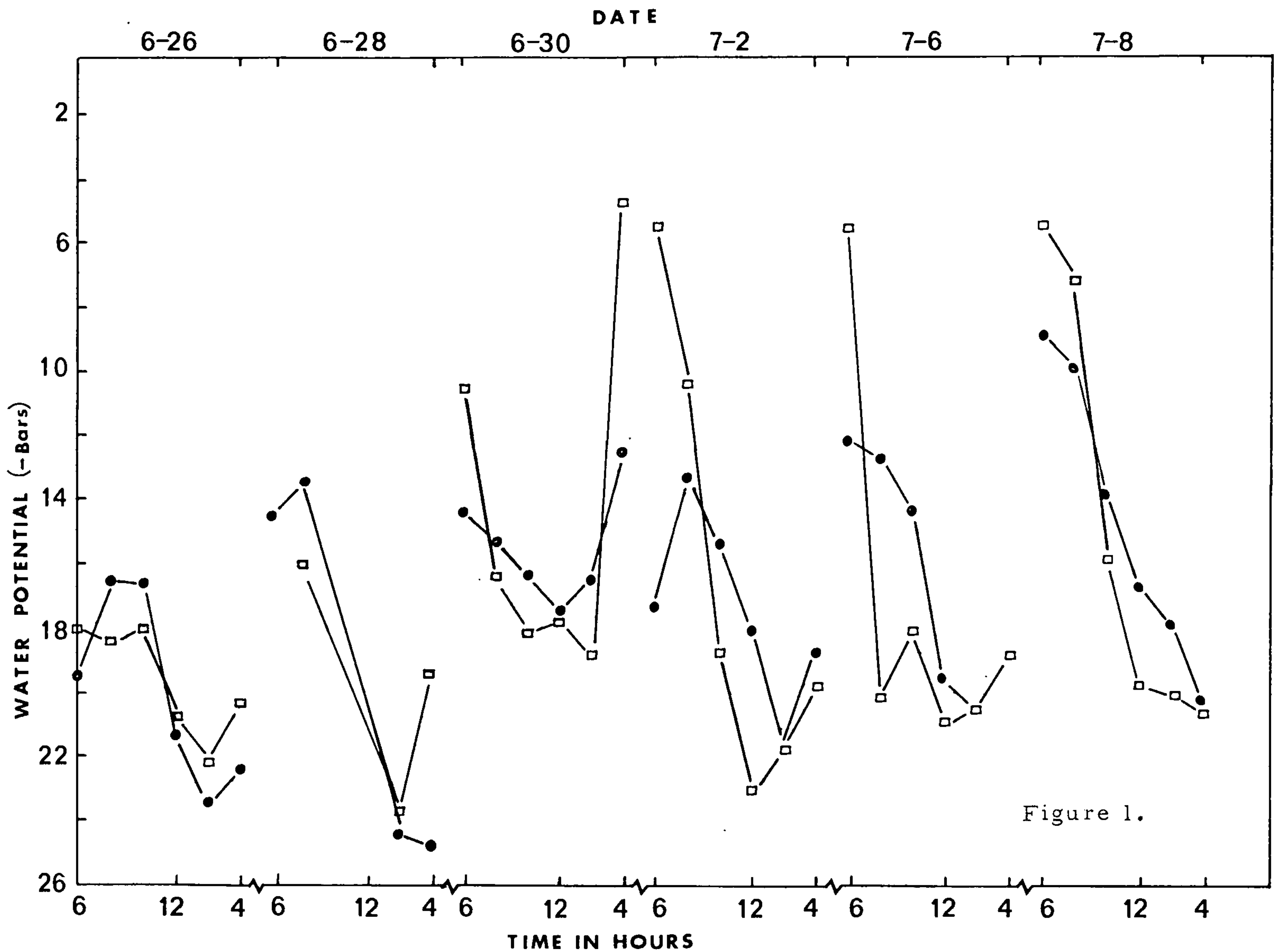
DATE
6-26
6-28
6-30
7-2
7-6
7-8
WATER POTENTIAL (-Bars)
2
6
10
14
18
22
26
6
12
4
TIME IN HOURS

Figure 1.

Fig. 2

Diurnal Water Potential Fluctuations of

'Royal Ann' Fruit and Leaves

during the Harvest Period

between 6 A.M. and 4 P.M.

Legend

o : Fruit

□ : Leaf

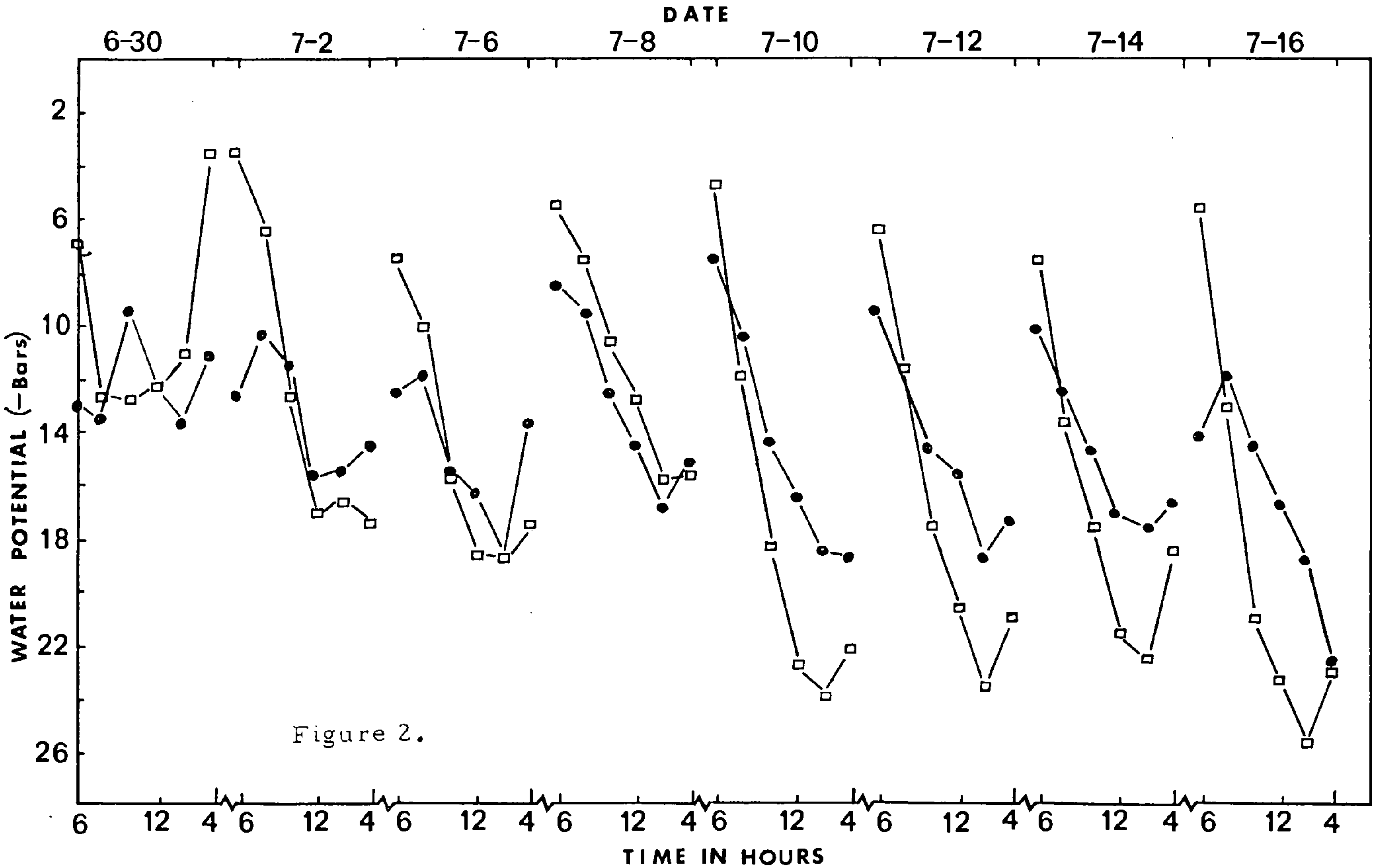
DATE
6-30
7-2
7-6
7-8
7-10
7-12
7-14
7-16
WATER POTENTIAL (−Bars)
2
6
10
14
18
22
26
6
12
4
TIME IN HOURS

Figure 2.

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APPENDICES

Appendix A

Statistical Analysis of Regression Equations

of the Pull Force X Time Relationship

for Sweet Cherries in Table 2

Calculated t Values (critical)

Description	B_0 [z/]	B_1 [z/]
'Royal Ann'		
1 = 2	2.21 (2.23*)	0.55 (1.81**)
1 = 3	0.54 (1.81**)	0.83 (1.81**)
2 = 3	1.92 (2.23*)	1.52 (1.81**)
8 = 9	2.16 (2.23*)	2.17 (2.23**)
E = M	5.80 (2.02*)	0.35 (1.68**)
'Corum'		
5 = 7	4.19 (2.07*)	7.41 (2.09*)

* and ** Values are critical t values at 0.05 and 0.01 respectively.

[z/] Calculated using t test.

Appendix B

Statistical Analysis of Regression Equations of the Soluble Solids X Time Relationship for Sweet Cherries in Table 3

Calculated F Values (critical)

Description	B_0	B_1 and B_2 [z/]
'Royal Ann'		
1 = 2 = 3	2.53 (2.60*)	1.76 (2.84*)
8 = 9	11.21 (3.29*)	0.63 (2.79*)
E = M	0.01 (4.05*)	3.49 (2.17*)
'Corum'		
5 = 7	2.24 (4.45*)	4.55 (3.68*)
Early season		
1 = 2 = 3 = 5	15.93 (4.11*)	3.72 (2.30*)
Mid season		
7 = 8 = 9	0.02 (4.20*)	29.35 (2.64*)

* Values are critical F values at 0.05.

[z/] Calculated using F test where $F = \frac{\text{MSE (full model)}}{\text{MSE (restricted model)}}$

Appendix C

Statistical Analysis of Regression Equations of the Weight X Time Relationship for Sweet Cherries in Table 4

Calculated F Values (critical)

Description	B_0	B_1 and B_2 [z/]
'Royal Ann'		
1 = 3	--	2.88 (3.34*)
8 = 9	--	4.51 (3.49*)
E = M	27.68 (4.12*)	26.79 (2.27*)
'Corum'		
5 = 7	14.69 (4.54*)	0.17 (3.88*)
Early season		
1 = 3 = 5	20.15 (4.22*)	9.77 (2.75*)
Mid season		
7 = 8 = 9	2.28 (3.40*)	6.19 (2.66*)

* Values are critical F values at 0.05.

[z/] Calculated using F test where $F = \frac{\text{MSE (full model)}}{\text{MSE (restricted model)}}$

Appendix D

Statistical Analysis of Regression Equations of the Pull Force X Weight Relationship for Sweet Cherries in Table 5

Calculated t Values (critical)

Description	B_0 z/	B_1 z/
'Royal Ann'		
1 = 2	4.40 (2.23*)	1.96 (2.23*)
1 = 3	2.20 (2.23*)	1.18 (1.81**)
2 = 3	3.68 (2.23*)	1.34 (1.81**)
8 = 9	1.35 (1.81**)	1.75 (1.81**)
E = M	5.48 (2.02*)	1.18 (1.68**)
'Corum'		
5 = 7	18.80 (2.09*)	4.00 (2.09*)

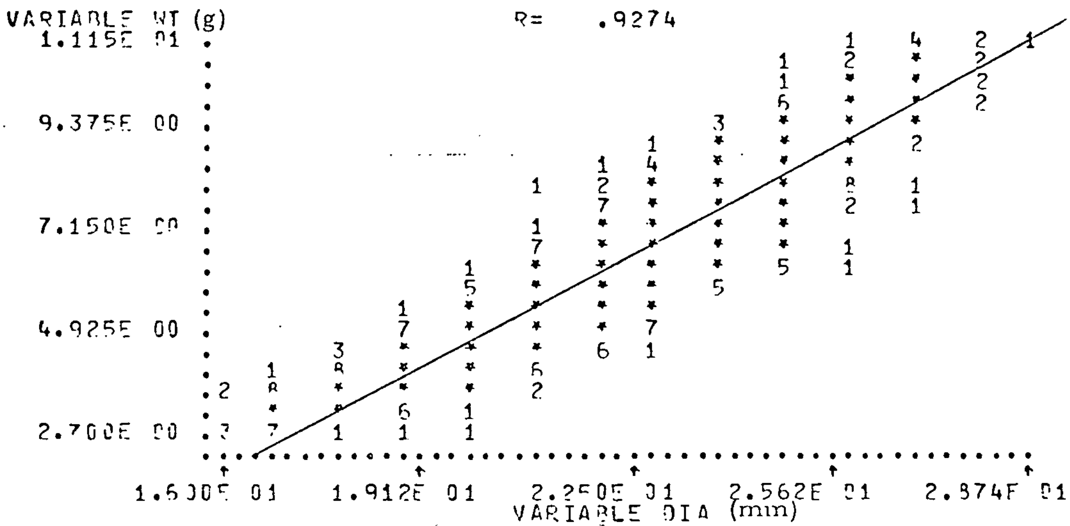
* and ** Values are critical t values at 0.05 and 0.01 respectively.

z/ Calculated using t test.

Appendix E

Regression Line and Equation for Weight X

Diameter Relationship for 'Royal Ann'



Royal Ann variety

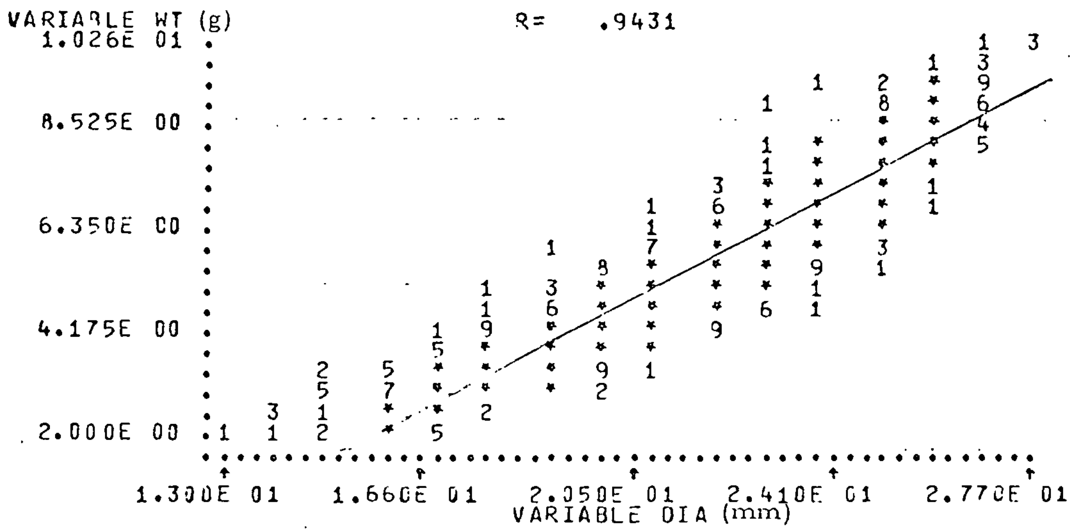
Wt = -10.19 + .746 (diam)

Confidence interval at 95% is ± 0.06g

Appendix F

Regression Line and Equation for Weight X

Diameter Relationship for 'Corum'



Corum variety

Wt = -7.53 + .609 (diam)

Confidence interval at 95% is $\pm$ 0.09g

Appendix G

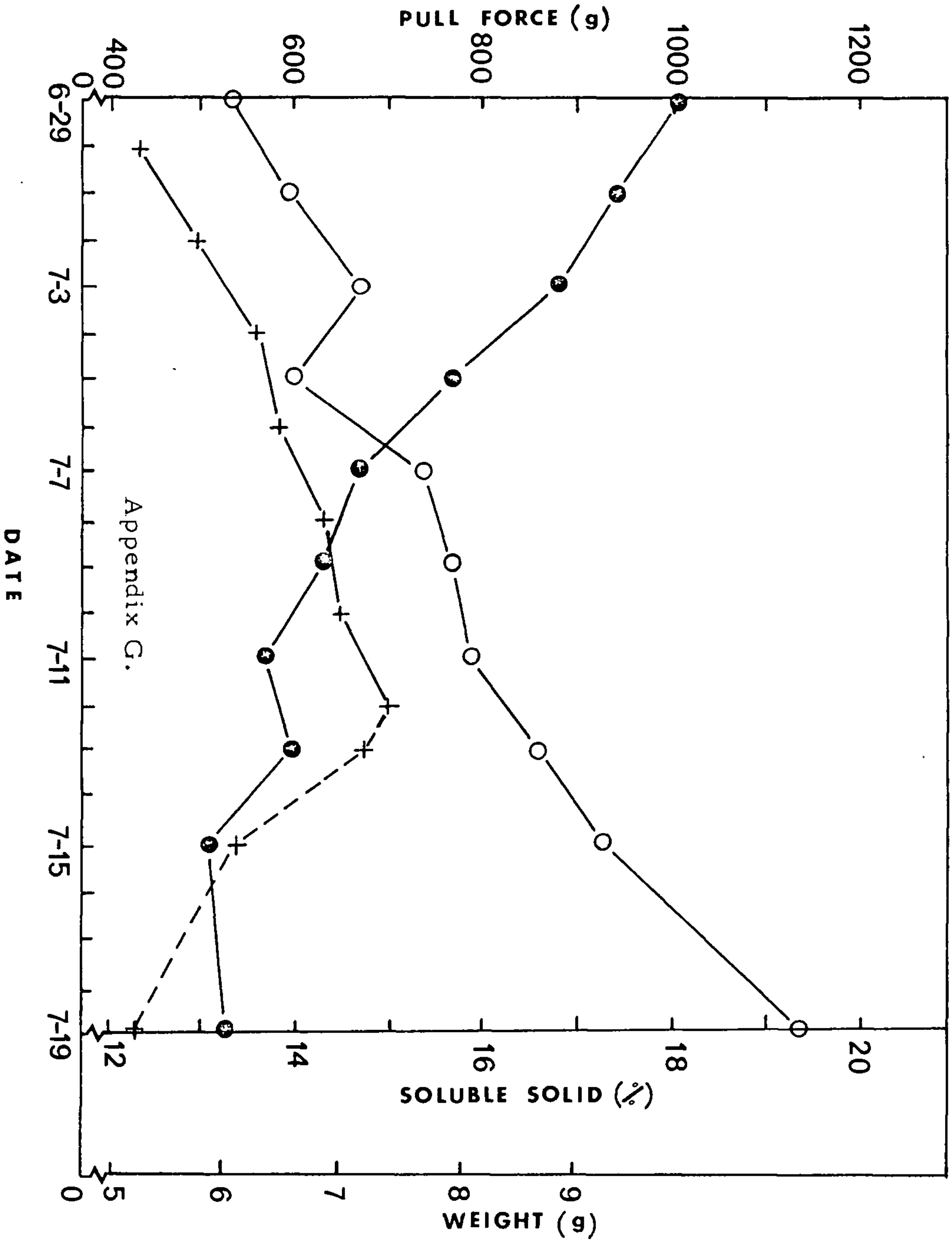
Composite Showing Pull Force X Weight X Soluble Solids X Time Relationships for Early Season 'Royal Ann' Sweet Cherry Fruit

Legend

● : Pull force

○ : % Soluble solids

+ : Weight


PULL FORCE (g)
400
600
800
1000
1200
0
6-29
7-3
7-7
7-11
7-15
7-19
DATE
12
14
16
18
20
SOLUBLE SOLID (%)
0
5
6
7
8
9
WEIGHT (g)

Appendix G.

Appendix H

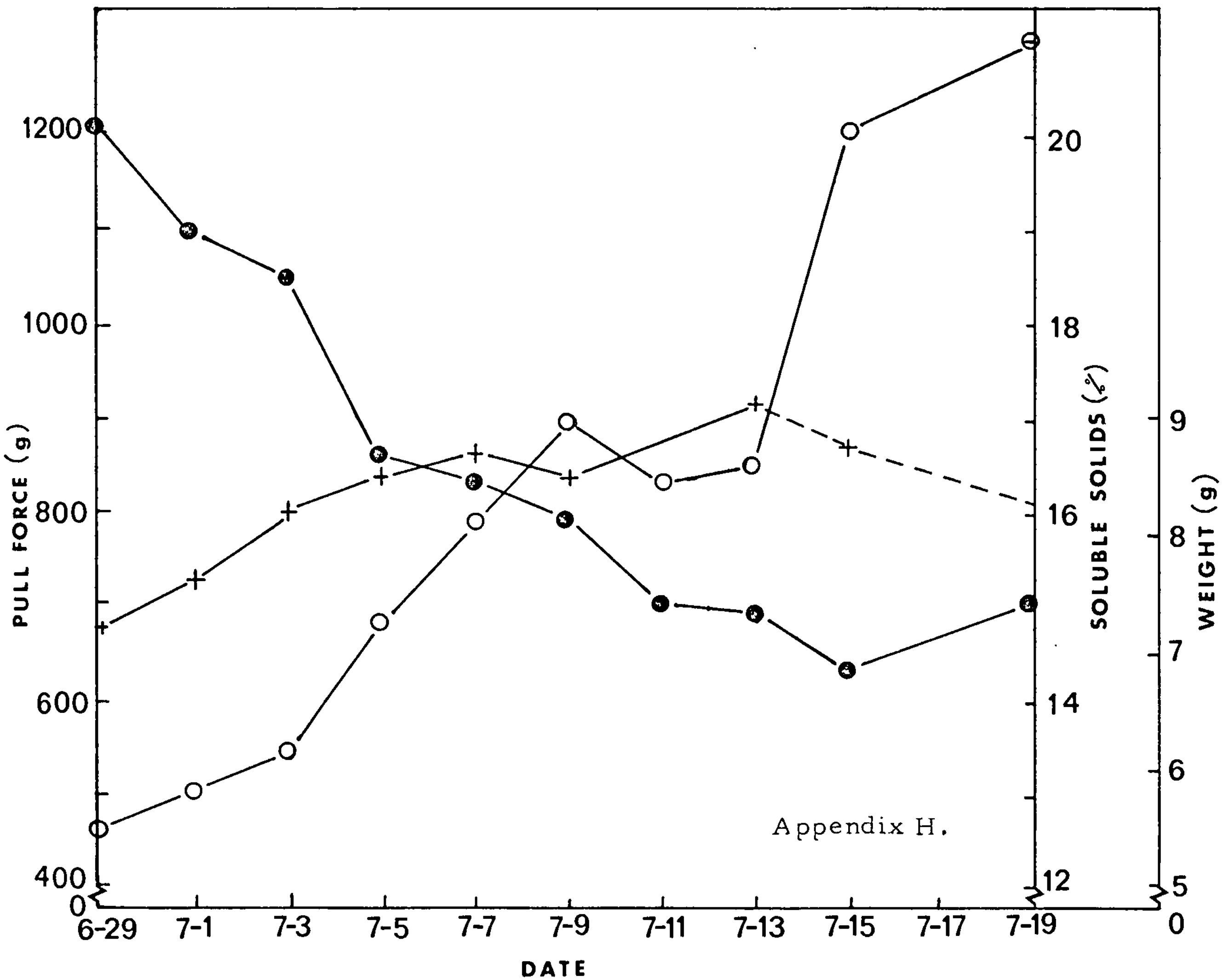
Composite Showing Pull Force X Weight X Soluble Solids X Time Relationships for Mid Season 'Royal Ann' Sweet Cherry Fruit

<u>Legend</u>

● : Pull force

○ : % Soluble solids

+ : Weight


PULL FORCE (g)
1200
1000
800
600
400
0
SOLUBLE SOLIDS (%)
20
18
16
14
12
WEIGHT (g)
9
8
7
6
5
0
6-29
7-1
7-3
7-5
7-7
7-9
7-11
7-13
7-15
7-17
7-19
DATE
Appendix H.

Appendix I

Composite Showing Pull Force X Weight X Soluble

Solids X Time Relationships for Mid Season

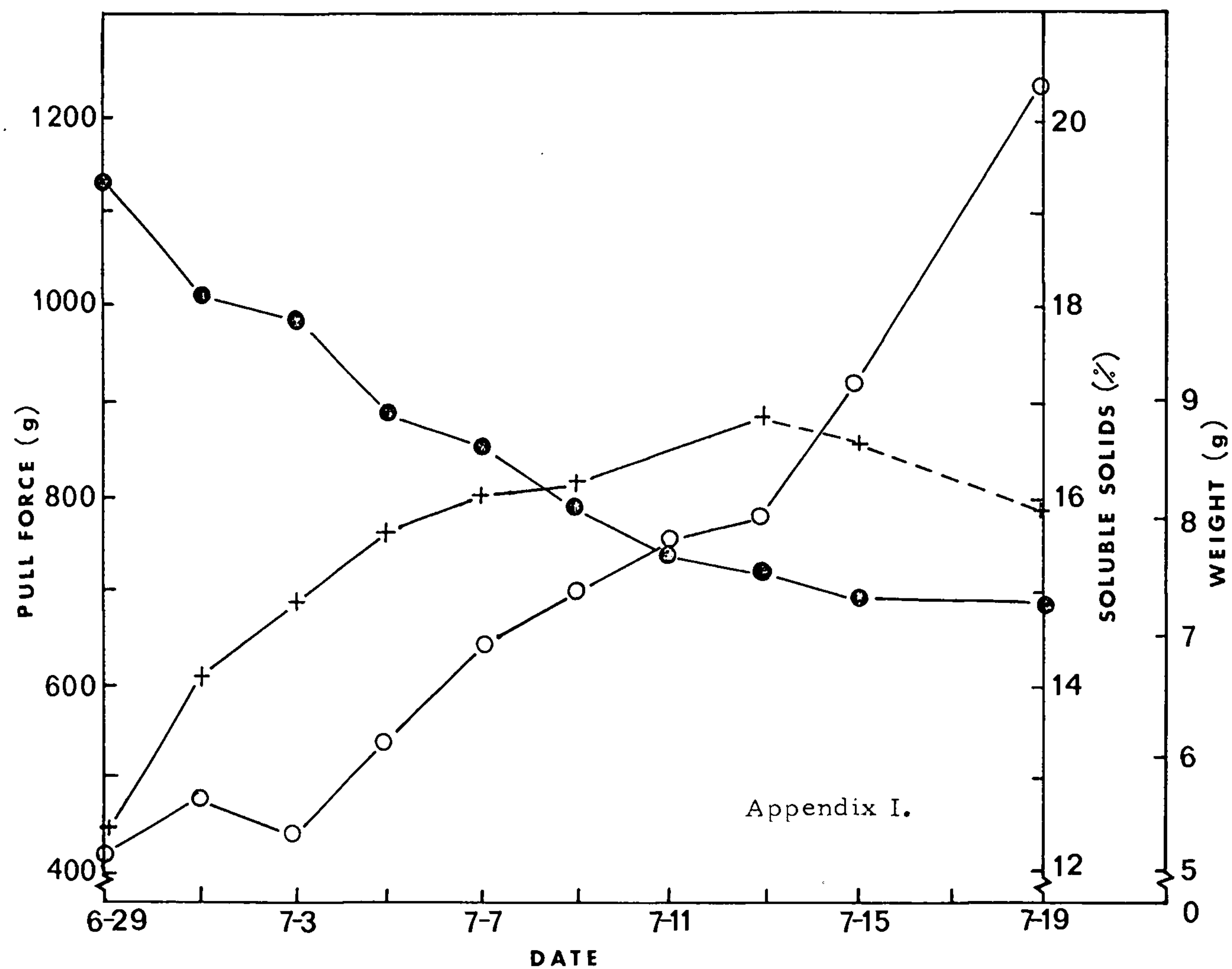
'Royal Ann' Sweet Cherry Fruit

Legend

●: Pull force

O: % Soluble solids

+: Weight


PULL FORCE (g)
400
600
800
1000
1200
DATE
6-29
7-3
7-7
7-11
7-15
7-19
SOLUBLE SOLIDS (%)
12
14
16
18
20
WEIGHT (g)
0
5
6
7
8
9

Appendix I.