Research Report on
Virginia Apple Objective Count Surveys

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Report on Virginia Apple Objective Counts Survey

I. Introduction

The apple project was conducted for three seasons, 1963 through 1965, within a commercial orctard in northern Virginia. The purpose was to develop objective yield procedures by periodic counts and measurements of apples on sample trees. This project was undertaken jointly by the Research and Development Branch of the Standards and Research Dvision and the Virginia State Office of the Field Operations Division, both of the Statistical Reporting Service, USDA.

II. Background

Before describing field procedures and analysis of data, it is helpful to explore the thinking behind the choice of the methods employed in the survey.

First of all, just what is to be estimated, and to what point in the season? Primarily, the objective of the survey is to be able to predict the number of bushels of apples to be harvested per tree as early in the season as possible. A supplementary objective is to be able to project size distribution of apples at harvest time as early in the season as possible.

Apple flower buds are initiated during the season prior to their opening. Thus it is possible to get some clue to next year's production potential before the current crop is harvested. Since environmental factors affect fruit bud development, however, there is a great deal of uncertainty at that point. For example, intensity and duration of light affect the differentiation of apple fruit buds.

Studies have been made concerning the relationship of the number of blossoms and the yield of apples.1/ While there is significant correlation between the profusion of blossoms on a tree and the harvest yield, there is still too much uncertainty concerning pollination, damaging freezing temperatures, June droppage, and thinning to justify a major effort at this point in the season.

In Northern Virginia, by July 1 the apples that remain on the tree undergo little droppage from then until harvest. Consequently, as soon as the June drop has occurred, sufficient stability has been achieved to provide a basis for projecting apples to be harvested and an indication of harvest size distribution. Subsequently, during the growing season, periodic measures of growth can be made to "zero in" growth rates.

The number of bushels to be harvested can be projected from July 1 data by estimating (1) number of apples on trees at July 1, (2) expected fruit droppage at harvest, (3) expected harvest size of fruit, and (4) the expected proportion of fruit reaching maturity but not harvested.

1/ "A Study of the Relationship Between The Amount of Bloom and Yield of Apples", R. P. Langley, Canadian Journal of Plant Science, 40:52-57

Various methods are available for estimating the number of apples on trees on July 1. A complete count of fruit on a tree is extremely time consuming, tedious, and prone to errors. An unbiased and consistent method is to sample terminal branches with probabilities proportional to the cross sectional area of the branch, since a correlation exists between the size of a branch and the number of fruit on a branch. This method for selecting terminal branches is described by R. J. Jessen.2/ This involves a random path within the sample tree. Another sampling technique that is sometimes used is the sector approach in which fruit is counted within a sample sector of the tree. The probabilities of selection are proportional to the size of sector. Defining sector boundaries and accurately counting fruit within sectors are difficulties encountered with this method, although its estimates are also unbiased and consistant. The method used in this study was to chose one random path in each sample tree. For efficient sample design, estimates of variances (1) between branches within tree, (2) between trees within orchards, and (3) between orchards within state should be available as well as cost estimates for each stage of cluster sampling. In addition, samples would ordinarily need to be allocated by varieties or varietal types.

Rate of fruit droppage after the June drop until harvest is relatively stable from year to year. The droppage rate is affected by (1) extreme weather, including temperature extremes and high winds, (2) animal and insect pests and desease, (3) cultural practices such as thinning, and (4) numbers of fruit on trees. Of these factors, the first three are difficult to predict but not considered as major variables over large regions. The latter factor should be considered in predicting normal droppage since it is obvious that the larger the number of fruit on trees, the more fruit there is to drop.

It has been observed that the greater the leaf area per fruit, the greater the total size of fruit, although the relationship is not directly proportional.3/ Since leaf area on a branch is also highly correlated with the cross sectional area of the branch, the number of apples per one square inch cross sectional area provides an indication of leaf area per fruit. Studies of the relation ship between fruit sizes to temperature and rainfall have not shown a sugnificant relationship. Batjer4/ found highly significant correlation coefficients between the diameter sizes of Winesaps at various periods after full bloom with harvest diameter sizes for the seasons 1949-52 as follows:

2/ "Determining the Fruit Count on a Tree by Randomized Branch Sampling", R. J. Jessen, Biometrics, Vol. II, No. 1, March 1955, p. 99-109

3/ "Relation of Roliage to Fruit Size and Quality in Apples and Pears", Magness and all, State College of Washington Experimental Station, February, 1931.

4/ "Predicting Harvest Size of Apples at Different Times During the Growing Season", Batjer et al, Wevatche, Washington.

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Year	No. Orchards	35 days	55 days	75 days
1949	5	.85	.88	.89
1950	4	.66	.73	.86
1951	4	.72	.79	.81
1952	5	.80	.83	.87

It can be observed that in each year correlation coefficients become higher as the season progresses and that variations between years decrease. July 1 survey data corresponds most nearly to the 55 days after full bloom observations, ranging from 50 days to 63 days for 1963-1965 for the test orchard. These observations indicated that while an estimation of harvest size distribution is obtainable from July 1 apple size measurements, August 1 measurements are much more reliable indicators. To convert number and sizes of apples to bushels is relatively easy since there is an inverse and fairly consistent relationship between harvest diameters and the number of apples per bushel.

The expected proportion of fruit reaching maturity but not utilized called harvest loss, depends primarily upon two factors: (1) fruit left in orchards and (2) fruit harvested but not utilized. The latter is not usually considered much of a factor because of the diverse pattern of utilization and extent of salvage available. The amount of fruit left in orchards is of more importance and of a complex nature. It is a function of (1) number of apples reaching maturity (2) degree of maturity at harvest (3) availability and quality of harvest labor, and (4) returns of apples for by-products. Maturity of apples at harvest can be affected by extending the harvest period past the optimum stage due to a scarce labor supply. As apples become fully mature, they tend to be attached less firmly to the tree so that picking ladders cause heavier fruit fall. With less experienced crews, more fruit is knocked to the ground during harvest and trees are picked less clearly. Whether a grower will pick up ground falls depends upon the volume of fruit on the ground and the availability of labor. Returns of apples for by-products do not normally fluctuate widely from one year to the next, but do provide the grower guidelines as to the feasibility of picking up ground falls. Harvest losses would normally be objectively projected as a function of apples on tree on July 1 with other factors being considered equal.

III. Field Procedure

Chronology Three types of observations were made: (1) a count of apples on sample branches, (2) periodic diameter measurements of sample apples, and (3) harvest weight measurements of sample apples and sample tree production. The following table shows the timing of the survey:

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Table 1: Calender of Apple Survey 1963-1965

Event	1963 Date	Days After: Full Bloom	1964 Date	Days After: Full Bloom	1965 Date	Days Aft. Full Bl.
Full Bloom	April 24	0	May 8	0	May 10	0
First Measurement (Forecast Count)	June 26	63	June 30	53	June 29	50
Second Measurement	Aug. 1	99	July 31	84	July 30	81
Third Measurement	Aug. 29	127	Sept. 2	117	Aug. 31	113
Fourth Measurement	Sept. 27	156	Sept. 25	140	Oct. 6	149
Pre-Harvest Count and Measurement	Oct. 8	167	Oct. 14	159	Oct. 21	164
Harvest Period	Oct. 10-17	169-176	Oct. 24-25	169-170	Oct. 26-27	169-170
Post-Harvest Weights	None	None	Oct. 26	171	Oct. 27	170

Tree Section A block of 250 trees of the Red York variety was selected for study. This block was centrally located within the commercial orchard and consisted of four rows of trees. For the count survey a systematic ten percent sample of trees was made from a random start using a serpetine pattern. A twenty-five tree sample was selected in 1963 for the 1963 and 1964 counts, and a different sample of twenty-five trees was taken in 1965. The size growth study was made from a sub-sample of the twenty-five trees. For this study in 1963 and 1964, every other tree was selected and in 1965, every third tree was used.

Count Survey From each of the twenty-five sample trees, a count was taken of all apples on a sample limb as of about July 1 and again just before harvest. The sample limbs, termed "Count Limbs," was selected along a random path with probabilities proportionate to the cross sectional area (CSA). Selection was designed to obtain a count limb whose CSA of primary branches five percent of the combined total CSA of primary branches. Measurements of CSA was made with steel tapes especially calibrated to indicate cross sectional area, in square inches, from circumference measurements. Limbs were usually measured about one hand's width above the previous split with care taken to avoid limb swells that would not be representative of the limbs size. The exception in this procedure was in cases where pruning several branches of the next stage on these cases measurements were taken above pruning. The relationship of cross sectional area to limb circumference is based upon the assumption that limbs are fairly circular. This is probably a safe assumption for most apple trees. To prevent tape breakage, small sized branches were measured by comparing their sizes with wooden dowels of known CSA. At each stage of selection, branches were numbered and measured. These measurements, as well as the cumulative measurements, were entered for each branch on the schedule. A number was then selected between one and the cumulative total CSA for all

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branches, inclusive, from a table of random of numbers. The branch whose cumulative CSA was equal to or exceeded the random number was selected. If the branch so selected was considerably larger than the desired size, the selection process would continue out the branch. At each stage, small branches were grouped together into units of about the desired sample size. As a result, no intermediary fruit (fruit along path, but not on terminal branches) was encountered. Eventually, a terminal branch or group of terminal branches was selected representing five percent of the combined primary branch CSA's. The trees were makred to show tree number, and a yellow stripe spray painted around the selected terminal branch. To faciliate counting, the terminal branch was divided into up to five sub-branches, called sub-sections, each marked with white plastic tape. During the 1965 season it was found desirable to further break down there sub-sections into numbered and labeled count units containing generally no greater than twenty apples.

For counting apples, two man crews were used, equipped with ladders, counting hooks, and clip boards. Each man was to count each sub-section independentlly, and compare results. Any disparities in counts were to be examined and recounts were made to reconcile the differences. Unfortunately there was not time for adequate timing or to allow reconciling differences. For some limbs, the ladders used were not tall enough to allow the count of apples on upper branches by feel.[5] Sight counts were resorted to in the July 1 survey in these instances. This sometimes resulted in serious undercounts. In addition, other factors such as missed branches, intertwined branches, and small fruit sizes contributed to inaccurate July 1 counts. These; as well as the lack of checking counts accounted for the large numbers of July 1 counts being smaller than harvest counts on the same branch in each of the three season. At harvest time, all fruit was removed from the count limbs, so that accurate counts were obtained of fruit present.

Size Growth Study On each of the twelve sub-sample trees in 1963 and 1964 and from each of the eight sub-sample trees in 1965, a sample limb different from the count limb was selected for tree size measurements of apples. The sample limbs for size growth study, were called "tag limbs". They were selected to represent approximately five percent of the combined CSA's of the primary branches. In selected the tag limbs, a limb in the same stage as the count limb but other than the count limb was randomly selected with probabilities proportional to CSA. Further stage selection continued if the selected limb was larger than five percent of the combined primary branch CSA's until a terminal branch of the proper size was selected. Hence, except for the rare event on which limb was a primary branch, the tag limb and count limb were from the same primary branch, and often from the same secondary branch. For 1963 and 1964, a systematic sample of 20 apples was selected from the tag limb, and a sample of 15 in 1965. Where fewer than

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5/ Several sizes of picking ladders are necessary with a 20' ladder being required for the large trees.

these numbers of apples were found on the tag limb, all such apples were selected for measuring. The apples selected on the tab limbs were labeled with numbered plastic markers. After experiencing losses of tags due to orchard spraying during the 1963 season, improved tags were used in the 1964 and 1965 seasons which minimized this problem. The apple measurements were made with commercially available devices consisting of flexible steel tape loops which, when snuggly fit around an apples circumference, indicated the associated apple diameter in inches to the nearest hundredth. The measurements for each successive survey were recorded on the same form so that any large departures from normal growth could be detected and immediately checked. Where the tagged apple could not be located for measuring, this fact was noted on the recording sheet. In addition, any pertinent information was recorded such as bruising by rough handling and confirmed measurements that indicated negative growth.

Harvest Weight Survey Weights of apples at harvest were obtained in three phases. For tag limb apples, these were measured and then removed from the tree at pre-harvest time. For each tree, the removed apples were sorted into diameter groups at ¼" intervals and the counts and total weight in grams of each category recorded.

Also conducted at the pre-harvest survey time was the counting and weighing of apples on count limbs. Apples were removed from the count limbs and the total weight in points obtained for the count limb of each sample tree. The same twenty-five sample trees were used in 1963 and 1964, but a different twenty-five tree sample was drawn in 1965.

When the actual orchard harvest was conducted, the manager arranged to have the apples for sample trees to be picked into field crates and field crates left under the tree. In 1963 a count of field crates under each sample tree was taken and this converted to pounds using an assumed weight per field crate of 42 pounds. In 1964 and 1965, field crates were weighed on portable scales. Tare deductions were made for empty crates based upon observations of empty crate weights.

IV. Observations and Analysis

Count Limb Selection Measurements of the cross sectional area of limbs for each stage of branching is shown for the sample limbs in Tables 2a and 2b along with expansion factors for PPS Sampling at each stage. Expansion factors were computed as the product of the reciprocal of the probability of selection based on the cumulative CSA to the selected branch for that stage. For illustration, the expansion factor tree nine for 1963 and 1964 was calculated as follows:

$$\text{Expansion Factor} = \frac{201.4}{28.3} \times \frac{19.1}{9.6} = 7.06$$

Count Survey To provide an estimate of the actual numbers of apples on each sample tree, derivation of estimated harvest counts are shown in Table3 . For most trees, the derived harvest counts were computed by dividing the net

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weight of harvested production of the tree by the average harvest weight per apple for the tree using the apples from the sample limb. In the two cases where net harvest weights were not obtained for trees, expanded counts were used from count limbs as derived harvest counts and the product of the average harvest weight per apple and the expanded count was used as an estimate of weight of harvested production. In two other cases, no apples were left on the count limb to be weighed, so an estimate was made of average weight per apple by using a regression equation of weights of apples harvested for the tree per one inch across sectional of the combined primaries to obtain an average weight per apple. A comparison of counts of apples on the sample limbs on July 1 and at pre-harvest along with their expansions and the derived harvest counts are shown in Tables 4a and 4b . Table shows the July count and harvest data for the three years. Since the derived harvest counts exclude harvest losses, they are not strictly comparable to the expanded pre-harvest counts. One would expect the difference between expanded forecast counts and pre-harvest counts to represent drops during that period. As previously mentioned, however, inaccuracies in Forecast counts nullified their usefulness for this purpose, and in many cases would seemingly infer a negative drop. Accurate forecast counts would have given a good idea of fruit drop between July 1 and pre-harvest. The following percentages decline in numbers were observed during the three years:

Year	Forecast to Pre-Harvest	Forecast to Harvest	Pre-Harvest to Harvest (Harvest Loss)
1963	Negative	Negative	8.41
1964	3.65	15.35	12.15
1965	11.45	19.82	9.45

To the extent that forecast counts were low, these indicated percentage declines are underestimates. There may have been a slight offsetting factor, i.e. that fruit knocked off during counting and sizing operations. This is not considered a very large factor, however.

Size Growth Study For the sub-sample of trees for which apple diameter measurements were made periodically, Table 5 shows the number of apples observed for each tree on each survey date.

A comparison of the decline of apples measured during the seasons for 1963 and the latter two years indicates the effectiveness of the improved plastic tag in remaining on the sample apple. Tables 6a , 6b, and 6c show the average apple diameter for each tree by survey date. This is given for all apples measured on the survey date and also for just those apples remaining at harvest. For 1963, there were many cases in which apples were missed during interim measurements but were found at harvest. For 1963 the averages as shown in Table 6a , apples remaining at harvest include only those apples for which a complete series of reports were obtained during the season. For each year, the derived harvest counts were used as weights to compute a weighed average. Tables 7a, 7b , and 7c show the size distribution of apple diameter measurements by survey dates in tenths of inch intervals, for all apples measured. As one would expect, size distribution starts out with a strong control tendency and flattens out as the season progresses.

Tables 8a, 8b and 8c show the daily diameter growth rate for each tree, the number of apples per inch cross sectional area for both the tree and the count limb, the correlation coefficients between growth rates and apples per 1" CSA. Several interesting relationships can be observed. At the beginning of the growth season there is a faster growth rate for those apples on trees with a light set, but in the later stages of development, the growth rate for these apples slows down markedly while the apples on heavily laden trees continue growing at only a somewhat reduced rate. The change from negative to positive correlation coefficients is striking as the season reaches the final stages of growth. The apples per 1" CSA measure obtained from the count limb appears to be satisfactory measure of set. This is important since it is the only practical measure available at forecast time. Correlation coefficient between apple diameters on July 1 and August 1 survey dates and Pre-Harvest diameters are as follows:

Year	July 1 and Pre-Harvest	Aug. 1 and Pre-Harvest
1963	0.6994	0.9191
1964	0.8667	0.9413
1965	0.7135	0.8427

This would seem to indicate that while correlation is high at July 1, considerable improvement would result in waiting until August 1 to project harvest sizes.

The variation in the size of apples among trees and within trees on July 1 is of interest in deciding how many apples to measure on each tree. For the purpose of determining the average size of apple for projecting to a harvest weight per apple based on a regression equation (see page), the variance components derived from the table below indicate the variance is reduced by approximately two-thirds by sampling from three trees rather than one tree per block. For this study σ_b^2 (.0137) and σ_n^2 (.0150) are approximately equal.

ANOVA Table for Size of Apples Within Block July 1, 1963

Sources	D.F.	S.S.	M.S.
Between Trees	12	3.30	.275
Within Trees	242	3.63	.015
Total	254	6.93	.273

Harvest Weight Survey For apples on tag limbs, after diameters were measured, the apples were classified by diameter at intervals of one quarter inch. An average weight for each diameter class was then obtained. There was a negative correlation between average weight for a particular size category and apple per inch CSA, which was significient at this 5% level. This would tend to confirm that the apples from trees with light sets of fruit are sweeter, and hence denser than those with heavier sets. Tables 9a, 9b, and 9c show the distribution into each size category, by tree, and average weight per apple for the three years.

Tables 10a, 10b , and 10c show the calculation of the average weight per apple for each tree, including the numbers of apples weighed on count limbs and their total weight. These average weights were used to derive harvested counts as shown in Table , along with the total weight of tree production which is also shown on Tables , , and .

Table shows a comparison of expansions of weights of apples from count limbs at Pre-Harvest time, expansion of tree production weights, and reported orchard production. In order to project orchard production, it is obvious that a sample of twenty-five trees would be insufficient if this had been the purpose of this study. Analysis of the sample standard deviations between production weights per tree, indicate a sample of over 180 would be needed (if the finite correction factor is ignored) to yield a precision of 5% of the mean at the 95% confidence level. While the intent of the study was not to estimate for individual blocks, the variability within blocks is considerable and may be subject to reduction through further study. However, the sample variability for the finite population is evident when one compares the harvested production for the twenty-five trees, column 6, with the production for all 250 trees, column 11. In 1965, the twenty-five trees did not represent the entire block as well as the sample tree used in 1963 and 1964.

A comparison of columns (5) and (6) indicates an unharvested production, or a combination of bias in the count limb procedure and unharvested production of 6-10 percent. Based on harvesting loss experiences with other crops, which are usually average 5-10 percent, the procedure used at harvest time appears to be essentially free of bias.

Projection of Harvest Weight The major purpose of the study was to project harvest yields. Since the weight of apples at harvest time is positively correlated with its July 1 diameter and negatively correlated with the number of apples per one inch cross sectional area, a multiple regression of the two provided some promise. Also to be considered was cubing the July 1 diameter observations since weight is directly related to volumne. A study of the 1965 apples measured that were harvested revealed the following relationships:

(1) $\hat{Y}_{ij} = -0.009252 + 0.26928284\, X_{ij} - 0.006387254\, V_j$

(2) $\hat{Y}_{ij} = 0.273430 + 0.03525292\, X_{ij}^3 - 0.00629700\, V_j$

Where:

$\hat{Y}_{ij}$ =harvest weight of i^{th} apple on j^{th} tree.

X_{ij} =July 1 diameter of i^{th} apple on j^{th} tree

V_j =number of apples per 1" CSA (Forecast Survey-Count Limb) on j^{th} tree

The regression is as follows:

Harvest Weight per fruit vs. July 1 Diameter and fruit per 1" CSA
Analysis of Variance: Y_1 vs. X_1 and X_2

Source	df	SS	MS	F
Total	62	.518807		
Regression on X_1, X_2	2	.328705	.16435	51.89
Regression X_1 only	1	.22654	.22654	
Regression X_2 only	1	.28302	.28302	
Error (X_1, X_2)	60	.190102	.003168	

Harvest Weight per fruit vs. July 1 Diameter Cubed and fruit per 1" CSA
Analysis of Variance: Y_1 vs. X_2 and X_3

Source	df	SS	MS	F
Total	62	.518807		
Regression on X_2, X_3	2	.328798	.164399	51.89
Regression on X_3 only	1	.23178	.23178	
Regression on X_2 only	1	.28302	.28302	
Error (X_2, X_3)	60	.190009	.003167	

The weight per fruit is more strongly related to the set per tree (in a negative way) as measured by the fruit per 1" CSA, but both regression coefficients are siginificantly different from zero.

From these, it can be seen that there is little advantage in using the diameter cubed. A further refinement that should be added to this estimating procedure is to change the July 1 diameter measurement to a Full Bloom Date plus a specified number of days. Since in 1965, the July 1 survey took place on June 29, or 50 days after Full Bloom, the comparable survey dates for 1963 and 1964 would have been June 13 and June 27 respectively. By applying daily growth rate adjustment factors to the diameters observed on actual survey dates, (see chart I) one rectroctively converts the observed diameters to a "Bloom plus 50 day" equivalence. In operational conditions, the survey would be timed to take place about the desired time. Adjustments to the exact date size could be made based upon a sub-survey which would indicate the appropriate growth rate for the area and variety in that year. Once the regression equation was applied to the sample apples measurements, a weighed average would be computed to arrive at the indicated average apple weight at harvest. The expansion of forecast counts less deductions for expected losses until harvest and harvest losses would project the number of apples to be harvested. Apple production, in bushels, would then be the project of projected apple numbers and projected average apple harvest weight divided by weight per bushel.

Then:

$$\hat{Y}_j = \frac{1}{M_j} \sum_{i=1}^{M} Y_{ij} \qquad \text{(Projected number apples per tree)}$$

and,

$$P = \frac{N}{n} \frac{\sum_{j=1}^{n} Z_j \hat{Y}_j}{\sum_{j=1}^{n} Z_j} \qquad \text{(Projected Weight of Apples per tree)}$$

<u>Size Distribution at Harvest</u> An early season projection of harvest size distribution would be valuable to the apple industry for marketing planning purposes since the fruit is sold on the basis of harvest diameter size. While small apples at Forecast generally remain small apples at harvest, the distribution patterns of apples measured and dated harvest at first glance do not appear to be similar during the three seasons of the project. As can be seen in Charts II and III. Using the regression approach mentioned in the previous section using harvest diameters as the Y_{ij} value, gives a method of projecting harvest size distribution. Using 1965 size data again the following equations were computed:

$$Y_{ij} = 1.243248 + 1.039817\ X_{ij} - 0.010603\ V_j$$

Harvest Diameter per fruit vs. July 1 Diameter and Fruit per 1" CSA
Analysis of Variance: Y_1 vs. X_1 and X_2

Source	df	SS	MS	F
Total	62	3.62851		
Regression on X_1, X_2	2	2.12893	1.06446	42.59
Regression X_1 only	1	1.84740	1.84740	
Regression X_2 only	1	1.44782	1.44782	
Error (X_1, X_2)	60	1.49958	.024993	

In this case, the July 1 diameter is the most important single variable as might be expected based on Batjer studies.

Applying the above equation to the July 1 apple diameter measurements for 1964, one would have projected a size distribution as in Chart IV as compared with the final observed. Since the regression equation is based on 1965 data with the projected fruit sizes being from different trees in the 1964 season, similar regression parameters based on scattered trees over a larger geographic area would probably be valid, but question of whether such a relationship may be valid between seasons must be tested. However, a comparison of the projected diameters with actual diameters in Chart IV suggests that the prediction of the harvest size distribution may be practical. In deriving these size distribution charts, the distributions for each sample tree has been weighed by the expanded number of fruit at forecast time or derived numbers of fruit at harvest.

It would appear that a similar approach based upon a multiple regression equation over several years may have merit. It may be desirable to introduce additional variables in such approaches.

VI. Conclusion

Methods for using objective fruit counts and measurements for apples as early as July 1 were realized in the research conducted over the three year period. The basic results are as follows:

(1) Procedures for accurate counting of fruit on sample limbs were developed. The task requires a painstaking detailed counting by small sub-sections of the sample limbs. The need to recount sample limbs a second time and reconcile any large differences is necessary for accurate results. The sub-section counts are helpful for this purpose. Counts by inexperienced crews are not likely to be sufficiently accurate for forecasting purposes unless recounting and reconcilation of differences are resolved through adequate supervision.

(2) The droppage from July 1 to Harvest is fairly stable and measurable using tagged individual fruit.

(3) The repeated measurement of apple diameters starting around July 1 by tagging of indiviudal fruit is feasible and provides a basis for predicting harvest sizes and weights of apples. While care in handling the apples is required to avoid knocking off fruit, this problem is most troublesome as harvest approaches.

(4) Provision for determining the amount of unpicked fruit is necessary. Also, the loss of fruit dropped on the ground and recovered by the grower must be measured to insure that commercial production and biological production can be related.

Virginia Apple Counts Survey

Table 2a 1963-64 Count Limb Selection Random Paths, Cross Sectional Areas, and Expansion Factors

Tree	Selected Primary in^2 CSA	Cumulative Primary	Selected Primary in^2 CSA	Cumulative Primary	Selected 3rd Stage in^2 CSA	Cumulative 3rd Stage	Expansion Factor
9	28.3	201.4	9.6	19.1			7.06
19	14.5	254.1					17.52
29	50.5	220.5	13.7	68.9			21.96
39	39.0	139.5	11.0	38.0	7.6	12.6	20.49
49	40.2	268.7	13.0	43.0			22.11
59	62.0	205.6	15.6	70.8			15.05
69	6.2	62.9	2.1	4.9			23.67
79	36.5	117.1	15.1	49.1			10.43
89	49.0	124.0	13.0	60.9	8.5	13.0	18.13
99	42.7	152.2	7.0	37.8			19.25
109	33.0	154.8	9.1	39.1			20.16
119	35.5	222.8	20.5	40.8			12.49
129	25.4	179.5	11.7	24.0			14.50
139	15.0	214.0	9.0	16.4			25.00
149	31.5	202.2	9.3	32.2			22.23
159	9.6	194.5					20.26
169	6.5	13.2					2.03
179	10.8	108.3	4.3	10.8			25.19
189	14.5	257.8					25.12
199	10.0	251.2					17.78
[illegible]	24.[illegible]	141.[illegible]	6.45	24.[illegible]			[illegible]
219	8.2	101.2	3.3	8.2			30.67
229	26.2	113.6	14.0	24.3	5.8	14.3	18.56
239	32.5	192.5	9.1	39.0			25.38
249	22.0	148.2	8.8	22.9			17.53

Table 2b

1965 Count Limb Selection Random Paths, Cross Secetional Areas, and Expansion Factors

Tree No.	Selected Primary (in^2 CSA)	Comulative Primary	Selected 2nd Stage (in^2 CSA)	Cumulative 2nd Stage	Selected 3rd Stage (in^2 CSA)	Cumulative 3rd Stage	Selected 4th Stage (in^2 CSA)	Cumulative 4th Stage	Selected 5th Stage (in^2 CSA)	Cumulative 5th Stage	Expansion Factor
6	22.5	192.7	11 5	19.5							14.52
16	54.8	154.1	26.0	56.7	7.9	33.6					26.082
26	52.0	123.5	22.0	46.0	6.2	18.4					14.620
36	50.0	157.0	20	46.3	13.0	22.4	7.1	54.1			24.874
46	13.5	67.0	5.2	12.2							11.644
56	64.5	146.5	16.6	93.6	14.2	22.6	8.2	15.7			39.026
66	65.0	106.0	46.0	62	24.0	42.0	15.1	28.1	7.7	15.2	14.130
76	40.0	307.3	15.1	46.2							23.505
86	70.0	256.4	10.0	55.0							20.146
96	12.7	180.1									14.180
106	72.1	202.1	22.5	78.8	12.7	24.1					18.629
116	11.0	22.8	3.7	12.4							6.946
126	40.0	228.0	33.0	44.5	13.5	29.0					16.511
136	7.0	69.0									9.857
146	54.5	143.5	9.0	61.0							17 846
156	64.5	257.7	19.0	57.0							11.986
166	24.0	162.0	20.5	23.5	12.0	21.0					13 541
176	26.5	141.4	8.0	29.1							19.409
186	43.0	86.5	25.0	35.5	6.0	31.5					14.997
196	42.5	192.1	24.0	48.5	11.9	26.2					20.110
206	16.0	51.2	13.6	16.3	8.8	16.4	3.3	9.6			20.790
216	41.0	88.7	20.0	45.7	6.8	17.8					12.940
226	49.0	138.6	37.5	46.8	12.4	37.6					16.543
236	13.0	216.5									16.654
246	15.5	287.6									18.555

Table 3

Derivation of Harvest Counts of Apples, Sample Trees 1963, 1964, 1965

Tree	1963 Harvested weight	1963 Ave. Wt. per apple	1963 Derived Harvest Count	1964 Harvested weight	1964 Ave. wt. per apple	1964 Derived harvest count	Tree	1965 Harvested weight	1965 Ave. wt. per apple	1965 Derived harvest count
9	798	0.2693	2963	911	0.2183	4173	6	600	0.3235	1853
19	840	0.3566	2356	1288	0.2133	6038	16	137	3/ 0.3829	358
29	1218	0.1990	6121	263	0.3233	813	26	580	0.2871	2021
39	504	0.1474	3419	130	0.1895	686	36	734	0.1984	3696
49	1386	0.2458	5639	632	0.2824	2238	46	350	0.3250	932
59	1050	0.2537	4139	1096	0.2204	4977	56	1/ 56	0.4839	2/ 117
69	462	0.2863	1614	389	0.3163	1230	66	94	0.3085	305
79	756	0.2637	2867	648	0.3164	2048	76	128	0.3701	3461
89	840	0.2548	3297	930	0.1794	5184	86	1039	0.3124	3325
99	252	0.1806	1395	521	0.1129	4615	96	389	0.2929	1328
109	420	0.2386	1760	531	0.2508	2117	106	952	0.2970	3205
119	1008	0.4170	2417	2041	0.2249	9075	116	46	0.4474	104
129	1344	0.3020	4450	1297	0.1880	6899	126	857	0.3552	2413
139	714	0.2871	2487	1245	0.2194	5675	136	369	0.3676	1004
149	714	0.3105	2300	1194	0.2787	4284	146	80	0.3761	212
159	966	0.2265	4265	1092	0.2330	4687	156	1039	0.3397	3059
169	1/ 3.0	0.4017	1/ 8	0	0	0	166	346	0.4105	842
179	630	0.4920	1280	520	3/ 0.2626	1980	176	185	0.3371	550
189	1806	0.2458	7347	1101	0.3222	3417	186	434	0.3741	1160
199	798	0.2663	2997	401	0.3266	1228	196	1220	0.2294	5317
209	84	0.2028	414	127	0.5960	213	206	177	0.3080	574
219	630	0.2647	2380	478	0.2686	1780	216	0	0	0
229	840	0.2372	3541	155	0.3399	456	226	600	0.1870	3210
239	882	0.2481	3555	1000	0.2367	4225	236	1283	0.2922	4392
249	756	0.2823	2678	1155	0.2746	4206	246	2120	0.2748	7717
ALL	19,701	0.2603	75689	19146	0.2328	82,244		14968	0.2926	51155

1/ Harvested weight derived by multiplying DHC by WPA.
2/ No harvested production weights recorded.
3/ No apples left on count limb so no apple weights taken. Average weight estimates based upon regression of weight per 1" CSA and weight per apple.

Table 4a

Apple Counts, Expanded Counts, and Derived Harvest Counts, by tree 1963 and 1964

Tree	Forecast count 1/	Pre-Harvest Count	Expanded Forecast Count	Expanded Pre-Harvest Count	Derived Harvest count 2/	Forecast count	Pre-Harvest count	Expanded Forecast count	Expanded Pre-Harvest count	Derived Harvest count
9	428/123(130)	127	918	897	2,963	294	296	2,076	2,090	4,173
19	82	106	1,436	1,857	2,356	307	308	5,379	5,396	6,038
29	346/362(354)	370	7,774	8,125	6,121	7	9	154	198	813
39	148	348	3,033	7,131	3,419	18	19	369	389	686
49	355/359(357)	378	7,893	8,358	5,639	64	69	1,415	1,526	2,238
59	98	147	1,475	2,212	4,139	598	553	9,000	8,323	4,977
69	35	34	828	805	1,614	65	74	1,539	1,752	1,230
79	207	226	2,159	2,357	2,867	130	146	1,356	1,523	2,048
89	261/264(262)	263	4,750	4,768	3,297	448	446	8,122	8,086	5,184
99	33	36	635	693	1,395	278	264	5,352	5,082	4,615
109	165	198	3,326	3,992	1,760	273	296	5,504	5,967	2,117
119	187	312	2,336	3,897	2,417	966	903	12,065	11,278	9,075
129	157	150	2,277	2,175	4,450	587	484	8,512	7,018	6,899
139	34	70	850	1,750	2,487	298	299	7,450	7,475	5,675
149	123	162	2,734	3,601	2,300	212	243	4,713	5,402	4,284
159	183	215	3,708	4,356	4,265	200	179	4,052	3,627	4,687
169	5	4	10	8	8	274	0	556	0	0
179	146	25	3,678	630	1,280	1	0	25	0	1,980
189	213	176	3,787	3,129	7,347	44	38	782	676	3,417
199	290	255	7,285	6,406	2,997	63	64	1,583	1,608	1,228
209	1	0	21	0	414	13	13	280	280	213
219	21	17	644	521	2,380	38	35	1,167	1,073	1,780
229	178	211	3,304	3,916	3,541	51	40	947	742	456
239	132	233	3,350	5,914	3,555	329	316	8,350	8,020	4,225
249	319	293	5,592	5,136	2,678	366	347	6,416	6,083	4,206
ALL			73,803	82,634	75,689			97,162	93,614	82,244

1/ Where two counts are shown, no reconciliation was made. Counts in parenthases were expanded.
2/ See Table 3 for derivation of Harwest Counts.

Table 4b

Apple Counts, Expanded Counts, and Derived Harvest Counts, by tree 1965

Tree	Forecast count 1/	Pre-Harvest Count	Expanded Forecast Count	Expanded Pre-Harvest Count	Derived Harvest Count
6	16	17	232	247	1,853
16	0	0	0	0	358
26	125/131(128)	100	1,887	1,474	2,021
36	183	149	5,546	3,705	3,696
46	22	24	314	279	932
56	8/ 10(9)	3	312	117	117
66	74/107(91)	117	1,893	1,653	305
76	159/185(172)	184	5,194	4,324	3,461
86	165/182(174)	151	3,667	3,043	3,325
96	18/ 21(20)	14	298	199	1,328
106	309/336(323)	267	6,260	4,974	3,205
116	20	19	139	132	104
126	146/163(155)	154	2,691	2,543	2,413
136	26/ 28(27)	34	276	355	1,004
146	33/ 34(34)	22	607	393	212
156	83/ 93(86)	78	1,247	935	3,059
166	36/ 40(30)	19	542	257	842
176	71/ 72(72)	80	1,398	1,553	550
186	126/153(140)	108	2,055	1,620	1,160
196	389/405(397)	402	8,145	8,084	5,317
206	47/ 53(50)	58	1,102	1,204	574
216	2	0	26	0	0
226	409/443(426)	307	6,898	4,780	3,210
236	223/228(226)	282	4,995	4,695	4,392
246	400/435(418)	536	8,074	9,948	7,717
ALL			63,798	56,494	51,155

1/ Where two counts are shown, no reconciliation was made. Counts in parenthases were expanded.

2/ See Table for derivation of Harvest Counts.

Table 4c

Cross Sectional Areas of Sample Limbs with Associated Counts and Weights of Apples, 1963-1965

1963-1964 Sample Tree	Stage	Count limb GSA sq. inches	1963 July count 1/	1963 Harvest count	1963 Harvest weight lbs.	1964 July count	1964 Harvest count	1964 Harvest weight lbs.	1965 Sample tree	1965 Count limb CSA sq. inches	1965 July count 1/	1965 Varification Count 2/	1965 Harvest count	1965 Harvest weight (lbs.)
9	2	9.6	130	127	34.1	294	296	64.4	6	11.5	16	---	17	5.5
19	1	14.5	82	106	37.8	307	308	65.7	16	7.9	0	---	0	0
29	2	13.7	354	370	73.3	7	9	2.6	26	6.25	108	128	100	28.6
39	3	7.6	148	348	51.3	18	19	3.6	36	7.1	183	223	149	29.6
49	2	13.0	357	378	93.3	64	69	19.8	46	5.2	22	27	24	9.0
59	2	15.6	98	147	37.3	598	53	121.9	56	8.2	9	8	3	1.5
69	2	2.1	35	34	10.1	65	74	24.4	66	7.7	91	134	117	36.1
79	2	15.1	207	226	59.6	130	146	46.2	76	15.1	172	221	184	68.1
89	3	8.5	263	263	67.6	448	446	79.3	86	10.0	174	---	151	47.6
99	2	7.0	33	36	6.5	278	264	29.8	96	12.7	20	---	14	4.1
109	2	9.1	165	198	48.4	273	296	75.9	106	12.7	323	---	267	79.3
119	2	20.5	187	312	130.1	966	903	203.1	116	3.7	20	---	19	8.8
129	2	11.7	157	150	45.8	587	484	90.9	126	13.5	155	---	154	54.7
139	2	9.0	34	70	20.1	298	299	65.6	136	7.0	27	---	34	12.5
149	2	9.3	123	162	51.8	212	243	68.3	146	9.0	34	---	22	8.1
159	1	9.6	183	215	48.7	200	179	41.7	156	19.0	86	104	78	26.5
169	1	6.5	5	4	1.6	274	0	0	166	12.0	38	---	19	7.8
179	2	4.3	146	25	12.3	1	0	0	176	8.0	72	---	80	26.5
189	1	14.5	213	176	41.4	44	38	12.2	186	6.0	140	137	108	40.4
199	1	10.0	290	255	67.9	63	64	20.9	196	11.9	397	---	402	92.2
209	2	6.4	1	0	0	13	13	1.2	206	3.3	50	---	58	17.7
219	2	3.3	21	17	4.5	38	35	9.4	216	6.8	2	---	0	0
229	3	5.8	178	211	49.8	51	40	13.6	226	5.5	426	---	307	57.4
239	2	9.1	132	233	57.8	329	316	74.8	236	13.0	226	300	282	83.0
249	2	8.8	319	293	84.4	366	347	96.6	246	15.5	418	---	536	147.3

1/ Where two counts are shown there is nonreconcilation of counts

2/ Varification counts made on 1/15/65 by segmenting count limbs into small count units except for trees #26 and 56 for which recounts were made 7/19/65.

Table 5
Number of Apples Measured by Survey Date and Tree, 1963, 1964, 1965

Tree	1963					Tree	1964					Tree	1965				
	June 26	Aug. 1	Aug. 29	Sept. 27	Harvest Oct. 8		June 29	July 31	Sept. 2	Sept. 25	Harvest Oct. 14		June 29	July 30	Aug. 31	Oct. 6	Harvest Oct. 21
9	18	17	17	12	12	9	10	10	10	9	9	(26)3	12	11	9	8	8
29	16	14	11	10	10	29	17	17	17	17	15	(56)6	3	3	2	2	2
49	20	16	14	11	11	49	14	14	14	14	13	(86)9	15	14	12	11	9
69	22	20	20	20	15	69	18	16	14	13	13	(116)12	12	11	11	9	9
89	25	18	18	17	16	89	17	17	16	14	13	(146)15	15	12	10	9	8
104	22	19	13	13	10	109	16	16	16	15	15	(176)18	8	7	7	7	6
129	19	16	13	13	13	129	20	19	17	16	16	(206)21	15	12	10	7	7
149	20	17	18	16	16	149	20	20	18	15	15	(236)24	15	15	15	15	14
169	11	9	4	5	3	169	26	21	18	13	0						
189	20	18	17	15	14	189	24	24	24	24	22						
209	16	12	11	9	8	209	15	15	14	13	11						
229	21	20	18	18	18	229	15	15	13	11	11						
249	25	23	22	21	18	249	32	33	32	32	32						
Total	255	219	196	180	164	**Total**	244	237	223	206	185	**Total**	95	85	76	68	63

Table 6a

Tree	ALL APPLES MEASURED					APPLES REAMINING AT HARVEST 1/					
	June 26	Aug. 1	Aug. 29	Sept. 27	Harvest Oct. 8	June 26	Aug. 1	Aug. 29	Sept. 27	Harvest Oct. 8	Derived Harvest Count
9	1.60	2.11	2.41	2.65	2.61	1.65	2.15	2.42	2.62	2.64	2963
29	1.47	1.95	2.23	2.40	2.49	1.47	1.95	2.23	2.42	2.48	6121
49	1.40	1.86	2.12	2.38	2.39	1.47	1.90	2.17	2.35	2.38	5639
69	1.46	1.99	2.33	2.52	2.54	1.47	1.98	2.31	2.49	2.54	1614
89	1.44	1.96	2.17	2.36	2.43	1.43	1.95	2.21	2.39	2.43	3297
109	1.24	1.64	1.91	2.10	2.10	1.26	1.63	1.90	2.07	2.10	1760
129	1.59	2.13	2.42	2.58	2.63	1.61	2.15	2.43	2.69	2.64	4450
149	1.37	1.88	2.18	2.33	2.37	1.38	1.86	2.15	2.32	2.36	2300
169	1.55	2.29	2.73	2.93	3.00	1.56	2.33	2.80	2.96	2.98	8
189	1.61	2.22	2.59	2.78	2.88	1.63	2.26	2.64	2.83	2.88	7347
209	1.27	1.82	2.11	2.28	2.31	1.26	1.79	2.07	2.27	2.31	414
229	1.54	2.04	2.37	2.55	2.62	1.53	2.05	2.37	2.55	2.62	3541
249	1.52	1.96	2.23	2.39	2.52	1.55	2.00	2.30	2.49	2.53	2678
Σxi =	19.05	25.85	29.80	32.25	32.89	19.17	26.00	30.00	32.36	32.89	42132
					Simple Average						
x̄	1.47	1.99	2.29	2.48	2.53	1.48	2.00	2.31	2.49	2.53	
					Weighed Average						
ΣfiXi =	63,036.84	84,593.76	97,093.27	105169.36	107579.38	63,334.00	85,338.64	98,001.16	105728.66	107598.79	
WIX̄	1.50	2.01	2.30	2.50	2.55	1.50	2.03	2.33	2.51	2.55	

1/ Apples for which there were reports each time.

Table 6b

1964--Virginia Apple Counts Survey (Summary)

Tree	ALL APPLES MEASURED					APPLES REMAINING AT HARVEST					Derived No. of Apples
	June 30	July 31	Sept. 2	Sept. 25	Harvest Oct. 14	June 30	July 31	Sept. 2	Sept. 25	Harvest Oct. 14	
9	1.455	1.968	2.352	2.487	2.521	1.439	1.950	2.331	2.487	2.521	4173
29	1.486	2.166	2.592	2.721	2.767	1.507	2.193	2.616	2.744	2.767	813
49	1.426	2.002	2.381	2.533	2 569	1.416	1.996	2.378	2.475	2.569	2238
69	1.485	1.984	2.360	2.475	2.507	1 482	2.004	2.360	2.472	2.507	1230
89	1.416	1.954	2.319	2.436	2.441	1.429	1.972	2 306	2.422	2.441	5184
109	1.123	1.634	1.946	2.056	2.080	1.125	1.635	1.948	2.056	2.080	2117
129	1.440	1.934	2.217	2.342	2.388	1.436	1.928	2 088	2.342	2.388	6899
149	1.474	2.048	2.363	2.468	2.512	1.473	2.042	2.352	2.471	2.512	4284
169	1.156	1.555	1.672	1.691	---	1.154	1.561	1.671	1.691	---	556
189	1.558	2.193	2.570	2.725	2.820	1.564	2.215	2.605	2.764	2 820	3417
209	1.308	1.848	2.156	2.317	2.388	1.363	1.912	2.246	2.380	2.388	213
229	1.559	2.206	2.605	2.811	2 852	1.554	2.200	2.631	2.804	2.852	456
249	1.477	1.999	2.313	2.421	2.462	1.473	1.994	2.313	2.421	2.462	4206
$\Sigma xi=$	18.363	25.491	29.846	31.483	30.307	18.415	25.602	29.845	31.529	30.307	35786
	Simple Average										
$\bar{x}$	1.413	1.961	2.296	2.422	2.526	1.417	1.919	2.296	2.425	2.526	
	Weighed Average										
$\Sigma fiXi=$	51433.074	70,764.645	82800.131	87,224,258	87,696.728	51409.036	70319.361	81,875.108	87,193.229	87,696.728	
$(w)\bar{x}=$	1.44	1.98	2.31	2.44	2.49	1.44	1.98	2.29	2.44	2.49	

$\Sigma fi=35,230$ (All apples measured)

$\Sigma fi=35,230$ (Apples remaining at harvest)

Table 6c

1965--Virginia Apple Counts Survey (Summary)

Tree	ALL APPLES MEASURED					APPLES REMAINING AT HARVEST					Derived
	June 29	July 30	Aug. 31	Oct. 6	Harvest Oct. 21	June 29	July 30	Aug. 31	Oct. 6	Harvest Oct. 21	No. of Apples
26	1.478	1.965	2.422	2.706	2.728	1.512	2.019	2.454	2.706	2.728	2021
56	1.807	2.337	2.320	2.740	3.030	1.795	2.320	2.740	2.990	3.030	117
86	1.562	1.945	2.350	2.527	2.601	1.588	1.989	2.357	2.552	2.601	3325
116	1.713	2.293	2.717	2.906	2.913	1.698	2.281	2.707	2.906	2.913	104
146	2.684	2.303	2.749	2.971	2.963	1.699	2.259	2.751	2.945	2.963	212
176	1.549	2.106	2.527	2.734	2.918	1.578	2.140	2.625	2.875	2.918	550
206	1.674	2.161	2.582	2.730	2.770	1.613	2.080	2.529	2.730	2.770	574
236	1.533	1.931	2.271	2.468	2.563	1.539	1.946	2.308	2.514	2.563	4392
$\Sigma xi=$	13.000	17.041	19.938		22.486	13.022	17.034	20.471	22.218	22.486	11295
					Simple Average						
$\bar{x}=$	1.625	2.130	2.492	2.723	2.811	1.628	2.129	2.559	2.777	2.811	
					Weighed Average by derived apple number per tree						
$\Sigma fixi=$	17,473.029	22,318.193	26,691.558	29,033.938	29898.807	17635.697	22,599.148	27,014.011	29,420.378	29,898.807	
$\frac{\Sigma fx}{\Sigma f}=$	1.55	1.98	2.36	2.57	2.65	1.56	2.00	2.39	2.60	2.65	

Table 7a

Size Distribution of Apple Diameters for each Survey Data 1/

Diameter Size	June 26	Aug. 1	Aug. 29	Sept. 27	Pre-Harvest Oct. 8
0.90-0.99					
1.00-1.09	2				
1.10-1.19	11				
1.20-1.29	31				
1.30-1.39	43	2			
1.40-1.49	39	4			
1.50-1.59	70	10	3		
1.60-1.69	43	7	3	3	1
1.70-1.79	13	20	6	0	2
1.80-1.89	3	30	7	7	4
1.90-1.99		35	12	5	3
2.00-2.09		36	22	6	6
2.10-2.19		42	16	13	8
2.20-2.29		15	23	21	19
2.30-2.39		15	26	14	12
2.40-2.49		3	28	17	12
2.50-2.59			33	21	21
2.60-2.69			7	29	21
2.70-2.79			7	26	25
2.80-2.89			2	9	15
2.90-2.99			1	7	10
3.00-3.09				1	3
3.10-3.19				1	1
3.20-3.29					1
3.30-3.39					
3.40-3.49					
Total Apples	255	219	196	180	164

1/ All apples measured

Table 7b
Size Distribution of Apple Diameter for each Survey Data 1/

Diameter Size	June 29	July 31	Sept. 2	Sept. 25	Per-Harvest Oct. 14
0.80-0.89	1				
0.90-0.99	3				
1.00-1.09	9				
1.10-1.19	17				
1.20-1.29	26				
1.30-1.39	34	3			
1.40-1.49	64	7	1	1	
1.50-1.59	63	10	5	3	
1.60-1.69	21	15	7	7	
1.70-1.79	6	17	12	4	4
1.80-1.89		25	8	8	4
1.90-1.99		41	8	3	3
2.00-2.09		38	7	9	6
2.10-2.19		42	16	6	6
2.20-2.29		21	28	14	12
2.30-2.39		14	27	23	18
2.40-2.49		4	38	22	25
2.50-2.59			33	28	28
2.60-2.69			21	28	24
2.70-2.79			6	25	25
2.80-2.89			6	18	17
2.90-2.99				4	8
3.00-3.09				3	4
3.10-3.19					1
3.20-3.29					
Total apples	244	237	223	206	185

1/ All apples measured.

Table 7c

Size Distribution of Diameters for each Survey Date

Diameter Size	June 29	July 19	July 30	Aug. 31	Oct. 6	Pre-Harvest Oct. 21
0.09-0.99						
1.00-1.09						
1.10-1.19						
1.20-1.29	3					
1.30-3.39	2					
1.40-4.39	12					
1.50-1.59	24	2				
1.60-1.69	31	6	1			
1.70-1.79	15	3	5	1		
1.80-1.89	8	24	4	0	2	
1.90-1.99		17	22	1	0	
2.00-2.09		13	8	1	0	
2.10-2.19		9	17	8	1	
2.20-2.29		10	9	4	3	2
2.30-2.39		2	10	13	3	3
2.40-2.49			8	9	5	3
2.50-2.59			11	11	10	7
2.60-2.69				9	6	12
2.70-2.79				8	12	7
2.80-2.89				7	10	10
2.90-2.99				4	6	10
3.00-3.09					3	3
3.10-3.19					5	4
3.20-3.29					2	1
3.30-3.39						1
3.40-3.49						
3.50-3.59						
Total apples	95	86	85	76	68	63

Table 8a

Apples Harvested per 1" CSA for each tree

Tree	Harvested apples per 1" CSA (tree) 1/	Pre-Harvest apples per 1" CSA (Ct. Limb) 2/	DAILY DIAMETER GROWTH RATE PER APPLE: 6-26 to 8-1, 36 days	8-1 to 8-29, 28 days	8-29 to 9-27, 29 days	9-27 to 10-8, 11 days	6-26 to 10-8, 104 days	8-1 to 10-8, 69 days	8-29 to 10-8, 40 days
9	14.7120	13.2292	.0139	.0096	.0069	.0018	.0095	.0071	.0055
29	27.7778	27.0073	.0133	.0100	.0066	.0055	.0097	.0077	.0062
49	20.9974	29.0769	.0147	.0096	.0062	.0027	.0097	.0070	.0052
69	25.7393	16.1905	.0142	.0118	.0062	.0045	.0103	.0081	.0058
89	26.6210	30.9412	.0144	.0093	.0062	.0036	.0096	.0070	.0055
109	11.5310	21.7582	.0103	.0096	.0059	.0027	.0081	.0068	.0050
129	24.8245	12.8205	.0150	.0100	.0059	.0036	.0099	.0071	.0052
149	11.5183	17.4194	.0133	.0104	.0059	.0036	.0094	.0072	.0052
169	.6061	0.6154	.0214	.0168	.0055	.0018	.0137	.0094	.0045
189	28.9294	12.1379	.0175	.0136	.0066	.0045	.0120	.0090	.0060
209	2.9237	0	.0147	.0100	.0069	.0036	.0101	.0075	.0060
229	31.1776	36.3793	.0144	.0114	.0062	.0064	.0105	.0083	.0062
249	18.2119	33.2955	.0125	.0107	.0066	.0036	.0094	.0077	.0062
	Y_1	Y_2	X_1	X_2	X_3	X_4	X_5	X_6	X_7

Sample Correlation Coefficients

	X_1	X_2	X_3	X_4	X_5	X_6	X_7
Apples per 1" CSA (Tree)	-.225397	-.263931	+.178457	+.704762	-.175880	-.0346804	+.549524
Apples per 1" CSA (Count Limb)	-.542125	-.458451	+.0490273	+.465432	-.495923	-.323755	+.394922

1/ Total derived apple prod. number divided by cumulative primaries on each tree.
2/ Pre-Harvest count of apples divided by CSA for the sample limb for each tree.

Table 8b

Apples Harvested per 1" CSA for each tree

Tree	Apples per 1" CSA (Tree) 1/	Apples per 1" CSA (Ct. Limb) 2/	LY DIAMETER GROWTH RATE PER APPLE						
			6-30 to 7-31	7-31 to 9-2	9-2 to 9-25	9-25 to 10-14	6-30 to 10-14	7-31 to 10-14	9-2 to 10-14
			31 days	33 days	23 days	19 days	106 days	75 days	42 days
9	20.7299	30.8333	.0165	.0115	.0068	.0018	.0102	.0076	.0045
29	3.8776	.6569	.0221	.0128	.0056	.0012	.0119	.0077	.0036
49	8.3402	5.3077	.0187	.0116	.0042	.0028	.0109	.0076	.0045
69	19.8092	35.2381	.0168	.0108	.0049	.0018	.0097	.0067	.0035
89	41.9032	52.4706	.0175	.0101	.0050	.0010	.0095	.0063	.0032
109	13.9083	32.5275	.0165	.0095	.0047	.0013	.0090	.0059	.0031
129	38.4345	41.3675	.0159	.0048	.0110	.0024	.0090	.0061	.0070
149	21.2166	26.1290	.0184	.0094	.0052	.0022	.0098	.0063	.0038
169	0	0	.0131	.0033	.0009	---	---	---	---
189	13.2545	2.6207	.0210	.0118	.0069	.0029	.0118	.0081	.0051
209	7.2246	2.0312	.0177	.0101	.0058	.0004	.0097	.0063	.0034
229	4.0141	6.8966	.0208	.0131	.0075	.0025	.0122	.0087	.0053
249	28.4615	39.4318	.0168	.0097	.0047	.0022	.0093	.0062	.0035
	Y_1	Y_1	X_1	X_2	X_3	X_4	X_5	X_6	X_7
			Sample Correlation Coefficients						
Apples per 1" CSA (Tree)			-.64159	-.70154	+.25940	-.00787	-.677295	-.595561	+.155615
Apples per 1" CSA (Count Limb)			-.76676	-.59810	+.05673	-.11615	-.773036	-.656295	-.071404

1/ Total derived apple prod. numbers divided by cumulative primaries on each tree.
2/ Pre-Harvest count of apples divided by CSA for the sample limb for each tree.

Table 8c

Apples Harvested per 1" CSA for each tree

Tree	Apples per 1" CSA (Tree) 1/	Apples per 1" CSA (Ct. Limb) 2/	DAILY DIAMETER GROWTH RATE PER APPLE						
			6-29 to 7-30	7-30 to 8-31	8-31 to 10-6	10-6 to 10-21	6-29 to 10-21	7-30 to 10-21	8-31 to 10-21
			31 days	32 days	36 days	15 days	144 days	38 days	51 days
26	16.4291	16.0000	.0164	.0136	.0060	.0039	.0107	.0085	.0054
56	0.799	0.3659	.0169	.0131	.0069	.0027	.0108	.0086	.0057
86	12.8510	15.1000	.0128	.0115	.0054	.0033	.0089	.0074	.0048
116	4.3860	5.1351	.0188	.0133	.0055	.0005	.0107	.0076	.0040
146	1.5122	2.4444	.0181	.0154	.0054	.0012	.0111	.0085	.0042
176	3.9533	10.0000	.0181	.0152	.0069	.0029	.0118	.0094	.0057
206	11.3086	17.5758	.0151	.0140	.0056	.0030	.0101	.0083	.0047
236	20.1386	21.6923	.0131	.0113	.0057	.0033	.0090	.0074	.0050
	Y_1	Y_2	X_1	X_2	X_3	X_4	X_5	X_6	X_7

Correlation Coefficients

	X_1	X_2	X_3	X_4	X_5	X_6	X_7
Apples per 1" CSA (Tree)	-.76437	-.62693	-.38280	+.65066	-.71285	-.51461	+.06600
Apples per 1" CSA (Count Limb)	-.75561	-.49653	-.31131	+.67783	-.64047	-.37324	+.10893

1/ Total derived apple prod. numbers divided by cumulative primaries on each tree.
2/ Pre-Harvest count of apples divided by CSA for the sample tree for each tree.

Table 9a
1963 Average Weight Per Apple (Tag Limb) by Diameter Class by Tree (1 gm. = .0022046 lbs.)

Tree	Less 2.00		2.00-2.24		2.25-2.49		2.50-2.74		2.75-2.99		3.00 +		All Classes	
	No. of apples	Weight per apple (lbs.)	No. of apples	Weight per apple (lbs.)	No. of apples	Weight per apple (lbs.)	No. of apples	Weight per apple (lbs.)	No. of apples	Weight per apple (lbs.)	No. of apples	Weight per apple (lbs.)	No. of apples	Weight per apple (lbs.)
9	0		3	0.1396	0		5	0.2707	3	0.3836	1	0.4123	12	0.2780
29	0		1	0.1543	3	0.1874	5	0.2452	1	0.3638	0		10	0.2306
49	1	0.0904	0		4	0.1775	5	0.2469	1	0.2888	0		11	0.2112
69	2	0.9015	0		4	0.2143	6	0.2859	5	0.3457	0		17	0.2637
89	1	0.1190	4	0.1451	2	0.1918	7	0.2588	2	0.2976	0		16	0.2180
109	3	0.0910	6	0.1550	4	0.1885	0		0		0		13	0.1506
129	0		1	0.1301	2	0.1786	7	0.2758	4	0.3289	0		14	0.2668
149	3	0.1074	3	0.1404	4	0.2165	4	0.2888	2	0.3395	0		16	0.2152
169	0		0		0		0		2	0.3649	2	0.4431	4	0.4039
189	0		0		0		3	0.2961	10	0.3635	2	0.5082	15	0.3693
209	1	0.0992	0		5	0.2059	2	0.2458	0		0		8	0.2026
229	0		1	0.1367	4	0.1900	7	0.2507	6	0.3120	0		18	0.2513
249	2	0.0772	3	0.1396	7	0.1920	9	0.2546	1	0.3241	0		22	0.2050
Total	13	0.0955	22	0.1451	39	0.1955	60	0.2639	37	0.3428	5	0.4630	176	0.2436

Table 9b
1964 Average Weight per Apple (Tag Limb) by Diameter Class by Tree (1 gm. = .0022046 lbs.)

Tree	Less 2.00		2.00-2.24		2.25-2.49		2.50-2.74		2.75-2.99		3.00 +		All Classes	
	No. of apples	Weight per apple (lb.s)	No. of apples	Weight per apple (lbs.)	No. of apples	Weight per apple (lbs.)	No. of apples	Weight per apple (lbs.)	No. Of apples	Weight per apple (lbs.)	No. of apples	Weight per apple (lbs.)	No. of apples	Weight per apple (lbs.)
9	0	---	0	---	4	0.2067	4	.2590	1	0.2954	0	---	9	0.2398
29	0	---	0	---	0	---	4	.2921	11	0.3642	0	---	15	0.3449
49	0	---	0	---	3	0.2315	10	.2670	0	---	0	---	13	0.2588
69	1	0.1102	0	---	6	0.2201	6	.2833	0	---	0	---	13	0.2408
89	1	0.1036	2	0.1466	3	0.2589	6	.2579	1	0.3219	0	---	13	0.2340
109	4	0.0816	5	0.1349	6	0.1870	0	---	0	---	0	---	15	0.1415
129	1	0.0728	2	0.1543	8	0.1904	5	.2421	0	---	0	---	16	0.1947
149	1	0.0860	3	0.1543	2	0.2050	6	.2748	2	0.3164	1	0.3704	15	0.2407
169	0	---	0	---	0	---	0	---	0	---	0	---	0	---
189	0	---	0	---	0	---	8	.2792	10	0.3280	4	0.4012	22	0.3236
209	1	0.0948	3	0.1529	2	0.2238	4	.2436	1	0.3351	0	---	11	0.2100
229	0	---	0	---	0	---	2	.2568	8	0.3467	1	0.4365	11	0.3385
249	2	0.1047	3	0.1360	14	0.1989	8	.2770	5	0.3519	0	---	32	0.2305
Total	11	455 0.0912	18	1182 0.1448	48	0.2064	63	.2685	39	0.3437	6	0.4020	185	0.2500

1/ No apples left on tree; probably won't be harvested.

Table 9c

1965 Average Weight Per Apple (Tag Limb) by Diameter Class by Tree (1 gm. = .0022046 lbs.)

Tree	2.00-2.24		2.24-2.49		2.50-2.74		2.75-2.99		3.00-3.24		3.25 +		All Classes	
	No. of apples	Weight per apple (lbs.)	No. of apples	weight per apple (lbs.)	No. of apples	Weight per apple (lbs.)	No. of apples	Weight per apple (lbs.)	No. of apples	Weight per apple (lbs.)	No. of apples	Weight per apple (lbs.)	No. of apples	Weight per apple (lbs.)
26	0	---	0	---	5	0.2698	3	0.3527	0	---	0	---	8	.3009
56	0	---	0	---	0	---	1	0.4012	1	0.5181	0	---	2	.4597
86	0	---	1	0.1918	7	0.2661	1	0.3329	0	---	0	---	9	.2653
116	0	---	0	---	2	0.2976	4	0.4354	3	0.4630	0	---	9	.4140
146	0	---	0	---	1	0.2954	5	0.3902	2	0.4674	0	---	8	.3977
176	0	---	0	---	2	0.2932	2	0.4310	1	0.5291	1	0.5159	6	.4156
206	0	---	1	0.2161	2	0.3042	3	0.3432	0	---	1	0.4630	7	.3310
236	2	0.1698	4	0.2122	5	0.2712	3	0.3153	0	---	0	---	14	.2493
		154		570		3018		3775		1529		444		.9490
Total	2	0.1698	6	0.2097	24	0.2772	22	0.3783	7	0.4815	2	0.4894	63	.3321

Table 10a

Calculation of Weighed Average Harvest Weight Per Apple, by tree, 1963

Tree	Cumulative CSA (in)^2	Harvest Wt. Per Tree (lbs.)	Wt. of apples per 1"CSA tree(lbs.)	No. of apples weighed	Total Wt. of apples (lbs.)	Av. Wt. per apples (lbs.)	No. of apples weighed	Total Wt. of apples	Av. Wt. per apple	Weighed average (Weight per apple) (Ct. & Tag Limb)
9	201.40	798	3.962	127	34.1	0.2685	12	3.3	0.2780	0.2693
19	254.10	840	3.306	106	37.8	0.3566				0.3566
29	220.50	1218	5.524	370	73.3	0.1989	10	2.3	0.2306	0 1990
39	139.50	504	3.613	348	51.3	0.1474				0.1474
49	268.70	1386	5.158	378	93.3	0.2468	11	2.3	0.2112	0.2458
59	205.60	1050	5.107	147	37.3	0.2537				0.2537
69	62.90	462	7.345	34	10.1	0.2971	17	4.5	0.2637	0.2863
79	117.10	756	6.456	226	59.6	0.2537				0.2637
89	124.00	840	6.774	263	67.6	0.2570	16	3.5	0.2180	0.2548
99	152.20	252	1.656	36	6.5	0.1806				0.1806
109	154.80	420	2.713	198	48.4	0.2444	13	1.9	0.1506	0.2386
119	222.80	1008	4.524	312	130.1	0.4160				0.4170
129	179.50	1344	7.487	150	45.8	0.3053	14	3.7	0.2668	0.3020
139	214.00	714	3.336	70	20.1	0.2871				0.2871
149	202.20	714	3.531	162	51.8	0.3198	16	3.5	0.2152	0.3105
159	194.50	966	4.967	215	48.7	0.2265				0.2265
169	13.20	0	0.000	4	1.6	0.4000	4	1.6	0.4039	0.4017
179	108.30	630	5.817	25	12.3	0.4920				0.4920
189	257.80	1806	7.005	176	41.4	0.2352	15	5.6	0.3693	0.2458
199	251.20	798	3.177	255	67.9	0.2663				0.2663
209	141.60	84	0.593	0	0	---	8	1.6	0.2028	0.2028
219	101.20	630	6.225	17	4.5	0.2647				0.2647
229	113.60	840	7.394	211	49.8	0.2360	18	4.5	0.2513	0.2372
239	192.50	882	4.582	233	57.8	0 2481				0.2481
249	148.20	756	5.101	293	84.4	0.2881	22	4.5	0.2050	0.2823

Table 10b
Calculation of Weighed Average Harvest Weight Per Apple, by tree, 1964

Tree	Cumulative CSA (in)^2	Harvest wt. per tree (lbs.)	Wt. of apples per 1" CSA tree (lbs.)	No. of apples	Total wt. of apples (lbs.)	Av. wt. per apple	No. of apples weighed	Total wt. of apples (lbs.)	Av. wt. per apple	Weighed average (weight per apple) (Ct. & Tag Limb)
9	201.40	911	4.523	296	64.4	0.2176	9	2.2	0.2398	0.2183
19	254.10	1288	5.069	308	65.7	0.2133				0.2133
29	220.50	263	1.193	9	2.6	0.2889	15	5.2	0.3449	0.3233
39	139.50	130	0.932	19	3.6	0.1895				0.1895
49	268.70	632	2.352	69	19.8	0.2870	13	3.4	0.2588	0.2824
59	205.60	1097	5.336	553	121.9	0.2204				0.2204
69	62.90	389	6.184	74	24.4	0.3297	13	3.1	0.2408	0.3163
79	117.10	648	5.534	146	46.2	0.3164				0.3164
89	124.00	930	7.500	446	79.3	0.1778	13	3.0	0.2340	0.1794
99	152.20	521	3.423	264	29.8	0.1129				0.1129
109	154.80	531	3.430	296	75.9	0.2564	14	2.1	0.1415	0.2508
119	222.80	2041	9.161	903	203.1	0.2249				0.2249
129	179.50	1297	7.226	484	90.0	0.1878	16	3.1	0.1947	0.1880
139	214.00	1245	5.818	299	65.6	0.2194				0.2194
149	202.20	1194	5.905	243	68.3	0.2811	15	3.6	0.2407	0.2787
159	194.50	1092	5.614	179	41.7	0.2330				0.2330
169	13.20	0	0.000	0	0	---	0	---	----	----
179	108.30	520	4.801	0	0	---				1/ 0.2626
189	257.80	1101	4.271	38	12.2	0.3211	22	7.1	0.3236	0.3222
199	251.20	401	1.596	64	20.9	0.3266				0.3266
209	141.60	127	0.897	13	1.2	0.9231	11	2.3	0.2100	0.5960
219	101.20	478	4.723	35	9.4	0.2686				0.2686
229	113.60	155	1.364	40	13.6	0.3400	11	3.7	0.3385	0.3399
239	192.50	1000	5.195	316	74.8	0.2367				0.2367
249	148.20	1155	7.794	347	96.6	0.2784	32	7.2	0.2305	0.2746

1/ Derived through regression analysis of the (wt.) average wt. per apple (ct. and tag) on wt. of apples per 1" CSA.

Table 10c
Calculation of Weighed Average Harvest Weight Per Apple, by tree, 1965

Tree	Cumulative CSA $(in)^2$	Harvest wt. per tree (lbs.)	Wt. of apples per 1" CSA tree (lbs.)	No. of apples weighed	Total Wt. of apples (lbs.)	Av. Wt. per apple	No. of apples weighed	Total wt. of apples (lbs.)	Av. wt. per apple	Weighed Average (Weight per apple) (Ct. & Tag Limb)
6	192.70	599.50	3.111	17	5.5	0.3235				0.3235
16	154.10	137.00	0.889	0	0.0	----				2/ 0.3642
26	123.50	580.25	4.698	100	28.6	0.2860	8	2.4	0.3009	0.2871
36	157.00	734.34	4.677	149	29.6	0.1987				0.1987
46	67.00	349.50	5.216	24	9.0	0.3750				0.3750
56	146.50	0	0.000	3	1.5	0.5000	2	0.9	0.4597	0.4839
66	106.00	94.00	0.887	117	36.1	0.3025				0.3085
76	307.30	1280.75	4.168	184	68.1	0.3701				0.3701
86	256.40	1038.75	4.051	151	47.6	0.3152	9	2.4	0.2653	0.3124
96	180.10	388.98	2.160	14	4.1	0.2929				0.2929
106	202.10	952.00	4.711	267	79.3	0.2970				0.2970
116	22.80	46.50	2.039	19	8.8	0.4632	9	3.7	0.4140	0.4474
126	228.00	857.00	3.759	154	54.7	0.3552				0.3552
136	69.00	369.00	5.348	34	12.5	0.3676				0.3676
146	143.50	79.75	0.556	22	8.1	0.3682	8	3.2	0.3977	0.3761
156	257.70	1039.00	4.032	78	26.5	0.3397				0.3391
166	162.00	345.76	2.134	19	7.8	0.4105				0.4105
176	141.40	185.25	1.310	80	26.5	0.3312	6	2.5	0.4156	0.3371
186	86.50	434.00	5.017	108	40.4	0.3741				0.3741
196	192.10	1219.75	6.350	402	92.2	0.2294				0.2294
206	51.20	176.75	3.452	58	17.7	0.3052	7	2.3	0.3310	0.3080
216	88.70	0	0.000	0	0	----				2/ ----
226	138.60	600.25	4.331	307	57.4	0.1870				0.1870
236	126.50	1283.25	5.927	282	83.0	0.2943	14	3.5	0.2493	0.2922
246	287.60	2120.50	7.373	536	147.3	0.2748				0.2748
				$\Sigma fi=715$		$\Sigma fi=63$				

1/ Derived from a regression of average wt. per apple (ct. and tag limb) on weight of apples per 1" CSA (tree).

Table 11
Comparison of Expansions of Count Limb Weights, Tree Production Weights, and Actual Production, 1963, 1964, 1965

Year	No. of trees weighed	Expanded weights from count limbs (pounds)	Average weight per tree (pounds)	Harvest weight for sample trees (pounds)	Orchard Prod. from count limb weights (2) x Ten (pounds)	Orchard Prod. from Harvested tree weights (4) x Ten (pounds)	Orchard Prod. from Boxes Picked at commercial Harvest (Boxes)	Harvest of drops (Boxes)	Total Orchard Prod. (Boxes)	Picked prod. converted to lbs. @ 43.22 (pounds)	Total prod. converted to lbs. @ 43.22 (pounds)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1963	25	21,065.288	842.612	19,701	210,653	197,010	4,287	0	4,287	185,284	185,284
1964	25	21,368.070	854.723	19,146	213,681	191,460	3,920	504	4,424	169,422	191,205
1965	25	16,065.385	642.615	14,968	160,654	149,680	4,573	0	4,573	197,645	197,645

Chart I: Increase in Apple Diameters by Days After Full Bloom

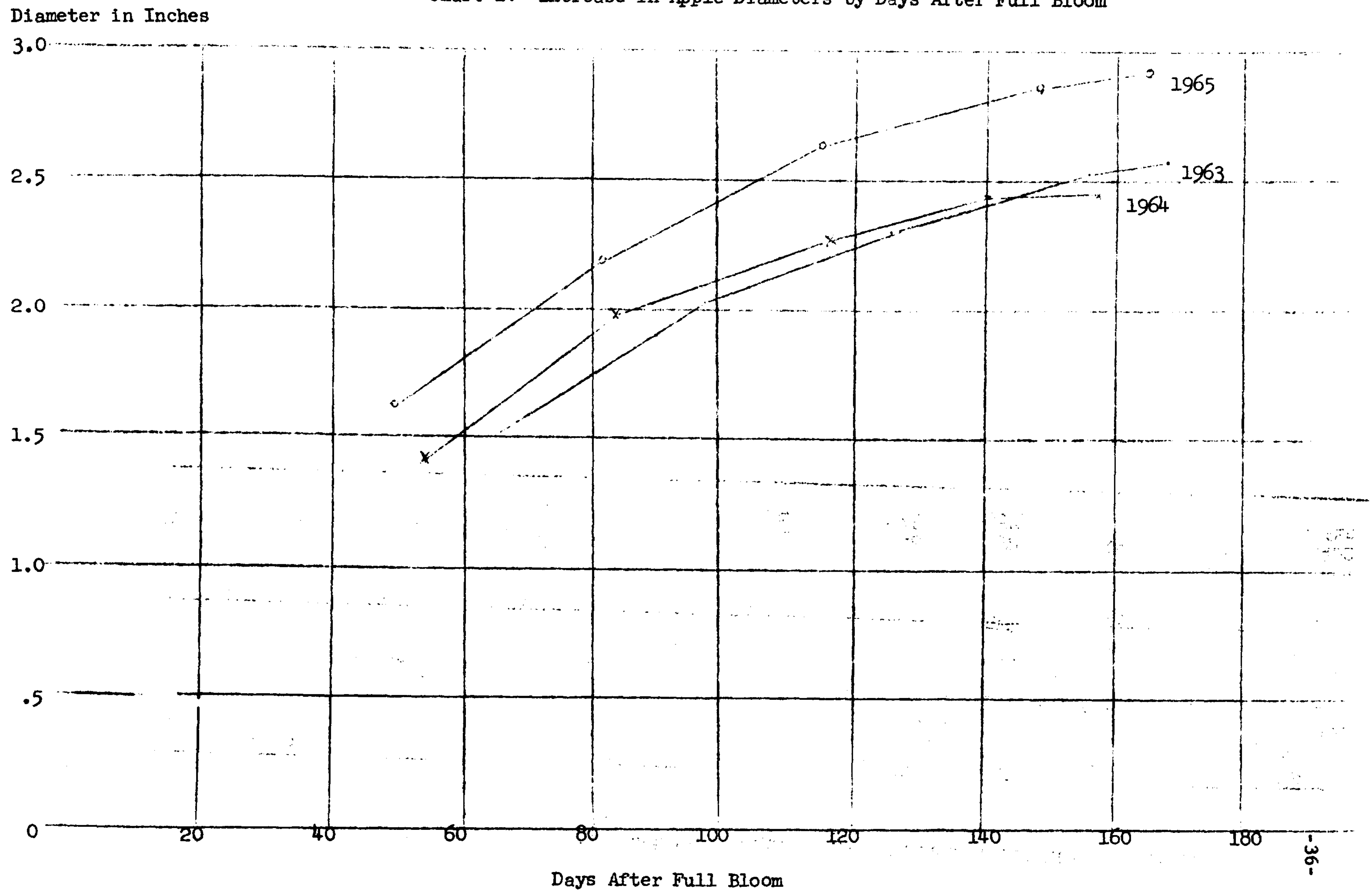

Chart II: Percentage Size Distribution July 1 Surveys 1963, 1964, 1965

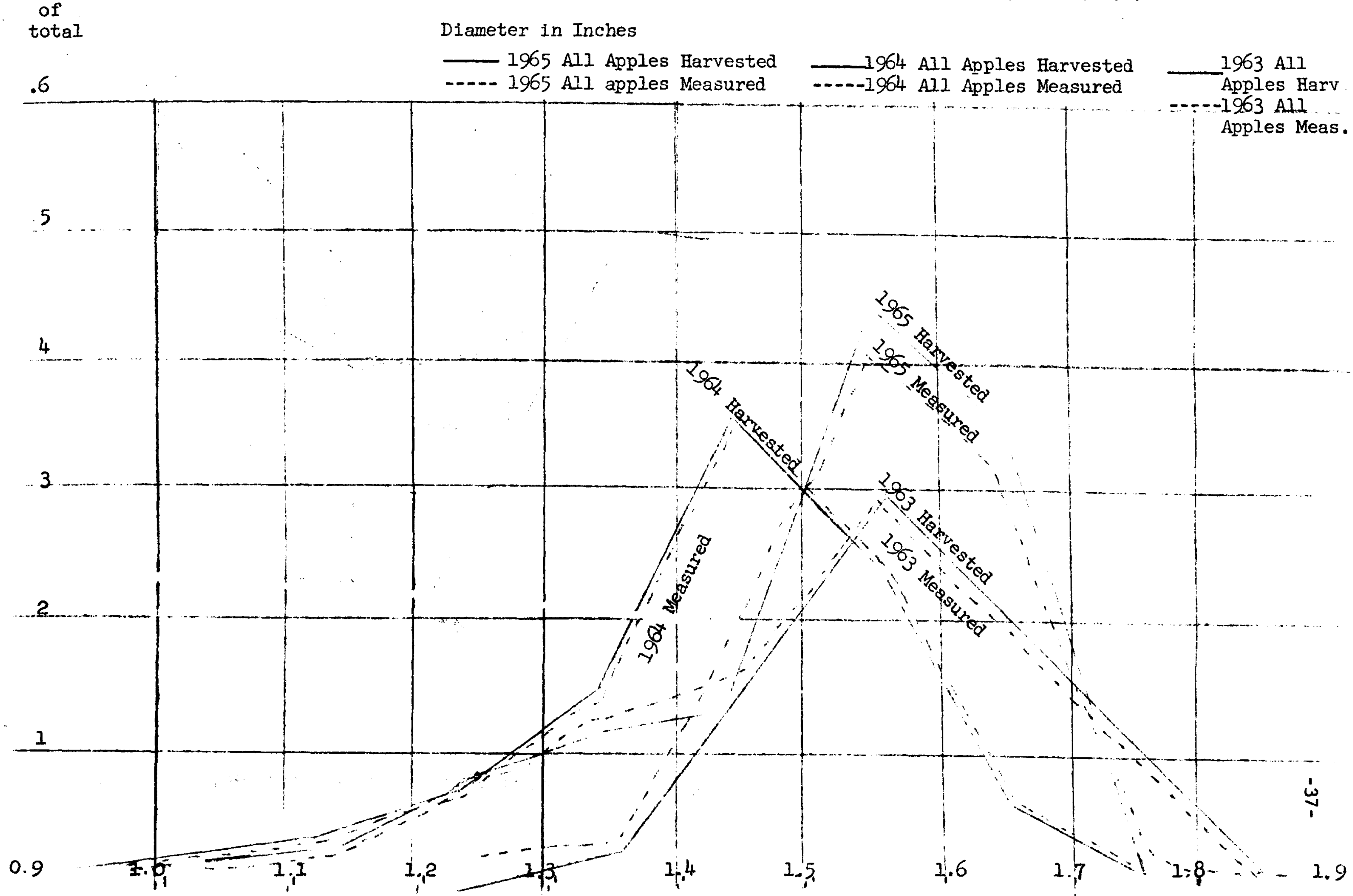

Chart III: Percentage Size Distribution at Harvest, 1963, 1964, 1965

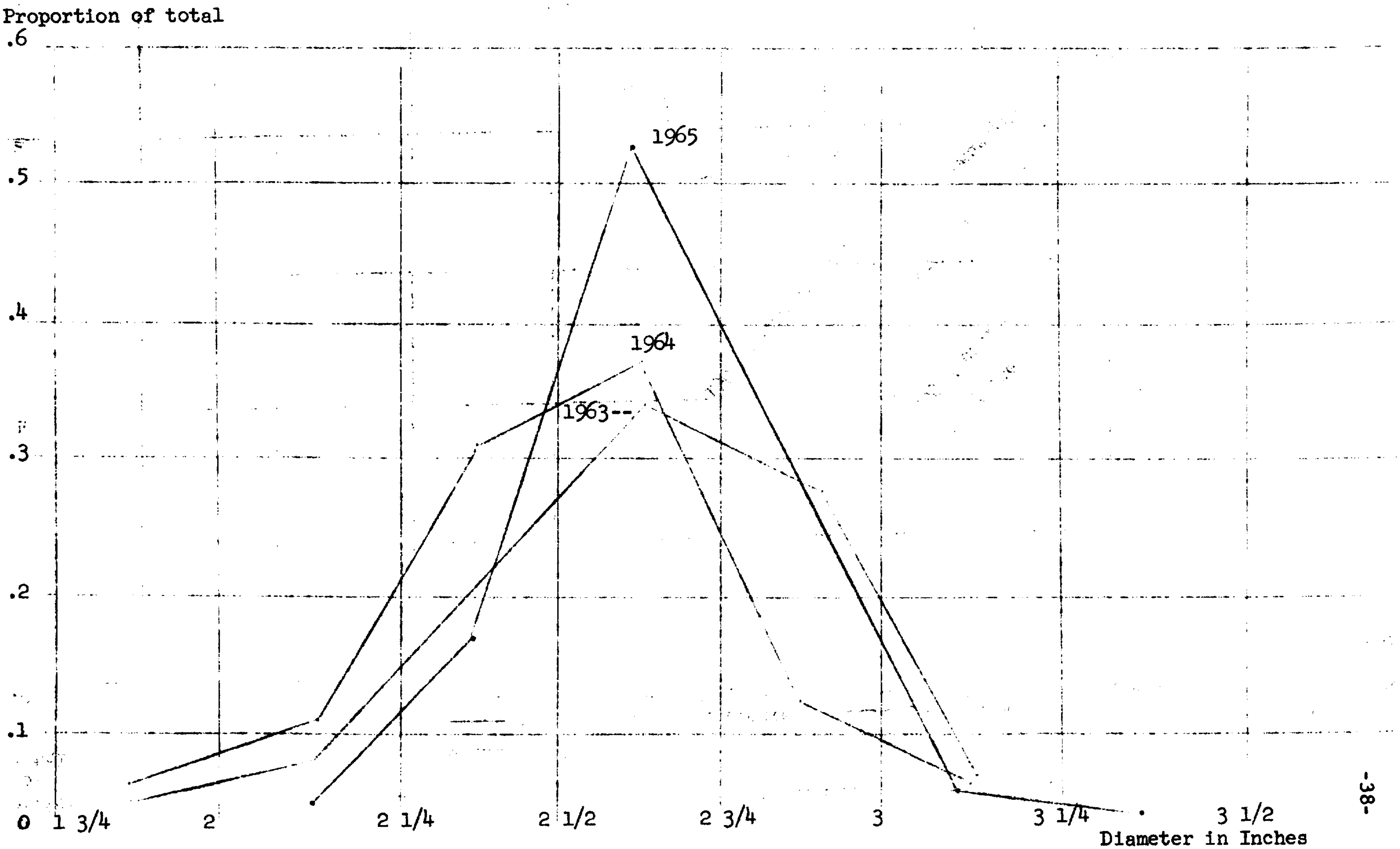

Chart IV: 1964 Projection of Apple Diameters From July 1 Diameter Measurements and Fruit per 1" CSA Compared with Harvest Diameters