THE USE OF PHOTOGRAPHY IN SAMPLING FOR OBJECTIVE YIELDS OF DECIDUOUS FRUITS *

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1. INTRODUCTION

Earlier objective yield work on cherries, apples, and peaches has pointed up several places in the procedures where increased sampling efficiencies were desirable.

1. Sample limb selection using the random path method might be done independent of the fruit counting phase. An independent limb selection phase could result in less training being required for the "fruit counters," reduce the time per tree, and selection of a more uniform set of sample limbs, i.e., a more efficient sampling of the trees.

2. The large variability within and between trees in orchards requires large sample sizes to attain acceptable levels of accuracy. A photo "count" of fruit which was highly correlated with actual fruit could be expected to reduce the variability due to subsampling of the tree as well as provide a measure of variation between trees.

3. The task of accurately counting fruit in conventional objective yield surveys requires a painstaking procedure by small subsections of the sample limbs. There are also instances where some degree of undercounting occurs and verification of actual tree counts is costly, or is not detected until it is too late to recount the fruit.

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It is hoped that the use of photography will provide quality control over field counts. However, the procedure has not been fully developed. The primary objective is to use photography to provide fruit counts which can be utilized as covariates in double sampling. This would reduce the number of trees on which fruit counts on sample limbs would need to be counted by conventional objective yield sampling procedures. Thus, it is not expected that the conventional objective yield counting work will be eliminated but merely reduced.

With these 3 basic problems in mind, the Research and Development Branch of SRS undertook some exploratory work with ground photography in 1965. The work in 1965 and 1966 led to the California and Virginia Research Projects initiated in the summer of 1967. Some photography was also obtained for several additional kinds of fruits and nuts in Michigan and Oregon.

The photography was utilized at several different times during the season.

1. 35mm color and color stereo photography was obtained of sample trees when no leaves were present.

2. 35mm color and color stereo photography was obtained after the "June drop" had occurred. Counts of immature fruit were made on all limbs on the same day as the photography was obtained.

3. 35mm color and color stereo photography was obtained several days ahead of the commercial harvest. In addition, a fruit count was obtained by picking all fruit on the tree.

The photography of the trees without leaves was designed to devise a means of using the photograph as a sampling frame for limb selection. Considerable labor and chance for error could be eliminated if sample limbs could be selected from photos of limb structure. Also, in an operational survey the possibility for considerable increases in efficiencies of limb selection exists. The limb selection could be optimized over all trees in the sample by considering trees as primary units (or clusters of limbs) of unequal size and number. The limb selection procedure commonly in use makes the limb selection independent for each tree without regard to the number or size of branches on the other trees.

The fruit counts by limbs or "tree mappings" were obtained to study alternative ways of selecting sample limbs and to provide a basis for measuring the effectiveness of the photography.

2. PRELIMINARY RESULTS OF 1967 WORK

The photography of fruit trees in late June provided information in Virginia and California on (a) 9 Red Win peach trees in Virginia, (b) 16 Lodel peach trees in California, (c) 6 Golden Delicious apple trees in Virginia, and (d) 2 Stayman apple trees in Virginia. The Red Win variety is an early maturing peach which was almost ripe when the photography was taken. However, the Lodel peaches and Golden Delicious apples were green and quite immature when the photography was taken in June.

Use of Photography for Counting Fruit - The fruit counts for each tree were obtained in two ways: (1) The total fruit on each tree was secured by enumerators "mapping" or taking a census of all the fruit on each tree. (2) Counts of fruit on photography from two sides of each tree were obtained. The two positions from which the photography was taken were 180^{o} apart. Two to four slides were required to obtain the tree count corresponding to each side of the tree. An aluminum frame, about 16 x 16 feet, was used to divide the tree into four parts so no fruit would be counted twice from the same side. Individual fruit near the top or outer edges of the tree could have been counted from both sides of the tree. The counts from the two sides of the tree were added together to get the "photo count" for each tree.

The fruit counts for the trees listed in a, b and (c + d) above are shown in table 1. The relationships are good with the sample correlations coefficients being .852, .855 and .984 for a, b and (c + d), respectively. The ratio of the fruit counted on the photos to the total number on the tree appears to be fairly constant for a given size tree. The average ratios were .326 for green Lodel peaches, .491 for green Golden Delicious apples, and .555 for mature Red Win peaches. Ripe fruit is easier to see on the photography than green fruit, and apples are easier to see than peaches. The attempt to count the fruit on individual sample limbs from photos to compare with the enumerator's count was not satisfactory because of the presence of the leaves and the overlapping of individual limbs on the photo. To overcome these difficulties, the use of stereo photography of the bare tree is required so the "path" of individual limbs will be known more exactly. For this purpose each slide will be divided into subareas corresponding to individual limbs. The fruit counts by subareas will be related to the actual counts by enumerators for the "principal" sample limbs, which occupy the area designated on the slide.

Table 1. Fruit counts—actual vs. photo

Virginia peaches		California peaches		Virginia apples	
Number on tree	Number counted on photograph	Number on tree	Number counted on photograph	Number on tree	Number counted on photograph
184	122	185	48	214	216
250	155	225	130	403	271
370	210	319	106	1,043	529
401	138	361	104	1,110	552
431	300	388	124	1,448	691
443	247	397	119	1,575	710
460	272	442	216	1,658	840
720	473	726	260	1,901	783
800	335	730	164		
		850	288		
		854	226		

In each case the slides were projected on a white background and counted by cells (small square subsections of the slide). The most satisfactory technique found for accurately counting fruit from the slides is as follows: (1) Project the slide on a white piece of paper at a distance of about 10 feet using a 500-watt projector with a remote control device for focusing. (2) One interpreter counts the fruit by placing a small dot on the paper corresponding to each fruit. (3) A second interpreter counts the same slide and places a circle for any additional fruit seen and an "X" if the second interpreter does not concur with a previous dot. The circles and "X's" are then reconciled by the two interpreters.

The use of two projectors and interpreters working at the same time is the most efficient arrangement. They can check or recount each others work and only need to project each slide once. Based on the experience to date in interpreting photographs the average time required to make fruit counts by a semi-skilled interpreter from a single 35mm color slide projected on a white background (or screen) are approximately as shown in table 2 below.

Table 2. Average times per slide

Fruit	Minutes	Distance from tree trunk to lens
Peaches (immature)	7	15 feet
Peaches (ripe)	5	18 "
Apples (immature)	7	22½ "
Apples (ripe)	7	22½ "
Cherries (ripe)	15	20 "
Walnuts (immature)	14	25 "

The total number of slides required per tree will vary from four to eight depending on the size of tree and the distance from the tree trunk to the lens. For most situations good quality 35mm slides are satisfactory for counting fruit. The 35mm stereo pairs may be helpful in certain difficult counting situations and where it is not possible to eliminate limbs of adjacent trees from the background of the sample tree. Of course, each member of the stereo pair can be viewed as a single slide by using only one lens of the projector. The second member of the pair can also be projected so the fruit can be viewed from a slightly different position.

Efficiency of Alternative Methods of Objective Fruit Counting (Equal Costs) - The fruit on each tree was mapped by terminal limbs and counts recorded for each limb. These tree mappings made it possible to compare several different methods of sampling the trees. Only two procedures of sampling limbs were considered: (1) EPS - Equal Probability of Selection at each stage, and (2) PPS - Probability Proportional to Size at each stage. These results are shown in table 3.

The procedure used in defining terminal limbs for Red Win peaches and Golden Delicious apples resulted in considerable variation in the size of the individual limbs; consequently, it was appropriate to consider whether PPS sampling might be superior to EPS selection of limbs. For PPS sampling of limbs to be superior to EPS, the number of fruit must also be correlated (positively) with the measure of size used, i.e., cross-sectional area (table 4).

In California the single stage of selection was more efficient when EPS was used. This was due to the smaller correlation between number of fruit and measure of size. Also, the procedure used to define terminal limbs may have resulted in more uniform limbs being selected. However, in selecting limbs by stages, PPS is superior to EPS for all situations examined. This phase of work has not been completed and we plan to explore alternative ways of subdividing the tree into terminal limbs from the photos of the bare tree. The single stage selection of terminal limbs either by PPS or EPS is slightly more efficient than the random path method using limbs selected by PPS.

Table 3. Variances for alternate methods of sampling trees based on current procedure for defining terminal limbs

Method of sampling	Red Win peaches	Lodel peaches	Golden Delicious apples
Number of trees	9	16	6
Random path-selection in several stages: EPS	121,058	207,532	1,851,884
PPS	68,458	89,142	353,267
Single stage-random selection of terminals:			
EPS	112,075	76,538	738,233
PPS	63,281	110,827	349,989

Table 4. Correlation between number of fruit and cross-sectional area of terminal limbs

Kind of fruit	Correlation coefficient (w/in tree)	Number of trees	Number terminal limbs	Average number fruit per limb	Average c.s.a. per limb (sq.in.)
Peaches - Red Win	.709	9	125	27.9	1.58
Lodel	.460	16	320	23.7	1.84
Apples - Golden Delic.	.645	6	134	51.6	1.42
Stayman	.318	2	92	21.6	1.58
Cherries - Montmorency	.504	2	103	128.9	1.11

Use of Photography for Selecting Sample Limbs - A technique of selecting sample limbs from photography of bare trees to be used for conventional objective fruit surveys was investigated. The use of 35mm stereo slides was found to be most suitable for this purpose. However, the stereo slides are also viewed as nonstereo single frames by turning off one lens of the projector. In the tree mapping procedure being considered, the stereo slides are projected alternately as pairs and as singles.

Each primary limb (a major limb which branches off the main trunk) is viewed for purposes of identifying all terminal limbs using a stereo hand viewer. Each primary is viewed from the side of the tree which shows the limb most clearly, or using slides from both sides of the tree if necessary. After the number of terminals for each primary has been determined, the slide is then projected on to a white paper screen and the limbs labeled. A photograph of the projected slide with the limbs of the tree labeled is taken for use by the workers in the field. Figures 1 and 2 show sketches of terminal limbs of a tree from two positions.

3. LIST OF EQUIPMENT USED

Cameras: Miranda Automex
Kodak Stereo F 3.5 lens

Film: Kodachrome II

Projectors: Kodak Carousel 800 (remote control focusing)
Compoco 500 Stereo

FIGURE I— LIMBS OF APPLE TREE MAPPED FROM PHOTOGRAPH OF BARE TREE. APRIL 19, 1967
(LIMBS NOT IDENTIFIED ON THIS FIGURE ARE MAPPED ON FIGURE II)

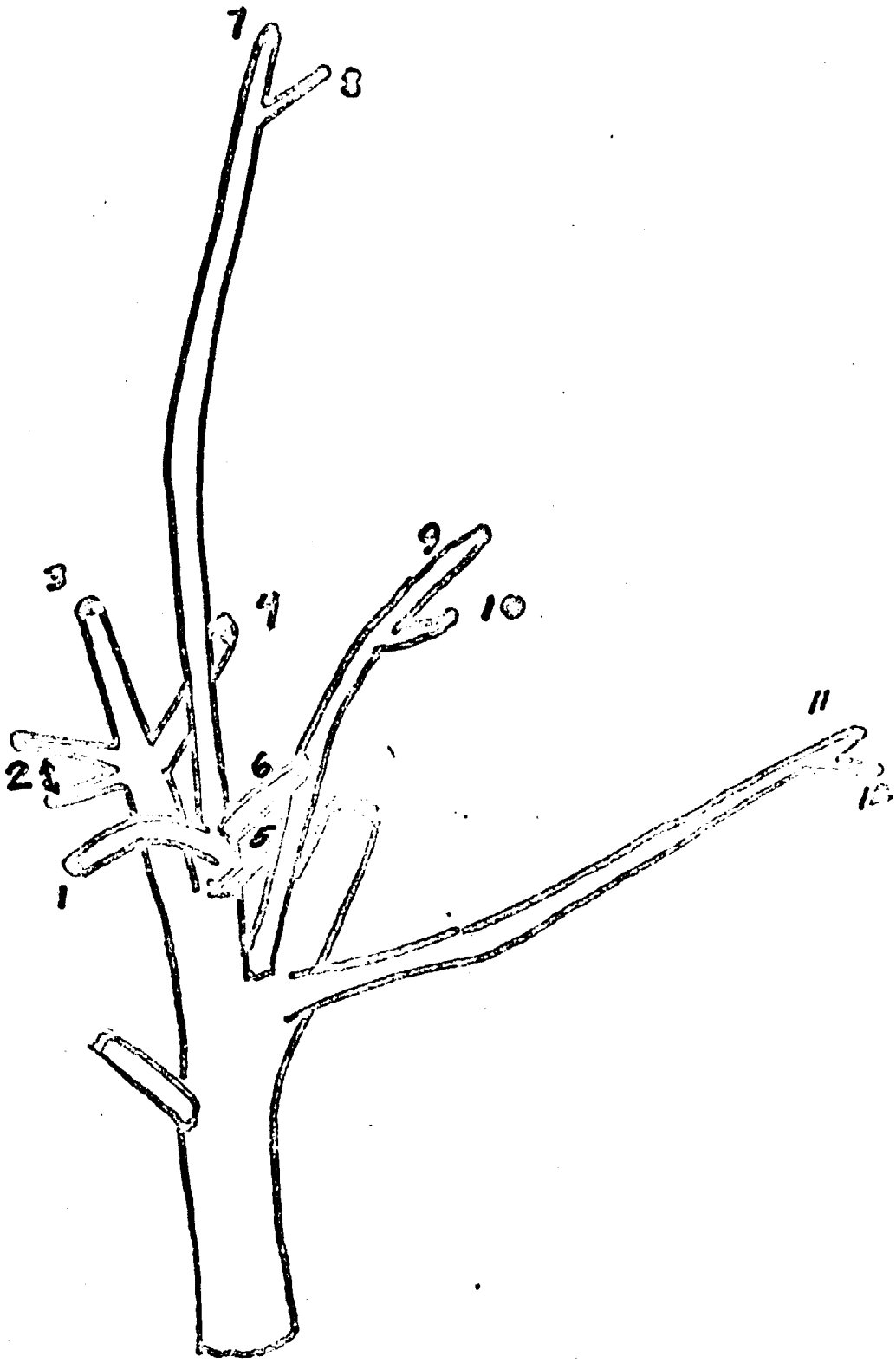
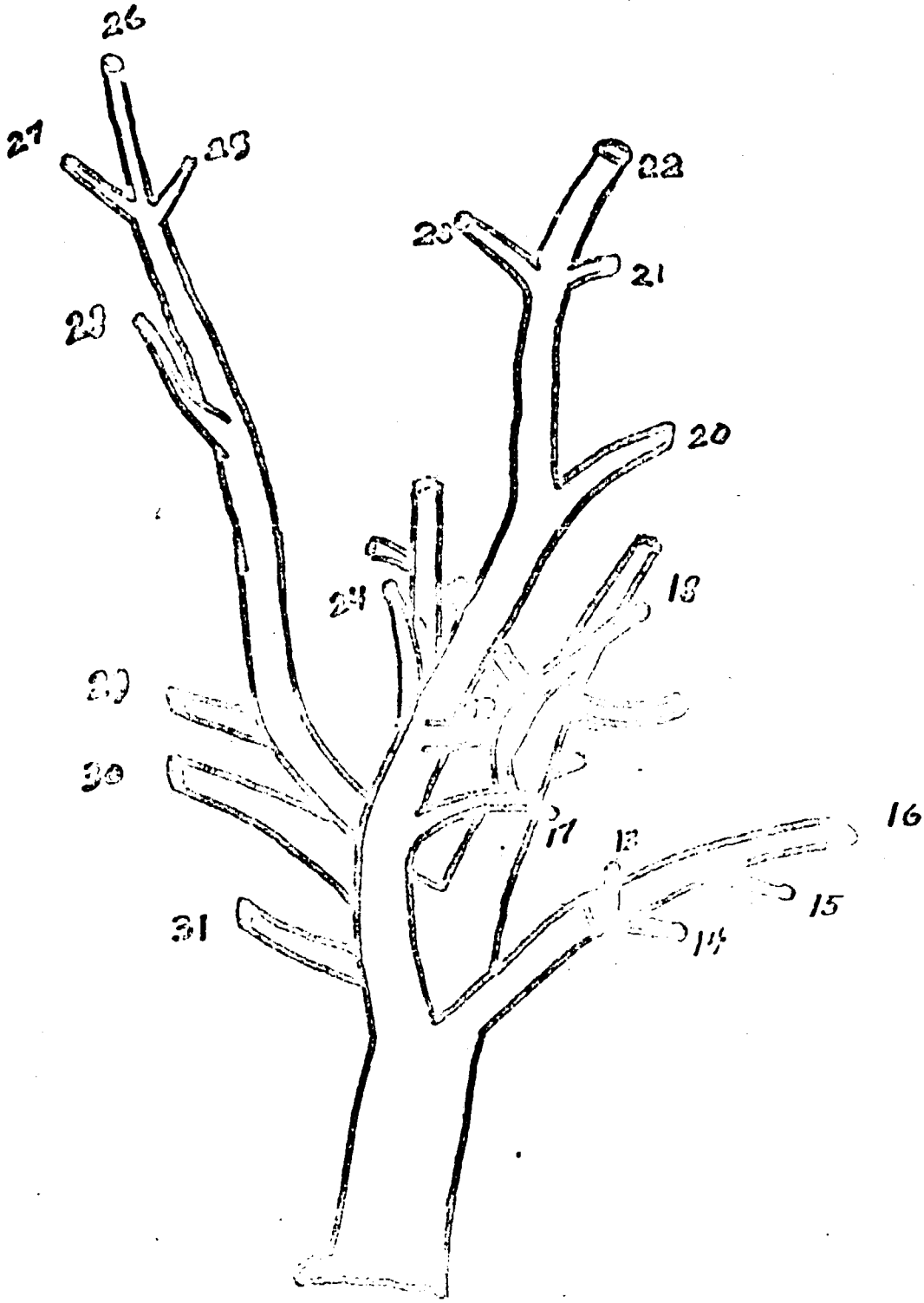


FIGURE II--LIMBS OF APPLE TREE MAPPED FROM PHOTOGRAPH OF BARE TREE. APRIL 19, 1967 (LIMBS NOT IDENTIFIED ON THIS FIGURE ARE MAPPED ON FIGURE I)



Handviewer: Realist stereo viewer model 2062 (AC and battery)

Screen: Lenticular
Good quality 3'x3' sheets of white bond paper
Transparent plastic screen on stand for rear viewing

4. LIST OF PRINCIPLE PARTICIPANTS

Richard P. Small, California, Principle Investigator
Charles E. Rogers, Washington, D. C., Principle Investigator
William Wigton, Washington, D. C., Photo Interpretation and Analysis
Edward Camara, Washington, D. C., Photography and Photo Interpretation

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