that limiting variables in the environment proportionately reduce photosynthetic rate regardless of the value of the other limiting variables. Each efficiency parameter represents a particular environment constraint on the photosynthetic rate. Net photosynthesis is computed by multiplying potential photosynthesis by the efficiency parameter for temperature and soil water, and then subtracting nighttime respiration losses.

Mean ambient temperature was used to approximate the crop temperature, because plant temperatures rarely are available and net photosynthesis is relatively insensitive to small differences between leaf and air temperatures.

Reductions in net photosynthesis because of scarcity of soil moisture were considered to be proportionate to the reduction in plant evaporation resulting from limited water availability. Plant evaporation is not affected until a threshold extractable soil water value is reached. The threshold value is dependent on the particular soil and crop under consideration. Extractable soil water is determined daily, using a soil water balance model (based on a modified Penman equation). When approximately 80 percent of the extractable soil water has been depleted by evapotranspiration, net photosynthesis is reduced, because the efficiency parameter becomes less than 1. This relation is speculative and net photosynthesis may be affected more if it is limited by soil-water status more than is evapotranspiration.

2.6.2.6 Stage of Development

There are 10 stages which have been found useful in describing the plant development: (1) emergence, (2) three-leaves, (3) five-leaves, (4) growing-point differentiation, (5) flag leaf visible, (6) boot stage, (7) half bloom, (8) soft dough, (9) hard dough, (10) physiological maturity.

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Three stages in particular are important in determining what plant parts are increasing in weight: growing-point differentiation (GPD), half bloom (HB), and physiological maturity (PM). Because leaf appearance and expansion were simulated in the grain sorghum model, phasic development was defined with respect to the appearance of leaves. For example, GPD normally occurs about midway between five leaves fully expanded and flag leaf visible in the whorl. The date GPD occurs was defined as the midpoint between the computed date that leaf 5 (counting from the base) reaches maximum area and the computed date that the flag leaf emerges.

2.6.2.7 Daily Dry-Matter Gain

Net photosynthesis (p) is computed and converted to dry matter, using the following relation:

$$DM = \frac{12}{44} \times \frac{1}{0.4} \times p$$

where DM is dry matter, 12/44 is the ratio of molecular weights of C and CO_2 respectively, and 0.4 is the proportion of the plant dry matter which is carbon. The proportions allotted to each organ were empirically derived. However, the absolute amount of dry matter apportioned to a particular organ was dependent on the amount of photosynthate produced that day. The daily allocation of the plant dry matter to the various plant parts is shown in Figure 8 on page 96.

Figure 8: Dry Matter Partitioning To Plant Parts
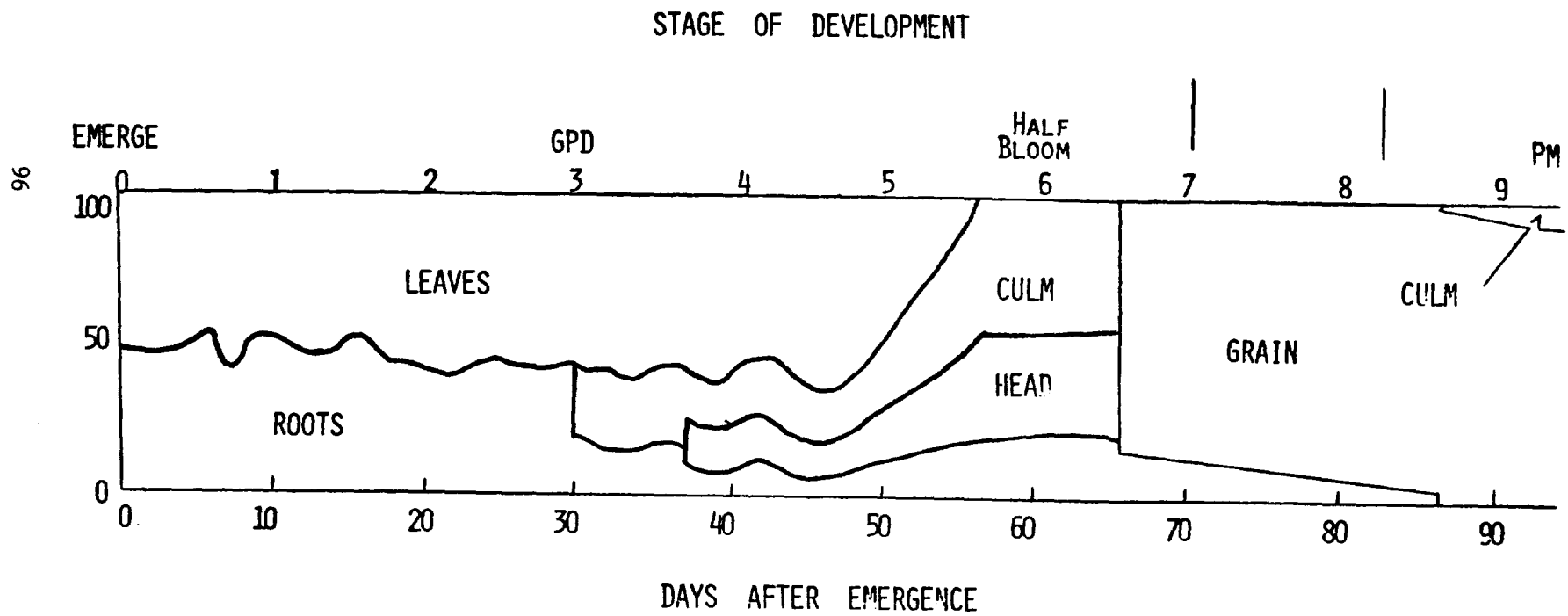
2.6.3 Data Input

It is clear from Table 20 that rather detailed and exacting input data are required to run a crop simulation model. Moreover, the daily climatic data is needed for an entire crop season. Consequently, a forecast of the four daily climatic variables is needed for each day after the seed is planted. These values can be generated by simulating daily values from the empirical distributions of these four variables for a base period of 10 to 25 years. Or, if long-range forecasts of weather are available, the empirical distributions can be modified by shifting the mean vector for forecasted departures from the base period and then used for simulation. In either case, the simulated weather data are substituted for actual climatic data which are yet to occur and the model is run from the date of the forecast to maturity or harvest. In order to reduce the model's reliance on the historically derived parameters in simulating the response characteristics (plant parts), the observed plant parts can be used at key times during the season. Likewise, the observed plant characteristics may be useful in adjusting or correcting the model to agree with the average plant in the commercial field stand for the current year by inputting actual plant data at several times during the growing season. This leads to an additional subroutine in the flow diagram of Figure 7, referred to as "plant feedback" subroutine, which can be made as detailed as it is possible to observe or measure plant parts for an average plant in a field. Some key plant inputs for this purpose are as follows: (1) dry weight of plant, (2) dry weight of head, (3) dry weight of grain, (4) number of leaves, and (5) size of individual leaves. The inputted value replaces the model-computed value for the date of the observation, and the model is restarted on the following day and the daily growth is continued until physiological maturity. Likewise, the daily weather variables which need to be inputted must either be forecast

or simulated from historical records to obtain the yield per plant. These types of modifications in the Arkin, Vanderlip, and Ritchie model were undertaken to make the model more useful for large-area yield estimating.

2.6.4 Example of Model Results for Observed Plant Data

A feedback subroutine and the simulation of daily weather variables were developed to aid in forecasting yields for sorghum grown over a rather extensive area. A weather generating model enabling simulation of probable daily weather during the growing season was employed. The generated weather data were derived by a procedure that reproduces the observed historical weather data prior to the current season.

Average field observed plant characteristics for an individual field were used for grain sorghum growth simulation from the date of the feedback (i.e., date plants were observed) to physiological maturity. A sample of the use of the feedback submodel is given in Table 21.

Note that on June 7, the following ground-truth information was fed back to the model: 14 leaves full grown, LAI* = 2, plant dry weight = 20.05 grams, head dry weight = 3.69 grams. The model then simulated both the total plant dry weight and the head dry weight and computed the date of physiological maturity. The observed plant and modeled plant characteristics are shown for comparison. This forecast was made approximately one month before physiological maturity and two months before harvest. LAI was always overestimated, because the senescence submodel was not responsive to limited soil-water conditions.

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* Leaf area index

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Table 21--Plant Characteristics Observed and Simulated by Model

Date and characteristic	Observed plant data	Model with no feedback	Model with feedback
May 3			
# Leaves full	8	14	
LAI	0.83	3.35	
Plant dry wt (gm)	2.36	16.16	
Head dry wt (gm)	0.00	2.22	
May 18			
# Leaves full	10	14	
LAI	1.51	3.16	
Plant dry wt	6.03	29.94	
Head dry wt	0.00	7.05	
June 7			
# Leaves full	14		14
LAI	2.00		2.00
Plant dry wt	20.05		20.05
Head dry wt	3.69		3.69
June 24			
LAI	2.40		2.59
Plant dry wt	44.92		46.44
Head dry wt	21.27		17.25
Phys. Maturity			
Day	July 3	June 3	July 10
LAI	1.40	2.95	2.43
Plant dry wt	50.70	50.05	50.04
Head dry wt	35.70	31.93	33.05
Emergence	March 15	March 11	March 15
Anthesis	June 7	May 10	June 7

2.7 Forecasting Yields for Small Geographic Areas

2.7.1 Introduction

In Chapter 1 it was pointed out that attempts to employ
auxiliary data or double sampling for adjusting crop-cutting
surveys to obtain current yields for small geographic regions
have been largely unsuccessful. However, the combining of sat-
ellite information with appropriate plant or field response data
may offer a basis for developing statistical estimators with
measurable standard errors for small areas. The technique illus-
trated is potentially cost effective, because the satellite
coverage is for large geographic areas and the field data re-
quired are increased only marginally over that needed for large-
area yield estimates. Similarly, small-area acreage estimates[*]
may be obtained, so that production is derived as a product of
yield times acreage. A procedure is described for obtaining corn
yield estimates by counties in Illinois during the 1975 crop year.

2.7.2 Sampling Methodology

A subsample of corn fields was selected, based on a probability
area sample, for the source of the individual corn fields. A sub-
set of these corn fields based on pixels (i.e., picture element
equal to approximately 1.1 acre) classified as corn using a qua-
dratic discriminant function was used to develop the yield relations.
That is, the crop classification of all pixels is completed first
and the yield relation is based on the data for corn fields classi-
fied as corn fields by the discriminant function. These fields
were then located on the LANDSAT digital tapes and a mean vector
derived from the four spectral-channel values for all pixels in
each corn field and paired with the forecasted and harvested yield
based on objective yield data for these same fields.

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[*] "A New Approach to Small Area Crop-Acreage Estimation," Harold F.
Huddleston and Robert M. Ray III, Annual Meeting of the American
Agricultural Economics Association, Pennsylvania, August 1976.

In addition, a mean vector for the four channels was derived for all pixels classified as corn in each county, as well as the mean vector for all pixels classified as corn in the total analysis district of 10 counties. That is, the entire population of pixels is classified by crops for each county as well as the group of counties on the LANDSAT scene. The pixels in the sample corn fields which are also classified as corn are a subset of all acres classified as corn. The mean vectors for the spectral data were obtained from the LANDSAT imagery for August 4, 1975, while the plant and field data relate to a 10-day period centered on August 28, 1975. Categorical data from the classified tape were matched to the unclassified tape with the spectral values to derive the LANDSAT information needed for the yield-estimation procedure.

2.7.3 Yield Estimation Model

The yield models are the same as those used for acreage, except the independent variable is now a vector of four channel values. The estimation of the yield for a county or any small area was achieved through a double-sampling regression estimator using the LANDSAT data and a probability sample of fields for the large area comprising the LANDSAT frame. Consequently, it was possible to derive a double-sampling regression estimator using individual fields over a large area and apply the relation to individual counties. Several possible regressions were developed to correspond to variations of the component yield model for several dates. One regression relates yield based on plants per acre on August 1 as the principal variable to the four spectral values from LANDSAT, while the second regression relates the yield based on number of ears with grain per acre as the principal variable to the same four spectral values from LANDSAT. For an early forecast of yield, the grain per plant or per ear would be based on a short-term moving average. The estimated average number of plants (or stalks) per acre derived from a regression for each county is then multiplied by a historical weight of grain per plant to obtain the gross

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or biological yield per acre. A second model considered was based
on the estimated average number of ears per acre on September 1
for each county, which was multiplied by a historical weight of
grain per ear to obtain the gross yield. The average grain weight
used was on a per stalk and per ear basis. In this model, stalks
and plants have a slightly different meaning, because suckers were
counted as stalks. These weights were derived using a transitory
moving-average model truncated after five years for Illinois with
$a = \frac{1}{2}$. That is, the formula for weight per ear is:

$$\bar{w}_E = \frac{\frac{1}{2} w_1 + \frac{1}{4} w_2 + \frac{1}{8} w_3 + \frac{1}{16} w_4 + \frac{1}{32} w_5}{\frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \frac{1}{16} + \frac{1}{32}}$$

where w_1, w_2,.... w_5 were the weights per ear for 1974 back to 1969
and $\bar{w}_E$ = .340.

If $a = \frac{1}{3}$, the weight per ear is .332 and the corresponding
formula is:

$$\bar{w}_E = \frac{\frac{2}{3} w_1 + \frac{2}{9} w_2 + \frac{2}{27} w_3 + \frac{2}{81} w_4 + \frac{2}{243} w_5}{\frac{2}{3} + \frac{2}{9} + \frac{2}{27} + \frac{2}{81} + \frac{2}{243}}$$

However, an alternative weight per ear for individual fields was
derived by using a weight estimator based on current-year ear
length measurements on September 1 and multiplied by the number
of ears per acre to obtain a forecast yield per acre for each
field. This yield per acre was actually used to derive the county
yield estimator for counties as of the September 1 date.

While a number of different variables or combinations of vari-
ables based on the field mean vectors and variance vectors were
investigated using the August 1975 imagery in western Illinois,

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only two sets of spectral variables gave statistical significance consistently: (1) means of channel 2 and channel 4, and (2) means of channel 2 and channel 4 plus variances of channel 2 and channel 4. The regressions based on data set (1) for September 1 yield forecast and final harvest yield for the 10-county area within the LANDSAT frame of August 4 are as follows:

September 1 forecast: $\hat{Y}_s = \bar{y}_s - 8.68(\bar{x}_2 - \bar{X}_2) - 2.16(\bar{x}_4 - \bar{X}_4)$

$$R = .56$$

Harvest yield: $\hat{Y}_h = \bar{y}_h - 10.68(\bar{x}_2 - \bar{X}_2) - .56(\bar{x}_4 - \bar{X}_4)$

$$R = .49$$

where $\hat{Y}_s$ = forecasted corn yield per acre for geographic area on September 1

$\hat{Y}_h$ = corn yield per acre for the geographic area at harvest

$\bar{y}_s$ = forecasted corn yield per acre for a sample of fields on September 1

$\bar{y}_h$ = crop-cutting corn yield per acre for the sample fields at harvest

$\bar{x}_2$ = mean spectral value for channel 2 on August 4 for all classified corn pixels in county

$\bar{x}_4$ = mean spectral value for channel 4 on August 4 for all classified corn pixels in county

$\bar{X}_2$ = mean spectral value for channel 2 on August 4 for the entire geographic area of 10 counties

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$\bar{X}_4$ = mean spectral value for channel 4 on August 4 for the entire geographic area of 10 counties

B_2 and B_4 = -8.68 and -2.16 or -10.68 and -.56 = regression coefficients

R = multiple-correlation coefficient

The gain in information by use of spectral data for yield estimation may be computed, based on the ratio of variances. For corn yields these information gains are in the range of 1.27 to 1.42. Based on these data sets for western Illinois in 1975, the potential information gain is much less than that for acreage estimation. However, the relation could be improved (i.e., correlation increased) by increasing the number of plots per field. However, the use of the LANDSAT spectral data for both acreage and yield would result in an information gain of approximately 7.0 x 1.3 = 9.1 for estimation of corn production for a single frame or group of 10 counties.

2.8 Summary of Yield Modeling for Forecasting

The techniques discussed in this chapter can be grouped into six categories based on the source and type of data employed, as follows: (1) grower opinions or appraisals, (2) plant components and characteristics, (3) agrometeorological relations based on plant and weather-dependent factors, (4) historical climate-yield relations, (5) auxiliary environmental variables and yields, and (6) plant growth models.

In general, categories (3) and (4) place greater reliance on historic data over years while (2), (5), and (6) rely on increasingly detailed data and the observance of plant responses within years. Category (1) can be relatively free of both between-year and within-year relations when the growers are fairly skillful forecasters of the yield of a crop. However, acquiring the needed data to implement the forecasting model in each case can be the key criterion in selecting a technique to employ. Several questions concerning data acquisition need to be answered before making a selection: (1) What is the cost of the data to be collected? (2) Can the needed data be collected in a timely manner to meet the forecast date(s)? (3) What agency(s) has responsibility for data collection? (4) Are the basic "relations" or are trial values of the necessary parameters now available for evaluating the technique? (5) What type of training or staff is needed? (6) Are the variables needed simple data collection tasks or is instrumentation needed in order to use the concepts?

Based on the alternative forecasting techniques discussed, guidelines for these techniques may be set forth when a new program is to be started or a major change is to be made in an existing program. In general, techniques which require long historical data sets are not well suited to a changing or highly competitive agricultural situation. Consequently, systems are preferred that will be valid for forecasting in future years where the dependence can be confined to a short period consisting of the last 3 to 4 years or key parameters can be observed each year. If there are no major trends in yield, then a system which can use information from a series of years to forecast the current year is likely to be valid.

Systems based on techniques falling under (1) or (2) above are
preferred as a starting point for estimating and forecasting yields,
since harvested yields need to be measured as a basis for evaluating
forecasting techniques. Consequently, one of these two will probably
be required for this purpose (i.e., determining harvest yields from
grower reports or crop cutting). If growers are reasonably skillful
in forecasting crop yields and know their production by farms or fields,
the use of grower reports from a probability sample can be expected to
produce fairly accurate forecasts at reasonable costs in a timely manner.
However, there is frequently a tendency to discount a technique based
on crop appraisals, because of technical shortcomings reported in some
studies due to sampling the wrong population, or no sampling frame,
defining the wrong populations to be estimated, lack of agreement with
existing production data, and fears that growers are not truthful in
their reporting. In many cases, harvested-yield reports have been
found to be satisfactory, but production data were unsatisfactory be-
cause the harvested area was not known accurately due to biased or
erroneous estimates of area planted or harvested. Sometimes the infer-
ence is also made that, because local officials or leaders cannot provide
timely or reliable reports on yields, growers also cannot provide use-
ful data. Methods that rely on probability samples of growers who
report yield and area by fields are probably not used enough. However,
if growers cannot provide reliable yield data, then forecasts relying
on mature plant or harvested plant components are preferred. Another
reason for preferring category (2) in this situation is that modifica-
tions can be easily introduced into the model which will utilize weather
or environmental variables suggested for categories (3) and (5). Tech-
niques employed from this category generally require training and advance
preparation for field work as well as careful derivation of the parameters
for the forecasting models. Such a system can serve the market-management
needs and provide a basis for measuring changes in crop techniques as
shown by changes in yield components in the model over years. For a
system to also provide information on the response of the plants during

the crop season to water and other factors, a more sophisticated model based on the ideas of category (6) is required.

About three years are needed to develop and implement an operating program of yield estimates for a crop employing preharvest observations. In fact, if the goal is to have a successful preharvest crop-cutting survey on an operational basis during the third year, a well-planned, intensive effort by experienced crop specialists and mathematical statisticians in yield work is needed.

Typically, the first year's effort would be limited to a small number of fields to obtain preliminary measures of variability for establishing size of plots and other aspects of sample design, and to develop operational definitions and instructions for the concepts to be used for a pilot survey the next year. Alternative techniques of measuring the yield on small plots would be tried. This would include consideration of various means of locating sample plots objectively and ascertaining the advantages of alternative instruments, equipment or concepts. Potential sources of error or bias would be identified and means of control considered. In addition, a means of estimating harvesting losses based on either sample plots being gleaned after harvest or obtaining production records for check fields is quite helpful. Thus, the goal of the first year's effort is to develop, as fully as possible for trial the following year, a set of sound, detailed operating specifications, including training plans and a well-designed plan for measuring the quality of the work done.

The second year's effort could be regarded as an intensive and extensive pilot operation using a sample that might be one-fifth or one-fourth the size anticipated for a fully operational program. From the second year's experience much better information should become available on variance components and time requirements for various parts of the job, so that the sample design can be optimized. Quality checks on the fieldwork should provide a basis for improvement of field procedures, which must be rigorous and tightly controlled.

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The third year would be regarded as the first attempt to implement a program on an operational level. The matters of sampling design would be reviewed and discussed at length; being stressed, however, is the importance of a balanced effort giving rigorous, tightly controlled procedures regarding all important sources of error. Experience has indicated that inherent biases can be eliminated or controlled effectively by intensive training of the field staff, close supervision, quality checks, and providing clear, concise, well-defined field procedures; but astute observation is essential for the identification and control of factors affecting the quality of results. This type of experience must either be found or developed in the early years of a program.

Estimates derived from preharvest sampling are available earlier than estimates from farmers' postharvest reports. Prior to harvest, a farmer can report only his appraisal of the crop prospects. On the other hand, estimates based on preharvest sampling must rely on previous years' harvesting losses or be delayed until such time as harvesting losses can be determined from gleaning sample plots after harvest or commercially harvesting ears and recovering the grain from known numbers of ears.

For tree crops there is frequently a major interest in forecasts several weeks prior to crop maturity. These surveys are substitutes for preharvest sampling or crop cutting when growers' reports on amounts sold for processing (especially when the total crop is harvested within a short period) will be available. The harvested quantities are complicated by the fact that the amount of some crops left unpicked as a result of selective harvesting for tree crops may vary considerably from year to year.

In addition to the advantage of objectivity, preharvest sampling provides a means of getting much valuable information that cannot otherwise be easily obtained. By means of laboratory analysis of samples taken from fields, information on various attributes of crop quality can be made

available. Crop quality, components of yield, and harvesting losses can be related to varieties, cultural practices, weather, harvesting equipment or methods used, and other factors. Also, if deemed worthwhile, information on some types of insect damage, such as the number of ears of corn damaged by corn earworms, can be readily obtained.

The forecasting of the yield of a crop at periodic intervals during a growing season is more difficult than estimating yield at time of harvest. It is necessary to discover plant characteristics or variables which may be used to predict components of yield. Forecast formulas should be based upon observable plant characteristics and a comprehensive knowledge of the fruiting behavior of the crop. The formulas must translate plant characteristics observed on any date into accurate forecasts. These techniques are illustrated for corn, and tree crops in the next chapter. In contrast to the development of a program for preharvest sampling, any time-schedule for developing and perfecting forecasting procedures is much more tenuous. A major reason for this is the necessity of having "between-years' experience" for the formulation and testing of models. In fact, one may continue to use more than one model for a particular crop after a forecasting program becomes operational, in order to give the most promising alternatives a longer test.

Research work on early-season forecasting from plant measurements has been less extensive than for late season. For some tree crops the duration of "late season" is quite long, and "early season" forecasts have not been attempted. Cotton, wheat, corn, soybeans, citrus and nut crops have received the most attention in the development of early-season forecast models.

Growth patterns among different plant species are so varied that not much can be said about a general approach for finding a forecasting model. The nature of the problem obviously changes rapidly with and related to the stage of development. An important aid in developing good hypotheses might be examining existing detailed research or experimental farm data on fruiting and plant characteristics, starting in advance of the first

forecast date and continuing at intervals up to harvest. Such data, how-
ever, usually come from isolated and controlled studies and therefore
should be regarded as unreliable for purposes of establishing model
parameters.

Some crops set fruit over a relatively long period and may have many
fruit on a plant with a wide range of maturity. Cotton and lemons are
good examples. A forecast of number of fruit, when only part of the
fruit is set, requires modification of the fruit component in the model
so that a term for additional fruit expected at harvest from fruit not
set can be included. For an early-season forecast of cotton, the relation-
ship between "the number of cotton bolls at harvest from fruit not set"
and a maturity index has been tried. To establish this relation, fruit
set at time of observation must be tagged so that bolls at harvest from
fruit not set can be counted. Another model for early-season cotton
forecasts, called "the rate of fruiting" model, has been developed. This
type of model is more complex and will not be discussed here, but a sig-
moid type of growth curve frequently will give satisfactory results for
bolls set.

For winter wheat, a May forecast of number of heads is made from
stalk counts using a relation established from historical data. Weight
of grain per head is related in a somewhat imprecise manner to plant
density. Hence, head weight can be adjusted for plant density rather
than merely assuming the average for several years, or standard varieties.

It appears that a historical average weight per head or fruit may be
a satisfactory basis for a forecast when cultural practices are fairly
static; such practices as irrigation and the thinning of fruits are
controlled, so the density varies only moderately from year to year. A
historical average weight may also be satisfactory if the forecast is
for a large area, say several States, so that the average environment
and crop practices for the whole area are about the same from year to
year even though there may be differences or trends for individual lo-
calities which vary considerably from year to year.

Knowing the probable quantities of the crop by weight may not supply
sufficient data for all needs. For example, in some countries a large
portion of the citrus crop is exportable. It is obvious that knowing
only the total weight of the expected yield may not be enough. A market-
ing organization may need information about the quantities qualified for
export and the reasons why some of the fruits fail to meet export standard
requirements. Once this extra information is available, better planning
of the exporting strategy is possible and remedies might be applied in
order to increase the quantities qualified for export. Another important
by-product of crop forecasting is projections of the average harvest fruit
sizes by variety for use in marketing the crop.

These by-products of crop forecasting provide more accurate data
about the weight and size of the expected export-qualified crop. At
the same time the causes of disqualifications can be pinpointed, classi-
fied, and analyzed by type, time of the year, variety and the region so
that scientists can attempt (based on feasibility studies) to limit the
impact of these damages that can be controlled. Table 22 is a good
example of information on damage for several recent Israeli citrus crops
that has been found useful in marketing the crop.

Table 22--Distribution of the Different Fruit Damages by Variety and
Season (by percentage)

Type of fruit damages	Shamouti oranges			Late oranges			Grapefruit		
	1972-73	1973-74	1974-75	1972-73	1973-74	1974-75	1972-73	1973-74	1974-75
Natural causes*	25	34	20	16	34	25	19	29	25
Shape of fruit	18	28	29	15	15	18	18	27	27
Physiological damages	23	15	18	36	26	29	23	16	13
Insects	15	10	14	21	11	14	28	13	20
Green fruit	11	8	7	4	9	6	1	4	3
Picking damages	7	4	11	7	4	7	6	6	8
Diseases	1	1	1	1	1	1	5	5	4

* Natural causes are sunburn, wounds, abrasions and hail.

CHAPTER 3 - DATA COLLECTION CONCEPTS USED IN FORECASTS FOR SPECIFIC CROPS

3.1 Introduction

The data-collection needs for yield measurement and forecasting can be considerable and exacting if objective data is to be provided on a uniform basis by different workers and over years. Information collected in this manner is also quite valuable both in evaluating the transfer of agricultural technology from the researcher to the farm and in meeting crop production goals by developing countries. For developing yield relationships involving plant and environmental variables, the joint participation of several agencies in the data collection effort can be difficult, due to different objectives as well as timing priorities in collecting and releasing basic data.

The value of crop yield statistics is dependent on being able to collect data in such a manner that the same statistical concepts can be accumulated or made additive over broad areas to represent an entire country or region. Consequently, a careful plan of operation encompassing a definite timetable for planning, training, and all data collection phases is extremely important. The data needs depend on the different demands which the yield modeling imposes.

Following the illustrations of the operational data-collection concepts, an actual model along with the survey statistics is used to calculate specific yield forecasts. In addition, alternative models are postulated and yield forecasts made not only for comparison purposes, but also to suggest that approximately the same forecasts or preharvest estimates are frequently obtained when using the same sample data in different but appropriate models. It should not be inferred that many different models or forecasts should be used in preference to using a single model which is based on realistic estimates of parameters (i.e., operational concepts can be defined) for which representative sample data can be made available. The emphasis in making the choice of model should be based on the field workers being able to collect the desired data in the prescribed manner and the ability to validate all or most of the model parameters each year.

3.2 Sample Design Considerations

3.2.1 Introduction

The sample design and size must be planned to give estimates for the desired geographic areas at an acceptable level of reliability. Most yield surveys are stratified by major geographic areas or political divisions. Where possible, many surveys are also substratified by major varieties, crop type, age of trees, or irrigated and nonirrigated lands. The total sample size is usually set to control the errors desired for the primary strata or geographic areas for the plant or crop characteristics at harvest. The sample sizes for the other levels of stratification are usually made proportionate to the area planted to the crop. When the allocation is proportionate to area in the crop or number of trees, the sample data on a per acre or per tree basis is self-weighted. This self-weighting feature is desirable for summarizing the data as well as examining the yields by alternative areas other than the initial strata. Where the information on crop area or production is not available by strata and substrata, farm numbers or frame sampling units must be used in the survey design. In most practical cases, several sampling stages and a number of sampling units will be used within strata. If the strata are large political or administrative divisions, a sample of districts within these divisions might be selected at the first stage and a sample of subunits within the districts at the second stage. Villages with identifiable boundaries that account for all the land within their boundaries can serve as suitable units at some stage of sampling. The ultimate unit at the third or lower stage will be the individual holding, field or parcel having the crop planted or for harvest.

3.2.2 Selection of Farm Holdings and Fields

The following examples illustrate some procedures that can be used to select farm holdings and fields in the final stages of the sample design.

(1) Farm holdings can be selected from lists, if lists are available or can be constructed. Lists of farm holdings for individual crops would be needed only for the units (villages, subdistricts, etc.) actually selected in the sample at the preceding stage; if necessary, these could be compiled as part of the field operation. The selection of holdings can be made either with equal probabilities or with probability proportionate to size (assuming that information on size is available or can be obtained). The measure of size might be total land, or cultivated area in the holding, but preferably total area planted in the particular crop for which the yield was to be determined.

Similarly, within each selected holding, a list of fields would be compiled and a sample field(s) selected. Again, selection would be made either with equal probabilities or with probability proportionate to size of the area in the crop of interest.

(2) If maps or aerial photographs are available, these can be used to select fields directly without first selecting holdings. One way to do this is to superimpose on the map or photo a grid on which dots have been placed either in a systematic pattern or at random; each field into which a dot falls is then included in the sample, thus giving the fields (and holdings) probabilities of selection proportionate to their sizes. This procedure requires, of course, that the maps or photos be sufficiently detailed so that the point and the corresponding field can be located on the ground. (This procedure is not easily adaptable

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to estimating number of holdings, if that is desired, since it involves identifying the holder and determining the total land in the holding so that the proportion of the selected field to the total holding is known.)

(3) Area segments are very useful sampling units for determining which holdings and/or fields are to be included in the sample. The segments may be constructed either with natural boundaries that can be located on the ground or with imaginary boundaries drawn on a photo or map; the choice depends upon the particular situation. Holdings and/or fields may be associated with area segments in any of the following ways:

(a) Area segments with imaginary boundaries could be used as first-stage sampling units and a sample of segments selected; within the sample segments, fields could be selected as second-stage units in the manner described above in (2).

(b) An alternative procedure would be to include in the sample all fields (or holdings) for which a uniquely defined point falls within the segment boundaries. With this procedure, fields (or holdings) would not be selected with probability proportionate to their sizes; the probability of selection would be the same as the probability of selection of the segment into which the point falls. This is known as an open-segment approach. The segments determine which units are included in the sample, but data are tabulated for some fields (or holdings) lying partly outside the segment, and are not tabulated for other fields (or holdings) lying partly inside the segment when the corresponding unique point falls outside the selected segment.

The unique point must be defined with care. Usually a particular corner of the field (holding) would be designated as the unique point. Because fields (holdings)

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may not be rectangular, a specific rule for locating this corner would be needed as well. For example, if the northwest corner were the designated unique point, it could be defined either (1) by identifying the boundary points that lie farthest west and then designating the most northern of these points as the northwest corner, or (2) by identifying the boundary points that lie farthest north and then designating the most western of these points as the northwest corner. If the holding were the unit of analysis, the residence of the holder (provided all such residences had a chance of being included in the sample) would generally be preferred as the unique point, since it would be the easiest point to locate. A combination of rules is, perhaps, even more useful. For example, the residence of the holder might be used when the holder lives on the holding, and a particular corner used when he does not live on the holding. In any case, the point must be defined in a way such that it is truly unique (that is, each unit must have one, and only one, chance of being included in the sample); it should also be fairly easy to identify.

(c) If the unit of analysis is the farm holding, the weighted-segment approach will usually be more efficient than the open-segment approach, but this costs more per unit to enumerate. With this procedure, all holdings having any land in the segment are included in the sample and hence must be contacted. In the estimation, the data from each holding are weighted by a factor based on the proportion of the entire holding lying inside the segment. In almost all applications, the weighted-segment approach requires that the segments have natural boundaries that can be identified on the ground.

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(d) Still another possibility is to use the so-called
    closed-segment approach, in which only those fields
    or parts of fields lying within the segment are included
    in the sample. One advantage of this procedure is that
    it avoids the difficulty of having to define the holding.
    The fields in the crop of interest may be identified by
    observation, hence it may not be necessary to contact
    the holder or farm operator. Of course, if yield infor-
    mation is desired on a farm unit basis, the closed-
    segment approach is not appropriate since some farms
    or holdings will certainly extend beyond the segment
    boundaries.

3.3 Determining Land Area in Yield Surveys

3.3.1 Introduction

In the preceding chapters it was assumed that the area stand-
ing in the crop could be determined from planted or reported land
areas in a manner consistent with the area of the crop harvested.
When the appropriate area figure cannot be, or has not been, de-
rived through a questionnaire, then special procedures must be
employed to define the area that corresponds to the area occupied
by the crop to be harvested, so that production can be obtained
by multiplying area times yield. If the gross area planted to
the crop was available from a crop survey, this area could be
adjusted to obtain the net area standing in the crop. However,
if the growers who grew the crop were known but were unable to
report the area planted for individual crops, then the area
occupied by the crop must be measured. For interplanted or mixed
crops, the gross area planted to all crops constitutes the area
occupied by the crop of interest.

3.3.2 Deriving Net Area From Gross Area Planted

The acres for harvest can be derived in many cases for the
sampling unit and individual fields as is shown in Table 23,
page 128 of this chapter. In cases where column 4 is greater
than column 5, the area which will not be harvested must be elimi-
nated from the area where sample plots (or plants) are located.
This is generally relatively straightforward identification for
the grower or by inspection for fields planted to a single crop,
but is more difficult for interplanted crops. For interplanted
crops, the harvested area for the crop of interest in the yield
survey would not be reduced unless the gross area planted to the
combination of crops is reduced by a similar amount. That is,
the gross area standing for harvest for the combination of crops
planted should be used as the harvested area for both crops unless

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the area is void of all plants of both crops. If the yield surveys are based on a subsample of sampling units, several alternative estimators of the area for harvest would be considered. A ratio or difference estimator would be used to estimate the area for harvest as a percentage of, or reduction in, the planted area estimate. If all the sampling units used to estimate planted area are included in the yield survey, the harvest area figure will be estimated in the same manner as the original planted area.

3.3.3 Deriving Net Area When Planted Area Is Not Known

In this case, the growers with the crop of interest have been identified in an earlier agricultural survey or will need to be identified during the first phase of the yield survey. The fields used for the yield survey will be based on selecting a probability subsample of farms or growers (identified during the first phase of the yield survey) with the crop for which the yield plots are being observed. If the selected growers have more than one field or parcel, only one will be selected at random with a known probability. Frequently, the grower may know only the number of fields planted to the crop or possibly only the number of parcels with the crop (a parcel being a cleared or cultivated area planted to one or more crops, which may include grain crops, root crops, and a home garden). For the selected field or parcel the area to be harvested must be determined either by the grower or enumerator by direct measurement of land area. Generally, this means using plane-surveying techniques, including measurement of distances, angles, differences in elevation, and a sketch drawn to a suitable scale of the area under the crop (or the combination of crops in the case of interplanted crops). The area measurements need to be made rather precisely, but these methods usually require only limited training based on techniques involving a measuring tape, standardized cord, Smith's wheel, topofil, rangefinder compass or a sighting device, without fear of introducing any large systematic errors in the area measurements. The net area for harvest is measured and identified on the sketch of the area.

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3.4 Yields From Crop-Cutting Surveys

Generally, the data-collection needs and problems are easier and fewer for crop-cutting or preharvest surveys than for early-season forecasts. If the yield procedures are to be evaluated or the quality of field workers is to be assessed, the data-collection requirements are somewhat increased. Prudent survey management requires that both of these be undertaken periodically on a subsample basis, but they are generally mandatory whenever a new program is started. Certain additional information will be needed or at least highly desirable from a preharvest survey if forecasting is to be undertaken for the same crop.

If validation, for example, is to be a part of a corn crop-cutting survey, the collection of information on number of ears and the recovery of weight of grain per ear may be necessary. For example, situations may arise wherein it is necessary to determine if (1) harvesting ears by hand from small plots results in a greater number of ears per acre than that obtained by commercial harvesting equipment, or (2) removing grain from ears using a hand sheller results in a greater weight of grain per ear than that obtained by commercial shelling equipment. The specific data needed to resolve such doubts depend on the survey procedures and the commercial harvesting practices. A second set of questions (or check items) may need to be formulated to determine if the survey definitions and procedures are being followed by the field workers.

To insure that the crop cutting (or objective-yield forecasting surveys) can be carried out in a timely and efficient manner, the total program must evolve over a period of months. The following 10 items are the major steps which normally should be spread over a 6-month period to insure proper execution, but in an emergency these steps might be completed in a 3-month period by an experienced data-collection staff.

(1) Determine plant and plot characteristics and measurements that will be needed.

(2) Order new or replacement equipment and supplies.

(3) Prepare forms for field-plot and laboratory work.

(4) Prepare training materials.

(5) Obtain results of acreage surveys to prepare acreage estimates and select sample fields.

(6) Conduct training school for collection of plant data:
   a. Cover field-work instruction manual.
   b. Present slides of important field tasks and discuss data concepts.
   c. Demonstrate plot work in the field.
   d. Give practical experience to workers using field forms.

(7) Conduct survey - calendar dates (i.e., Oct. 7-21).

(8) Review daily the completed forms (by field supervisors).

(9) Process plant parts in the laboratory.

(10) Transmit or transfer completed forms to data-analysis unit.

The following summary form, Exhibit A, shows the data-collection concepts derived from the crop-cutting survey for one field where validation work is planned, such as reported in Table 8, page 54. The summary form permits a comparison of the individual yield components as well as verifying whether the composite differences in harvesting pro-cedures are accounted for by the postharvest gleaning work. Most of the data-collection techniques employed are illustrated in the next section. In the case of very large fields, it may be desirable to sub-divide the field into smaller subfields for sampling purposes and restrict the commercially harvested area so each phase of the field work can be completed in one day.

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A - Preharvest   Field Identification _____

Line No.	Item and Computation	
1	No. samples harvested	
2	No. ears husked per 30 ft of row (15-ft unit in 2 adjacent rows)	
3	No. ears with grain husked	
4	Ears with grain per 30 ft of row (line 3 ÷ line 1)	
5	Field weight of ears with grain	
6	No. reports of moisture content	
7	Average shelling fraction	
8	Average moisture fraction	
9	Average dry-matter fraction (1.000 - line 8)	
10	Average field weight per 30 ft (line 5 ÷ 1)	
11	Average field weight per ear (line 5 ÷ 3)	
12	Average weight of grain per 30 ft at 15.5% moisture (line 10 x line 7 x line 9) ÷ (.845)	
13	Average weight of grain per ear at 15.5% moisture (line 11 x line 7 x line 9) ÷ (.845)	
14	Conversion factor to gross yield per acre (25.929 ÷ average row spacing)	
15	Gross yield per acre (line 12 x line 14)	
16	Gross ears per acre (line 3 x line 14)	
17	Weight of grain per ear (line 15 ÷ line 16)	

B - Postharvest Cleaning of Grain

18	Average weight of grain per 30 ft of row	
19	Average moisture content	
20	Average weight of grain per 30 ft of row at 15.5% moisture	
21	Conversion factor to grain left in field per acre (.02858 ÷ row width)	
22	Total grain per acre left in field (line 20 x line 21)	

C - Net Yield from Crop Cutting

23	Preharvest net yield per acre (line 15 - line 22)	

D - Data from Commercial Harvest

24	Total ears in equipment bin taken from field	
25	Total pounds of ear corn in equipment bin taken from field	
26	Total pounds of shelled corn recovered	
27	Moisture content of grain	
28	Total pounds of ear corn at 15.5% moisture	
29	Total pounds of shelled corn at 15.5% moisture	
30	Net acreage harvested (as measured)	
31	Pounds of corn per acre a. Shelled (line 24 ÷ line 26) b. Ear corn	
32	Bushels per acre a. if shelled (line 31 ÷ 56) b. if ear corn (line 31 ÷ 70)	
33	Number ears per acre (line 24 ÷ line 30)	
34	Weight of grain per ear (line 32 ÷ line 33)	

E - Yield Difference

35	Preharvest net yield minus commercial harvest yield (line 23 - line 32)	

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3.5 Forecasting Corn Yields From Plant Parts

A forecasting model which has been commonly used is based on counts or observations of the individual plant parts, because the data-collection concepts involve known yield components. These components can be identified without additional research to determine what pertinent variables are needed to forecast yields, since agronomists and other agricultural scientists have already identified the basic components. Of course, alternative yield models can be formulated which would require initial research to identify critical factors or the correct time for the scheduling of data-collection activities that could lead to a superior model. However, the choice of this type of model is based on identifying an initial model which can provide useful results with no practical risk of selecting an unworkable model.

The inventory-component type of model may be formulated in several ways involving only minor differences in the components used. For corn a very basic model with several variations would be:

Model (1) Yield per hectare = plants per hectare x weight of grain per plant,

or   Model (2) Yield per hectare = ears per hectare x weight of grain per ear,

or   Model (3) Yield per hectare = ears with grain per hectare x kernels per ear with grain x weight per kernel.

The components in the above models can be verified at harvest, so the validity of each component can be evaluated.

If three forecasts were to be made prior to harvest, perhaps all three models might be used: model (1) about 90 days prior to harvest, model (2) about 60 days prior to harvest, and model (3) 30 or fewer days prior to harvest. Assuming use of one of the variations in this type of model, the data-collection requirements are given in Exhibit B where corn is planted in rows. The listing and selection of fields for

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a sampling unit are given in sections 3.5.1 and 3.5.2. A variation in the procedure for determining number of plants per hectare would be required if plants are planted in an irregular manner.

Exhibit B could be used at any time after emergence, but the form would be materially shortened if only one of the model variations was to be used on a given occasion. For instance, model (3) might be used 60 days prior to physiological maturity by assuming a norm or historical weight per kernel. In this case, the key data items would be 7 and 11, with item 10 providing an alternative basis for forecasting weight of grain per ear. The weight forecast might be based on developing a linear relation between kernel-row length and harvest weight of grain per ear. It should be clear that similar reductions in the data items to be collected could be made for a specific single-date forecast.

Yield forecasts based on agrometeorological models likewise would use only a very limited amount of the information in Exhibit B, but would require environmental data from another source. However, the verification of the forecasts would require that some data be collected either at physiological maturity or at the time of commercial harvest. Certainly, the field work to collect plant data would be less frequent and greatly reduced if repeated forecasts during the season were not needed.

The information in Exhibit B permits several different ways each model could be used during the season, and the particular variables adopted might be determined either as a result of a pilot study or previous experience of agriculturalists in the area. Table 22 shows the components and how they might be used in different variations of a forecast model.

UNIT LOCATION

	UNIT 1	UNIT 2
Number of rows along edge of field.......		
Number of paces into field..............		

Observe Rule 1 and Rule 2 when laying out the sample units.

	UNIT 1	UNIT 2	
1. *Measure distance from stalks in Row 1 to stalks in Row 2...Feet & Tenths*			
2. *Measure distance from stalks in Row 1 to stalks in Row 5...Feet & Tenths*			

COUNTS WITHIN 15-FOOT UNITS

	Row 1	Row 2	Row 1	Row 2	
3. Number of plants.............................					
4. Number of plants with ears or silked ear shoots...........................					
5. Number of plants with ears with kernel formation...........................					
6. Number of ears and silked ear shoots.......					
7. Number of ears with evidence of kernel formation...........................					

COUNTS BEYOND UNIT, ROW 1 ONLY:

Maturity Stage	Code No.
(No kernel development)	
Preblister.....................	2
Blister........................	3
Milk...........................	4
Dough..........................	5
Dent...........................	6
Mature.........................	7

Husk the first 5 ears or silked ear shoots beyond Row 1 and examine for maturity. If ears or silked ear shoots are not yet present enter "zero" in Total Column and skip Items 8-14.

	Ear Number					Total 5 Ears	Unit
	1	2	3	4	5		
8. Maturity of 5 ears or silked ear shoots							1
							2

If total in Item 8 is
12 or less, skip Items 9 through 13.
13 or more, continue. (If any ears in Item 8 are Code 2, replace Code 2 ear with a Code 3-ear and enter in Item 9.)

	Ear Number					Unit
	1	2	3	4	5	
9. Maturity stage of first 5 ears Code 3 or higher.............. Code No.						1
						2

Does Item 9 have 3 or more Code 7 ears?

☐ YES, If yes complete Items 13 & 14 only.

☐ NO, If no complete Items 10 to 12 only.

---

10. Average length of kernel rows.................... Inches & Tenths						Unit
						1
						2

11. Number of rows with grain (a) and number of kernels for selected row (b) ....

a|b: No. Rows per Ear/Kernels per Row						Totals	
Ear →	1	2	3	4	5	1a	1b
Unit 1							
Unit 2							

MEASUREMENTS WITHIN UNIT 2, ROW 1

12. Measure <u>length and circumference of cob</u> for all ears counted in Item 7 for Unit 2, Row 1.

Do NOT remove "ear" or pull back husk. Record to nearest 1/10 inch. If more than 24 ears, use blank space on right.

Len. Cir.	Len. Cir.	Len. Cir.	Len. Cir.
1. ___ ___	7. ___ ___	13. ___ ___	19. ___ ___
2. ___ ___	8. ___ ___	14. ___ ___	20. ___ ___
3. ___ ___	9. ___ ___	15. ___ ___	21. ___ ___
4. ___ ___	10. ___ ___	16. ___ ___	22. ___ ___
5. ___ ___	11. ___ ___	17. ___ ___	23. ___ ___
6. ___ ___	12. ___ ___	18. ___ ___	24. ___ ___

.......STOP AFTER COMPLETING ITEM 12...........

Total Cir. ☐
Total Length ☐
Total Ears ☐

13. HUSK and TAG 3rd and 4th ears in Row 1 of both units. Then husk remaining ears. Number of ears husked with grain....................

Unit 1 Row 1	Unit 2 Row 1	

14. Weight of ears with grain: Both units weighed together..Pounds & Tenths *(Exclude weight of containers)* Place 3rd and 4th ears of Row 1 in separate bags for each unit. (Check)

( ) ( ) ☐

15. After completing Items 13 and 14-- submit forms and 3rd and 4th ears to State Lab for grain weight determination at standard moisture content.

Ending Time (field edge) ☐

Status Code ☐

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Table 22--Components and Forecast Parameters

Time of Season	Component/Source	Forecast Parameter

90 days prior to harvest	Plants per hectare
	  Item 3
	
	Weight of grain per plant
	  Items 14, 15 at harvest
	
	  Items 6, 3
	
	  Item 3
	
	  Items 14, 15 at harvest
		Plants per hectare observed
		
		(a) Historical norm for area (or variety)
		(b) Number ears per plant observed x historical norm for grain per ear for area
		(c) Seasonal prediction based on linear regression of grain per plant
		    Per hectare or per plot (a historical regression equation)

60 days prior to harvest	Plants per hectare
	  Item 3
	
	Ears per hectare
	  Item 6
	
	Ears with grain per hectare
	  Item 7
	Weight per plant
	
	Weight per ear
	  Item 12
	
	  Items 14, 15 at harvest
	
	Weight of grain per ear
	  Item 11(a)
	  Item 11(b)
	  Items 14, 15 at harvest
	
	  Item 10
	
	  Items 14, 15 at harvest
		Plants per hectare observed
		
		Ears per hectare observed
		
		Ears with grain per hectare observed
		
		(a), (b), (c) above
		
		Ears per hectare observed x seasonal prediction based on linear regression of grain per ear on ear size measured, length x circumference (a historical regression equation)
		
		(d) Kernel rows per ear x kernels per row observed x historical norm for grain weight per kernel
		(e) Seasonal prediction based on linear regression of grain per ear on
		    length of kernel row per ear (a historical regression equation)

30 days or fewer to harvest (physiological maturity)	Ears with grain
	  Item 7
	Kernels per ear w/grain
	  Item 11
	Weight per kernel
	  Items 14, 15
	
	Weight grain per ear
	  Items 14, 15
		Observed
		
		Observed
		
		Observed and adjusted to standard moisture content
		
		Observed and adjusted to standard moisture content

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3.5.1 Listing of Crop Fields for Area Sampling Units

A sample of fields is selected from a probability area survey of crop acreages within each region or State based, on the closed-segment concept. The farm tracts and fields with the designated crop are selected with probabilities proportionate to the expanded acreage of the designated crop, hence the sample will be self-weighting if a constant number of plots is selected in each field. The sampling unit is a farm tract with the designated crop and all the fields planted to that crop.

Table 23 is completed for the desired crop only by entries in columns 2 through 5.

Column 2 - *The VARIETY planted is recorded in each field. A field should not consist of more than one variety. (Varieties are ignored in this example.)*

Column 4 - *Acres actually PLANTED are obtained in each field. Exclude acres in roads, ditches, rockpiles and other nonplanted areas.*

Column 5 - *Acres for HARVEST are obtained in each field. Exclude acres already abandoned or otherwise not intended for harvest.*

Column 5 - *HARVESTED acres are accumulated, field by field, to a total for the entire sampling unit.*

The accumulation is obtained by adding the acres for harvest in the top line for each field to the previous accumulated entry. Accumulated acres for last field will always equal the total acres for harvest in the entire sampling unit.

Table 23--Sampling Unit Data

Field no.	Variety	Office use	Acres planted	Acres for harvest Accumulated	
(1)	(2)	(3)	(4)	(5)	
1			15.0		15.0
				Accum.	15.0
2			20.0		20.0
				Accum.	35.0
3			10.0		10.0
				Accum.	45.0
4			13.0		13.0
				Accum.	58.0
5			23.0		23.0
				Accum.	81.0
6			15.0		15.0
				Accum.	96.0
7			10.0		10.0
				Accum.	106.0
8			17.0		15.0
				Accum.	121.0
9			7.0		6.0
				Accum.	127.0
10			5.0		5.0
				Accum.	132.0
11			115.0		5.0
				Accum.	247.0
(12)			65.0		63.0
				Accum.	310.0
13			87.0		87.0
				Accum.	397.0
14			120.0		120.0
				Accum.	517.0
15			150.0		145.0
				Accum.	662.0
(16)			160.0		152.0
				Accum.	714.0
17				Accum.	
18				Accum.	
19				Accum.	
20				Accum.	

The total acres (last accumulated entry) for
harvest on the land in the area unit is...... ACRES _____

IS THAT RIGHT?

   (a) ( ) NO -- Review all fields, correct Table 23, col. 4.

   (b) ( ) YES -- Make selection of sample field(s).

If column 2, Table 24 is zero, conclude interview.

3.5.2 Selection of Sample Fields

A sample field must be selected for each sample number listed
in Table 24 on the next page. The sample number and selected acre
for each sample have been entered by the statistical office. For
each of these samples, observations will be made and ears will be
harvested for the two separate units when mature.

The sample number and selected acre will determine in which
field(s) the sample(s) will be laid out. Large fields may have
more than one sample selected for the field. If only one field is
listed in Table 23, that field will automatically become the sample
field if a selected acre is listed in Table 24.

To select the sample field:

a. Select the first field in Table 23 in which the accumu-
    lated harvested acres equal or exceed the selected acre
    for the sample number listed for the sampling unit.

b. Enter selected field number in Table 24.

c. Circle the selected sample field number in Table 23.

d. For the additional sample shown in Table 24, repeat steps
    a, b, and c above.

The example on the next page shows that two samples will be
laid out for the sampling unit. Select the field for sample no. 24
first--this will be the first field listed in Table 23 for which
the accumulated acres equal or exceed 295.

Now select the sample field for sample 25. The selected acre
is 670 and the first field for which the accumulated acres equal
or exceed the selected acre is field No. 16. Enter this number in
Table 24 on sample 25. Circle the field number in Table 23 on
sample 25.

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Table 24--Selection of Sample Fields on Farm

Sample number	Selected acre	Selected field number
24	295	12
25	670	16

At this point the field enumerator is ready to go to the field to collect the data shown in Exhibit B.


3.5.3   Selection of Units Within Field

The enumerator proceeds from the point of interview to the sample field. The work proceeds in stages, starting with the layout of the field units, recording the various counts and observations, and perhaps (destructively) sampling several ears or plants depending on the model. Not all the data may be obtained at each visit, since the stage of development of the plant will determine what information is appropriate or obtainable. The units are located by use of the random-row and pace numbers entered at the top of the form. Figure 9 illustrates some of the key steps in laying out the unit.

HILLED   DRILLED
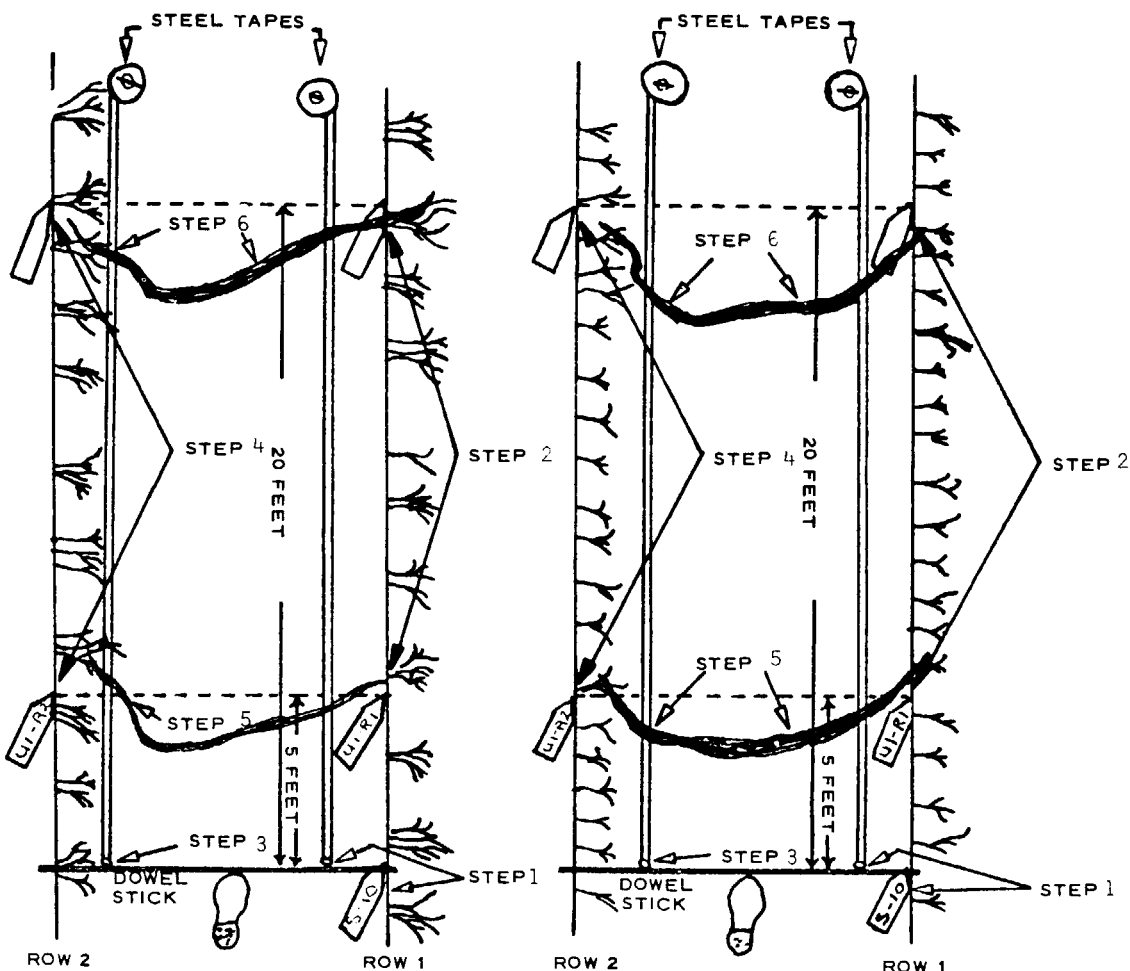
STEP NO. 1:

After the last pace into the field, place dowel stick perpendicular to rows. Anchor 50-ft steel tape just beyond the dowel in row 1. Insert a florist stake by the anchor.

STEP NO. 2:

Insert a starting florist stake EXACTLY 5 feet from the anchor and an ending stake EXACTLY at the 20-foot mark with flat sides at right angles to the row direction.

STEP NO. 3:

Repeat step 1 for row 2, except that no florist stake should be inserted at row 2 anchor.

STEP NO. 4:

Repeat step 2 for row 2.

STEP NO. 5:

Tie a 4-foot piece of flagging ribbon near the top of the first plant inside the unit in row 1 and across the row middle to the first plant in row 2 of each unit.

> **RULE 1:** If a plant emerges from the ground exactly at the starting stake, INCLUDE that plant in the unit. INCLUDE the entire hill if any plant in a hill is included at the starting stake.

STEP NO. 6:

Tie a 4-foot piece of flagging ribbon near the top of the last plant inside the unit in row 1 and across the row middle to the last plant in row 2 of each unit.

> **RULE 2:** If a plant emerges from the ground exactly at the ending stake, EXCLUDE that plant from the unit. EXCLUDE the entire hill if any plant in a hill is excluded at the ending stake.

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3.5.4 Concepts for Collection of Plot Data

After the plots have been laid out, the pertinent data in
Exhibit B is recorded for each plot.

1. *Measure distance from
   stalks in row 1 to stalks
   in row 2*.................... Feet & tenths

Unit 1	Unit 2	

At the dowel stick, measure the distance across the first
row space with the steel tape. Anchor at the *center* of
the stalks in the *first* row in the unit and measure to the
center of the stalks in the *second* row in the unit. This
is the distance across the first middle. Record this dis-
tance in feet and tenths of feet.

2. *Measure distance from
   stalks in row 1 to stalks
   in row 5*.................... Feet & tenths

Unit 1	Unit 2	

Measure the distance across 4 corn row spaces (5 adjacent
rows) and record in item 2. You should measure at the dowel
stick from the center of the stalks in row 1, to the center
of the stalks in row 5. All measurements will be made with
the tape in *feet* and *tenths of feet*. See example on page 134.

NOTE: Items 1 and 2, (row space measurements) should be made
       only on the first visit, or if the units are relocated
       on later visits.

In the event the field is "skip planted" so that there are
several rows of corn and then several rows of a second crop,
record the planting pattern in the margin. For example, if
the planting pattern is 2 rows corn, then 2 rows soybeans,
the measurement recorded in item 2 is the sum of the distances
between two rows of corn in four different strips. Apply the
same principle if corn is planted in strips of three or four

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rows. If corn is planted with one narrow middle and one wide
middle, (example: a 7-inch middle followed by a 40-inch middle)
the measure recorded in item 2 is the sum of 2 narrow middles
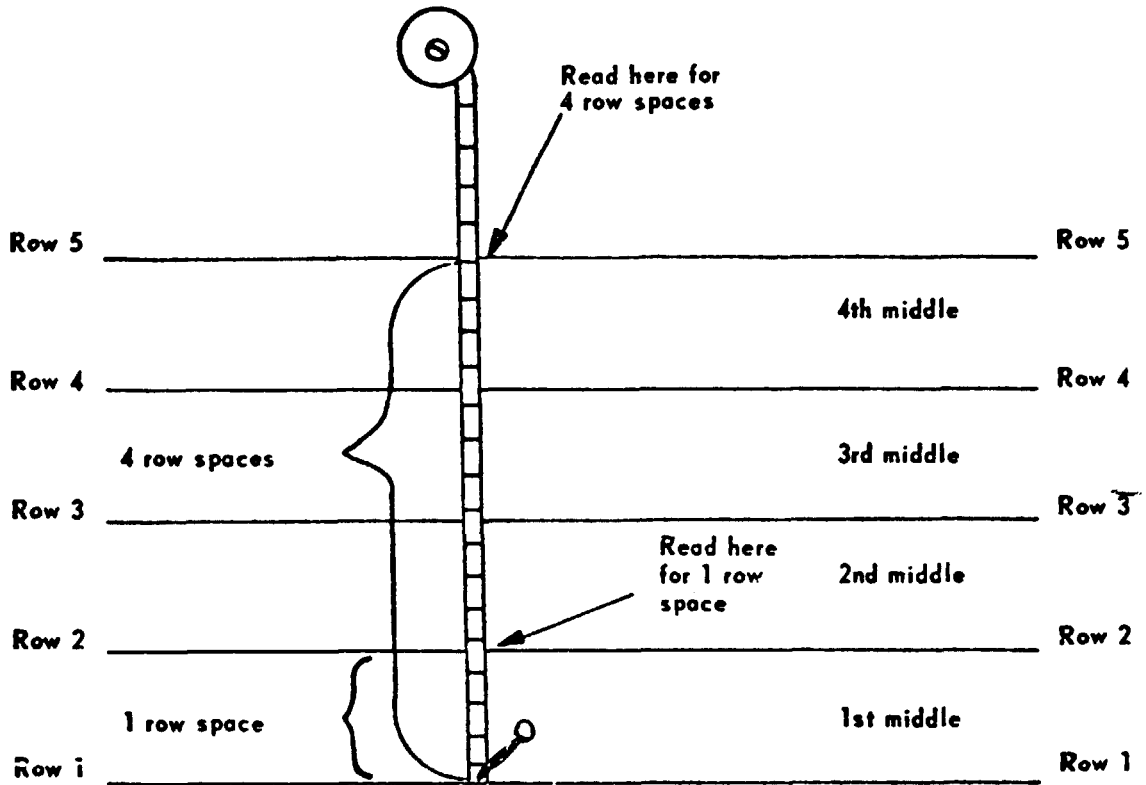plus 2 wide middles.

In all cases of unusual row spacing (very narrow or wide
row spacing), write an explanatory note in the margin of the
form.

MEASURE DISTANCE FROM STALKS IN ROW 1 TO STALKS IN ROW 2: At the
   dowel stick, anchor the tape at the center of the stalks in
   row 1 of the unit and measure to the center of the stalks
   in row 2 of the unit. Record in feet and tenths of feet.

MEASURE DISTANCE FROM STALKS IN ROW 1 TO STALKS IN ROW 5: At the
   dowel stick, anchor the tape at the center of the stalks in
   row 1 of the unit and measure to the center of the stalks
   in row 5. Record in feet and tenths of feet.

*Row measurements must be made with a tape
calibrated in feet and tenths of feet.*

Row-Space Measurement

Read here for
4 row spaces

Row 5   Row 5

4th middle

Row 4   Row 4

4 row spaces   3rd middle

Row 3   Row 3

Read here
for 1 row
space   2nd middle

Row 2   Row 2

1 row space   1st middle

Row 1   Row 1

Unit 1		Unit 2		
Row 1	Row 2	Row 1	Row 2	

3. *Number of stalks..............*

Count all stalks in each 15-foot row inside the unit, regardless of size or condition. Do not count tillers (suckers) as stalks. An important identifying characteristic of a tiller or sucker is that it emerges from the ground close to the main stalk, often at a slight slant. Other features are the generally smaller size of the tiller as compared with the main stalk, and usually the lack of brace roots on the tiller. A main stalk and its tillers come from the same seed (see illustration, page 141).

If you continue to be uncertain as to whether it is a tiller, go outside the unit and find a similar plant. Dig it up to determine whether it is a stalk or a tiller.

Any volunteer stalks growing in the row space between row 1 and row 2 are to be included in the count for row 1. Likewise, stalks between row 2 and row 3 should be included in the count for row 2.

Late in the growing season, after the seeded crop has matured, mature seed may fall to the ground and germinate. Any volunteer plants which come from the current year's crop should be excluded from the plant.

Unit 1		Unit 2		
Row 1	Row 2	Row 1	Row 2	

4. *Number of stalks with ears or silked-ear shoots........*

Count the number of stalks in item 3 having ears or silked-ear shoots on the main stalk, or if none on the main stalk, on a tiller from the main stalk. A silked-ear shoot is the early formation of an ear on a stalk with some silk protruding beyond the husk. Item 4 cannot be greater than item 3, "total stalks."

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5. *Number of stalks with ears showing evidence of kernel formation......*

Unit 1		Unit 2		
Row 1	Row 2	Row 1	Row 2	

Count the number of stalks in item 4 having ears in which the kernels have definitely begun to form. To have evidence of kernel formation, ears must be in BLISTER or later stages of maturity. Item 5 cannot be greater than item 4 (stalks with ears or silked-ear shoots). Make item 5 counts in row 1 of each unit.

Do not remove or pull back the husks of ears within the unit to inspect for kernels. Outlines of the kernel rows may be felt through the husks, or kernels may be seen at the top of the cob. See page 141 for a description.

6. *Number of ears and silked-ear shoots.......*

Unit 1		Unit 2		
Row 1	Row 2	Row 1	Row 2	

This count will include all ears and all ear shoots on which there is visible evidence that silks have emerged beyond the husks. Only one ear or ear shoot is to be counted from each *node*. A node is a fruiting position on the stalk. Do not count an ear shoot from a node which has an ear. *Ears* and *silked-ear shoots on tillers (or suckers) are to be included in this count.* In cases where a considerable period of time may have elapsed since silking, kernel formation may be taken as evidence of silking, even though silks are no longer visible.

7. *Number of ears with evidence of kernel formation...............*

Unit 1		Unit 2		
Row 1	Row 2	Row 1	Row 2	

This is to be a count of all ears in which kernels have definitely begun to form. An *ear of corn* is defined as a cob having at least *one kernel*. *Ears on tillers should be included in the count.* To have evidence of kernel formation, ears must be in *BLISTER* or later stages of maturity. Ears will have

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started to enlarge and will have a solid "feel" to them. Most silks protruding from the husks will be turning color or may be brown or dry.

Outlines of the kernel rows may be felt through the husks, or kernels may be seen at the top of the cob. Only one ear is to be counted from each node.

DO NOT remove or pull back the husks of ears within the unit to inspect for kernels. In doubtful cases, go outside the unit and inspect similar ears or ear shoots for the presence of kernels. After having done this, *exclude* any questionable ears from item 7.

Ears with kernel formation found loose on the ground in row 1 and row 2 middles are to be included in the count of ears for their respective rows.

Deformities emerging as part of the tassel which resemble a small cob with some kernels *are not considered ears* and should not be included in the count.

Next Step:	Maturity Stage	Code No.
Husk the first 5 ears or silked-ear	Preblister.......	2
shoots beyond row 1 for only the	Blister..........	3
designated unit, then examine for	Milk.............	4
maturity. If ears or silked-ear	Dough............	5
shoots are not yet present, CHECK ( )	Dent.............	6
and skip items 8-14. See page 142	Mature...........	7
for illustrations.		

For *August 1,* husk and inspect the first 5 ears or silked-ear shoots *beyond unit 2, row 1* for stage of maturity. Enter maturity codes in item 8.

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August 1 - *If the total of the maturity codes for the first 5 ears is* 12 or less, *skip items 9 through 14. If total is* 13 or more, *continue with item 9 on first 5 ears in maturity code-3 or higher. If any ears in item 8 are code-2, replace these ears with code-3 ears and enter in item 9.*

For *September 1,* husk and examine the first 5 ears or silked-ear shoots beyond unit 1, *row 1* for stage of maturity. Enter maturity codes in item 8.

September 1 - *If the total in item 8 is* 12 or less, *skip items 9 through 14. If total is* 13 or more, *continue with item 9 for first 5 ears in maturity code-3 or higher. If any ears in item 8 are code-2, replace each code-2 ear with a code-3 ear and enter in item 9.*

In case there is more than one ear on a stalk, always count the *top ear first for odd-numbered samples.* Always *count the bottom ear first for even-numbered samples.* Pull back the husks without removing the ears from the stalks and classify each ear as to stage of maturity. Enter the proper maturity-stage code number for each ear. The rule is: *TOP--ODD; BOTTOM--EVEN.*

If the field is in a very early stage of growth and as a result ears or silked-ear shoots are not yet present in the unit or beyond the unit, a check mark should be inserted in the appropriate space in the instruction above item 8; then skip items 8 through 14.

The maturity classification for each ear will be based upon external characteristics of the plant and ear as well as kernel characteristics.

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*Each maturity stage has several distinct character-
istics.* All of these characteristics should be considered
when assigning the maturity stage.

Maturity code 2 fits definition of "silked ear shoots
or cobs without evidence of kernel formation." Maturity
codes 3 through 7 refer to "ears with evidence of kernel
formation" (item 7).

9. *Maturity stage of first
   5 ears code 3 or higher*

   . . . .

   Code No.

   . . . .

Ear number					Unit
1	2	3	4	5	
					1
					2

Does item 9 have <u>3 or</u>
more code-7 ears?

☐ YES. Complete items 12 and 13 only.

☐ NO. Complete items 10 and 11 only.

<u>*August 1 and September 1*</u> *- If the sum of the maturity codes
for the 5 ears in item 8 totals* <u>*13 or more,*</u> *copy the maturity
code for each ear classified as code 3 or higher directly
below to item 9. Whenever the total of the 5 ears is 13 or
more and any code-2 ears are listed in item 8, you will select
the next ear beyond the unit which is maturity code 3. List
its maturity code in item 9.*

> NOTE: There should not be any ears in maturity code 2
> listed in any boxes in item 9. All ears must be
> code 3 or higher. Code 2 ears should have been
> replaced with code-3 ears.

For *October 1,* husk and examine the first 5 ears with evidence of kernel formation beyond unit 1, row 2 for stage of maturity. Enter maturity codes in item 9.

For *November 1,* husk and inspect the first 5 ears with evidence of kernel formation beyond unit 2, row 2 for stage of maturity. Enter maturity codes in item 9.

All Months - Before breaking an ear to determine the difference between maturity code 6 and code 7, measure and record the average length of kernel row in item 10.

Does item 9 have 3 or more code-7 ears?
> If YES, complete items 12 and 13 only.
> If NO, complete items 10 and 11 only.

12. *Measuring length of ear*

In determining the length of the ear, the zero point of the tape is held at the butt of the cob with one hand. With the other hand, the tape is drawn taut along the length of the ear. When the tip of the cob is felt between the thumb and forefinger, the point on the tape is marked by the thumbnail and the length of the ear read to the nearest one-tenth inch. Any husks projecting beyond the top of the cob should not be included in determining the length. (See page   .)

Enter measurements in decimal fractions: as 6.4 not 6 4/10, etc. Do not confuse this cob length measurement with the average length of kernel-row measurement in item 10. On the same ear, the cob length is usually from 1/2 inch to 2 inches longer than the average length of the kernel row.
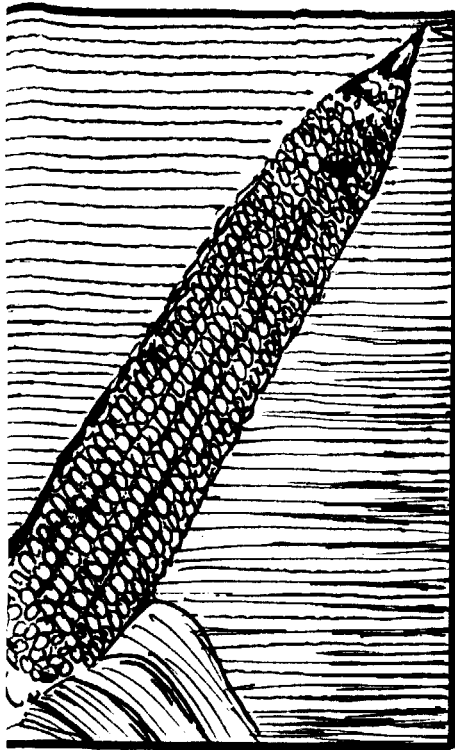
4 - Milk
kernels, although not fully grown,
full of a milklike substance and
little or no denting.
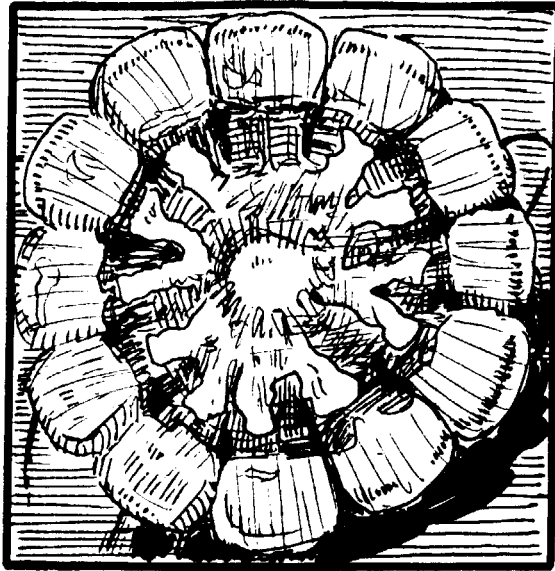
Code 5 - Dough
Kernels are fully grown with milk or
doughlike substance in all of them.
About one-half of the kernels are
dented. In this example, the maturity
line is noticeable but has not moved
halfway to the cob on a majority of
the kernels.

5 - Dough
is beginning to lean away from the
k and shucks are taking on a light
-colored appearance. Visible silk
completely brown and dry.

To measure the cob, hold the zero
point of the tape at the butt of the
cob, draw the tape up the ear until
the tip of the cob is felt, and mark
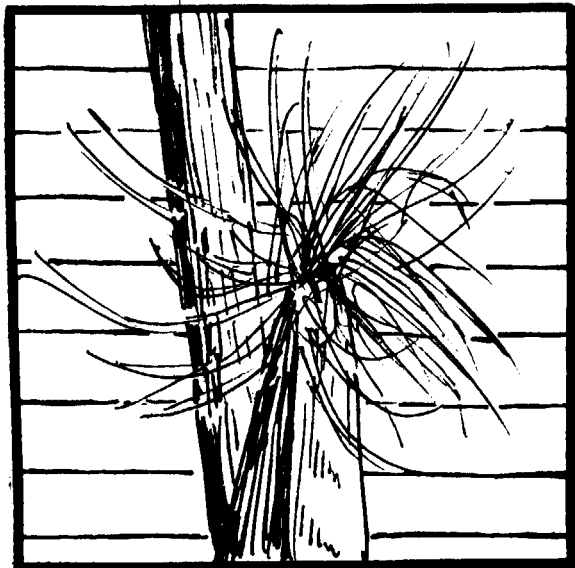that point on the tape with your
thumbnail.

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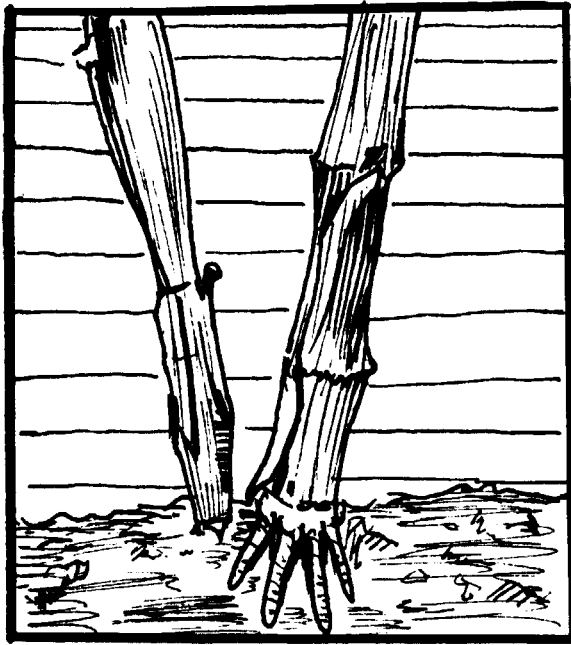
A tiller or sucker may emerge from the ground close to the main stalk, often at a slight angle. (This tiller is to the left of the stalk). Do *not* count tillers as stalks.
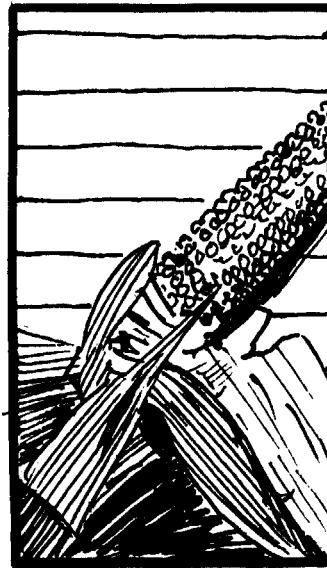
Code 3 - Blister
Silk is beginning to
the ear is filling ou
rather than just a ha
felt through the husk

Code
Most
are
have

Code 2 - Preblister
Silk still has green tint and has not begun to turn brown. Only the cob and/or hard spikelets can be felt through the husk.

Code 3 - Blister
Most spikelets have
kernels well enlarge
watery, clear liquid
silk has turned colo
somewhat dry.

Cod
Ear
sta
rus
is

3.5.5 Plant Growth Models

These models rely on detailed plant data collected more
frequently during the season, as well as on environmental data.
The additional plant data needed is primarily to provide in-
formation on the vegetative growth and the stage of development
of certain plant parts. These two additional data needs are
summarized in Exhibit C to typify the kind of information which
might be needed for corn. Meteorological and environmental
indices would probably be obtained from an alternative data
collection system, but due to the more frequent visits to the
fields it may be feasible to also collect the environmental data
with automatic recording instruments, using the same field workers.

EXHIBIT C. TYPICAL PLANT DATA NEEDED FOR CORN

Part A – Growth Model for Weight of Grain per Plant

Plant no. _____   Unit _____   (Form may have room for 20-50 plants per unit)

Field Data

1. Has plant tasseled? YES ( ) NO ( )   0 or 1 [_____]

2. Has plant silked? YES ( ) NO ( )   0 or 1 [_____]

    If "yes," enter silking date (day no., Jan. 1 = 1)   [_____]

For silked ears:

3. Primary ear on plant   Length   _____
                             Circumference _____
                             Evidence of kernel formation YES( ) NO( )

4. Secondary ear on plant   Length   _____
                             Circumference _____
                             Evidence of kernel formation YES( ) NO( )

5. Other ears   Length   _____
                             Circumference _____
                             Evidence of kernel formation YES( ) NO( )

Harvest ears on plants if 3 or 4 shows evidence of kernels and random number entered equals plant number RN = _____.

6. Number ears harvested   _____

    Identify each ear as from 3, 4, or 5, and forward to office or field laboratory.

Lab Data

7. Wet weight of ears (grams) by type

    #3. _____   #4. _____   #5. _____   Total weight [_____]

8. Number kernel rows

    #3. _____   #4. _____   #5. _____

9. Number kernels on random row _____ , _____ , _____

    #3. _____   #4. _____   #5. _____

Extract kernels from selected row and dry for 36 hours

10. Wet weight of kernels extracted from 3, 4, 5 (grams)   [_____]

11. Dried weight of kernels extracted from 3, 4, 5 (grams)   [_____]

12. Dry-matter percentage   line 11 ÷ line 10   [_____]

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EXHIBIT C. (cont.)

Part B - Vegetative Growth of Plant Parts

---

1. Date of planting   (day no., Jan. 1 = 1)   _____

2. Date of emergence   (day no., Jan. 1 = 1)   _____

3. Variety _____   Fertilizer applied _____

4. Soil moisture immediately after emergence at: .5 meter   _____
                                                   .10 meter   _____

5. Row direction _____

6. Height of plant   _____

7. Number of leaves   _____

8. Size of leaves

	L.	W.		L.	W.		L.	W.
a.	___	___	h.	___	___	o.	___	___
b.	___	___	i.	___	___	p.	___	___
c.	___	___	j.	___	___	q.	___	___
d.	___	___	k.	___	___	r.	___	___
e.	___	___	l.	___	___	s.	___	___
f.	___	___	m.	___	___	t.	___	___
g.	___	___	n.	___	___	u.	___	___

Plant
leaf area [_____]

9. Stage of development: (circle one):   a b c d
     e f g h

10. Leaf area index   LAI _____

11. Ground cover   Percent _____

Cut plant at ground level, if selected for laboratory sample.

12. Wet weight of plant parts   Dry weight of plant parts

    Stem   _____ grams   _____ grams

    Leaves   _____ grams   _____ grams

    Head   _____ grams   _____ grams

      Culm   _____ grams   _____ grams

      Grain   _____ grams   _____ grams

13. Number of grains _____

Figure 10: Mature Crop Samples Sent to Laboratory for Weight
and Moisture Determination

3.5.6 Corn Yield Forecasts

The yield-forecast technique being illustrated is based on
data (actual) collected in 1976 approximately in the dough stage
(around September 1) in a selected State in the Midwest region
of the U.S. The number of ears are counted and the length of ears
measured in plots 30 feet long consisting of two adjacent rows,
and the row spacing is measured so the area of the plot could be
converted to an acreage. The basic model for yield is: Biologi-
cal yield = ears per acre x weight of grain per ear. The statistics
which must be obtained are as follows:

(1) Average number of silked ears per 60-ft row plot = 103.9

(2) Average row spacing = 3.32 ft

(3) Acreage conversion factor for one plot = 218.5

(4) Average number of silked ears per acre = 22,695

(5) Average length of cob for silked ears measured over
    husk = 7.92 in.

(6) Historical regression equation (equation (4), page 60)
    for converting ear length to weight of grain at 15.5%
    moisture

    $\bar{W} = (.0854 \times 7.92) - .304 = .3724$ lb or 168.9 gm

(7) Biological yield per acre = #4 x #6 = 8451 lb

(8) Estimated net yield per acre to be taken from field (less
    field and harvesting losses) = 8451(.90) = 7606 lb or
    135.8 bu

In this forecast a global regression model for weight of grain
per inch of cob length was used in conjunction with the survey
averages of the inventoried components. Equation (4), page 60,
was derived from probability samples of ears from the early 1960's.

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An alternative model for the weight of grain per ear will be derived from the observed numbers of kernels per ear and a historical weight (global mean model) for the weight per kernel.

The calculations for the alternative yield model are:

(5a) Average number of kernels per ear = 543 (average count)

(6a) Historical weight per kernel (Table 13, page 65)

W = .300 gm per kernel at 15.5% moisture x number of kernels per ear converts to weight of grain per ear = 162.9 gm or .3591 lb

(7) Biological yield per acre = #4 x #6 = 8150 lb

(8) Estimated net yield per acre to be taken from field = 7335 lb or 131.0 bu (less field and harvesting losses: #7 x .90).

3.5.7 Corn Yield Forecast Based on Within-Year Growth Model

The use of the term "growth model" applies more correctly to just the dry-matter accumulation per ear or dry matter per kernel. The number of ears, number of kernels per ear and plants with ears at harvest are forecast based on a "survival model" rather than a growth model. The yield model implies the separate modeling of the individual components.

The field data have been collected from a somewhat different plot configuration. The plot is laid out from a random starting point in each field. The plot consists of two parts: the plants in a 50-ft section of a row from the starting point and the first 100 plants commencing with the starting point. The 50-ft section is a part of (a subset of) the 100 plants.

Figure 11: Plot Layout for Collection of Weekly Data for
Plant Growth Study

```
              ┌─────────────────── 50' ───────────────┐
              │                                        │
              └─────────────────────────────────────┤
1 2 3 4 5                              59 60      75              100
```

Plant numbers
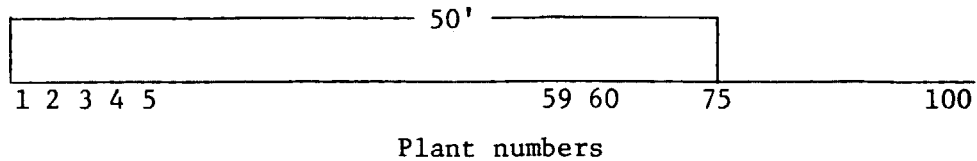
The 1976 statistics (same State) required for this model are as follows:

(1) Average number of plants per acre = 21,540

(2) Average row spacing = 3.32 ft

(3) Acreage conversion factor = 218.5

(4) Average number of silked plants per acre = 20,380

(5) Number of silked plants with grain at harvest per acre = 20,258

(6) Growth equation fitted to observed grain weight per plant after the fourth weekly visit since silking and evaluated at harvesttime $(t \geq 80)$ gives:

$\hat{\alpha} = 156.4$, $\hat{\beta} = 105.5$, and $\hat{\rho} = .863$ when the computer routine terminates based on change in y (ε), where

$$y = \frac{\hat{\alpha}}{1 + \hat{\beta}\hat{\rho}t_i}$$ and arithmetically $\hat{y} = 156.4$ gm when 180

is substituted for t_i .

(7) Expected weight of grain per silked plant at plant maturity adjusted to 15.5% = 181.8 gm or .4008 lb

(8) Biological yield per acre = #7 x #5 = 8119 lb or 145 bu

(9) Estimated net yield per acre to be taken from field = 7307 lb or 130.5 bu (less field and harvesting losses: #8 x .90).

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The actual weight of grain (with 1.8% moisture) per plant
at maturity was 166 grams rather than the 156.4 forecast. The
relative errors in the primary parameter in the growth model
were 9.2% for weight of grain per plant and 0.3% for the sur-
vival parameter for plants with grain. Thus, the differences
in the alternative yield forecasts for this sample of 24 fields
are well within the sampling error of the forecasts.

The methods illustrated for corn can be applied to almost
any crop. The specific plant characteristics used in the modeling
should be quite similar for all the grain crops, cotton, and soy-
beans, as well as vine and tree crops. The use of additional
characteristics in the concept of "fruit size" such as diameter,
circumference or volume may be needed to improve the size-weight
relations.

3.6 Grower Yield-Appraisal Models

3.6.1 Introduction

Crop reporters, observers or farm operators are frequently requested to report on either an absolute (i.e., bushels per acre) or on a relative basis. The reporting is usually voluntary. Consequently, the questionnaires are short and restricted to several crops planted at the same time.

The concept of "normal condition" or "full crop" was initiated for forecasts when the crop was in the vegetative stage of development. The evaluation of the crop was based primarily on the stand and vigor of the plants but also reflects the appearance of fruit on crops with short fruiting periods. The number "100" is frequently used to designate a normal condition if there has been no damage from unfavorable weather, insects, pests, etc. on field crops. As crops near maturity, reporters are asked to report the probable yield on their farms, fields or for their locality. In either case, the crop condition or probable yields are translated into harvested yields by means of regression charts or equations over a series of years. Consequently, it is necessary to keep the concepts over years, and the sample of reporters or growers must be representative of the crop planted over each region or country. Most growers report at regular intervals during the growing season, according to the crop appearance. As the crop approaches harvest, the forecasts are based on the fruit appearance. In general, crops with well-defined and visible fruiting habits which are subject to a relatively short "critical period" are more accurately forecast. By comparison, root crops are subject to rather large forecast errors.

Exhibit D shows the basic questions for reporting condition, while Exhibit E gives corresponding question for probable yields. Exhibit F combines the two concepts and is the basis for an example of the graded yield appraisal discussed in chapter 2, where similar questions are also asked after harvest.

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EXHIBIT D - GROWERS' REPORTED CONDITION FOR CROPS

Report for your locality

I. WINTER WHEAT

    1. For irrigated wheat, what is the condition now as
       compared with normal growth and vitality you would
       expect at this time if there had been no damage
       from any source?

       LET 100 PERCENT represent a normal crop.   Percent _____

    2. For nonirrigated wheat, what is the condition now
       as compared with normal growth and vitality you
       would expect at this time if there had been no
       damage from any source?

       LET 100 PERCENT represent a normal crop.   Percent _____

II. CORN

    3. For corn for grain, what is the condition now as
       compared with normal growth and vitality you would
       expect at this time if there had been no damage
       from any source?

       LET 100 PERCENT represent a normal crop.   Percent _____

III. PEACHES

    4. What is the condition of peaches now as compared
       with that of a full crop if there had been no
       damage from any source?

       LET 100 PERCENT represent a full crop.   Percent _____

IV. SWEET CHERRIES

    5. What is the condition of sweet cherries now as
       compared with that of a full crop if there had
       been no damage from any source?

       LET 100 PERCENT represent a full crop.   Percent _____

Report for your farm

I.   CORN

    1.   For irrigated corn, what probable yield per acre
        do you expect this year on your farm in 70-lb ear
        or 56-lb shelled bushels?   _____

    2.   For nonirrigated corn, what probable yield per
        acre do you expect this year on your farm in
        70-lb ear or 56-lb shelled bushels?   _____

II. SORGHUM FOR GRAIN

    3.   For irrigated sorghums, what probable yield per
        acre do you expect this year on your farm in
        56-lb bushels?   _____

    4.   For nonirrigated sorghums, what probable yield
        per acre do you expect this year on your farm
        in 56-lb bushels?   _____

III. SPRING WHEAT

    5.   For Durum wheat, what yield per acre do you
        expect this year on your farm in 60-lb
        bushels?   _____

    6.   For spring wheat other than Durum, what yield
        per acre do you expect this year on your farm
        in 60-lb bushels?   _____

EXHIBIT F - GRADED YIELD APPRAISAL BY CROP FIELDS

RICE

1. How many tareas are planted on irrigated land alone?   _____

2. How much rice do you expect to harvest from the irrigated
   tareas?

   Quantity _____   Unit _____   Dry weight per unit _____

   3. How would you describe the expected harvest?
      Very good ☐ Good ☐ Average ☐ Poor ☐ Very poor ☐

4. How many tareas are planted on dryland alone (this land
   will not be irrigated)?   _____

5. How much rice do you expect to harvest from the dryland
   tareas?

   Quantity _____   Unit _____   Dry weight per unit _____

   6. How would you describe the expected harvest?
      Very good ☐ Good ☐ Average ☐ Poor ☐ Very poor ☐

CACAO

7. How many hectares are planted alone this year?   _____

8. How much cacao do you expect to harvest from these
   hectares planted alone?

   Quantity _____   Unit _____   Dry weight per unit _____

   9. How would you describe the expected harvest?
      Very good ☐ Good ☐ Average ☐ Poor ☐ Very poor ☐

10. How many hectares are interplanted with another crop
    this year?   _____

11. How much cacao do you expect to harvest from these
    interplanted hectares?

    Quantity _____   Unit _____   Dry weight per unit _____

    12. How would you describe the expected harvest?
        Very good ☐ Good ☐ Average ☐ Poor ☐ Very poor ☐

In general, eye estimates by farmers or field workers show considerably less variation than actual yields. Consequently, the regression or relation between reported condition and yield may not be successful in eliminating bias from condition reports. Market prices may also introduce a cash-crop bias in reports by growers on harvested yields.

3.6.2 Dry Bean Yield Based on Growers' Appraisals

Each quarter a forecast is made of the yield of beans, which is then multiplied by the tareas (1/16 hectare) to get a forecast of production. All the data are collected as part of a quarterly probability survey. The survey is a stratified area sample in which the sampling units within strata are selected with equal probabilities and the closed-segment concept is used. Yield appraisal data were obtained for all fields in the segment. Consequently, the tareas in each field are additive, but any field characteristics must be weighted by the tareas to insure unbiased estimates for the characteristics. Information on yields is obtained for all fields in each area sampling unit. The grower-graded-yield appraisal technique in chapter 2, page 33, is employed. The results for one quarterly survey are summarized in Table 25. The $E(z)$ based on the reported data = 1.20 = (1.92)(.000) + (1.68)(.427) + (1.00)(.443) + (.32)(.130) + (.08)(.000) for the forecast period; $E(z) = 1.0$ for an average crop.

The growers' appraisals indicate a yield 20 percent above average for the coming quarter and approximately 10 percent above their harvested yield (not shown) for the last quarter (or crop). Since the absolute level of the yield (1.23 cwt/tarea) indicates a better-than-average crop, it is meaningful to ask if the growers' idea of the average yield is higher or lower than might be expected. The derived average yield 1.23 ÷ 1.20 = 1.03 cwt/tarea as compared with an after-harvest derived average yield of .98 cwt/tarea for a

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year ago. The growers' idea of normal appears to be somewhat higher than that of last year; perhaps this is just the result of sample variability. However, this may also be a result of greater use of fertilizers, or other factors.

Table 25--Calculations for Dry Bean Yield

Condition of beans	Centroid of probability in interval	Fraction of tareas in interval for normal crop	Fraction of reported tareas in interval for this year's crop
Very good crop	1.92	.036	.000
Good crop	1.68	.238	.427
Average crop	1.00	.452	.443
Poor crop	.32	.238	.130
Very poor crop	.08	.036	.000
Expectation	$E(z)$ = 1.00	$E(z) = 1.20$	
Growers' expected yield (weighted by tarea)		1.23 cwt/tarea	
Derived average yield based on appraisal of forecasted crop		$1.23 \div 1.2 = 1.03$ cwt/tarea	
Growers' harvested yield for forecasted quarter 1/		1.05 cwt/tarea	

1/ Obtained from following quarterly survey.

A second method is available which leads to essentially the same information. It can be referred to as the "growers'-average-yield-and-appraisal" method. For each planting of their crop, early in the season the growers are asked for the expected yield and what the growers consider an average yield to be for the crop planted in the same field. The grower's expected yield (or

production) and the average yield for the same acreage are reported for the data user's evaluation. The grower's within-year average yield permits the user to judge whether this figure is consistent with the reported yield of the previous year or years.

An equally important phase of the yield information is to obtain similar information from the same growers or a probability sample after harvest. The growers reported a yield of 1.05 cwt/tarea after harvest, which was very close to the derived average yield. This second survey provides information on annual harvested acreage and crop production as well as a grower's evaluation by five categories of the crop just harvested. That is, the grower is asked to grade the harvested yield (or production) by the categories given. This information provides a basis for evaluating how good the growers are at forecasting their crop during the seasons and whether they evaluate the harvested crop in a manner consistent with the model. Based on several years experience, there appears to be a tendency for the growers to be somewhat pessimistic early in the season and after harvest to have a brighter evaluation with regard to the past crop season for beans.

3.7 Forecasting Walnut Yields

3.7.1 Introduction

The forecasting models developed have relied on marketed-production data and objective measurement variables for a midseason forecast of production. In general, the models tested have employed regression methods requiring a series of data points over years before reliable forecasts can be achieved. The forecast date is September 1 and is based on a single field survey in late July and early August of approximately 600 blocks of walnuts for data collection. The crop is mature and harvest is active by October, but the date varies by districts because of the large number of varieties being grown.

3.7.2 Block and Tree Selection

The sample of 600 blocks was distributed in proportion to the bearing acreage in each county. The sample blocks were selected at the beginning of the program and retained in the years following. However, the sample is revised each year for blocks removed plus the addition of new blocks to represent new acreage coming into bearing. The blocks were selected with probabilities proportionate to the variety and year of planting. Within each block, two trees were selected with equal probabilities. Each sample consists of two "units" of one tree each. The orchard map has a small table at the upper left which lists the row number and space number for the location of tree 1 and tree 2. Each sample tree is shown and labeled on the orchard map. Near each of these numbers is a small arrow showing which direction is to be traveled in counting rows and spaces. If a sample tree falls into one of the categories listed below, an alternative tree is selected:

(1) The selected tree space is blank space (no tree).

(2) The selected space is occupied by a young, nonbearing tree.

(3) The selected space is occupied by a dead tree.

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(4) The selected tree is obviously of a variety other than that specified in the heading of the orchard map.

(5) The selected tree is not a walnut tree.

(6) The selected tree is being used for experimental purposes by someone else (usually can be told by tags, grafts, or other markings on the tree).

(7) The accessible branches have been pruned or none are available.

In selecting an alternative tree, proceed away from the BIT (Block Identification Tag) in the same row as the original tree until you come to the next tree that meets all of the criteria for selection to be counted. If there are no eligible trees for counting in the same row away from the BIT, then select the next eligible tree in the next row towards the BIT. Be sure the alternative tree selected is the proper variety.

3.7.3 Measurement of Tree Spacing

In order to determine the number of trees per acre, the tree spacing is determined for each sample block. The procedure requires measuring the distance between trees within rows and between rows, at each sample tree. Each team has a 50- or 100-foot tape for measuring the distance between trees. They measure the perimeter of one triangle of trees for most sample trees. The only time the spacing measurements are not made is when the sample trees are in border or irregular orchards. Border plantings have two or three rows of trees; irregular plantings have variable spacing between rows and are usually contour plantings. Irregular and border plantings are described in comments.

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Tree-spacing measurements must be taken with both samplers cooperating. Distances are measured from center to center, as shown:
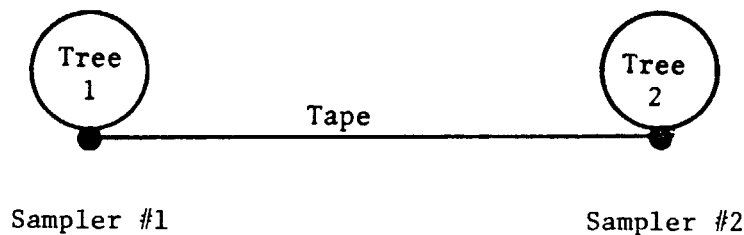
Sampler #1   Sampler #2

Each sampler positions his tape at the middle of the trunk when measuring spacing between two trees.

The sample tree is used as one point of the triangle. The two nearest trees to the sample tree are selected as the other two points of the triangle, and are identified with heavy chalk marks around both trunks. The three measurements do not have to be taken in a specific order. The tape is pulled taut, and each distance is read to the nearest foot.
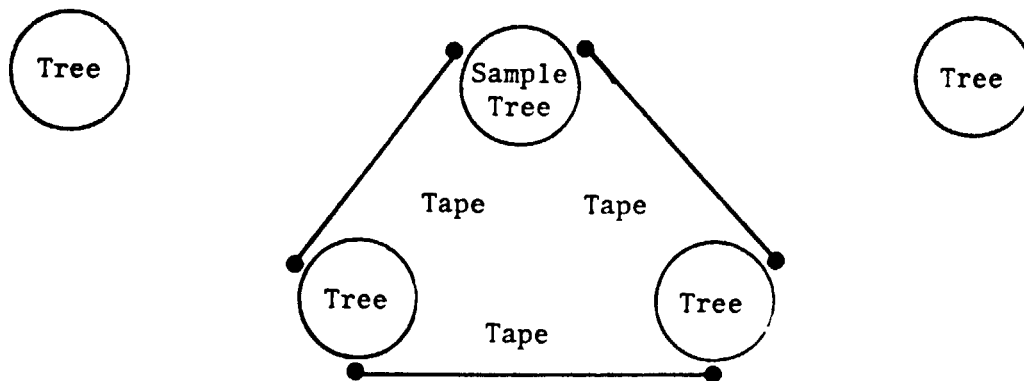
Illustration of required tree spacing measurements

Record each distance on the Random-Path Schedule under "Spacing."

3.7.4 Limb Selection

The limb selection has been limited to "accessible branches"; that is, branches which can be reached from a 12-foot ladder. The supervisor chooses by the random-path method the accessible branch to be used for nut counts. The c.s.a. should be between 5 and 15 percent of the tree's accumulated c.s.a. of the primary limbs. A completed form A which follows on page 165 shows the procedure for one tree. The count of nuts (i.e., 42) is also shown at the bottom of the form. Sampler uses a CSA (cross-sectional area) tape to measure for the cross-sectional area of the trunk and of each primary scaffold stemming directly from the trunk. The primaries are numbered starting with 1 in the direction of the BIT and going clockwise around the tree and are also measured and recorded in this order. After trunk and primary CSA are recorded, continue along the primary on which the accessible branch is located. If the accessible branch is itself a primary, then measurements will be completed. However, in most cases it will be necessary to measure the secondary splits and record these measurements. If these measurements to this point do not take in the measurement of the sample branch, then continue the procedure along the path of the accessible branch until the measurement of this branch and alternative branches are recorded. Finally, after the measurement of the accessible branch, blacken in the small box which corresponds to the accessible branch and indicate on the schedule the path followed back to the trunk by blackening in the proper box for each stage. The TIT (tree identification tag) is hung at the point where the accessible branch starts.
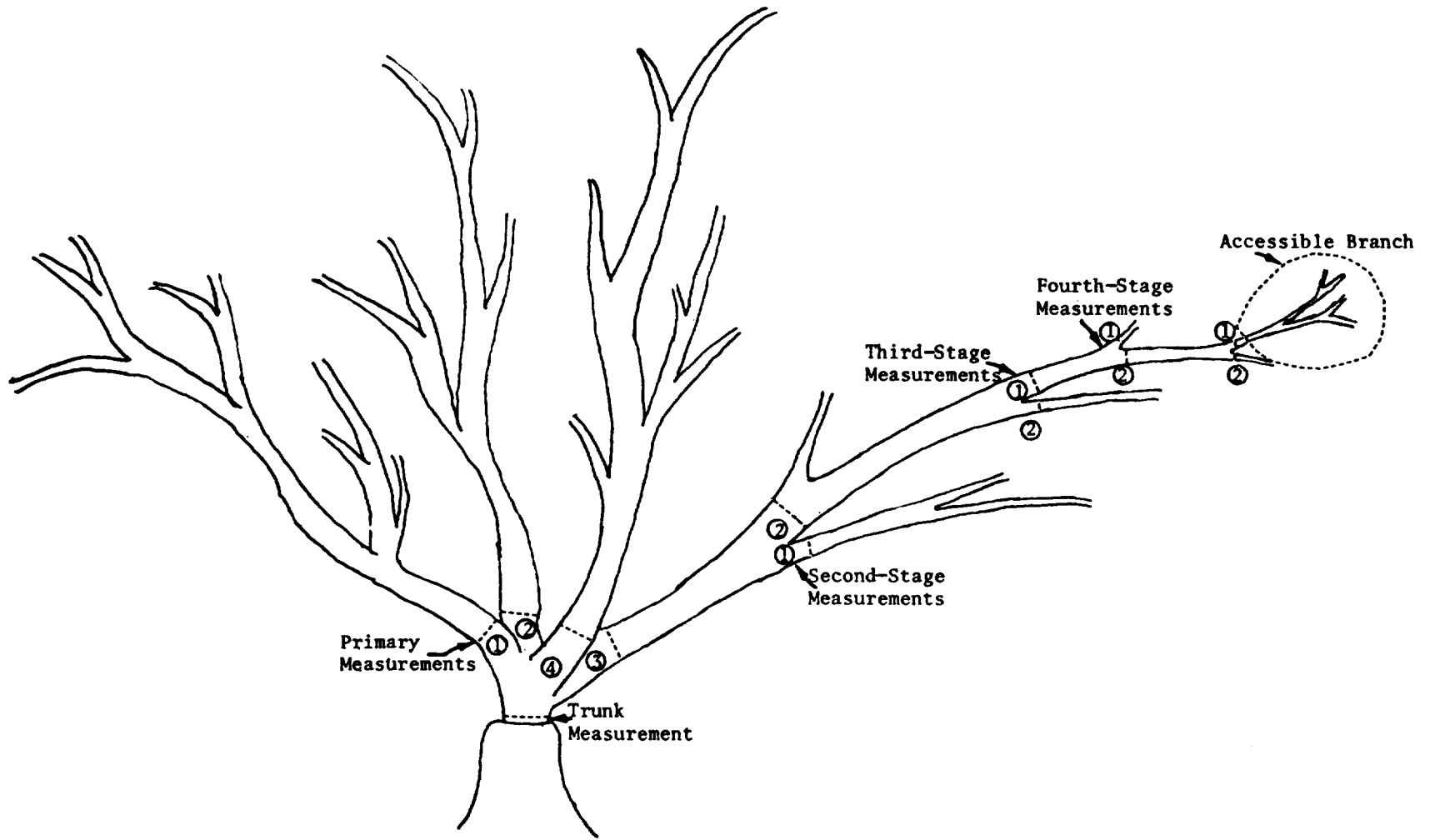
Walnut tree with predetermined random path and accessible branch

The figure below illustrates where to measure branches with
bulges. To aid in understanding bulges, illustrations of an un-
pruned branch and a pruned branch are included. Solid lines
indicate correct placement of measurements. Figure A shows a
branch which is not pruned. One measurement is made below the
branch split and two measurements are taken above the split.
Figure B shows the same branch which has been pruned. The pruned
branch has a CSA greater than 0.5 and must therefore be considered.
Only one measurement is taken, and it must be made above the
prune scar. That is the only location which will reflect the
bearing surface. Figure C illustrates the same branch with a
bulge. The bulge is the healed wound caused by pruning. Measure
all bulged branches (with healed prune scars) above the bulge.
As in B, that is the only location which will reflect the bearing
surface.
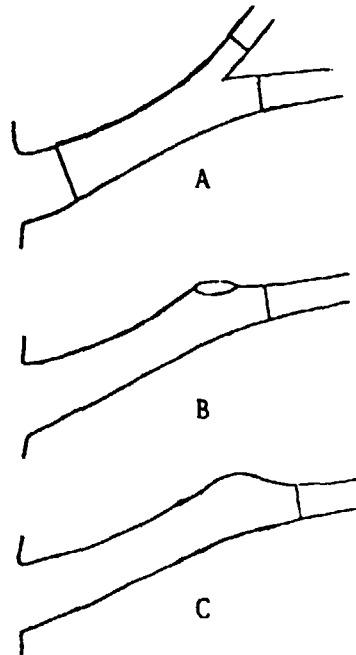
3.7.5 Counting Nuts

The nut count is started at the base of the accessible limb to be counted or, on old sample blocks, from the tree identification tag that is hung. The lateral branches are counted as they are encountered, progressing from the base of the branch to the terminal end of the branch. The sampler feels along the main part being counted for lateral branches and at the same time uses the marking crayon to mark along the main branch as he proceeds. Each nut is counted as it is encountered, and marked with a crayon. Every fifth nut is picked off and placed in the picking bag. A tally sheet is provided; the sampler recording the nut count will check off each nut as counted by his partner and tally every fifth nut counted in the tally column as follows:

one	two	three	four	tally or pick
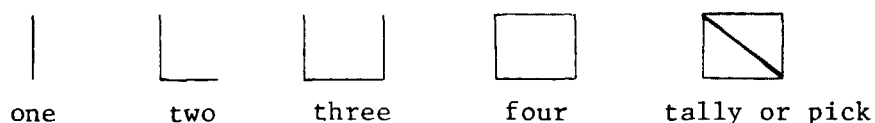
The odd count is entered in the tally column and the total count computed for each stage, recording this in the tally column and also on the schedule in the box provided. The branch stage is labeled in the left margin and a line drawn across the tally columns before proceeding with the next stage.

This procedure continues with the picking off of every fifth fruit; thereafter, the count is recorded and the nuts placed in the picking bag. If it is necessary to move the ladder before completing the count on the sample branch, a marker tag should be hung just past the last lateral counted, so that the starting place for the next ladder set can be easily seen from the ground. The exact off-count at the end of the branch is the last count entered on the schedule. A sizer nut is not picked except when the count reaches 5. Occasionally, terminal branches will extend so high that some nuts

Survey code	Year	County	Variety	Block number	Tree number	Checker code	Update code	Form number	Month/ day	Block status	Number stages
291	74	10	15	44	1			1	7/1		3

Tags:	Block	Row	Tree	Start time	End time	Minutes	Team	Recorder	Measurer
Found	✓	✓	✓					K. McPeak	D. Okimura
Replaced				0820	0905	45			

BLOCK STATUS CODE: 1 Sampled, 2 Wet, 3 Pulled out, 4 Abandoned,
5 Sprayed, 6 Substitute, 7 Not visited, 8 Refusal, 9 Not found

	Branch	Trunk 0	Primary 1	2	3	4	5	6	7	8
1	CSA	66.0	41.0	4.3	4.1	.	.	.	.	.
2	CSA		28.0	36.0	3.9	.	.	.	.	.
	Total		69.0	40.3	8.0	.	.	.	.	.
3	CSA		.	.	32.0	.	.	.	.	.
	Total		.	.	40.0	.	.	.	.	.
4	CSA		.	.	.	.	.	.	.	.
	Total		.	.	.	.	.	.	.	.
5	CSA		.	.	.	.	.	.	.	.
	Total		.	.	.	.	.	.	.	.
6	CSA		.	.	.	.	.	.	.	.
	Total		.	.	.	.	.	.	.	.
7	CSA		.	⊠⊠⊠						
	Total		.	⊠⊠⊠ ⊠⊠L						
8	CSA		.							
	Total		.							
9	CSA		.							
	Total		.							
10	CSA		.							
	Total		.							
Random number			.	.	.	.	•	‣	.	•
Selected branch			1	2	1					
Fruit count					42					
Check										

TABLE OF RANDOM NUMBERS

316.7	66.1	64.4	94.3	16.6	91.9	3.1	6.7	3.6
041.3	54.1	55.8	34.3	63.5	35.2	3.6	1.9	0.0
184.1	72.8	48.1	18.3	47.9	98.2	3.4	0.5	6.1
192.4	18.6	19.1	36.7	41.8	61.1	7.4	5.2	4.7
159.9	74.6	27.7	37.0	75.8	31.9	0.7	1.7	2.4
179.4	32.3	92.1	97.6	36.1	19.9	6.3	3.1	4.1
408.7	78.4	64.2	25.0	11.8	62.7	0.1	3.7	4.2
089.9	62.0	95.3	67.8	70.0	44.1	8.7	1.5	9.8
186.9	12.3	02.8	07.8	33.2	62.4	8.3	0.0	2.3
234.8	76.3	78.4	16.0	56.5	96.1	0.5	0.8	6.7
340.6	05.0	41.4	98.0	72.0	28.8	0.7	4.2	8.4
459.3	46.9	78.3	54.8	25.9	36.2	8.2	4.2	4.3
434.7	47.6	65.6	43.8	29.9	78.2	8.2	3.0	2.9

COMMENTS:

will be counted by sight only. Samplers should have with them a
stick with a hook at the end to help them sight-count the nuts
and to pick off the sample nuts. Include all nuts in the count
except those which are totally shrivelled, totally blighted, or
dwarfed; generally these will fall off when tapped lightly.

3.7.6 Selecting Subsamples of Nuts for Sizing and Weighing

    (1)   Place all nuts stripped from the terminal branch on
            the counting board, spreading them in a continuous
            line, single file.

    (2)   Count the nuts and enter the total counted on the
            Random Path Schedule in the box which corresponds
            to the last stage where the terminal branch is
            recorded.

    (3)   Select 20 nuts for a sizing sample as follows:

        (a) Divide the total counted by 20 and round to the
            next largest whole number. This is the "sampling
            interval."

        (b) Use the third line of the table of random numbers
            (on the Random Path Schedule), ignoring the last
            digit to the right of the decimal. Choose the first
            number which is 01 or greater but which is not larg-
            er than the interval. The number chosen designates
            the first nut to choose from the line of nuts
            described above (see (1)).

        (c) Select the second nut by adding the "interval" to
            the random number.

        (d) Select the third nut by adding the "interval" to
            the number for the second nut.

(e) Select the fourth nut by adding the "interval" to the number for the third nut. Proceed until 20 nuts are selected. If you reach the end of the line of nuts before the 20th nut is obtained, continue the count at the beginning of the line.

(f) If the total of nuts counted is between 10 and 20, include all nuts for your sample.

(g) Place the sample just selected in a neoprene bag. Place the sizing sample identification marker in the bag.

(h) Date sized. Enter the calendar date when you size the nuts on the sizing card. Use 2 digits for the month, 2 digits for the day, and the last 2 digits for the year in that order.

3.7.7 Nut Measurements

a. Hull characteristics

The first two characteristics described will be recorded for every nut sized.

(1) Width

Place the caliper jaws on the hull at the widest point of the hull, making sure that the caliper jaws are parallel to the longest axis of the nut. Rotate the hull so that the calipers are measuring the widest point of the hull. See Figure 11, page 172.

(2) Grade

Make a visual determination of the grade of the hull. Descriptions of the grades are as follows:

(a) SOUND. No damage is visible except for wind scarring and superficial hull damage.

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(b) SUNBURN. The hull will begin to turn yellow first.
Gradually, the yellowing increases as the center of
discoloration turns yellowish brown, then dark
brown. Usually, there is no depression in the hull.

Sunburning can cause a flat side on the hull if
it occurs before the shell hardens. After the shell
hardens no flat sides develop.

Consider the nut sunburned whenever 10 percent
or more of the hull surface is affected. You should
cut some nuts to determine if the meat has been
damaged. In advanced stages, meat turns black and
shrivels. There will not be any wet substance in-
side the skin. Meat damage will vary by district
and orchard.

(c) LARVAL DAMAGE. Look at the upper portion of the nut
hull near the stem for larvae of the walnut husk fly.
The larvae may be tiny whitish specks or larger
mature maggots. Blackened hulls are characteristic
of nuts infected by husk flies. Cut into the black-
ened area. Husk-fly larvae should be clearly visible.

(d) BLIGHT. There will be a depression in the hull and
the hull inside the depression turns dark brown to
black. Generally, the blight will darken the meat
by the time the depression is about 3/8" in diameter.
Depressions 3/8" and larger in diameter will be coded
as blight damage.

(e) SHRIVEL. The outward appearance of the hull indi-
cates that the nut will not mature. The hull shrivels
due to factors other than blight and sunburn.

Use the following codes for grades:

SOUND   = 1

SUNBURNED   = 2

LARVAL DAMAGE   = 3

BLIGHT   = 4

SHRIVEL   = 5

The following measurements will be made only on every 5th nut beginning with nut number 3.

(3) Cross width

Place the caliper jaws on the nut so that the long axis of the nut and caliper jaws parallel each other. Rotate the nut 90 degrees from the position in (1) "Width." See Figure 12. Record the measurement of the nearest millimeter under "C. width" on Form B (measurement cards).

(4) Length

Place the calipers on the nut so that one caliper jaw passes through the stem scar on the end of the nut. The other jaw should pass over the point on the other end of the nut. See Figure 13. Record the measurement to the nearest whole millimeter under "Length."

(5) Weight

Place the nut on the Mettler balance. Weigh the nut to the nearest one-tenth gram, and record under "Weight."

b. Shell characteristics

Cut away the hull at the suture line to expose the walnut
shell.

(1) Width

Place the caliper jaws on the shell at the widest
point of the shell so that the caliper jaws are
parallel to the longest axis of the nut. See
Figure 14, page 173. Record the measurement to the
nearest millimeter under "Width."

(2) Cross width

Place the caliper jaws on the shell so that the suture
line and caliper jaws parallel each other. The suture
line should be about 90 degrees from each caliper jaw.
See Figure 15. Record the measurement to the nearest
millimeter under "C. width" - Form B (measurement cards).

(3) Length

Place the caliper jaws on the shell so that they embrace
the longest dimension of the nut. Position the shell
so that the suture line parallels the calipers. The
suture line should be nearest the stationary part of
the calipers. See Figure 16. Record the measurement
to the nearest whole millimeter under "Length."

(4) Grade

Cut the shell in half at the suture and make a visual
determination of the grade. Descriptions of the grades
are as follows:

(a) SOUND. No damage is visible.

(b) SUNBURN. The kernel turns black and shrivels.

(c) LARVAL DAMAGE. Husk-fly larvae will be visible.

(d) BLIGHT (black kernel). The kernel turns very
    dark.

(e) SHRIVEL. The kernel pulls apart from its original
    area.

c. Complete appropriate steps for the remaining nuts as
    required.

d. If less than 20 nuts are in the sample, draw a line across
    the card through spaces provided for the next nut.

e. After the last nut has been sized, make a visual check of
    the recorded data, the numbers directly below measurement
    headings indicate the number of digits to be recorded in
    a particular field for each nut. Check each column from
    top to bottom to detect errors in recording measurements
    before proceeding to the next sample.

    Dispose of the nuts in an acceptable manner.
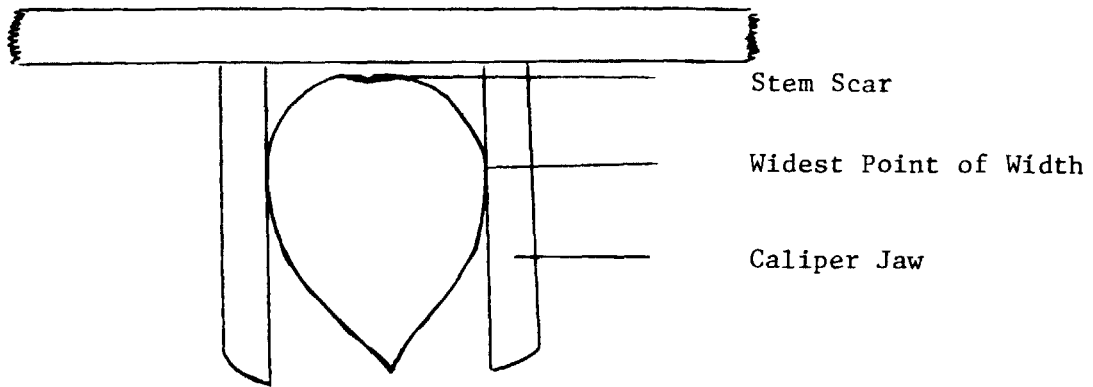
Figure 11. Measuring Width of Hull of a Walnut
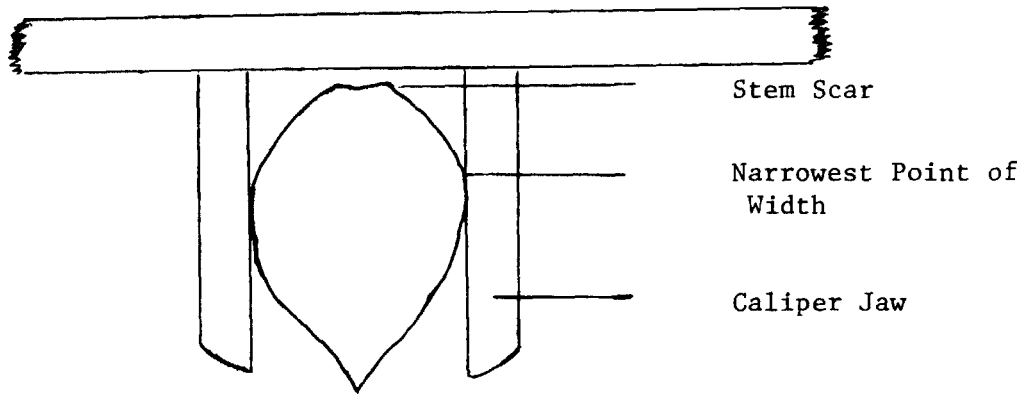
Figure 12. Measuring Cross Width of Hull of a Walnut
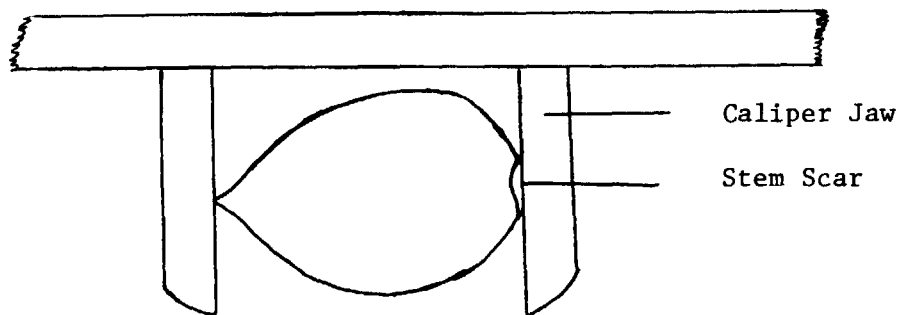
Figure 13. Measuring Length of Hull of a Walnut

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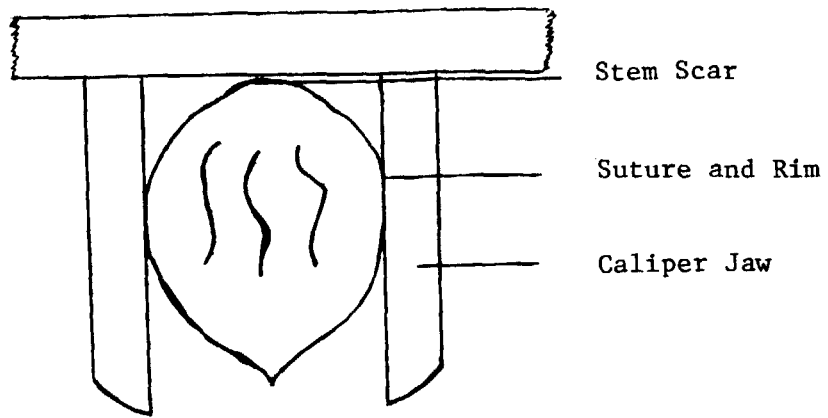
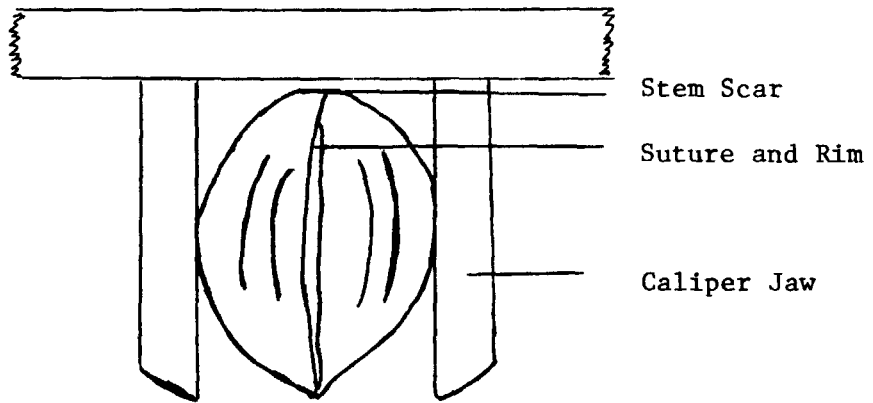Figure 14. Measuring Width of Shell of a Walnut
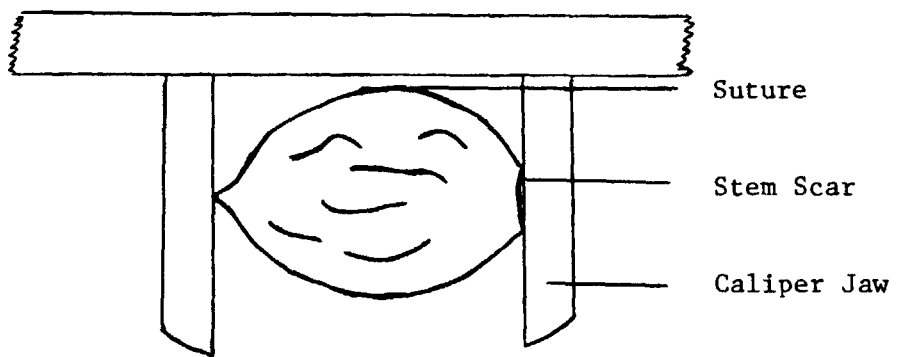

Figure 15. Measuring Cross Width of Shell of a Walnut

Figure 16. Measuring Length of Shell of a Walnut

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FORM B: WALNUT OBJECTIVE MEASUREMENT FIELD SURVEY

BLOCK IDENTIFICATION

SURVEY CODE	BLOCK CODE			TREE NUMBER	SIZER CODE	DATE SAMPLED	DATE SIZED
	COUNTY	VARIETY	BLOCK				
1-3	4-6	7-8	9-11	12	13	14-16	17-18
045	020	08	044	2	7	226	227

Measurement cards

Nut #	IN HULL MEASUREMENTS					IN SHELL			
	Width mm	Grade	C. width mm	Length mm	Weight grams	Width mm	C. width mm	Length mm	Grade
20-21	22-23	24	25-26	27-28	29-31	32-33	34-35	36-37	38
01	44	1							
02	44	1							
03	45	1	44	56	60.1	36	36	42	1
04	42	1							
05	43	3							
06	44	1							
07	46	1							
08	46	1	46	50	59.6	36	37	41	1
09	39	1							
10	46	2							
11	43	1							
12	41	1							
13									
14									
15									
16									
17									
18									
19									
20									

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3.7.8 Forecast Based on Tree Data and Market Production Records

In each orchard, a limb on each of two trees has been sampled. The total set per tree is obtained by using a ratio-type expansion, since limb selection is restricted to an accessible limb. The nuts counted on the sample limb are expanded to a total tree count, based on the ratio of the cross-sectional area of the limb sampled to the total cross-sectional area of limbs for the tree. A systematic subsample of every fifth nut is selected to be sized, weighed and number of "sound" nuts determined. The yield-per-tree models are as follows:

Yield per tree = Sound nuts per tree x harvested weight per nut.

The production model is:

Production = Bearing acres x trees per acre x yield per tree.

The model which performs the best in practice consists of adjusting the gross yield (and production) to a net production harvested, based on industry-reported production. A regression based on the historical series is used for this purpose. A further refinement is introduced into the estimated weight per nut based on the set per tree and the in-hull weight of nut. The regression derived is as follows:

P - harvested production

$\hat{p}$ = gross production = B x T x S x W_h

B = bearing acreage

T = trees per acre

S = sound nuts per tree

W_h = harvest weight per nut in shell

$P = ae^{k\hat{p}}$ or after taking natural logarithms $LnP = Ln(a) + k\hat{p}$

where a and k are model parameters to be estimated and e = 2.7183, the natural logarithm base (Ln). The components in the above model

are developed as follows: The yield per tree is a product of W_h and S and converted from grams to tons by the divisors 453.59 (grams per pound) and 2,000 (pounds per ton).

$$W_h = W \times \frac{\text{shell volume}}{\text{total volume}} = W \times \frac{(\frac{\text{shell suture}}{2})^3}{(\frac{\text{hull suture}}{2})^3} = W \times \frac{SS^3}{HS^3}$$

where   W = in-hull weight per nut on survey date

      SS = shell suture

      HS = hull suture

These are calculated as follows:

$$W = \frac{1}{N} \sum_{i=1}^{t} \sum_{j=1}^{N_i} W_{ij}$$

$$SS = \frac{1}{N} \sum_{i=1}^{t} \sum_{j=1}^{N_i} (SS)_{ij}$$

$$HS = \frac{1}{N} \sum_{i=1}^{t} \sum_{j=1}^{N_i} (HS)_{ij}$$

and W_{ij}, $(SS)_{ij}$ and $(HS)_{ij}$ are the weights and measurements for an individual nut on the ith tree where N_i is the number of nuts sampled on the tree and t is the number of trees sampled.

$$N = \sum_{i=1}^{t} N_i$$

The number of sound nuts per tree, S, is computed from the nuts sampled as follows:

$$S = S_A \sum_{i=1}^{t} \frac{S_i}{S_{Ai}} = S_A \cdot F_S$$

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where S_A = average number of nuts set per tree = $\frac{1}{t} \sum_{i=1}^{t} S_{Ai}$

S_i = sound nut on i^{th} tree

S_{Ai} = all nuts on i^{th} tree

F_S = fraction of nuts not damaged

The total number of trees is estimated from the bearing acreage times trees per acre, or B x T.

The sample averages give the following results:

$$W_h = 44.10 \times \frac{(32.5)^3}{(40.5)^3} = 44.10(.5168) = 22.79$$

S = 1729.8(.9601) = 1660.8

T = 29.4

B = 163,234

a = 1.29, k = .70

$\hat{p}$ = (163,234)1660.8 x (29.4)22.79 ÷ (454 x 2000) = 200,048 tons

LnP (1974) = 10.3796 + .000007984(200,048) = 11.9768
   or P = 158,906 tons

The adjustment of the gross production from 200,048 tons to the 158,906 tons is the result of a number of undetermined factors of which the following play a major role.

(1) Weight loss in nuts due to moisture and hull removal from survey date to maturity
(2) Possible bias in procedure for estimating in shell green weight
(3) Market order thinning or delivery quotas
(4) Harvesting losses.

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Models based on several regression relations (over years) with factors which are undetermined, plus unknown factors, generally require frequent modification and reevaluation of the parameters when there are obvious trends in yield components. Likewise, the degrees of freedom used in the modeling result in a relatively small number for error determination, unless a long series of historical data exists.

3.7.9 Forecast Based on Objective Tree Data

A variation or alternative yield model might be employed; the same survey data are used to illustrate such an alternative.

Weight per nut (in shell) = in-hull weight x adjustment factor
to convert to an in-shell weight.
(Based on weight per unit volume)
= 44.10 x .620 = 27.34 grams

Harvest weight per nut (in shell) = 27.34 x (1-.00514 D); adjustment of weight for days to harvest (D = 55)
= 27.34 x .7173 = 19.61 grams

Harvest gross yield per tree = number sound nuts x harvest weight per nut
= 1660.8 x 19.61 = 32,568 grams or 71.80 lb

Net yield per tree = 71.80 x adj. for net losses in nuts due to droppage and harvesting
= 71.80(.93) or 66.77 pounds

Production = number of trees x net yield per tree
= 4,628,910 x 66.77 = 309,072,320 pounds or 154,536 tons

Any adjustment due to marketing orders would need to be applied on either a tree basis or the fraction of sound nuts to be marketed.

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3.8 Forecasting Yields from Historical Crop and Weather Data

3.8.1 Introduction

The yield forecasting based on historical data of this type assumes that a global regression model is valid. Since the network of data points is usually limited and the variables are available only for large geographic areas, the weather factors should not be expected to explain differences in yields over small geographic areas. Consequently, the variables used represent averages which do not reflect the full range of the variables within any year and predictions frequently experience larger errors for individual years than the conventional error levels calculated from the regression model.

3.8.2 Corn Yield Forecast

The technique described in chapter 2, section 2 will be used for illustration purposes. The daily temperature values were averaged. The precipitation for the month for each weather station in the State is shown in monthly published reports of NOAA[*]. The individual station values were then averaged by 10 districts within the State. Predetermined weights (approximately equal) were applied to the district averages to obtain the monthly values for the State. The State yield for corn was obtained from the published SRS report giving harvested yield based on a statewide survey. The variables for 1972 are given in the table below. The "normal" yield due to technology for 1972 is derived from the moving average shown in Chart 7, page 181.

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[*] National Oceanic and Atmospheric Administration

Table 26--1972 Variables for Corn Yield

Variable	June	July	August
Average daily temperature ($^\circ$F)	69.6	74.4	73.7
Monthly precipitaion (inches)	3.88	6.02	5.43

Moving-average yield (i.e., technology):   100 bushels

Growers' harvested yield: 110 bushels

The predicted yield departures from technology level by months were derived from the following equation:

June $\Delta y_{1i} = 173.801 - 43.275R - 2.475T + 0.6208RT = 1.280$

July $\Delta y_{2i} = 89.939 - 23.666R - 1.263T + 0.3397RT = 5.651$

August $\Delta y_{3i} = 114.710 - 16.328R - 1.559T + 0.2261RT = 1.635$

June and July $\Delta y_{1i} + \Delta y_{2i} = 6.931$

June, July & August $\Delta y_{1i} + \Delta y_{2i} + \Delta y_{3i} = 8.566$

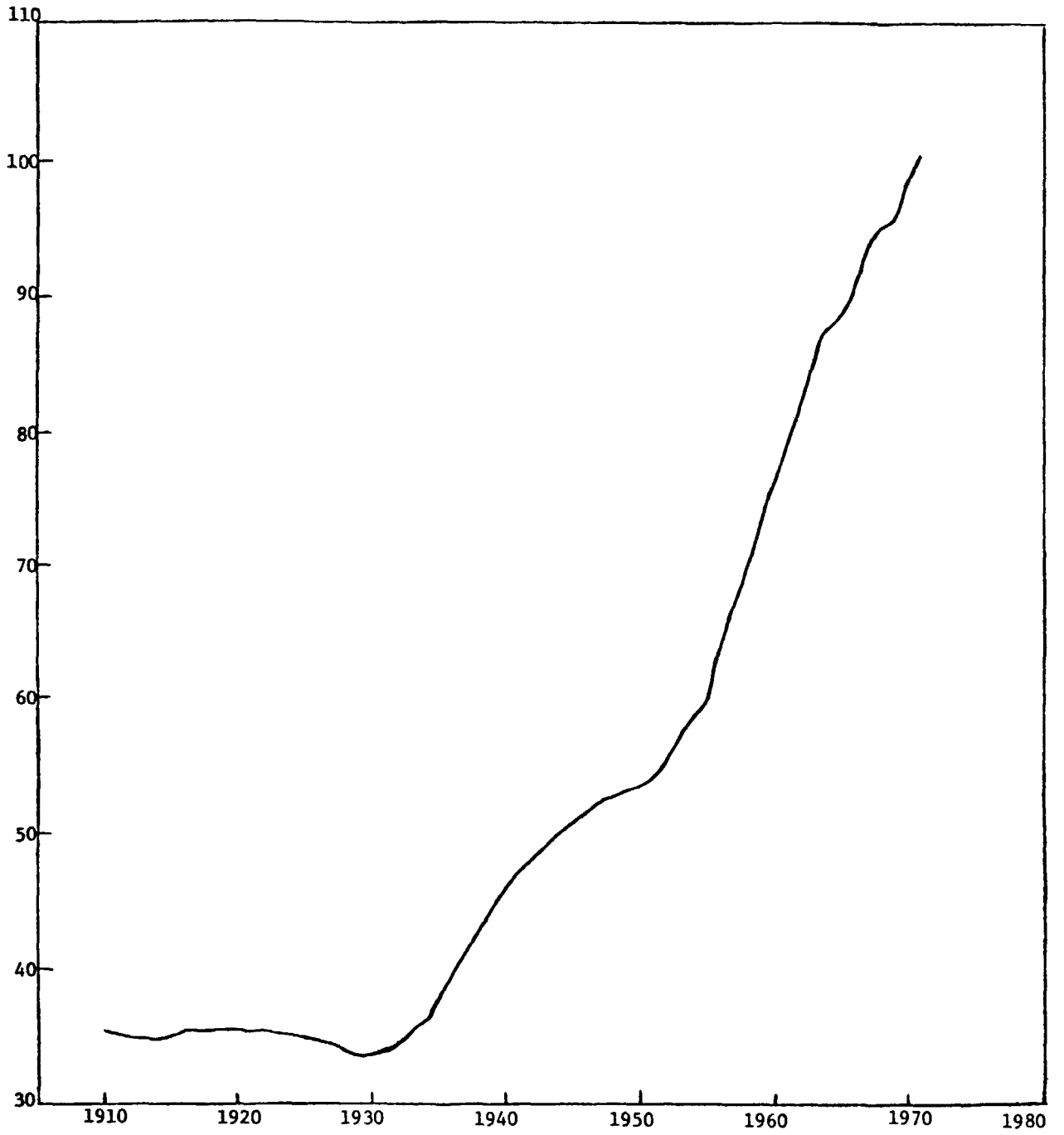The accumulative yield forecasts are summarized below:

June $= 100 + 1.3 \doteq 101.3$

June and July $= 100 + 6.9 \doteq 106.9$

June, July and August $= 100 + 8.6 \doteq 108.6$

CHART 7 — TEN-YEAR SIMPLE MOVING AVERAGE OF ILLINOIS CORN YIELDS

3.9 Forecasting Citrus Yields

3.9.1 Introduction

The forecasting model as first developed was discussed in chapter 2. The basic model has changed very little except that the estimators of the key components are now derived mathematically rather than graphically. The first forecast of the crop season is made in early October by type of citrus.

3.9.2 Block and Tree Selection

The survey uses the stratified multistage probability sample design by the major citrus types described in chapter 2. The strata within type are four age groups. All trees of bearing age (4 years or older) and all citrus-producing areas are proportionally sampled within strata.

The sample of blocks is selected from an inventory of all commercial citrus plantings (1/3 acre or more). The inventory is obtained from an aerial photography survey of all citrus-producing areas in the State, combined with ground inspections of any previously unidentified plantings. The aerial surveys are done at two-year intervals.

The selected groves are identified by township, range, section, and block. All groves have aerial photo blueprints (ozalid copies), county maps, and instructions giving the location. If for any reason a sample grove does not conform to the description on the instructions, the crew supervisor notifies the statistical office and an appropriate substitute is made.

Within a grove, the procedure discussed in chapter 2 has been modified from the cluster of four trees, and three sample trees are now selected for all oranges, grapefruit, Temple and tangelo groves. In all groves the crew supervisor must (1) cut a fruit from each sample tree to verify proper fruit type, and (2) verify that the tree is in the proper age group. The three trees are obtained

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from the cluster of four trees by eliminating one tree at random. Sample trees are changed every 3-5 years in a gradual rotation pattern around the pivot tree. This gradual rotation maintains a high degree of tree identity in successive years and yet provides for unsurveyed trees to enter the population; it also provides a measure of any sample longevity effects on the trees retained for several years.

3.9.3 Limb Selection

The final stage of sampling is the selection of a portion of the tree on which the fruit is to be counted. The portion of the tree is selected by the random-path technique discussed in chapter 2. When this multiple-stage process terminates, the selected portion had a probability of selection proportionate to limb cross-sectional area (c.s.a.). The reciprocal of this probability of selection times the fruit count provides an unbiased method of estimating the total fruit on the tree. If the limb selected is not too small, the method is more efficient than equal-probability selection because of the positive correlation between limb c.s.a. and fruit numbers.

After the sample limb is selected, it is divided into smaller units for counting purposes. Two separate fruit counts are made, each by a different member of the survey crew. If the two counts do not agree within 5 percent, additional counts are made. A random selection of one limb in a 10-percent random subsample of groves is made as a quality check.

3.9.4 Fruit Drop Surveys

A measure of fruit mortality prior to harvest must be introduced into the computed crop forecasts, because initial estimates of the average number of fruit per tree are established from counts in August and September. Natural loss of fruit, from August until the month in which each type of fruit is considered mature, is

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measured by a sequence of monthly surveys. Maturity is considered to be reached in predetermined cutoff months which precede the heaviest harvest period. Cutoff dates are: December for tangelos and tangerines, January for early and mid-season oranges, February for Temples and grapefruit, and April for late-season oranges.

The sample trees for droppage surveys are drawn from a route frame rather than the limb count frame, since the route frame is more readily accessible for monthly observations. This sample frame consists of all bearing commercial groves fronting on a 1,600-mile route which traverses producing areas of the most important counties. This microcosm of the citrus population provides a satisfactory base for sampling drop and other relatively uniform characteristics.

The sample for each variety is stratified into four areas (homogeneous county groupings) and the four age groups previously discussed. The sample size within strata is based on productivity in a base year.

A sample limb approximately two percent of the trunk c.s.a. is selected near shoulder height, on a designated side of the tree. This limb is tagged and all fruit beyond the tag are counted during successive surveys. The monthly counts are entered on the pocket-notebook-size field sheets. The differences between the initial survey counts and later survey counts indicate the droppage to the time of the survey. The average drop for each age-area stratum is computed and then combined by production weights into the average drop for the State. The sample counts are weighted, because groves are selected with probability proportionate to historical production and the "two percent limb" sampling method tends to put a disproportionate part of the sample in older, more productive trees.

The monthly droppage is projected to the cutoff month to estimate seasonal drop rate for use in the forecast models.

Drop Count Survey 1969-70 Season

Area _____   Route _____   County _____

Type _____   Grove _____   Age _____

Tree #1   Tree #2

___ x ___ Row Tree	Location of tree	___ x ___ Row Tree
	Location of fruit	
Fruit count	Month of survey	Fruit count
	Aug	
	Sept	
	Oct	
.	Nov	
	Dec	
	Jan	
	Feb	
	Mar	
	Apr	

3.9.5 Size of Fruit

The fruit size survey coincides with the drop survey. More-over, the same subsample of trees in sample groves drawn from the route frame is used for both sets of monthly observations. In the size survey 10 sample fruit per tree are measured from a two-tree cluster per sample grove. Frequency distributions of standard fresh-fruit sizes and the estimated average size are obtained each month.

The fruit to be measured are determined by minimum size cate-gories at a specified point on the tree at about shoulder height. This point on the tree is tagged and, for each survey, horizontal circumferences are measured on the 10 regular-bloom fruit nearest

the tag. The photograph illustrates the position of measurements and the device used to obtain the circumference.

These circumference measurements are entered as a tally on the 240-cell field form. Summarization is done in volume, which is linearly correlated to weight and, therefore, additive.

The growth rates of various citrus types were shown in chapter 2. The dates shown are the month in which surveys were conducted; usually surveys were near the third week of each month. The annual growth curves generally parallel each other, thereby allowing these relationships to be a fairly effective tool in forecasting size at maturity. It should be noted that fruit measured on-tree does not reflect harvest size. Early observations are of immature fruit and measurements for forecasts usually cease prior to volume harvest. The size of fruit at maturity is defined as the average size of fruit in groves in a specific month. These cutoff months are the same as in the drop surveys. Prior to the cutoff month, it is necessary to estimate the average size that fruit will attain in the cutoff month.

Figure 16. Measuring Circumference of Citrus Fruit
(on the tree) with Calipers
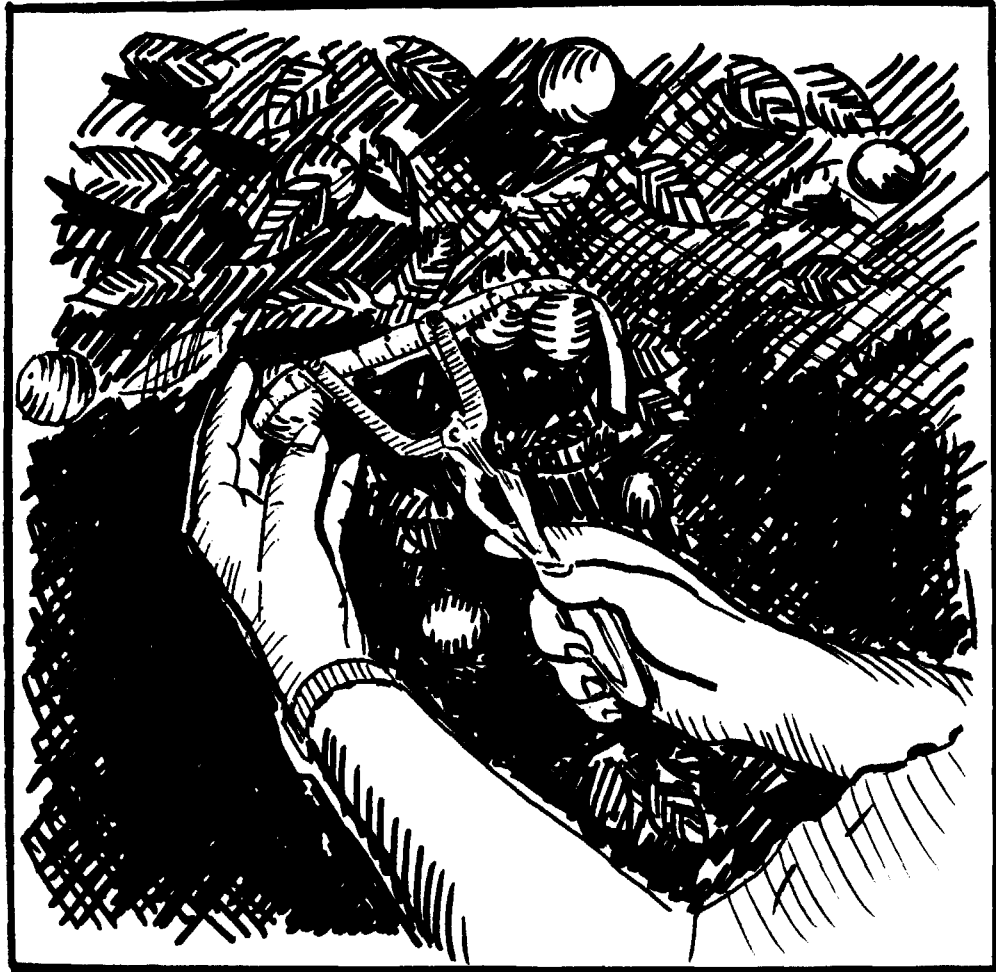
FIELD FORM FOR DERIVING VOLUME OF CITRUS FRUIT (cu. in.)

Florida Crop and Livestock Reporting Service
1222 Woodward Street
Orlando, Florida 32803

CITRUS GROWTH SURVEY   CIRCUMFERENCE CALIPER MEASUREMENTS

Route_____ Area_____   Navels ( ) *W. Sdy. Gft.( ) Tangerine ( )

                           Ear. Org.( ) *P. Sdy. Gft.( ) Temple   ( )

Grove_____ Co. _____   Mid. Org.( ) *W. SS. Gft.( ) Tangelo ( )

Date _____ Age Grp.___   Late Org.( ) *P. SS. Gft.( ) Murcott ( )

In.	7	8	9	10	11	12	13	14	15	16	17
	0579	0865	1231	1689	2247	2917	3710	4634	5699	6917	8297
$\frac{1}{16}$											
	0594	0885	1257	1721	2285	2964	3764	4696	5771	6998	8388
$\frac{2}{16}$											
	0610	0906	1283	1753	2324	3010	3818	4759	5843	7080	8481
$\frac{3}{16}$											
	0626	0927	1310	1786	2363	3057	3875	4821	5616	7163	8574
$\frac{4}{16}$											
	0643	0948	1337	1819	2403	3104	3928	4884	5989	7246	8668

* W = white, P = pink

Sdy. = seedy, SS. = seedless

3.9.6 Florida Citrus Forecast

The objective estimate of citrus production by type is computed from the results of four surveys or different types of data collection activities:

(1) The total number of commercial trees is determined biennially, but is adjusted in intervening years based on trend and data on tree plantings.

(2) Fruit per tree is determined from the limb count survey in August and September.

(3) A fruit loss or "drop" survey is run monthly to give an indication of the changes, and project fruit remaining at harvest.

(4) A fruit size survey is run monthly to determine growth and project fruit volume at harvest.

The estimated number of fruit per tree for early oranges was $\hat{F} = 696$. The estimated drop from August to September was .1439. The drop to harvest was estimated using a multiple-regression equation:

$$D_h = a + b_1 \sqrt{x_1} + b_2 x_2 + b_3 x_3$$

where x_1 = .1439 or fraction of fruit dropped through September 15

x_2 = 696 or estimated fruit per tree in September

x_3 = 7.25 cu. inches or estimated volume per fruit in September

$D_h = -.7050 + 1.472(.3793) + .00001(696) + .045(7.25) = .1865$

The fraction of the September fruit to be harvested is:

$$H_h = 1 - D_h = .8135$$

The fruit size or volume in cubic inches at harvest is estimated using a multiple-regression equation as follows:

$$V_h = a + b_1x_1 + b_2x_2 + b_3x_3$$

where x_1 = 7.25 or average September volume per fruit in cubic inches

        x_2 = 696 or estimated fruit per tree in September

        x_3 = 2 or monthly change in volume per fruit from August to September

$$V_h = 2.909 + .915(7.25) - .0028(696) + 1.085(2) = 9.764 \text{ cu. in.}$$

The regression estimate of volume per fruit is used to derive the number of fruit per box using a regression equation as follows:

$$\hat{S} = 65.87 - 1.95\ V_h + 1772 \div V_h \qquad \text{fruit per box at cutoff month}$$

$$S = 65.87 - 1.95(9.764) + (1772 \div 9.764) = 228.313$$

The forecasted yield per tree in boxes of fruit is:

$$\hat{Y} = \frac{F \cdot H}{S} = \frac{696(.8135)}{228.3} = 2.48$$

The expected production is obtained by multiplying yield per tree times number of trees:

$$\hat{P} = T \cdot \hat{Y} = 14,256,000\ (2.48) = 35,355,000 \text{ boxes.}$$

3.9.7 Costs of Objective Yield Surveys, 1967-68

Table 27--Costs of Objective Yield and Related Surveys, 1967-68

Survey	Unit of cost	Cost classification					Total
		Field				Office	
		Wages		Mileage	Per diem	Supplies, clerical & ADP	
		Within grove	Between groves				
Limb count 1/	Sample grove	$ 9.43	$ 6.29	$ 4.87	$ 1.02	$ 1.62	$ 23.23
Size & drop 2/	Sample grove	.84	1.25	.45	.27	.82	3.63
Maturity 3/	Sample grove	.23	1.30	.47	.10	.21	2.31
Row count 4/	Survey	620.00	110.00	200.00	35.00	100.00	1065.00

1/ Costs are based upon a five-man crew consisting of four fieldmen and a supervisor.

2/ Treated as one survey, as both types of observations are made on the same sample trees. Surveys conducted each month. Information usually collected by a two-man crew.

3/ Survey conducted twice each month.

4/ Cost per month.

3.10 Conclusions

A dilemma usually faces the person in charge of the yield-forecasting program: (1) Do I choose the simpler model which I know will be reasonably satisfactory four out of five years and give poor results the fifth year? or (2) Do I choose a more elaborate model that is slightly more satisfactory and may provide clues that an unusual season may be occurring in the fifth year? Traditionally, the former has been chosen because of the cost savings and in the convenience of data collection. Also, there is some evidence to suggest that the complicated models may not necessarily reflect the seasonal influences even if they are based on the growing crop. This evidence is not conclusive nor is it based on complete yield-component modeling. Likewise, there is no conclusive evidence to suggest that combining weather or environmental variables with plant character-istics in a model will be any more successful, and these auxiliary data will inflate data acquisition costs. The problem is not hopeless or insolvable theoretically but it may be so practically, because of costs and the unpredictability and dissimilarity of the one in five years with marked departures from near-average crop seasons.

There are perhaps two approaches which will give better answers than are probably currently in use by those providing public informa-tion. (1) Greater seasonal detail on plant characteristics and the interrelation among the lead and lag yield components, and (2) A sea-sonal discriminant analysis to identify the unusual season before harvest from which a decision can be made to employ an alternative set of model parameters or procedures. The discriminant analysis will involve not only more detailed seasonal information on plant characteristics but also a means of measuring and predicting the nutrient uptake or accumu-lation by the plant parts.

The first solution or approach is realistic in terms of known yield components used in models. For example, in poor and excellent yield years for corn, the change in grain per ear is only partially reflected

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in the average cob or kernel-row length, for the number of kernels and weight per kernel are also factors. The clues are present well before harvest, but the model or procedure used in forecasting must be selected by the analyst so it will discriminate such a season from the more typical conditions under which most of the crop data are collected. Of course, the relation between the lead and lag characteristics must then be employed. However, it will be clear what the direction of the lag component is even if the exact relation may be imprecise, since the effects are usually cumulative.

The second approach is probably considerably more costly and involves agricultural scientists not usually involved in operational data-collection procedures for making inferences or forecasts for large geographic areas. However, there are many benefits or research uses which can be obtained from these more detailed measurements of the development of plant parts besides those concerned with the yield modeling.