

A SAMPLE SURVEY OF CITRUS

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D.T.A. Report

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PART 1: GENERAL INTRODUCTION

1. Introduction.

The sample survey project for session 1957-58 was conducted by a team of six postgraduate students, namely Alexander, Amazigo, Barrie, MacLean, Myers and York. The team met regularly during the first term under the chairmanship of Dr. Jolly to discuss the problems which arose in the organisation of the survey. The writer, with the assistance of Myers, was made responsible for the statistical parts of the survey and his report will deal in rather more detail with those aspects of the survey than others. Reference should be made to the reports of the other members of the team for a more balanced description of the survey.

Before reporting ^{on} ~~of~~ this citrus survey it is necessary to give a general account of sampling and its uses.

2. The Need for Statistics.

Howard C. Grieves, Assistant Director of the Bureau of the Census, U.S.A., in his foreword to Sample Survey Methods and Theory (Hansen et al., 1953) writes, "Business, the government, and the professions, in a free and progressive society, all seek the broadest possible factual basis for decision making, policy formation and the development of social and economic theory." He goes on to state that the development of sampling has made possible the production of many of the statistics required for the above purposes.

It will be generally agreed that statistics, i.e. the systematic collection of numerical facts, is a pre-requisite for the proper utilisation of resources, whether they belong to an individual, a business or a nation.

In agriculture, an industry producing a variety of products for a variety of uses, it is essential that statistics be available so that farmers and governments can plan future production. In Britain, which is a well developed country, many agricultural production statistics are collected by means of quarterly returns giving information on crop acreages, livestock numbers, etc., which must be made for each holding in the country. There is no need, therefore, of sample surveys in the field to collect this information, although sampling methods may be used to obtain the results since there is a limit to the amount of information which can be handled quickly by census methods.

In less developed countries it is not possible to collect statistics in this way since the farmers may be illiterate and so unable to complete even the simplest of questionnaires. It is possible to obtain some production statistics in these countries without consulting the farmers. This is especially so in the case of export crops like cocoa or coffee where the total amount sold by the farmers can usually be obtained from marketing organisations. Statistics of this sort, however, are not particularly useful unless estimates can be made of such facts as the acreage under the crop, the number of producers and the distribution of the crop. It is virtually impossible to obtain statistics of locally consumed food crops by this method because of the lack of large, central marketing organisations.

Britain's colonial territories are economically under-developed by European standards, with a correspondingly high incidence of illiteracy and subsistence production. To assist in agricultural development, agricultural statistics on a variety of topics are, therefore, an urgent requirement in these territories.

Being relatively poor economically, they cannot afford to maintain the large staffs required to carry out complete surveys or censuses, nor has education proceeded far enough to allow the use of "form filling" to which British farmers are subjected. It is the writer's opinion that there is very great scope for the use of sampling methods to provide the necessary information for economic progress in these areas.

The agricultural departments of most British colonies publish annual reports containing numerous tables showing crop acreages, yields and livestock numbers. The writer has been assured that the majority of these figures are intelligent guesses or obtained by very indirect methods, e.g. if the department supplies all the seed for a particular crop, the acreage planted to the crop may be calculated from the total amount of seed distributed to farmers. Estimates such as these cannot be relied upon and may possibly be very misleading. There is, therefore, great need of a method which will give more reliable agricultural statistics in the colonies.

The First Conference of Colonial Government Statisticians (1950) agreed that basic information on agriculture in the colonies is at present inadequate or lacking and stated that one of the priorities for statistical development in less developed countries is "the rapid development of basic agricultural statistics". Both the First Conference (1950 a) and the Fourth Conference (1956) have pointed out that sampling methods are very suitable for the collection of basic information on agriculture in the colonies.

3. Sampling and Its Uses.

Yates (1953) defines sampling as "the selection of part of an aggregate of material to represent the whole aggregate". By this process information can be collected from a small part of a population and regarded as being

representative of the whole population. By contrast, the information could be collected by means of a complete census, but this is usually expensive and time consuming, in under-developed countries often prohibitively so.

The possible advantages of a sample over a complete census are:

1. The cost is usually less.
2. The number of enumerators required is less and they can be of a higher standard.
3. More detailed information can be obtained.
4. Less time is required both for field work and analysis.
5. The results may be more accurate since errors can be assessed and effective precautions taken to ensure the accuracy and completeness of the results.
6. Although an element of error will always arise in estimating a population from a sample, the sampling errors can be calculated and can, with a good design, be kept satisfactorily low.

A sample from a population can never be exactly representative of the whole population; it is subject to what are known as sampling errors. However, the random sampling errors can be estimated from the variability within the sample, providing that a proper process has been used to select the sample. A satisfactory sample is one that has low errors.

The sampling errors can be reduced by increasing the size of the sample or by ensuring the minimum, unavoidable variability between units; this latter is a process of minimising the sampling error and can be achieved by the use of suitable designs and analyses. Increasing the size of the sample reduces error since the sampling error of the estimate of the mean of a large population from a random sample is inversely proportional to the square root of the number of

units in the sample, and also directly as the complement of the sampling fraction (Yates, 7. 1).

The methods by which random sampling errors can be reduced are:

1. Stratification: the population to be sampled is subdivided into a number of groups or strata having similar characteristics and each stratum is sampled at random. Sampling errors are then calculated within these strata; e.g. in a survey where farms are the sampling units stratification of the farms is a useful method of minimising the variation between the units.

2. The use of supplementary information: e.g. in a survey to determine the acreage and production of a crop from a sample of farms, the total yield of the crop may be estimated by multiplying the average yield obtained from the sample by the total acreage of the crop obtained from farmers' returns, or by some other means. If errors for this estimate of total acreage are low, the estimate of the total yield so obtained is likely to be more accurate than one obtained from the sample data alone.

3. The use of variable sampling fractions: different proportions of units are selected from the different strata, thus enabling the more variable parts of the population to be sampled more intensively so that these sampling errors are lower than otherwise.

4. Multi-stage sampling: e.g. in a sample of a tree crop, the population can be divided into farms which are sampled and then trees are sampled on selected farms, giving a two-stage sample. This design does not usually of itself reduce sampling errors, but it reduces costs, and so may allow more intensive sampling, thus reducing sampling errors.

The results of a sample survey may be affected by bias in the selection process, during the enumeration, or in the analysis. Hansen et al. (1953 a) define bias as being "equal to the difference between the expected value of the estimate and the true value being estimated", where the expected value of a sample estimate is the average value of the estimate obtained from all possible samples from the population provided that all the possible samples have the same chance of selection. If this difference is zero then the estimate is unbiased. Errors introduced by bias will not be assessed in the estimation of the sampling error and care must be taken not to introduce bias unless under carefully controlled conditions.

Bias may be due to:

1. Deliberate selection in an effort to secure a "representative" sample, e.g. a sample of farms where all the selected farms are, in the opinion of the selector, "average" farms (i.e. no very good or no very poor farms are included in the sample).
2. A selection method depending on some characteristic which is correlated with the properties of the units to be estimated, e.g. if it is desired to estimate the acreage of, say, wheat on farms which is correlated with the acreage of the farms, then a sampling method which depends on farm size (e.g. the selection of "average" sized farms) will give biased results.
3. A selection process which does not conform to a correct random sampling process, e.g. the selection of the farms by sticking pins into a map of the district.
4. Substitution of a convenient unit of the population when there is difficulty in obtaining information from the selected unit (known as bias towards convenience), e.g. the selection of a farm in the vicinity of a selected farm which cannot easily be located.

5. Failure to cover the whole of the chosen sample, e.g. missing some of the fields on a selected farm.

6. Faulty demarcation of the sampling units, e.g. the sampling of a field which was thought to belong to the sampled farm but which, in fact, belongs to a neighbouring farm.

7. Bias in the estimation of the results; e.g. a weighted average will normally give a more accurate estimate of mean yield per acre than the arithmetic mean,

8. Bias in enumeration; e.g. consistent over or under estimation in making eye estimates on, say, the number of fruit on a tree.

Before a sample can be drawn from a population, the sampling units must be defined and a frame listing all the units in the population must be available. If a proper frame is not available a correct sample cannot be drawn since each unit must have the same chance of selection within the restrictions of the sampling scheme as any other unit in the population. It is also necessary that the units can be unambiguously identified.

Frames may be subject to several defects which can be listed as:

1. Inaccuracy; e.g. where inaccurate acreages have been listed for a frame of farms or where farms are included which do not exist.

2. Incompleteness; e.g. where some farms have been omitted.

3. Duplication; e.g. where some farms have been included more than once.

4. Inadequacy; e.g. where small holdings have not been included in a frame of farms if it is desired to obtain information from them.

5. Out of date; e.g. where there has been an increase in the number of farms since the frame was constructed.

Before sampling from a frame it is necessary to check it thoroughly to ensure that none of the above defects is serious.

Selection of frames for agricultural surveys in well developed countries is usually quite simple since good maps and accurate lists of farms are usually available. In the British colonies, however, this is seldom the case and provision of a suitable frame for a sample often presents great difficulty. Often the only suitable frame is a list of villages or other administrative districts. Line sampling has been used in many sample surveys, particularly for soil and land use classification, but is not very applicable for estimating livestock numbers, crop yields, land tenure, etc. However, aerial photography is expediting map making which can provide a satisfactory territorial frame.

Sampling, a fairly new development of statistics, has not yet been incorporated in the organisation of Agricultural Departments, though sporadic examples of surveys using sampling methods which have been carried out by District Agricultural Officers are to be found.

Overpopulation is becoming serious in many colonies and hence resettlement schemes have been promoted in some areas. Purseglove (1946), working as an Agricultural Officer in Kigezi, Uganda, carried out a resettlement scheme involving the moving of over 20,000 people after making a sample survey of soils and land use.

Another example of the type of work an Agricultural Officer may be called upon to do is the report by Priestly and Greening (1956) of a land utilisation survey in Northern Rhodesia where sampling methods were used in obtaining data on soil, crop yields and population.

It is probable that this type of work may become a normal part of the Agricultural Officer's work in the future.

4. Choice of the Survey.

The survey was conducted with rather peculiar objectives:

- (a) as an exercise in sampling, and
- (b) to collect information of local agricultural interest, and within unusual limitations:

- (i) the time for enumeration was restricted to the Christmas vacation,

- (ii) postgraduate students were to act as unpaid enumerators, and

- (iii) limited funds were available to pay for the costs incurred during the survey.

In previous surveys conducted by I.C.T.A. students, enumeration in the field was the responsibility of the student team alone. The scope of their surveys was, therefore, limited by the amount of field work that could be done in the period of the Christmas vacation. In the Food Gardens Survey of 1956-57 only the counties of Caroni, St. David and St. Andrew were surveyed; in the Land Utilisation Surveys of 1954-55 and 1955-56 only county Caroni was surveyed.

This year, however, it was possible to have an island wide survey since the Director of Studies had agreed that all postgraduate students be asked to assist with the enumeration in order to give them some experience of the problems encountered in enumeration.

The six members of the survey team discussed the choice of a subject at some length. Extensions of previous surveys of land utilisation (1954-55 and 1955-56) and food gardens (1956-57) were rejected because it was felt that many of the problems encountered in these surveys had been solved and the survey team wanted to do something new.

Surveys of land tenure and fertiliser use were considered, but there would be little chance to make measurements and most of the information would have to be gained by question and answer. The survey team had agreed that some direct observation and measurement be used in the survey and could not allow the more time absorbing question and answer to prejudice the size of a measurement survey.

A survey to estimate cattle numbers was suggested. However, there would be great difficulty in identifying many animals which are often grazed far from their owners' homes. A survey to estimate pig numbers showed promise, but probably there are too few pigs in the colony to make a good survey.

Finally it was decided to do a survey of citrus to estimate the incidence and severity of melanose, a disease which may render fruit unacceptable for export as fresh fruit. Most commercial varieties of citrus are susceptible to this disease. At the moment only grapefruit is exported from Trinidad as fresh fruit, although attempts are being made to build up an export trade in fresh oranges. It was, therefore, decided to confine the investigation to grapefruit grown for export.

The advantages of such a survey from the point of view of the survey team's peculiar conditions were:

- (a) a suitable frame was available (see Part 2, Section 1);
- (b) the survey team could apply any sampling scheme chosen to this frame;
- (c) most citrus is grown near roads and thus access to sample units was relatively easy;
- (d) the incidence of melanose on grapefruit was of local agricultural interest.

5. Description of Melanose.

This disease is caused by the fungus Diaporthe citri (Faw.) Wolf and occurs on the fruit, leaves and small twigs, especially in dead wood which can harbour the spores in great quantity. Batchelor and Webber (1948) state that melanose is more prevalent in countries having abundant summer rainfall, which is the case in Trinidad.

Fawcett (1936) noted that the predisposing factors for the infection and development of melanose are:

- (a) age of tissue - only young tissue is infected.
- (b) presence of moisture.
- (c) temperature - the optimum is between 75°F. and 81°F.
- (d) presence of dead twigs in the tree, where the infective spores are produced.

Ruehle and Kuntz (1940) found that grapefruit are susceptible to infection from five to eight weeks after petal fall and that they can be considered immune when the diameter of the fruit has reached three inches.

The symptoms of the disease on the fruit are circular spots which vary in size from minute to a diameter of one millimetre. The minute spots are usually produced from an infection when the fruit is nearing the immune stage. At first the spots are light brown and sunken, later becoming dark brown or black and distinctly raised owing to the development of corky tissue beneath. The spots are often single, but in severe infections they may coalesce giving rise to the condition known as "mudcake melanose". The spots may also occur in "tear-streaked" patterns caused by drops of spore laden water flowing over the fruit surface.

Once the spots have appeared on the fruit they cannot be removed by washing or other mechanical means and their presence spoils the appearance of the fruit and thus

affects its saleability as fresh fruit. The infection only occurs on the rind of the fruit, and fruits too badly infected for sale as fresh fruit can be used in the manufacture of juice. However, there is a considerable price differentiation between fresh fruit and fruit for juicing (amounting to eighty cents per box in Trinidad this year), and so a severe attack of melanose can markedly reduce the cash return from the crop.

PART 2. PRELIMINARY WORK

1. The Frame of the Sample.

It had been decided in choosing the survey to confine the investigation to grapefruit grown for export. A suitable frame would, therefore, be a list of estates growing grapefruit for export. Citrus export from Trinidad is a monopoly of the Co-operative Citrus Growers' Association of Trinidad and Tobago Limited (hereinafter referred to as C.C.G.A.) and all growers of export citrus are members. Since grapefruit is the only citrus species which is exported as fresh fruit from Trinidad, a list of members of C.C.G.A. provided a very suitable frame for the sample. Mr. F.W. Allen, manager of C.C.G.A., provided a list of members of C.C.G.A. for the season 1957-58 and this list was used as the frame for the sample.

The frame listed 275 growers of citrus, giving (in most cases) the name and address of the estates and also the acreage of citrus grown on each estate. Examination of the frame showed that growers with more than one estate were listed for each estate they owned, but each estate occurred only once in the frame. Estates were, therefore, selected as the sampling units.

The 275 estates in the frame were listed to contain an approximate 7,500 acres of citrus. It was known that a considerable part of this acreage was in oranges and, by consultation with Mr. Allen, estates producing only oranges were eliminated from the frame.

2. Design of the Sample.

There is wide variation in the amount of citrus grown on the estates in the frame, the maximum being 419 acres and the minimum 0.5 acre, with an average size of 27.22 acres of citrus per estate. In a random sample from this whole

population, the variability per unit is great and one would expect that sampling errors would be high unless a very large number of estates were included in the sample. The survey team decided to stratify into three size groups in order to reduce the overall sampling errors. A further reason for stratification in this way is the assumption that management and disease control might be better, or at least different, on the larger than the smaller estates.

The definition of the size groups was as follows:

1. Estates with 0 - 10 acres of citrus.
2. Estates with 10.1 - 100 acres of citrus.
3. Estates with over 100 acres of citrus.

Camp (1956), in his report of a survey of Trinidad citrus carried out at the request of C.C.G.A., has suggested that the incidence of melanose is low in areas of high rainfall, probably due to the heavy rains which wash the spores off the fruit entirely and that infection is favoured by the light, misty rains more prevalent in the lower rainfall areas. In an attempt to take advantage of and to verify this suggestion, the team decided to stratify the estates into two further groups, estates in low rainfall areas (under 100 inches per annum) and estates in high rainfall areas (over 100 inches per annum).

The estates were, therefore, stratified for two characters, this process being known as multiple stratification with control of sub-strata (the number of estates in each sub-stratum is known).

Table 1 shows the division of the estates into the six strata.

TABLE 1. DEFINITION OF SIX STRATA.

Acreage in Citrus	0 - 10 acres	10.1 - 100 acres	Over 100 acres
Under 100" Rainfall	Stratum 1	Stratum 3	Stratum 5
Over 100" Rainfall	Stratum 2	Stratum 4	Stratum 6

The first step in listing the estates into their strata was the preparation of a map showing the approximate location of the estates and also the 100" isohyet which allowed allocation of the estates into the rainfall strata. The 100" isohyet was taken from an isohyetal map produced by Wehekind and Smith (1955) based on Trinidad rainfall data from 1933 to 1952.

The second step was to arrange the estates into the appropriate size groups and so stratify by the second characteristic.

Some difficulties arose in classifying the estates since the frame did not always give either the address or the acreage of citrus for each estate. However, after a meeting with Mr. Allen of C.C.G.A. the estates were all classified. In Table 2 the number of estates in each stratum is shown, and in Table 3 the approximate acreage of citrus (obtained from the frame).

TABLE 2. NUMBER OF ESTATES IN THE STRATA

Acreage in Citrus	0 - 10 acres	10.1 - 100 acres	Over 100 acres	Totals
Under 100" Rainfall	67	123	8	198
Over 100" Rainfall	38	35	4	77
TOTALS	105	158	12	275

TABLE 3. APPROXIMATE CITRUS ACREAGE IN THE STRATA

Acreage in Citrus	0 - 10 acres	10.1 - 100 acres	Over 100 acres	Totals
Under 100" Rainfall	383	3,666	1,582	5,631
Over 100" Rainfall	224	1,036	592	1,852
TOTALS	607	4,702	2,174	7,483

The number of trees on the estates is very large (assuming 90 trees per acre, there are almost 700,000 trees on the estates in the frame), and so, in order to save time, and also to allow as many estates as possible to be sampled, the team decided to sample trees on estates and also fruit on trees.

The estates then represented the first stage units of the sample. The second stage was trees; at this stage no stratification was involved and the trees were selected at random (see Part 2, section 3).

An investigation of several estates in the Sangre Grande, Montserrat and St. Augustine districts showed that the distribution of melanose on the tree and within the field was relatively uniform. The survey team decided, therefore, to select as many estates as possible since it was expected that the greatest variation would be between estates rather than between trees and fields within estates.

To improve the efficiency of the sample by ensuring adequate representation of estates which would contribute most to the results, variable sampling fractions were used at the first and second stages. The sampling fractions to be used, however, were not decided upon until a pilot survey had been carried out on several estates to obtain information on the practicability of tree sampling and also to have some estimate of the time required to do the field work.

(The sampling scheme may be stated briefly as a multi-stage sample with multiple stratification at the first stage, having control of sub-strata, and with a three stage sample in each sub-stratum.)

3. Field Observations.

The sampling of the second stage units (trees) presented a few problems. There were several possible methods of sampling.

The method of selecting sub-plot areas in each field and then examining each tree in that area was rejected for two reasons, although this type of sampling would have given a good random sample. The reasons were:

(a) difficulty in delineating the sub-plot areas, and (b) although the team expected that melanose distribution in the field would be uniform, if the disease did occur in patches then these patches might not be sampled at all and the results would be biased. *Sampling error large*
NO

A second possibility was a systematic sample of all the trees in the field. This method involves walking up and down each row counting the trees and sampling every nth tree. The principal objection to this method was the amount of time required to walk up and down the rows in the field.

Another method was to make a random sample of all the trees in the field. The difficulty here was to locate the correct tree for sampling without having to walk up and down the rows counting the trees.

There was considerable discussion on this problem and the team eventually decided upon a method in which three rows of trees were to be counted simultaneously by walking down the centre row and counting only the trees in that row, disregarding any missing trees on the assumption that their distribution would be uniform. *random* The practicability of this method was tested in the pilot survey using a sampling fraction of 1 in 50. Starting at a randomly selected corner of a field, the enumerator walked along the centre row of three counting the trees. In each 50 trees counted

in the centre row, three trees were selected at random for sampling, one in the left hand, one in the centre and one in the right hand row respectively.

The third stage in the sample was the selection of fruit to be examined for melanose infection. Since melanose distribution was assumed to be uniform on the tree, the team decided to sample only ten fruit on each selected tree. The sampling fraction thus varied with the number of fruit on the tree. Also the distribution of fruit on the tree had been found to be relatively uniform and so these ten fruit could be sampled in one position on the tree. The team selected eye level as being most convenient. To avoid sampling always from the same position on every tree, four positions were defined and named A, B, C and D, and the sampling position selected at random (see Part 2, section 6).

For the estimation of the incidence of melanose on the selected fruits, three categories of infection were defined after consultation with C.C.G.A. as follows:

- (a) category N - fruits showing no visible melanose;
- (b) category PA - fruits showing melanose, but still acceptable for fresh fruit shipment;
- (c) category PU - fruits showing melanose to such an extent as to be unacceptable for fresh fruit shipment.

The division between categories PA and PU was the C.C.G.A. packing shed standard for the maximum amount of melanose permitted on fruit for fresh fruit shipment. Examination of a few samples obtained from the packing shed gave a melanose count of from 80 to 120 spots per square inch, depending on the size of the spots, for that standard.

To have an estimate of the number of fruit in each category on a selected tree, it was also necessary to make an estimate of the number of fruit on the tree. The most accurate method of doing this would be to strip all the fruit off the tree and count them, but this ^{might} ~~would~~ have involved the paying of compensation and would also have been extremely laborious. The method adopted was to make an eye estimate of the number of fruit to the nearest hundred fruit.

The observations on selected trees in the field were to be:

1. Grading of selected fruit.
2. Eye estimate of the number of fruit.

To test this scheme and also the proposed method of tree sampling, the survey team carried out a pilot survey on three estates.

4. The Pilot Survey.

The three estates surveyed in this investigation were deliberately selected from the frame to represent as widely varying conditions as possible (with the limitation that they must be near enough to I.C.T.A. to allow the investigation to take place in one afternoon). The selected estates were:

1. Mount Pleasant, Talparo, 121.5 acres citrus, over 100" rainfall.
2. Mon Valmont, Santa Cruz, 85 acres citrus, under 100" rainfall.
3. Estate of J.I. Frederick, Maracas, 4 acres citrus, under 100" rainfall.

The team divided into three groups of two and each group visited one of the estates during the afternoon of 29th November, 1957. The groups were instructed to call on the owners or overseers first to obtain permission

to look at their citrus and this was readily granted. During the investigation the groups attempted to sample trees by the three row system previously described, sampling two lots of ten fruit at eye level on each selected tree.

The results of these investigations showed that the three row method of tree sampling was quite practicable where a pure stand of grapefruit, planted in orderly rows, was grown. Where mixed stands occurred, or the planting was haphazard, the method was impracticable, but good results were obtained from a single row method.

Each group recorded the number of trees sampled in 30 minutes, in two fields if there was more than one field on the estate, obtaining an average value of 6 trees per 30 minutes. With a sampling fraction of 1 in 50 for trees, this value is equivalent to approximately 6 acres per man hour.

The grading of the fruit was found to be relatively simple, little difference being noted in the two samples taken from each tree.

Eye estimates of the crop yield, to the nearest 100 fruit, were made on selected trees. These estimates were checked by counting the fruit on one quarter of the tree and multiplying by four to give an estimate of the total number. Good agreement between the two estimates was obtained after a little practice.

There was considerable difficulty in locating the estate at Maracas, and it seemed likely that this would be the case with many of the estates in the size group 0-10 acres.

The results obtained from this pilot investigation showed that the tree sampling scheme and the methods of grading the fruit and estimating the number of fruit on

the tree were practicable. Useful information on the time required for sampling in the field was also provided.

5. Sampling Fractions Used.

In choosing the sampling fractions for the first stage units (estates) the main considerations were the number of enumerators and the number of days available for sampling. The team estimated that 20 postgraduate students would be available each day for 7 days which is equivalent to 140 man days. Allowing 4 hours actual enumeration per man day, 560 man hours were available for enumeration. The pilot survey had shown that a sampling rate of 6 acres per man hour was possible, thus 3,360 acres could be sampled in the stated time. If uniform sampling fractions were used in the strata, a 1 in 2 sample of estates would have been suitable. However, the team had previously decided to use variable sampling fractions for estates.

The estates in size groups 0-10 acres (strata 1 and 2) represented only 8 per cent. of the total acreage in the frame and thus will not contribute a great deal to the results. In addition the team suspected that many of those estates would be difficult to locate. Strata 1 and 2 were, therefore, sampled at the fairly low intensity of 1 in 10.

By contrast, estates in the large size group, over 100 acres (strata 5 and 6), represented 29 per cent. of the acreage in the frame and their location presented no difficulty. The team decided to sample all the estates in strata 5 and 6.

The remaining estates, in size group 10.1-100 acres (strata 3 and 4), representing 63 per cent. of the total acreage in the frame, were sampled with a medium intensity of 1 in 5.

This sample will cover just over 3,000 acres which is within the calculated limit of 3,360 acres.

A sampling fraction of 1 in 50 was used for the second stage units (trees) because the team expected that the variation between trees within fields would be small. In strata 5 and 6, comprising only 12 estates which were all to be sampled, a sampling fraction for trees of 1 in 150 was used to allow sampling of every field in these estates in the limited time available.

To obtain this 1 in 150 sample of trees in the field a modification of the three row method previously described was used in which three adjacent rows out of every nine were sampled at 1 in 50, giving an overall sampling fraction of 1 in 150. The use of this modified method enabled the same field sheets to be used for enumeration in all strata.

The sampling fractions for the first and second stages of the sample are shown in Table 4.

TABLE 4. SAMPLING FRACTIONS AT THE FIRST AND SECOND STAGES

Strata	Sampling Fractions	
	1st Stage	2nd Stage
1 and 2	$\frac{1}{10}$	$\frac{1}{50}$
3 and 4	$\frac{1}{5}$	$\frac{1}{50}$
5 and 6	1	$\frac{1}{150}$

6. The Sample.

The first step in drawing the sample was the calculation of the number of estates to be sampled in each stratum. Where the number of estates in a stratum (see Table 2) was not exactly divisible by the sampling fraction the nearest whole number of estates was selected, e.g. 1/10th

of 67 estates gave a sample of seven estates in stratum 1. Table 5 lists the number of estates in the sample by strata.

TABLE 5. NUMBER OF ESTATES IN THE SAMPLE

Acreage in Citrus	0 - 10 acres	10.1 - 100 acres	Over 100 acres	Totals
Under 100" Rainfall	7	25	8	40
Over 100" Rainfall	4	7	4	15
TOTALS	11	32	12	55

The second step was the selection of the estates which was made using a table of random numbers, selecting the appropriate number of estates for each stratum in turn.

A list of the estates in the sample is included in the Appendices and also a map showing their approximate location (Appendices 1 and 2). Table 6 shows the approximate acreage in citrus of the estates in the sample (obtained from the frame).

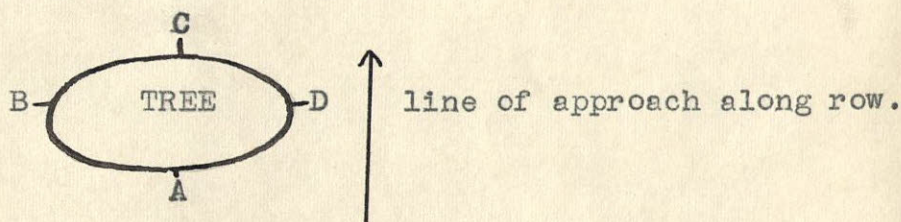
TABLE 6. APPROXIMATE ACREAGE IN CITRUS OF THE SAMPLED ESTATES

Acreage in Citrus	0 - 10 acres	10.1 - 100 acres	Over 100 acres	Totals
Under 100" Rainfall	31	748	1,582	2,361
Over 100" Rainfall	14	211	592	817
TOTALS	45	959	2,174	3,178

For tree sampling the team prepared a field sheet (see Appendix 3) which was used for every selected estate. Three columns marked L., M. and R., left, middle and right hand rows respectively, contained the number and the letter indicating the sampling position of each tree to be sampled. The numbers were selected using tables of

random numbers, selecting numbers between 1 and 50. The appropriate factor, e.g. 50, 100, 150, etc., was added to the random number obtained to obtain a progressive list of tree numbers. Thus, the first three random numbers for the left hand row were 37, 31 and 30; these were recorded in the field sheet as 37, 81 and 130 respectively.

The following sketch illustrates the sampling positions defined for selected trees.



The order of the sampling positions was selected at random using tables of random numbers and was (A,D,C,B), (B,A,D,C) and (C,B,A,D) in the left, middle and right hand rows respectively.

The field sheet also had three columns for the recording of melanose infection on the sampled fruit (N, PA and PU) and a column for the crop estimate. One sheet was sufficient for the recording of 26 acres with a 1 in 50 tree sample and 78 acres with a 1 in 150 tree sample.

Some doubt was expressed that the sample of trees was ~~not~~ a correct random sample, but the writer is satisfied that each tree in every selected field had the same chance of selection as any other when the sample was drawn.

7. Preparations for Enumeration.

A list of instructions to enumerators was prepared which gave clear instructions for the sampling procedure in the field and which was designed to answer any likely queries which might arise during enumeration. A copy of this list is included in the appendices (Appendix 4).

The postgraduate students who were to act as enumerators were asked to attend a seminar on 13th December, 1957, when the sampling scheme and the procedure for enumeration in the field were briefly outlined. Cyclostyled sheets of the instructions to enumerators were issued and queries regarding these instructions answered. Field record sheets were also issued and the method of recording observations on them was explained.

Several samples of fruit in the categories N, PA and PU had been obtained from C.C.G.A. Enumerators were asked to examine them to obtain some preliminary training in fruit grading. The writer feels that the training given to the enumerators was inadequate in that no practical training in the field was possible due to the limited time available and also to the other commitments of the enumerators. However, the six members of the team, who were to act as supervisors during the enumeration, agreed to give some field training to enumerators assigned to them at the beginning of the enumeration. Enumerators were also to be supplied with specimen samples of fruit in the three categories to assist in the grading of selected fruit.

During the period from 9th to 13th December, 1957, members of the team were able to locate and make sketch maps of about half the number of estates in the sample. The sketch maps showed the location of the estate and the fields to be sampled. Starting positions for counting which were selected at random from the corners of the field were marked by dots on the sketch map.

PART 3. FIELD WORK

1. General Description.

The writer proposes to deal briefly with this topic being more concerned with the statistical aspects of the survey. Reference should be made to the reports of other members of the team for a full description of this part of the survey.

The enumeration commenced on 16th December, 1957, and was completed by 20th December, 1957. This considerable saving in time over the estimated time (7 days) was due to:

(a) the sampling rate was much greater than 6 acres per hour, especially on large estates sampled at 1 in 150.

(b) single row sampling was necessary on only a few of the small estates.

(c) prior location of many of the estates by the supervisors.

(d) the fruit was very clean which speeded the grading of the ten selected fruit on each tree.

(e) a large part of the acreage in the sample was planted in oranges and so the actual acreage surveyed was considerably less than was estimated from the frame.

The enumerators quickly became familiar with the sampling method, fruit grading and yield estimation, and so the scheme proved workable in the field.

2. Defects in the Frame.

The identification of some of the estates in strata 1, 2 and 3 was very difficult, and impossible in a number of cases, even after visits to the local police station and post office and also after discussion with local inhabitants. The estates the team was unable to

sample due to this difficulty were:

Stratum 1. Nos. 32 and 79.

Stratum 2. No. 278.

Stratum 3. Nos. 101, 142, 158, 168, 243 and
291 (see Appendix 2).

This finding justified the low sampling intensity in strata 1 and 2 and it was noted that the unidentified estates in stratum 3 were all listed in the frame to have rather small acreages in citrus which suggests that the team could have increased the upper limit of strata 1 and 2 from 10 acres to, say, 25 acres.

There are two possible defects in the frame which will account for these difficulties in identification; either the frame was out of date in that these estates no longer existed, or the frame was inaccurate due to insufficient information being given to identify the estates. The writer believes that the majority of these cases was due to inaccuracy.

All the estates in strata 4, 5 and 6 were identified and sampled, although in stratum 5 estate No. 176 could not be identified until it was discovered that this estate had been taken over by the owners of an adjoining estate, No. 167, and had been sampled along with No. 167. In this respect the frame was out of date.

Two estates were found to be in the wrong strata. In stratum 1, No. 287 had been wrongly allocated in the below 100" rainfall group due to ignorance of local geography on the writer's part. In stratum 3, No. 180 was found to have more than 100 acres of citrus. It had been listed as having 31.5 acres in the frame which was an inaccuracy of the frame. The supervisor responsible for sampling this estate instructed his enumerators to sample the trees at 1 in 150.

Another difficulty, not strictly due to a defect in the frame, but to a defect in the timing of the survey, occurred when the team discovered that all the grapefruit had been picked on three estates. Trees were sampled on these estates and recorded as having "no fruit" on the record sheets. These estates were:

Stratum 1. No. 89.

Stratum 2. No. 170.

Stratum 4. No. 262.

The difficulties and defects of the frame noted above affected the analyses and are discussed later (see Part 4, section 2).

PART 4. ANALYSIS OF DATA AND RESULTS

1. Theory of the Analysis.

In the Food Gardens survey of 1956-57 the raw data was coded and transferred to clip-cards before analysis. In this survey, however, there was no necessity for using clip-cards since there were only two sets of observations for each unit in the sample (the category assessment and the crop estimate). The main advantages of using clip-cards are that a large amount of information can be assembled on a small card which is easily stored and sorted and that a large number of comparisons can be made without the labour of tabulating results for each comparison. There would be no advantage, therefore, in using clip-cards in this survey where the amount of information on each unit is small and the number of comparisons limited.

Prior to analysis, the category assessment for each tree was multiplied by its crop estimate thus giving an estimate of the number of fruit in the various categories. These figures were entered as hundreds of fruit on the right hand columns of the field sheets. These columns were convenient and available since none had actually been used for enumeration.

This procedure allowed accurate checking (see Appendix 3) and the chance of introducing mistakes when transferring the data to another sheet was eliminated.

Notation.

The notation used in the analysis is similar to that used by Yates [(1953) 6. 2]. A super bar denotes a mean value, e.g. $\bar{r}$ is the mean of a number of values of r , and a sub-bar denotes an estimated as opposed to a known value, e.g. $\underline{r}$. The notation used is listed below:

f' = working sampling fraction for first stage.

f'' = working sampling fraction for second stage.

g' = working raising factor for the first stage ($g' = \frac{1}{f'}$).

- g'' = working raising factor for the second stage ($g'' = \frac{1}{f''}$).
- n' = number of estates in the sample in a stratum.
- n'' = number of trees sampled in a selected estate.
- $\underline{N}$ = estimated number of trees in a stratum.
- $\underline{N}_2$ = estimated number of bearing trees in a stratum.
- x = crop estimate in 100's for a tree.
- $\underline{X}$ = estimated crop yield in 100's for a stratum.
- y = estimated number of fruit in 100's in a particular category for a tree. (The categories being denoted y_N , y_{PA} and y_{PU} for category N, PA and PU respectively.)
- $\underline{Y}$ = estimated number of fruit in 100's in a particular category for a stratum. (Similarly $\underline{Y}_N$, $\underline{Y}_{PA}$ and $\underline{Y}_{PU}$.)
- r = ratio of y/x for an estate.
- $\underline{r}$ = mean ratio of y/x for a stratum.
- $\underline{r}$ = estimated mean ratio of $\underline{Y}/\underline{X}$.
- S' = summation of values over first stage units (estates).
- S'' = summation of values over second stage units (trees on estates).
- u' = number of estates in the sample possessing a given attribute.
- u'' = number of trees in the sample possessing a given attribute.
- $\underline{U}'$ = estimated number of estates possessing a given attribute.
- $\underline{U}''$ = estimated number of trees possessing a given attribute.
- $\underline{p}$ = proportion of estates in the sample possessing a given attribute.
- $\underline{p}'$ = proportion of trees in a stratum possessing a given attribute.
- $\underline{p}''$ = proportion of trees on an estate possessing a given attribute.
- $\underline{q}$ = $1 - \underline{p}$. $\underline{q}' = 1 - \underline{p}'$. $\underline{q}'' = 1 - \underline{p}''$.

- s' = a part of variance due to first stage sampling.
 s'' = a part of variance due to second stage sampling.
Var. = an estimated variance.
S.E. = an estimated sampling error.

In the analysis each stratum is regarded as being a separate two-stage sample and estimated totals with their sampling errors are calculated for each stratum. The strata are amalgamated to give results for the whole survey. Two analyses were carried out for each stratum:

(a) a quantitative analysis to determine the population totals with their sampling errors, and

(b) a qualitative analysis to estimate the proportions of units possessing a given attribute with their sampling errors.

The first stage units (estates) were sampled with a varying sampling fraction. In strata 5 and 6 (estates with over 100 acres of citrus) all the estates were sampled. For these strata, therefore, there is no component of variation due to first stage sampling and the formulae used require modification from those used in strata with estates of under 100 acres citrus.

The following formulae were used in the computations. The figures in square brackets refer to the relevant sections in Yates (1953).

Quantitative Analysis.

(a) Stratum totals - all strata.

Estimated number of trees.

$$\underline{N} = g'g'' \cdot S'(n'').$$

Estimated number of bearing trees at the time of the survey.

$$\underline{N}_2 = g' \cdot g'' \cdot S'(n''), \text{ where } n'' = \text{the number of bearing trees sampled in a selected estate.}$$

Estimated crop yield.

$$\underline{X} = g' \cdot g'' \cdot S'S''(x).$$

Estimated number of fruit in a particular category.

$$\underline{Y} = g'.g''.S'S''(y).$$

Estimated ratio of fruit in a particular category to crop yield.

$$\underline{\bar{r}} = S'S''(y)/S'S''(x).$$

(b) Sampling errors - strata with estates of under 100 acres citrus.

The number of trees was determined on the first stage units of the sample and there is, therefore, no component of error due to second stage sampling.

$$\underline{N} = g'.g''.n'.\bar{n}''$$

$$\text{therefore, Var.}(\underline{N}) = (g'g'')^2 \cdot n'^2 \cdot \text{Var.}(\bar{n}''). \quad (1).$$

We are dealing with a finite population and the term $(1-f')$ must be introduced [7. 2]. (1) now becomes

$$\text{Var.}(\underline{N}) = (g'g'')^2 \cdot (1-f') \cdot n'^2 \cdot \text{Var.}(\bar{n}'') \quad (2).$$

$$\text{Var.}(\bar{n}'') = \text{Var.}(n'')/n' = s'^2 n''/n',$$

$$\text{where } s'^2 n'' = [S'(n''^2) - \{S'(n'')\}^2/n'] / n' - 1 \quad (3) \quad [7.1.d]$$

Substituting for $\text{Var.}(\bar{n}'')$ in (2), we have,

$$\begin{aligned} \text{Var.}(\underline{N}) &= (g'g'')^2 (1-f') n'^2 s'^2 n''/n' \\ &= (g'g'')^2 (1-f') n' s'^2 n'' \end{aligned} \quad (4)$$

which was the formula used in the computations.

The sampling error of the estimated number of bearing trees ($\underline{N}_2$) is calculated similarly, using the appropriate values of n'' .

The estimate of error of the crop yield is obtained from an analysis of variance splitting the variance into its two components; that due to first stage sampling, and that due to second stage sampling. The analysis of variance table is as follows: [8. 11].

Variance	d.f.	S.S.	M.S.
Between estates	$n' - 1$	$S'\{S''(x)\}^2/n'' - \{S'S''(x)\}^2/S'(n'')$	$s'^2 = A/\bar{n}_0$
Between trees within estates	$S'(n'') - n'$	difference	$s''^2 = B$
Total	$S'(n'') - 1$	$S'S''(x^2) - \{S'S''(x)\}^2/S'(n'')$	

$$\underline{X} = g' \cdot g'' \cdot n' \cdot n'' \cdot \bar{x}$$

$$\text{therefore, Var.}(\underline{X}) = (g'g'')^2 \cdot (n'n'')^2 \cdot \text{Var.}(\bar{x})$$

$$\text{Var.}(\bar{x}) = \frac{(1-f')}{n'} s'^2 + f' \frac{(1-f'')}{n'n''} s''^2 \quad (5) [7. 17]$$

$$\text{Therefore, Var.}(\underline{X}) = (g'g'')^2 \cdot (n'n'')^2 \cdot \left\{ \frac{(1-f')}{n'} s'^2 + \frac{f'(1-f'')}{n'n''} s''^2 \right\} \quad (6)$$

The number of trees sampled on each estate is not constant for the stratum and n'' is replaced by $\bar{n}_0''$ [8. 11d], where

$$\bar{n}_0'' = \left\{ s'(n'') - s'(n''^2)/s'(n'') \right\} / n' - 1 \quad (7)$$

$$\text{Var.}(\underline{X}) = (g'g'')^2 (n'\bar{n}_0'')^2 \left\{ \frac{(1-f')}{n'} s'^2 + \frac{f'(1-f'')}{n'\bar{n}_0''} s''^2 \right\} \quad (8)$$

On substituting for s'^2 and s''^2 from the analysis of variance and multiplying throughout by $(n'\bar{n}_0'')^2$, (8) becomes

$$\begin{aligned} \text{Var.}(\underline{X}) &= (g'g'')^2 \left\{ \frac{1-f'}{n'} \cdot \frac{A}{\bar{n}_0''} (n'\bar{n}_0'')^2 + \frac{f'(1-f'')}{n'\bar{n}_0''} \cdot B \cdot (n'\bar{n}_0'')^2 \right\} \\ &= (g'g'')^2 \left\{ (1-f')n'\bar{n}_0'' A + f'(1-f'')n'\bar{n}_0'' B \right\} \end{aligned} \quad (9)$$

If $\mathcal{L} = (1-f')n'\bar{n}_0''$, and

$\beta = f'(1-f'')n'\bar{n}_0''$, (9) can be rewritten as

$$\text{Var.}(\underline{X}) = (g'g'')^2 (\mathcal{L} A + \beta B) \quad (10),$$

which was the formula used in the computations. A similar formula is used to compute $\text{Var.}(\underline{Y})$.

The variance of $\bar{r}$ is estimated from the variation between first stage units since x and y are both estimated from the second stage units and there will be no gain in accuracy by including the variation between second stage units unless x is known or it has been estimated from a larger sample than is available for y [6. 8]. The variance is therefore estimated by the methods appropriate to random samples.

$$\text{Var.}(\bar{r}) = \frac{1-f'}{\{s's''(x)\}^2} \cdot n'n'' s^2_q \quad (11) [7. 8]$$

Omitting $(1-f')$ and substituting for n'' (7), we have

$$\text{Var.}(\bar{r}) = \frac{n' \cdot \bar{n}_0''}{\{s's''(x)\}^2} \cdot s^2_q \quad (12),$$

which was the formula used in the computations.

s^2_q is the estimated mean square deviation from the true ratio line and is given by $s^2_q = Q/n' - 1$, where Q is the sum of the squares of the deviations of the y 's from the values given by the ratio line [6. 8] and [7. 8].

$Q = A_y - 2\bar{r}A_{xy} + \bar{r}^2 A_x$ where A_y and A_x are the between estates mean squares and A_{xy} the between estates mean product.

(c) Sampling errors - strata with estates of over 100 acres citrus.

In these strata $f' = 1$ and errors are calculated from the variation between second stage units ($f'' = 1/150$).

$\text{Var.}(\underline{N})$ and $\text{Var.}(\underline{N}_2)$ are zero since these estimates were obtained from the first stage units which were all sampled.

$\text{Var.}(\underline{X}) = g''^2 \cdot S'(n'')B$, ignoring $(1 - f'')$ which is almost unity. $B = s''^2$ and is a pooled estimate of variance obtained from the analysis of variance.

$\text{Var.}(\underline{r}) = \frac{S'(n'')}{\{S'S''(x)\}^2} \cdot s^2_q$, where $s^2_q = Q/S'(n'' - 1)$ and $Q = B_y - 2\bar{r}B_{xy} + \bar{r}^2 B_x$. B_y and B_x are the between trees mean squares and B_{xy} is the between trees mean product.

Qualitative Analysis.

This analysis was carried out to determine for each stratum the estimated proportion of trees bearing all their fruit in

- (i) category N
- (ii) category PA
- (iii) category PU,

and the estimated proportion of trees bearing any diseased fruit. These proportions were all of the total number of bearing trees (N_2).

Where relevant, the proportions of estates with all their trees in one of the above categories of the total

number of estates in the stratum was determined.

The formulae obtained apply to any of the above determinations. Using trees bearing all their fruit in category N, we have,

(a) For strata with estates of under 100 acres in citrus:

Estimated proportion of trees bearing fruit in category N only on an estate $\underline{p}'' = u''/n''$ [6. 4.]

Estimated proportion of such trees in the stratum,

$$\underline{p}' = S'(u'')/S'(n'')$$

Estimated number of such trees in the stratum,

$$\underline{U}'' = N_2 \cdot \underline{p}' \quad [6. 4c.]$$

In a random sample from the whole population the variability of a qualitative variable depends only on the proportion of units possessing the given attribute in the population. No estimation of the variability of the sampling units themselves is required as is the case when a quantitative variate is under consideration [7. 4]. For a multi-stage sample, however, the variability of a qualitative variate depends on both the proportion of units possessing the given attribute and the variability of the sampling units. It is calculated in the same way as with a quantitative variate [7. 4]. Thus, $\text{Var.}(\underline{p}') = \frac{1-f'}{n'} s'^2 + \frac{f'(1-f'')}{n'n''} s''^2$ (13) [7. 17]

s'^2 and s''^2 are pooled estimates of variance obtained from the analysis of variance:

Variance	d.f.	S.S.	M.S.
Between estates	$n' - 1$	$S'(u''^2/n'') - \{S'(u'')\}^2/S'(n'')$	$s'^2 = A/\bar{n}_0''$
Between trees within estates	$S'(n'') - n'$	$S'(n'' \cdot \underline{p}'' \cdot \underline{q}'')$	$s''^2 = B$
Total	$S'(n'') - 1$	$S'(n'') \underline{p}' \cdot \underline{q}'$	

Substituting for s'^2 and s''^2 and replacing n'' by $\bar{n}_0''$ (7),

we have, $\text{Var.}(\underline{p}') = \frac{(1-f')}{n'\bar{n}_0''} A + \frac{f'(1-f'')}{n'\bar{n}_0''} B$ (14)

If $\alpha = (1 - f')/n'\bar{n}_0''$, and

$\beta = f'(1 - f'')/n'\bar{n}_0''$, (14) becomes

$$\text{Var.}(\underline{p}') = \alpha A + \beta B \quad (15)$$

which was the formula used in the computations.

$$\text{Var.}(\underline{U}'') = N_2^2 \cdot \text{Var.}(\underline{p}')$$

$$\text{S.E.}(\underline{U}'') = N_2 \cdot \text{S.E.}(\underline{p}') \quad (16) \quad [7. 4].$$

Estimated proportion of estates with all trees bearing fruit in category N only, $\underline{p} = u'/n'$

$$\text{Var.}(\underline{p}) = \underline{p} \cdot \underline{q} \cdot (1 - f')/n' \quad (17) \quad [7. 4].$$

This is an attribute of the first stage units, and so each stratum can be regarded as a random sample and the appropriate formula used.

(b) For strata with estates of over 100 acres in citrus:

$$\underline{p}'' = u''/n'' \quad \text{and} \quad \underline{p}' = S'(u'')/S'(n'').$$

There is no variation due to first stage sampling ($f' = 1$) and estates behave as strata, each estate being regarded as a stratum containing a random sample of the trees in the estate ($f'' = 1/150$).

Then, $\text{Var.}(\underline{p}'') = \underline{p}'' \cdot \underline{q}''/n''$ [7. 4], ignoring $(1 - f'')$ which is almost unity and,

$$\text{Var.}(\underline{p}') = S' \{ \text{Var.}(\underline{p}'') \}$$

$$\underline{p} = u'/n' \quad \text{and} \quad \text{Var.}(\underline{p}) = 0 \quad \text{since} \quad f' = 1.$$

2. Computations.

Separate computation sheets were prepared for the quantitative and qualitative analyses.

The quantitative computation sheet, of which a worked example is given in Appendix 5, was designed in such a manner that all the calculations, for any one quantitative variate, of the estimated totals, ratios and sampling errors could be shown on one sheet. Apart from the columns headed n'' , $n''-1$, x , y and r , the computation sheet consists of two analyses of variance (one for x , one for y) and an analysis of co-variance (xy). Thus the column headed $\{S''(y)\}^2/n''$ was an estimate of the raw sum of squares for the between estates variation of y ; the column headed $S''(y^2)$ was an estimate of the raw sum of squares for the total variation, and the column headed "difference" was an estimate of the corrected sums of squares for the between trees within estates variance of y . Similar columns were prepared for the analysis of variance of x and for the analysis of covariance of xy . The column totals were the estimates of the components of variation and co-variation for the particular stratum.

Below the line of column totals there were lines for the correction factor for the mean (C.F.M.), corrected sums of squares (S.S.), degrees of freedom (d.f.) and mean squares (M.S.); corrected sums of products and mean products in the case of the covariance columns.

Correction factors were calculated in the usual way

$$\left[\text{e.g. C.F.M.y} = \{S'S''(y)\}^2/S'(n'') \right].$$

The value of $S'(n''^2)$, required in the estimation of $\text{Var. } (\underline{N})$, was entered below the estates column and its mean square ($s_{n''}^2$) calculated. The mean squares and products calculated from the other columns gave the values of A_y , B_y ,

A_x , B_x , A_{xy} and B_{xy} for the formulae worked out in the previous section from which the variances of $\bar{X}$, $\bar{Y}$ and $\bar{r}$ were calculated. The sampling errors were found by taking the square root of the appropriate variance and entered along with their estimated totals on the line marked Est. Total.

Three quantitative computation sheets were required for each stratum for the variates y_N , y_{PA} and y_{PU} respectively. In strata 5 and 6 it was not necessary to calculate $\text{Var. } (\bar{N})$, A_x , A_y or A_{xy} .

The qualitative computation sheet for strata of under 100 acres (see Appendix 6 for a worked example) contained columns for n'' , $n''-1$, u'' , $\underline{p''}$, $\underline{q''}$, but only one analysis of variance to obtain the values of A_u and B_u required for the estimation of $\text{Var. } (\underline{p'})$. The number of bearing trees sampled on each estate was entered under n'' . Only two columns are required for the analysis of variance since the between trees within estates variation was estimated directly for each estate ($n''.\underline{p''}.\underline{q''}$) and not by difference as in the quantitative analysis. Although not a qualitative computation the estimated number of bearing trees in the stratum ($\underline{N}_2$) with its S.E. was calculated on this sheet since it was required in the estimation of $\underline{U''}$ $\left\{ \underline{U''} = \underline{N}_2.\underline{p'} \pm \underline{N}_2.\text{S.E.}(\underline{p'}) \right\}$.

The qualitative computation sheet prepared for strata of over 100 acres citrus differed in that it was unnecessary to compute A_u and B_u , the variance of $\underline{p'}$ being obtained as the sum of the variances of $\underline{p''}$ which were estimated directly for each estate ($\text{Var. } \underline{p''} = \underline{p''}.\underline{q''}/n''$).

Four qualitative computation sheets were required for each stratum for the following variates:

- (1) trees with all their fruit in category N.

- (ii) trees with any fruit showing melanose.
- (iii) trees with all their fruit in category PU.
- (iv) trees with all their fruit acceptable for export ($N + PA$).

In both quantitative and qualitative computation sheets the values for the stratum of n' , g' , g'' , $\bar{n}_0''$, $n'\bar{n}_0''$, α and β are given at the top of the tables. In all sheets estimated totals, ratios and proportions with their estimated sampling errors are underlined.

Before proceeding with the computations, however, several adjustments were necessary due to the defects in the frame described in Part 3, section 2.

The team decided to include in the computations the three estates where all the fruit had been picked giving the appropriate values for n'' (number of trees sampled per estate) and $n'' - 1$, but giving zero values for all the other columns in the quantitative analysis. The estates concerned occurred in strata 1, 2 and 4. The effect of giving these zero values is to increase the sampling errors for $\underline{X}$, $\underline{Y}$ and $\underline{\bar{r}}$ since the variability of the data is increased. The reasons for including these estates were:

(a) if these cases occurred in the sample it is reasonable to expect that they will occur with a similar frequency in the population from which the sample was drawn.

(b) the team had not adjusted the frame prior to sampling to exclude all such cases.

The estimates of the totals for $\underline{X}$ and $\underline{Y}$ are unaffected and thus they are lower than they would have been had the survey been conducted at a time when no fruit had been picked. These estates were omitted from the qualitative computations since the estimates derived therein were proportions of bearing trees.

Estate No. 180 was transferred from stratum 3 to stratum 5 (it had been sampled at 1 in 150). Thus the sample in stratum 3 was reduced to 24 estates from 122 estates which is still a 1 in 5 sample. The sampling fraction in stratum 5 was unaffected ($f' = 1$) and the number of estates in the sample remained at 8 since estates Nos. 167 and 176 were considered as one estate.

Estate No. 287, wrongly allocated to stratum 1, was visited and found to have no grapefruit. It was excluded entirely from the computations leaving a sample of 6 estates from 66 in stratum 1. Thus the sampling fraction here was 1 in 11 and f' was given this value in that stratum.

Nine estates had not been sampled due to non-identification. It is possible that these estates do not exist, but the writer contends that they could not have vanished without leaving some evidences of their existence and, since this was never forthcoming, it is reasonable to assume that they do exist and could not be identified because the information on their location was inadequate. The team decided, therefore, to substitute values for these estates from sampled estates in the same stratum. Substitute estates were selected using tables of random numbers.

Throughout the computations working sampling fractions were used and not exact sampling fractions (which were not known for second stage units).

Each member of the team was responsible for all the computations in one stratum as follows:

- Stratum 1 - Amazigo.
- Stratum 2 - Myers.
- Stratum 3 - MacLean.
- Stratum 4 - Alexander.
- Stratum 5 - Barrie.
- Stratum 6 - York.

It is recognised that the only valid check on these computations would have been to do them twice independently. Unfortunately, there was not sufficient time available for this, or even to check a sample of them, but the writer checked all the calculations below the total line on each computation sheet to ensure that the correct formulae had been used and also the calculations of $\bar{n}_0''$, $\mathcal{L}$ and β . Arithmetic checks were possible for raw sums of squares, corrected sums of squares and degrees of freedom (see Appendix 5).

On completion of the checking, the writer amalgamated the individual results from the strata to obtain the results for the whole survey.

3. Results.

In the amalgamation of the strata totals, ratios and proportions to give overall results for the population, a series of two way tables were prepared to obtain sub-population and population values with their sampling errors. The sub-populations were the three size groups and the two rainfall zones. Where numbers were concerned (i.e. numbers of trees, fruit, etc.), the sub-totals and totals were obtained by adding the totals from the appropriate strata, and sampling errors by taking the square root of the sum of the variances of these strata totals. In the case of estimated percentages (e.g. percentage of fruit in category N) the percentages for the individual strata were obtained from the $\bar{r}$ values computed for the strata, but the sub-population and population values were calculated from the two way ^{tables} ~~totals~~ giving the sub-population and population ^{totals} ~~tables~~ for the units concerned (e.g. numbers of fruit in category N as a percentage of the sub-population and population totals for crop yield). Estimated sampling errors for these

percentages were calculated as the square root of the weighted mean of the variances of the appropriate strata percentages (weighted by the number of sampled trees in each stratum). The two way tables prepared are given in full in Appendix 7. The results given in this section have been prepared in summary form from these tables. These results have been derived from analyses based on a sample of 53 from 275 estates growing grapefruit for export in Trinidad.

Table 7 summarises the estimated population totals obtained in the survey.

TABLE 7. ESTIMATED POPULATION TOTALS

T O T A L	Est. Value $\pm$ S.E.	% S.E.
No. of trees	232,100 $\pm$ 15,164	6.53
No. of bearing trees	217,000 $\pm$ 16,303	7.15
Crop yield in 100's	655,700 $\pm$ 35,632	5.43
No. of fruit showing no melanose in 100's	322,555 $\pm$ 24,099	7.47
No. of fruit showing melanose but acceptable for export in 100's	246,530 $\pm$ 31,825	12.91
No. of fruit showing melanose and unacceptable for export in 100's	86,615 $\pm$ 15,148	17.49
No. of trees with all fruit showing no melanose (N only)	81,449 $\pm$ 6,053	7.43
No. of trees bearing any fruit showing melanose (PA and/or PU)	135,551 $\pm$ 16,042	11.83
No. of trees with all fruit acceptable for export (N and/or PA)	166,507 $\pm$ 3,263	1.96
No. of trees with all fruit unacceptable for export (PU only)	9,438 $\pm$ 1,164	12.33
Acreage of grapefruit	2,578 $\pm$ 168	6.53

The number of bearing trees at the time of the survey at an estimated 217,000 is approximately 6.5 per cent.

less than the estimate of the total number of trees. This difference, however, is mainly due to the three estates where all the fruit had been picked prior to the survey in which trees were recorded as non bearing.

Of the total crop yield estimated at 65,570,000 fruit an estimated 49.19 per cent. showed no melanose, 37.60 per cent. showed melanose but were acceptable for export, and 13.21 per cent. showed melanose to such an extent as to be unacceptable for export.

Of the estimated 217,000 bearing trees at the time of the survey an estimated 37.53 per cent. showed no symptoms of melanose on the fruit and 62.47 per cent. showed some evidences of melanose on the fruit. However, 76.73 per cent. of the bearing trees had no fruit severely affected with melanose and only 5.52 per cent. of the bearing trees had all their fruit unacceptable for export due to melanose.

The estimated sampling errors of the estimates given in Table 7 are low, being of the order of 12 per cent. or less. The estimated sampling error of the estimated number of fruit showing melanose and unacceptable for export is higher at 17.49 per cent., but this can be accounted for by the greater variability in the data from which it was obtained, there being relatively few fruit in this category.

The following tables summarise the more important results obtained for the sub-populations.

TABLE 8. SUB-POPULATION PERCENTAGES OF FRUIT IN THE THREE CATEGORIES

Sub-Population	% Fruit in Category N	% Fruit in Category PA	% Fruit in Category PU
Under 100" Rainfall	42.84 $\pm$ 0.76	41.35 $\pm$ 0.21	15.81 $\pm$ 0.41
Over 100" Rainfall	80.03 $\pm$ 1.52	19.37 $\pm$ 0.69	0.60 $\pm$ 0.09
TOTALS	49.19 $\pm$ 0.36	37.60 $\pm$ 0.12	13.21 $\pm$ 0.27
0 - 10 acres citrus	35.66 $\pm$ 6.65	56.76 $\pm$ 4.46	7.11 $\pm$ 0.59
10.1 - 100 acres citrus	38.80 $\pm$ 1.92	45.84 $\pm$ 1.16	15.36 $\pm$ 0.62
Over 100 acres citrus	72.21 $\pm$ 0.02	15.79 $\pm$ 0.01	12.00 $\pm$ 0.02

A comparison between the two rainfall zones shows a considerably reduced incidence of melanose in the over 100" rainfall zone. The standard error of the difference was calculated for all three categories and in all cases the difference was more than three times greater than the standard error obtained. Thus the differences between the rainfall zones were statistically very highly significant. The following example illustrates the method of calculating the standard error of the difference:

Est. % of fruit in Cat. N under 100" rainfall = 42.84 ± 0.76

Est. % of fruit in Cat. N over 100" rainfall = 80.03 ± 1.52

Difference between zones = 37.19%.

S.E. (diff.) = $\sqrt{0.76^2 + 1.52^2} = \pm 1.69$.

Thus the difference here is 22 times greater than the S.E., and so is extremely significant statistically (i.e. the probability of this difference being due to chance is almost negligible).

It is less easy to show that the incidence of melanose varies ^{regularly} with the size groups, although the general trend is for melanose infection to decrease with increasing acreage of citrus. This trend is reversed for fruit in category PU, but this can be accounted for by the occurrence of a severely infected estate in stratum 5 (No. 31) which considerably increased the estimate for the size group over 100 acres citrus. The other estates in this group had very little severe melanose on the fruit.

From Table 9 a comparison between the sub-populations gives statistically very highly significant differences between the rainfall zones for both trees with all fruit in category N and trees bearing any diseased fruit. The incidence of melanose is again less in the over 100" rainfall group.

TABLE 9. SUMMARY OF TABLES 14 AND 15 IN APPENDIX 7

Sub-population	% Trees with all fruit in category N	% Trees bearing any diseased fruit
Under 100" Rainfall	30.24 ± 2.20	69.76 ± 7.04
Over 100" Rainfall	64.60 ± 10.30	35.40 ± 9.45
TOTALS	37.53 ± 2.79	62.47 ± 8.69
0 - 10 acres in citrus	11.88 ± 8.22	88.12 ± 8.22
10.1 - 100 acres in citrus	29.93 ± 2.47	70.07 ± 4.84
Over 100 acres in citrus	57.45 ± 6.43	42.55 ± 19.47

The general trend of decreasing incidence of melanose with increasing citrus acreage is more obvious from these results.

TABLE 10. SUMMARY OF TABLES 16 AND 17 IN APPENDIX 7

Sub-population	% of Trees with all fruit acceptable for export	% of Trees with all fruit unacceptable for export
Under 100" Rainfall	71.32 ± 1.48	5.52 ± 0.68
Over 100" Rainfall	96.83 ± 4.50	nil
TOTALS	76.73 ± 1.50	5.52 ± 0.68
0 - 10 acres in citrus	73.62 ± 5.58	nil
10.1 - 100 acres in citrus	74.98 ± 1.84	7.31 ± 1.13
Over 100 acres in citrus	80.39 ± 2.67	4.57 ± 0.24

The difference between the rainfall zones in Table 10 is again statistically very highly significant, but the general trend in the size groups is just discernible in the estimates of the percentage of trees with all fruit acceptable for export and is non-existent in the estimates of the percentage of trees with all fruit unacceptable for export. The value obtained for the over 100 acres citrus size group is again almost entirely due to the severe infection in estate No. 31.

Tables 18, 19 and 20 in Appendix 7 were prepared from the qualitative computation sheets to obtain estimates of the percentages of estates possessing given attributes. Table 11 summarises the sub-population and population values obtained.

TABLE 11. SUMMARY OF TABLES 18, 19 AND 20 IN APPENDIX 7

Sub-population	% of Estates with all fruit in Category N	% of Estates with any trees bearing diseased fruit	% of Estates with all trees bearing acceptable fruit
Under 100" Rainfall	8.67 $\pm$ 0.89	93.33 $\pm$ 1.13	14.99 $\pm$ 1.67
Over 100" Rainfall	33.03 $\pm$ 13.08	66.97 $\pm$ 12.32	65.79 $\pm$ 15.81
TOTALS	16.96 $\pm$ 3.57	83.04 $\pm$ 3.56	29.31 $\pm$ 4.63
0 - 10 acres in citrus	24.49 $\pm$ 9.61	75.51 $\pm$ 9.13	24.35 $\pm$ 9.86
10.1 - 100 acres in citrus	10.83 $\pm$ 1.11	89.17 $\pm$ 1.39	31.03 $\pm$ 4.74
Over 100 acres in citrus	0.00 $\pm$ 0.00	100.00 $\pm$ 0.00	50.00 $\pm$ 0.00

The differences between the rainfall zones are again well marked, giving further evidence that melanose infection is less in the high rainfall zone. The general trend for the size groups has been reversed except in the estimates of estates with all trees bearing acceptable fruit. However, these results are not of great significance since the presence of only one slightly infected fruit in the samples from an estate makes that estate ineligible for inclusion in the number of estates with all the fruit in category N. With regard to the percentage of estates bearing acceptable fruit only, the general trend of less infection with increasing acreage of citrus is again established. The main purpose of this table is to show that melanose is well distributed among the estates growing grapefruit for export, some 83 per cent. being classed as having some trees bearing fruit with visible signs of melanose.

The acreage of grapefruit in the strata and the numbers of fruit per tree were calculated from the results as supplementary observations. The estimated acreage in the strata is given in Table 12. These estimates were obtained by dividing the total number of trees in the strata (Table 1, Appendix 7) by 90 which is an accepted average value for the number of trees per acre for grapefruit.

TABLE 12. ESTIMATED ACREAGE OF GRAPEFRUIT IN THE STRATA

Rainfall	Under 100"	Over 100"	TOTALS
0 - 10 acres	244	100	344
10.1 - 100 acres	1,194	183	1,377
Over 100 acres	547	310	857
TOTALS	1,985	593	2,578

Sampling errors were not calculated for these estimates, but they are directly related to the sampling errors obtained for the estimated number of trees (i.e. of the order of 5 - 12 per cent.).

A comparison of the estimated acreages in Table 12 with the total acreages of citrus in the strata (see Table 3 in Part 2, section 2) shows a considerable decrease. The estimated total acreage of grapefruit is only 34.3 per cent. of the total acreage in citrus obtained from the frame. This difference can be accounted for in two ways:

(a) estate owners may have over-estimated their acreages of citrus when reporting these to C.C.G.A., or

(b) a large part of these acreages are planted in oranges or other citrus species.

The writer believes that both reasons are valid. Considerable plantings of oranges were noted on many estates during the field work.

The estimated number of fruit per tree for bearing trees was obtained by dividing the strata values and totals for estimated crop yield by the appropriate values from the Table giving the estimated numbers of bearing trees (Tables 2 and 3 of Appendix 7). The values obtained are given in Table 13.

TABLE 13. ESTIMATED NUMBERS OF FRUIT PER TREE
(BEARING TREES)

Rainfall	Under 100"	Over 100"	TOTALS
0 - 10 acres	374	292	355
10.1 - 100 acres	323	180	307
Over 100 acres	286	262	278
TOTALS	318	243	302

The difference between the rainfall zones is expected, but it is surprising to note that the numbers of fruit per tree tend to decrease with increasing size of estate. It is known that some fruit had been selectively picked on some estates for the Christmas market in fresh fruit and this may have affected these estimates. Sampling errors have not been calculated for these estimates, it being assumed that they would be similar to those obtained for other estimates (i.e. of the order of 10 per cent.).

A detailed time and cost study was not attempted in this survey, but the following facts were obtained:

TABLE 14. SAMPLING TIMES (OBTAINED FROM FIELD SHEETS)

STRATUM	Time		No. of trees sampled	Average sampling time per tree (minutes)
	Hours	Minutes		
1	2	00	19	6.32
2	-	50	9	5.55
3	34	55	313	6.69
4	5	25	59	5.51
5	42	30	329	7.75
6	22	55	186	7.39
TOTALS	107	15	915	7.03

The average sampling time per tree for strata 5 and 6 is higher than for the other strata due to the sampling fraction for trees being 1 in 150 as opposed to 1 in 50 for the other strata, and thus it took longer to locate trees for sampling.

TABLE 15. MILEAGE AND COSTS

Reason	Miles	Cost \$ B.W.I.
Preliminary work	178	26.70
Mapping	763	114.45
Enumeration	1,814	262.75
TOTALS	2,782	403.80

Thus an average distance of 50.6 miles at an average cost of \$7.34 was travelled per estate during the survey.

No figures are available for the other costs, i.e. enumerators, supervisors, office work, etc., but the writer estimates that at least \$1,000 B.W.I. would be required to carry out a survey of this type.

4. Discussion and Conclusions.

The survey was useful and practical. The team gained much useful information on sampling methods and on the computation of the results. The survey was also a good illustration of how factual information of a required accuracy may be obtained quickly. As an exercise in sampling, the survey was an unqualified success. In addition, results of local agricultural interest of sufficient accuracy to be of practical value were obtained.

The frame, although in the main quite suitable for the survey, could have been improved by the exclusion of

estates growing oranges only and by ensuring that all the estates listed could be identified. A more suitable frame would be a list of all the estates delivering grapefruit to C.C.G.A. in the previous crop season.

The results obtained from the survey fully justified the decision to stratify the estates into two rainfall groups, although the division between them at 100" rainfall per annum was purely arbitrary. The basis of the stratification into size groups was not primarily because the team thought that management would be different, or better, on the large estates, but to allow the use of variable sampling fractions in order to sample more intensively those estates which would contribute most to the results. Sampling errors for strata sampled intensively were, of course, reduced. The writer feels that the definition of the size groups could have been altered to include estates of up to 25 acres in citrus in the first group. During the survey the most difficult estates to identify were the ones of up to 25 acres in citrus. This group of 0-25 acres in citrus would not contribute a great deal to the results and it could be sampled at a low intensity without much effect on the total sampling errors.

The estimated sampling errors obtained for the total population estimates ranged from 0.32 per cent. to 21.07 per cent., but were mostly within the range of 4 per cent to 12 per cent. This probably reflects a greater accuracy in the results than is required for a survey of this type and it might be advantageous to reduce the sampling intensity, particularly for the small estates which may be difficult to identify and contribute little to the overall results, when overall sampling errors would be increased

slightly, but time required and costs would be less. The following sampling fractions might be usefully employed in a future survey:

- (a) 0 - 25 acres citrus - estates sampled at 1 in 15.
- (b) 25.1 - 100 acres citrus - estates sampled at 1 in 4.
- (c) over 100 acres citrus - estates sampled at 1 in 2.

The use of these sampling fractions would give a sample of approximately 45 estates from the existing frame. It has been shown that the bulk of the estimated acreage in grapefruit occurs in the size group 10.1 - 100 acres of citrus (some 53 per cent.). Even if this group was altered to estates with 25.1 - 100 acres of citrus it would still contain about 40 per cent. of the total acreage. A 1 in 4 sample is, therefore, suggested for this group to increase its representation in the sample while reducing the representation of the over 100 acres citrus group (33 per cent. of the estimated total acreage) by half.

Several criticisms of the field observations can be made, especially of the method of estimating crop yield. The criteria on which the fruit were classified into categories N, PA or PU were not exact, but they were related to the exportability of the fruit which determines the economic effect of the disease. The great advantage of this method was the speed with which sampled fruit could be graded. A more precise method involving lesion counts on selected areas of the fruit, while more accurate, would have been time consuming.

The estimation of crop yield by eye estimates to the nearest hundred fruit is not the most accurate method which could have been employed. The most accurate method would be to strip all the fruit from the tree and count them. Not only is this time consuming and costly in labour

but it may also require compensation to be paid. An alternative method in which an attempt was made to count the fruit on the tree, although possibly more accurate than an eye estimate, would have been laborious. The writer is satisfied that the eye estimates gave results of sufficient accuracy for the purposes of the survey.

The main criticism of the eye estimates is that they are subject to bias on the part of the enumerators. A study of the estimates of crop yield made by the enumerators shows quite wide variation (from 100 to 1,300 fruit per tree). Undoubtedly much of this variation is due to actual differences in yield of the sampled trees, but it cannot be denied that some of it may have been due to bias among the enumerators. Unfortunately no steps were taken to assess this bias if it in fact existed. Eye estimates of yield should have been calibrated by counting the fruit on a randomly selected sub-sample of the trees sampled by each enumerator and then calculating the regression co-efficient (see Yates 6. 12.). If this had been done the tendency of individual enumerators to over- or under-estimate could have been corrected and results known to be more accurate obtained.

It can be argued that bias introduced by individual enumerators would tend to cancel out, i.e. over-estimation would be approximately equal to under-estimation. However, even if this was the case, only a reasonably accurate estimate of the overall total would be obtained and bias would still be present in the individual results. Moreover, it is impossible to predict what effect it would have on sampling errors which could be higher or lower than the true value.

Mention has already been made that some fruit had been selectively picked prior to the enumeration. This will obviously lead to an under-estimation of the crop yield on any such estates. However, it is believed that selective picking had occurred on only a very small proportion of the estates and thus should have no appreciable effect on the results.

The exclusion of the estate which had no grapefruit from the analyses does not invalidate the results. Although one can expect 4 other estates in the population to come into the same category (an overall sample of 1 in 5 estates was taken), the quantitative results will not be increased greatly and the qualitative results will be unaffected since they are based on the number of bearing trees sampled. To be strictly accurate a number of estates equal to the product of the number of estates rejected from the sample and the inverse of the sampling fraction (i.e. $1 \times 5 = 5$ estates) should have been rejected from the frame when the overall sampling fraction would have been unchanged. However, the problem of rejecting estates from the frame is rather difficult when the estates have been stratified and variable sampling fractions used in the strata.

The substitution of values from sampled estates for estates which could not be identified only invalidates the results if those estates do not in fact exist. The belief that they do exist is held (see Part 4, section 2) and the writer, therefore, contends that this substitution has not invalidated the results.

In common with the food gardens survey last year, the term $\angle A$ invariably accounted for at least 90 per cent. of the variation within a stratum for any given variate and consequently the labour of the computations

could have been considerably reduced by using this term only in the estimation of the required variances without introducing any gross inaccuracies.

Soon after the enumeration was completed, MacLean prepared a summary report giving a brief indication of the sampling scheme used and some provisional results (without errors) for the survey. For full details of this summary, reference should be made to MacLean's report. The provisional results he produced are not in full agreement with the final results although the main trends can be shown from both sets of results. The differences are due to several reasons, the chief ones being that MacLean used exact raising factors and did not transfer estate No. 180 from stratum 3 to stratum 5.

The general conclusion which may be drawn from the results of the survey is that melanose infection was not severe in the export grapefruit of Trinidad during crop season 1957-58, but it should be noted that a reservoir of infection exists in most of the estates. Camp's suggestion that melanose infection is less in the wetter areas of Trinidad has been confirmed and the disease is less serious on the larger estates. It is probable that the very dry conditions experienced throughout the crop season had a marked effect in reducing the incidence of the disease on the fruit and that infection would be more severe in a crop season when the normal rainfall for the island was attained. Before a final answer can be given to this problem further surveys are necessary to estimate the infection under different rainfall conditions.

5. Recommendations.

From the results of the survey, the team could recommend to Government that no action on an island wide scale

appears to be necessary to control melanose infection of export grapefruit, but that individual planters who have severe infection on their fruit should be given some assistance in the form of technical advice on the methods of control.

However, in view of the peculiar weather conditions during the crop season for which the survey was carried out, it would also be necessary to recommend that further surveys be carried out at intervals so that the situation can be reappraised. With experienced staff the survey and estimation of results could be carried out in as short a time as four weeks.

It would be advantageous to use a slightly different frame from the one used in this survey - a suitable frame would be a list of estates delivering grapefruit to C.C.G.A. in the previous crop season. Enumeration should be made at the beginning of November before any fruit has been picked and, finally, a less intensive sample than the one taken in this survey would give sufficiently accurate results.

Summary.

A sample survey to estimate the incidence and severity of the disease melanose in export grapefruit of Trinidad has been described.

A brief description of sample survey methods together with details of the frame, the sampling scheme and the methods of estimation in the field are given.

The theory of the analysis has been worked out and examples of the computations included.

The results of the survey have been tabulated and discussed and some recommendations made.

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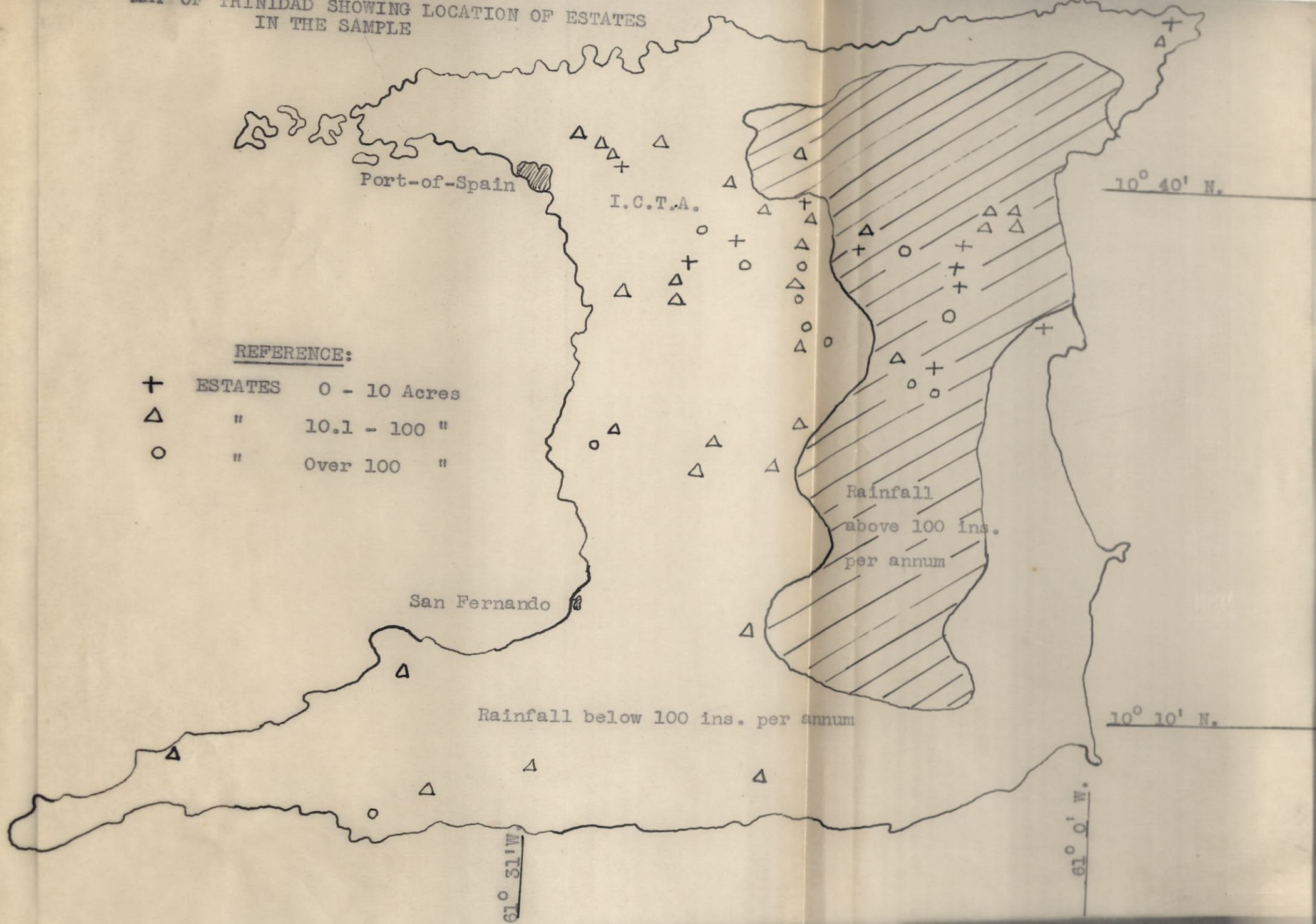
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APPENDICES.

1. Map showing approximate Location of the Estates in the Sample.
2. List of Estates in the Sample.
3. Field Record Sheet.
4. Instructions to Enumerators.
5. Computation Sheet 1 (Quantitative Analysis).
6. Computation Sheet 2 (Qualitative Analysis).
7. Tables of Results and Errors.

APPENDIX 1
 MAP OF TRINIDAD SHOWING LOCATION OF ESTATES
 IN THE SAMPLE



APPENDIX 2
LIST OF ESTATES IN THE SAMPLE

No.	Name of Owner	Name of Estate	Location of Estate	Acreage in Citrus
<u>STRATUM 1. (0 - 10 acres, below 100" Rainfall)</u>				
32	Frank Paul Thomas	Frankie's	St. Helena, Las Lomas, Arouca.	5.00
79	Freida A. Meyer	Valee Ville	Arima.	5.00
89	F.H. Kellman	Kellman	Saddle Road, San Juan.	3.00
194	John A. King	Brookes	Caigual, Manzanilla.	3.00
232	C. Mar & R. Marchie	St. John	Sans Souci, Toco.	4.00
275	Nagassar Mathura	Hermitage	Kelly Village, Caroni.	5.00
287	R.L.J. Pierre	Good Hope	2½ Mile Post, Cunapo Southern Road	6.25
<u>STRATUM 2. (0 - 10 acres, above 100" Rainfall)</u>				
170	Geo. B. Harris	Perseverance	Warden's Local Road, Sangre Grande.	3.00
224	Geo. W. Huggins	Grosvenor	Coal Mine Road, Sangre Grande.	5.00
231	V.E. Ledee	La Confidence	Crespo Trace, Tamana.	1.50
278	Jugdeo Sieunarine	St. Rose	Little Coora Road, Cumuto.	6.00
<u>STRATUM 3. (10.1 - 100 acres, below 100" Rainfall)</u>				
5	F.A. Agostini Estates Ltd.	San Juan	Pepper Village, Gran Couva.	16.60
7	A.V. Stollmeyer Ests. Ltd.	El Carmen	Talparo.	42.00
40	Gustave Krogh	Santa Maria	San Raphael, Tumpuna.	39.75
48	Charles Leotaud & Sons Ltd.	Santa Barbara	Maracas Valley	25.00
50	A.L. Owens	Mausica	Arima.	84.00
51	Endeavour Estates Ltd.	Endeavour	Chaguanas.	32.10
61	Samsoodin Ashraff Ali	Los Amigos	Brasso Piedra, Mamoral.	11.00
70	Kern Trinidad Oilfields	Kern Plantations	Ward of La Brea.	76.00
86	James Campbell & K. Potter	Stones Orchard	Santa Cruz.	34.00
94	F.A. Agostini Estates Ltd.	Corsica	Brasso.	22.80
101	Est. of A.G. deCaires		St. Madeleine Village.	21.00
106	Est. of Mrs. D. Barnado	Va Toute	Santa Cruz.	20.00
137	D. McBride	Caledonia	Santa Cruz.	75.50
142	Cecil McKenzie Cook	Saint Anne	Arima.	12.00
144	H. Fahey & Ors.	La Concordia	14 Mile Post, Moruga.	39.00
158	Trinidad Royalties Ltd.	St. Anns Alta Garcia	St. Anns Siparia	15.00
168	A.E. Watson		Arima.	10.00
177	Greig (Cedros) Est. Ltd.	St. Marie	Cedros.	35.00
180	Palo Seco Estates Ltd.	Cyrnos	Siparia & Palo Seco.	31.50
203	David Satnarinesingh		Chin Chin Road, Cunupia.	26.00
214	Ramsod Maharaj	Liverpool	Chin Chin Road.	14.00
243	Ramnarine Mahabir	La Hope	Montserrat Ward.	26.00
253	Koorban Ali		Calcutta Road #1 & 2.	17.00
258	Rupert W. Edwards	Alandale	Cumana, Toco.	10.00
291	Mrs. E.M. Harrison	Harrison	Lopinot Road, Arouca.	12.75

No.	Name of Owner	Name of Estate	Location of Estate	Acreage in Citrus
<u>STRATUM 4. 10.1-100 acres, above 100" Rainfall</u>				
22	Stanley B. Robinson	Barcelona	Comparo Local Road, Sangre Grande.	49.00
23	Critchlow Watch	El Carmen	Tamana.	10.00
25	Ramprasad Bhoolai	Rydal Hall	Sangre Grande.	56.50
56	Est. of Mrs. J. Small	La Resource	Caigual, Sangre Grande.	28.75
97	R. & G. Tang Choon	St. Yves	Caigual, Sangre Grande.	13.00
175	Victor B. Herde	Mount Pleasant	North of Arima on Blanchisseuse Road.	30.00
262	Allum Bros. Ltd.	La Trinidad	Tumpuna Road, Cumuto District.	24.00
<u>STRATUM 5. (Over 100 acres, below 100" Rainfall)</u>				
31	Sir Harold E. Robinson	Verdant Vale	Couva.	391.60
33	Est. of Carr Brown	El Quemado	Talparo.	102.50
37	Est. of Geo. F. Huggins	Erin	Erin.	419.00
43	Dr. K.U.A. Inniss	Mount Pleasant	Talparo.	121.50
73	Est. of Geo. F. Huggins	Esmeralda	Guanapo, Las Lomas.	200.00
165	Central Experiment Stn.	Central Expt. Stn.	Piarco.	107.00
167	Nariva Cocal Ltd.	Las Hermanas.	San Raphael.	100.50
176	John Samuel	Santa Rita	San Raphael.	140.00
<u>STRATUM 6. (Over 100 acres, above 100" Rainfall)</u>				
52	Bolah Bros. & Sons	Perseverance	Four Roads Tamana.	100.00
84	Geo. F. Huggins & Co. Ltd.	Sta. Teresa	Cumuto.	143.00
102	Geo. F. Huggins & Co. Ltd.	Coryal	Coryal.	112.00
125	Gordon Grant & Co. Ltd.	La Louisa	Tamana.	239.50

APPENDIX 3

MELANOSE SURVEY

Enumerator's Name:

Estate & Field No. 25. Yield 1

H. MacLean

Date 19th Dec., 1957.

Recording Times: Commenced 11.50 a.m.

Completed 12.25 p.m.

STRATUM: 4

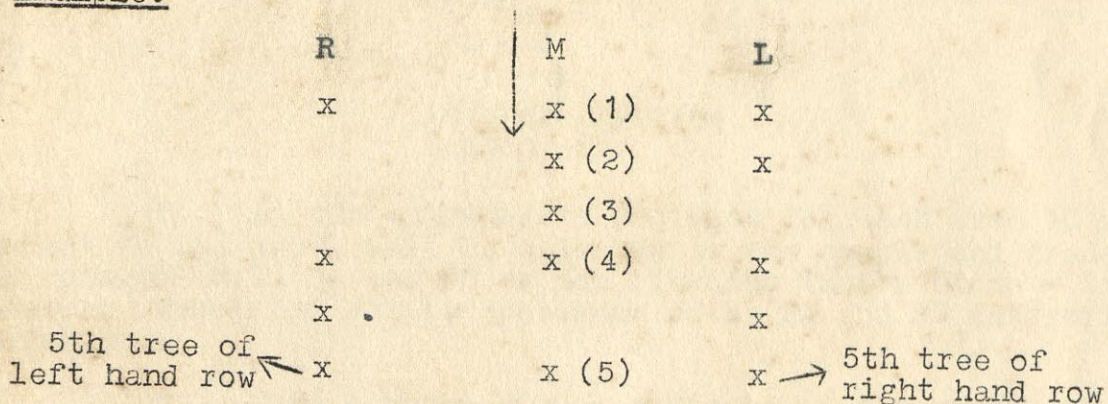
						x							gn gn gn (in 100's)
Tree No. & Row			Category			Crop Estimate (100's)	Tree No. & Row			Category			Crop Estimate (100's)
L	M	R	N	PA	PU		L	M	R	N	PA	PU	
37A			-	10	-	3			446C	-	3.0	-	
		39C	4	6	-	3	458D			1.2	1.8	-	
	48B		4	6	-	2		483A		0.8	1.2	-	
		80B	2	8	-	3		485B		0.6	2.4	-	
81D			-	9	1	3	522C			-	2.7	0.3	
	94A		"no fruit"			-			533A	-	-	-	
		102A	4	6	-	1		542D		0.4	0.6	-	
130C			TOTALS			15*			572D	3.0	11.7	0.3 + 15*	
	141D						576B						
	158C							592C					
		167D						614B					
195B									626C				
	201B						648A						
		206C						651A					
245A							652D						
	254A								681B				
278D									712A				
		283B						718D					
		302A					735C						
							755B						
	333D							757C					
348C									776D				
	370C												
392B							816A						
		397D						836B					
425A									838C				
	445B						860D						

APPENDIX 4 MELANOSE SURVEY

Instructions to Enumerators:

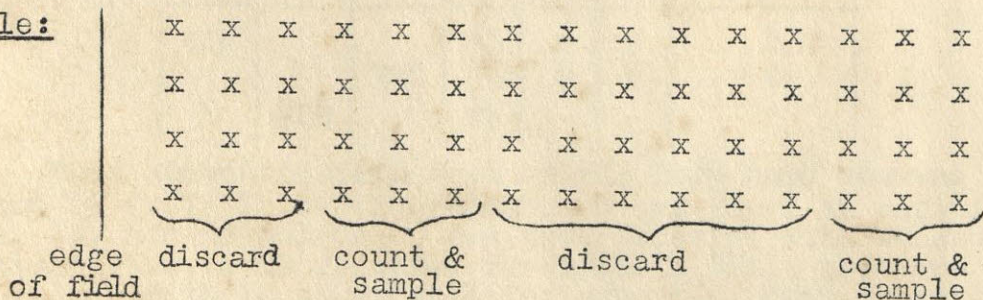
1. Enumerators will be provided with (a) maps clearly demarcating those fields in the estate that are included in the survey, (b) a combined record sheet and list of random numbers - the latter indicating those trees to be sampled within each field, (c) specimen samples of N, PA and PU categories for the grading of fruit.
2. In the case of any irregular field this also will be shown by the map and any necessary modification of the counting procedure will be issued in the form of special instructions to the enumerators concerned with such a field.
3. The starting point and direction for counting (not for sampling) in each field is indicated by a red dot on the map.
4. Trees will be counted using a "3-row counting" technique. In this the procedure is to count trees in the middle row of each 3 rows of trees, disregarding any spaces which may occur within any row, i.e. actual trees only, and in the middle row only, are counted.

Example:



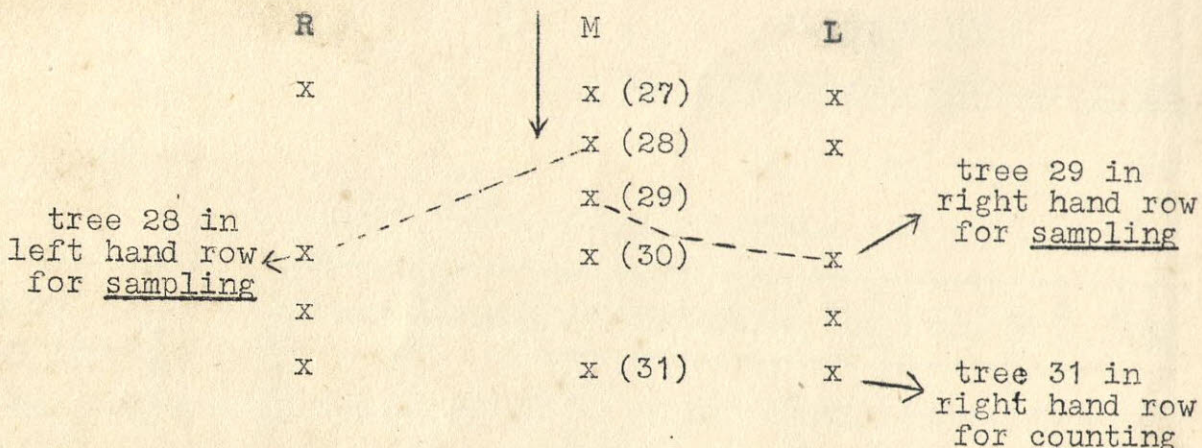
5. In the case of larger estates (those estates concerned will be indicated to the enumerators) this "3-row counting" technique will be somewhat modified and only 3 adjacent rows within each nine rows will be counted and sampled. Thus enumerators will disregard the first three rows (at the edge or boundary of a field), count and sample (as in 4.) the next three rows, then disregard the next 6 rows before counting and sampling a further three rows.

Example:

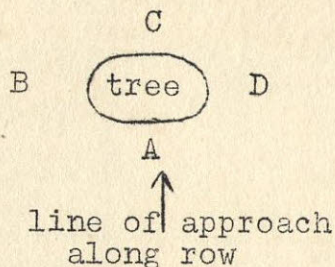


6. Counting is commenced at the tree indicated on the map and is continued along the middle row (of each 3 rows) until the first (lowest) number on the list of random numbers provided is reached. Random numbers are printed in three columns, each of the columns from left to right representing the left, middle and right hand row of trees respectively. If, when the tree number of, say, 28 is reached in the middle row, it is found that the required tree 28 for sampling in, say, the left hand row is missing then the next tree in progression (i.e. further on) is counted as the required tree in that row.

Example:



7. The position from which the enumerator should sample each tree is indicated by a letter after each random number, Letters A, B, C and D are used and correspond to the following positions:



8. At the appropriate position for each tree 10 fruit nearest to eye level will be selected as the sample and graded into the categories N, PA and PU as per previous instructions - if necessary using the sample specimens of N, PA and PU categories for comparison.

9. Make a rough visual estimate of the number of fruit per tree sampled. Crop estimates are to the nearest 100 fruit.

10. Record results clearly on the record sheets provided according to the following example:

Tree No. & Row			Category			Crop Estimate 100's
L	M	R	N	PA	PU	
28A		72C	2	6	2	2
				4	6	2
	75B		10			3

Thus above the 28th tree in the left hand row was sampled and of the 10 fruit inspected nearest to eye level at position A on the tree, two had no melanose, six were infected with melanose but insufficiently as to be rejected for export, while two were too heavily infected to be acceptable for export. Crop estimate was 200 fruit to the nearest 100.

11. Each enumerator will keep a log book in which will be recorded time of leaving College, time of return and number of miles travelled.

APPENDIX 5

MELANOSE SURVEY COMPUTATION SHEET 1.

STRATUM 4. $n' = 7, g' = 5, g'' = 50, g'g'' = 250, (g'g'')^2 = 62,500, \bar{n}_0 = 9.19$
 $n'\bar{n}_0 = 64.33, \alpha = 51.46, \beta = 12.61$

ESTATE	n"	n"-1	S"(y)	{S"(y)} ² /n"	Diff.	S"(y ²)	S"(x)	{S"(x)} ² /n"	Diff.	S"(x ²)	$\bar{x}$	S"(x).S"(y)/n"	Diff.	S"(xy)
22	14	13	17.40	21.63	13.13	34.76	18.00	23.14	14.86	38.00	0.96	22.37	13.83	36.20
23	13	12	13.10	13.20	5.31	18.51	16.00	19.69	2.31	22.00	0.83	16.12	2.98	19.10
25	10	9	4.10	1.68	1.53	3.21	19.00	36.10	10.90	47.00	0.22	7.79	0.71	8.50
56	7	6	3.00	1.28	3.72	5.00	20.00	57.14	12.86	70.00	0.15	8.57	4.43	13.00
97	3	2	2.40	1.92	0.00	1.92	10.00	33.33	2.67	36.00	0.24	8.00	-1.60	6.40
175	12	11	8.10	5.46	3.17	8.63	9.00	6.75	4.25	11.00	0.90	6.08	3.62	9.70
262	7	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	66	59	48.10	45.17	26.86	72.03	92.00	176.15	47.85	224.00	3.30	68.93	23.97	92.90

S'(n"²) 716.00

C.F.M. 622.29

S.S. 93.71

d.f. 6

M.S. 15.62

Var. 5,467,000

Est.
Total $16,500 \pm 2,338$
(N)

35.05

10.12

6

Ay = 1.69 By = 0.46

5,798,000

$12,025 \pm 2,408$
(Y_N)

1

Q = 3.5281

$s_d^2 = 0.5580$

35.05

26.86 36.98

59 65

Ax = 7.99 Bx = 0.81

26,336,219

$23,000 \pm 5,132$
(X)

$\bar{r}^2 = 0.2704$

$n'\bar{n}'' / S'S''(x)^2 = 0.0076$

$\bar{r} = 0.47 \quad \bar{r} = 0.5228 \pm 0.0669.$

128.24

47.91 47.85 95.76

6 59 65

Axy = 0.31 Bxy = 0.41

26,336,219

$23,000 \pm 5,132$

$\bar{r}^2 = 0.2704$

$n'\bar{n}'' / S'S''(x)^2 = 0.0076$

67.05

1.88

6

Axy = 0.31 Bxy = 0.41

26,336,219

$23,000 \pm 5,132$

$-2\bar{r} = -1.04$

Var.($\bar{r}$) = 0.0044689216

S.E.($\bar{r}$) = ± 0.0669

23.97 25.85 Check

59 65 Check

x = Crop Estimate in 100's.

y = Y_N = Number of fruit without melanose in 100's.

APPENDIX 5

MELANOSE SURVEY COMPUTATION SHEET 1.

STRATUM 4. $n' = 7, g' = 5, g'' = 50, g'g'' = 250, (g'g'')^2 = 62,500, \bar{n}_0'' = 9.19$
 $n'\bar{n}_0'' = 64.33, \alpha = 51.46, \beta = 12.61$

ESTATE	n''	n''-1	S''(y)	{S''(y)} ² /n''	Diff.	S''(y ²)	S''(x)	{S''(x)} ² /n''	Diff.	S''(x ²)	$\bar{r}$	S''(x).S''(y)/n''	Diff.	S''(xy)
22	14	13	17.40	21.63	13.13	34.76	18.00	23.14	14.86	38.00	0.96	22.37	13.83	36.20
23	13	12	13.10	13.20	5.31	18.51	16.00	19.69	2.31	22.00	0.83	16.12	2.98	19.10
25	10	9	4.10	1.68	1.53	3.21	19.00	36.10	10.90	47.00	0.22	7.79	0.71	8.50
56	7	6	3.00	1.28	3.72	5.00	20.00	57.14	12.86	70.00	0.15	8.57	4.43	13.00
97	3	2	2.40	1.92	0.00	1.92	10.00	33.33	2.67	36.00	0.24	8.00	-1.60	6.40
175	12	11	8.10	5.46	3.17	8.63	9.00	6.75	4.25	11.00	0.90	6.08	3.62	9.70
262	7	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	66	59	48.10	45.17	26.86	72.03	92.00	176.15	47.85	224.00	3.30	68.93	23.97	92.90

S'(n''²) 716.00

$\bar{r} = 0.47 \quad \bar{r} = 0.5228 \pm 0.0669.$

C.F.M. 622.29 35.05 35.05 128.24 128.24 67.05 67.05
S.B. 93.71 10.12 26.86 36.98 47.91 47.85 95.76 1.88 23.97 25.85 Check
d.f. 6 6 59 65 6 59 65 6 59 65 Check
M.S. 15.62 $A_y = 1.69 \quad B_y = 0.46 \quad A_x = 7.99 \quad B_x = 0.81 \quad A_{xy} = 0.31 \quad B_{xy} = 0.41$
Var. 5,467,000 5,798,000 26,336,219

Est. Total $16,500 \pm 2,338$ $12,025 \pm 2,408$ $23,000 \pm 5,132$
(N) ($\bar{Y}_N$) ($\bar{X}$)

1

$\bar{r}^2 = 0.2704$

$-2\bar{r} = -1.04$

Q = 3.5281

$s_q^2 = 0.5580$

$n'\bar{n}''/S'S''(x)^2 = 0.0076$

Var. ($\bar{r}$) = 0.0044689216

S.E. ($\bar{r}$) = ± 0.0669

x = Crop Estimate in 100's.

y = $\bar{Y}_N$ = Number of fruit without melanose in 100's.

APPENDIX 6

MELANOSE SURVEY COMPUTATION SHEET 2.

STRATUM 4. $n' = 6$, $f' = 1/5$, $f'' = 1/50$, $\bar{n}_0'' = 8.27$,
 $n'\bar{n}_0'' = 49.62$, $\mathcal{L} = 0.0161$, $\beta = 0.00395$.

ESTATE	n''	$n'' - 1$	u''	$\underline{p}''$	$\underline{q}''$	u''^2/n''	$n'' \cdot \underline{p}'' \cdot \underline{q}''$	u'
22	11	10	10	0.91	0.09	9.09	0.9009	0
23	13	12	7	0.54	0.46	3.77	3.2292	0
25	9	8	0	0.00	1.00	0.00	0.0000	0
56	7	6	0	0.00	1.00	0.00	0.0000	0
97	3	2	0	0.00	1.00	0.00	0.0000	0
175	8	7	3	0.38	0.62	1.13	1.8848	0
TOTAL	51	45	20	1.83	4.17	13.99	6.0149	0

$$S'(n''^2) = 493.0$$

$$\underline{p}' = \underline{0.3922 \pm 0.1425}$$

$$C.F.M. = 433.5$$

$$7.84$$

$$S.S. = 59.5$$

$$6.15 \quad 6.0149$$

$$d.f. = 5$$

$$5 \quad 45$$

$$M.S. = 11.90$$

$$A_u = 1.23 \quad B_u = 0.13$$

$$Var. = 3,570,000$$

$$Var.(\underline{p}') = 0.0203165$$

Est.

total

$$\underline{12,750 \pm 1,889} \quad (N_2)$$

$$S.E.(\underline{p}') = \pm 0.1425$$

$$\underline{p} = \underline{0.00 \pm 0.00}$$

$$\underline{U}'' = \underline{5001 \pm 1,817} \quad (\text{at the time of the survey})$$

u'' = No. of trees bearing fruit in category N only per estate.

n'' = No. of sampled trees bearing fruit.

$\underline{U}''$ = Estimated no. of trees bearing fruit in category N in the stratum.

APPENDIX 7

MELANOSE SURVEY - RESULTS

1. Estimated Number of Trees (N)

Acres	Under 100" Rainfall	Over 100" Rainfall	TOTALS	% S.E.
0 - 10	22,000 $\pm$ 3,604	9,000 $\pm$ 1,643	31,000 $\pm$ 3,960	12.37%
10.1-100	107,500 $\pm$ 14,450	16,500 $\pm$ 2,338	124,000 $\pm$ 14,637	11.80%
Over 100	49,200 $\pm$ 0	27,900 $\pm$ 0	77,100 $\pm$ 0	-
TOTALS	178,700 $\pm$ 14,892	53,400 $\pm$ 2,858	232,100 $\pm$ 15,164	
% S.E.	8.33%	5.35%	6.53%	

2. Estimated Number of Bearing Trees at the Time of the Survey (N₂)

Acres	Under 100" Rainfall	Over 100" Rainfall	TOTALS	% S.E.
0 - 10	19,250 $\pm$ 3,502	6,000 $\pm$ 1,423	25,250 $\pm$ 3,780	14.97%
10.1-100	102,500 $\pm$ 15,745	12,750 $\pm$ 1,889	115,250 $\pm$ 15,858	13.76%
Over 100	49,200 $\pm$ 0	27,300 $\pm$ 0	76,500 $\pm$ 0	-
TOTALS	170,950 $\pm$ 16,130	46,050 $\pm$ 2,365	217,000 $\pm$ 16,303	
% S.E.	9.44%	5.14%	7.15%	

3. Estimated Total Number of Fruit in 100's (X)

Acres	Under 100" Rainfall	Over 100" Rainfall	TOTALS	% S.E.
0 - 10	72,050 $\pm$ 19,428	17,500 $\pm$ 6,656	89,550 $\pm$ 20,536	22.93%
10.1-100	330,750 $\pm$ 28,337	23,000 $\pm$ 5,132	353,750 $\pm$ 28,798	8.14%
Over 100	140,850 $\pm$ 3,447	71,550 $\pm$ 2,601	212,400 $\pm$ 4,318	2.03%
TOTALS	543,650 $\pm$ 34,529	112,050 $\pm$ 8,798	655,700 $\pm$ 35,632	
% S.E.	6.35%	7.85%	5.43%	

4. Estimated Number of Fruit in Category N in 100's (Y_n)

Acres	Under 100" Rainfall	Over 100" Rainfall	TOTALS	% S.E.
0 - 10	21,780 ± 9,051	10,150 ± 5,464	31,930 ± 10,541	33.01%
10.1-100	125,225 ± 21,088	12,025 ± 2,408	137,250 ± 21,225	15.46%
Over 100	85,875 ± 3,552	67,500 ± 2,556	153,375 ± 4,378	2.85%
TOTALS	232,880 ± 23,206	89,675 ± 6,495	322,555 ± 24,099	
% S.E.	9.96%	7.24%	7.47%	

5. Estimated Number of Fruit in Category PA in 100's (Y_{pa})

Acres	Under 100" Rainfall	Over 100" Rainfall	TOTALS	% S.E.
0 - 10	43,780 ± 9,605	7,050 ± 5,363	50,830 ± 11,000	21.64%
10.1-100	151,300 ± 29,274	10,875 ± 5,406	162,175 ± 29,770	18.36%
Over 100	29,745 ± 2,173	3,780 ± 944	33,530 ± 2,370	7.07%
TOTALS	224,825 ± 30,866	21,705 ± 7,674	246,530 ± 31,825	
% S.E.	13.73%	35.23%	12.91%	

6. Estimated Number of Fruit in Category PU in 100's (Y_{pu})

Acres	Under 100" Rainfall	Over 100" Rainfall	TOTALS	% S.E.
0 - 10	6,490 ± 1,979	300 ± 243	6,790 ± 1,994	29.37%
10.1-100	54,225 ± 14,918	100 ± 232	54,325 ± 17,961	33.06%
Over 100	25,230 ± 1,679	270 ± 271	25,500 ± 1,701	6.67%
TOTALS	85,945 ± 15,142	670 ± 432	86,615 ± 15,148	
% S.E.	17.62%	64.48%	17.49%	

7. Estimated Number of Trees bearing Fruit in Category N only

Acres	Under 100" Rainfall	Over 100" Rainfall	TOTALS	% S.E.
0 - 10	nil	3,000 $\pm$ 2,076	3,000 $\pm$ 2,076	69.20%
10.1-100	29,499 $\pm$ 2,194	5,001 $\pm$ 1,817	34,500 $\pm$ 2,849	8.26%
Over 100	22,199 $\pm$ 3,050	21,750 $\pm$ 3,860	43,949 $\pm$ 4,920	11.19%
TOTALS	51,698 $\pm$ 3,757	29,751 $\pm$ 4,745	81,449 $\pm$ 6,053	
% S.E.	7.27%	15.95%	7.43%	

8. Estimated Number of Trees bearing any Diseased Fruit.

Acres	Under 100" Rainfall	Over 100" Rainfall	TOTALS	% S.E.
0 - 10	19,250 $\pm$ 0	3,000 $\pm$ 2,076	22,250 $\pm$ 2,076	9.33%
10.1-100	73,001 $\pm$ 5,248	7,749 $\pm$ 1,853	80,750 $\pm$ 5,566	6.91%
Over 100	27,001 $\pm$ 14,366	5,550 $\pm$ 3,959	32,551 $\pm$ 14,902	45.78%
TOTALS	119,252 $\pm$ 15,295	16,299 $\pm$ 4,839	135,551 $\pm$ 16,042	
% S.E.	12.83%	29.69%	11.83%	

9. Estimated Number of Trees bearing Acceptable Fruit only
(i.e. N and PA)

Acres	Under 100" Rainfall	Over 100" Rainfall	TOTALS	% S.E.
0 - 10	13,090 $\pm$ 1,348	5,500 $\pm$ 415	18,590 $\pm$ 1,410	7.58%
10.1-100	74,175 $\pm$ 2,096	12,240 $\pm$ 320	86,415 $\pm$ 2,120	2.45%
Over 100	34,652 $\pm$ 364	26,850 $\pm$ 2,007	61,502 $\pm$ 2,040	3.32%
TOTALS	121,917 $\pm$ 2,518	44,590 $\pm$ 2,074	166,507 $\pm$ 3,263	
% S.E.	2.07%	4.65%	1.96%	

10. Estimated Number of Trees bearing Fruit in Category PU only

Acres	Under 100" Rainfall	Over 100" Rainfall	TOTALS	% S.E.
0 - 10	nil	nil	nil	-
10.1-100	7,175 $\pm$ 1,158	nil	7,175 $\pm$ 1,158	16.14%
Over 100	2,263 $\pm$ 118	nil	2,263 $\pm$ 118	5.21%
TOTALS	9,438 $\pm$ 1,164	nil	9,438 $\pm$ 1,164	
% S.E.	12.33%	-	12.33%	

11. Estimated Percentage of Fruit in Category N (Y_n) of the
Total (X)

Acres	Under 100" Rainfall	Over 100" Rainfall	TOTALS	% S.E.
0 - 10	30.24 $\pm$ 2.31	58.00 $\pm$ 15.40	35.66 $\pm$ 6.65	18.64%
10.1-100	37.86 $\pm$ 1.65	52.28 $\pm$ 6.69	38.80 $\pm$ 1.92	4.95%
Over 100	60.90 $\pm$ 0.24	94.34 $\pm$ 0.09	72.21 $\pm$ 0.01	0.03%
TOTALS	42.84 $\pm$ 0.76	80.03 $\pm$ 1.52	49.19 $\pm$ 0.36	
% S.E.	1.77%	1.89%	0.07%	

12. Estimated Percentage of Fruit in Category PA (Y_{pa}) of
the Total (X)

Acres	Under 100" Rainfall	Over 100" Rainfall	TOTALS	% S.E.
0 - 10	60.77 $\pm$ 2.02	40.28 $\pm$ 14.69	56.76 $\pm$ 4.46	7.86%
10.1-100	45.74 $\pm$ 1.43	47.28 $\pm$ 5.57	45.84 $\pm$ 1.16	2.53%
Over 100	21.10 $\pm$ 0.27	5.28 $\pm$ 0.09	15.79 $\pm$ 0.01	0.06%
TOTALS	41.35 $\pm$ 0.21	19.37 $\pm$ 0.69	37.60 $\pm$ 0.12	
% S.E.	0.51%	3.56%	0.32%	

13. Estimated Percentage of Fruit in Category PU (Ypu) of the total (X)

Acres	Under 100" Rainfall	Over 100" Rainfall	TOTALS	% S.E.
0 - 10	9.01 $\pm$ 0.75	1.71 $\pm$ 0.58	7.11 $\pm$ 0.59	8.30%
10.1-100	16.39 $\pm$ 2.79	0.43 $\pm$ 0.41	15.36 $\pm$ 0.62	4.04%
Over 100	17.91 $\pm$ 0.03	0.37 $\pm$ 0.03	12.00 $\pm$ 0.02	0.17%
TOTALS	15.81 $\pm$ 0.41	0.60 $\pm$ 0.09	13.21 $\pm$ 0.27	
% S.E.	2.59%	15.00%	2.04%	

14. Estimated Percentage of Trees bearing fruit in Category N only of the Total (N₂)

Acres	Under 100" Rainfall	Over 100" Rainfall	TOTALS	% S.E.
0 - 10	nil	50.00 $\pm$ 34.60	11.88 $\pm$ 8.22	69.20%
10.1-100	28.78 $\pm$ 2.14	39.22 $\pm$ 14.25	29.93 $\pm$ 2.47	8.26%
Over 100	45.12 $\pm$ 6.20	79.67 $\pm$ 14.14	57.45 $\pm$ 6.43	11.18%
TOTALS	30.24 $\pm$ 2.20	64.60 $\pm$ 10.30	37.53 $\pm$ 2.79	
% S.E.	7.27%	15.95%	7.43%	

15. Estimated Percentage of Trees bearing any Diseased Fruit of the Total (N₂)

Acres	Under 100" Rainfall	Over 100" Rainfall	TOTALS	% S.E.
0 - 10	100.00 $\pm$ 0.00	50.00 $\pm$ 34.60	88.12 $\pm$ 8.22	9.33%
10.1-100	71.22 $\pm$ 5.12	60.78 $\pm$ 14.53	70.07 $\pm$ 4.84	6.91%
Over 100	54.88 $\pm$ 29.20	20.33 $\pm$ 14.50	42.55 $\pm$ 19.47	45.78%
TOTALS	69.76 $\pm$ 7.04	35.40 $\pm$ 9.45	62.47 $\pm$ 7.39	
% S.E.	12.83%	26.69%	11.83%	

16. Estimated Percentage of Trees bearing Acceptable Fruit only of the Total (N₂)

Acres	Under 100" Rainfall	Over 100" Rainfall	TOTALS	% S.E.
0 - 10	71.43 ± 6.84	91.66 ± 6.92	73.62 ± 5.58	7.58%
10.1-100	68.78 ± 1.95	96.08 ± 2.51	74.98 ± 1.84	2.45%
Over 100	70.43 ± 0.74	98.35 ± 7.35	80.39 ± 2.67	3.32%
TOTALS	71.32 ± 1.48	96.83 ± 4.50	76.73 ± 1.50	
% S.E.	2.07%	4.65%	1.96%	

17. Estimated Percentage of Trees bearing Fruit in Category PU only of the Total (N₂)

Acres	Under 100" Rainfall	Over 100" Rainfall	TOTALS	% S.E.
0 - 10	nil	nil	nil	-
10.1-100	7.31 ± 1.13	nil	7.31 ± 1.13	16.14%
Over 100	4.57 ± 0.24	nil	4.57 ± 0.24	5.21%
TOTALS	5.52 ± 0.68	nil	5.52 ± 0.68	
% S.E.	12.33%	-	12.33%	

18. Percentage of Estates in the Strata with all Trees bearing Fruit in Category N

Acres	Under 100" Rainfall	Over 100" Rainfall	TOTALS	% S.E.
0 - 10	0.00 ± 0.00	66.67 ± 25.00	24.49 ± 9.61	39.29%
10.1-100	17.00 ± 1.85	0.00 ± 0.00	10.83 ± 1.11	10.22%
Over 100	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	-
TOTALS	8.67 ± 0.89	33.03 ± 13.08	16.96 ± 3.57	
% S.E.	10.22%	39.29%	21.07%	

19. Percentage of Estates in the Strata with any Trees bearing Diseased Fruit

Acres	Under 100" Rainfall	Over 100" Rainfall	TOTALS	% S.E.
0 - 10	100.00 $\pm$ 0.00	33.33 $\pm$ 25.00	75.51 $\pm$ 9.13	12.09%
10.1-100	83.00 $\pm$ 1.73	100.00 $\pm$ 0.00	89.17 $\pm$ 1.39	1.56%
Over 100	100.00 $\pm$ 0.00	100.00 $\pm$ 0.00	100.00 $\pm$ 0.00	-
TOTALS	93.33 $\pm$ 1.13	66.97 $\pm$ 12.32	83.04 $\pm$ 3.56	
% S.E.	1.21%	18.43%	4.29%	

20. Percentage of Estates with all Trees bearing Acceptable Fruit

Acres	Under 100" Rainfall	Over 100" Rainfall	TOTALS	% S.E.
0 - 10	0.00 $\pm$ 0.00	66.67 $\pm$ 27.00	24.35 $\pm$ 9.86	40.50%
10.1-100	29.00 $\pm$ 2.68	66.67 $\pm$ 18.80	31.03 $\pm$ 4.74	15.28%
Over 100	50.00 $\pm$ 0.00	50.00 $\pm$ 0.00	50.00 $\pm$ 0.00	-
TOTALS	14.99 $\pm$ 1.67	65.79 $\pm$ 15.81	29.31 $\pm$ 4.63	
% S.E.	11.13%	24.04%	15.80%	