

A SAMPLE SURVEY OF CITRUS.

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SYNOPSIS.

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A SAMPLE SURVEY OF CITRUS.

INTRODUCTION.

Surveys in agriculture have been carried out for a number of years in the more developed temperate countries, particularly in Europe and North America. The demands of these countries with their high living standards has made it essential that the governments of these countries be provided with the up-to-date vital information regarding such factors as population increase, food production, land resources, and other agricultural factors of immediate importance to the national economy. In the less developed countries, particularly in many tropical areas there has not been the same vital need for such detailed information. Consequently the need for agricultural survey or census work has been correspondingly less. However, with the increasing momentum of economic development in many tropical territories over the last few years the need for agricultural surveys in these countries is assuming increasing importance. The real value of surveys is that they provide important statistics and information which are necessary before efficient planning of improvements and new developments is possible.

Complete surveys, generally referred to as censuses, can be very costly and time-consuming, though the results obtained are usually accurate and are not subject to sampling errors. Sample surveys, as distinct from complete surveys, are surveys carried out on a properly selected sample. Although the cost of a sample survey is normally greater per unit than for a complete survey, the overall cost is usually much less in the case of the sample survey. This is particularly so where the size of the sample required represents only a small proportion of the total population. Sampling also facilitates ready follow-up work, which in some instances may make for greater accuracy of results. This is illustrated where in a population of individuals it is necessary for the purposes of the survey for each member in the sample to be personally contacted.

Greater detail of information in an allotted time is possible from the sample survey. When dealing with people for example, the individuals selected are still required to furnish the same amount of information but are usually more likely to be co-operative and responsive knowing that they represent a small selected sample of the population. Furthermore, the smaller volume of detailed material allows for a more ready and perhaps higher degree of analysis and evaluation.

Sampling has a further distinct advantage in that the information from a sample survey can be made available very quickly. This can be particularly important as certain information must be up-to-date if it is to be of any real value. An apt illustration of where important information was required, and supplied quickly, was the sample survey of Fertiliser Practices in Great Britain, reported in the British Agricultural Bulletin, (1951). This survey was carried out by Yates and Boyd when it was necessary to bring about a rapid rise in food production in the United Kingdom during World War II. The results of this survey carried out in 1942-43, were available in time to serve as a fertiliser guide for the 1943 cropping season. It would have been quite impossible to have conducted a complete census of fertiliser practices, and furnished results for the 1943 cropping season.

Over the last three years, sample surveys have been undertaken by teams of post-graduate students from the Imperial College of Tropical Agriculture of selected accessible areas of Trinidad. The survey reported and discussed herein describes the 1957-58 sample survey of citrus carried out by six post-graduate students under the guidance and direction of Dr. Jolly and Mr. Hednett. The object of the survey was to examine the incidence and severity of melanose disease on grapefruit in Trinidad. The incidence of the disease was also considered in relation to the annual rainfall and to citrus farm size as it was thought that the disease was less severe in the higher rainfall areas, and that management and disease control practices on larger estates were proportionately better.

PART A. PRELIMINARY ORGANISATION.

1. CHOICE OF SURVEY.

The reasons for choosing melanose disease on grapefruit for the purposes of a sample survey were:

- (i) It appeared a suitable choice for the primary aim of the exercise which was to give the members of the survey team practical training and experience in conducting a sample survey in agriculture.
- (ii) The survey team had limitations in that:
 - (a) All the field work and enumeration had to be completed by the end of the Christmas vacation, and the analysis of the results had to be completed by the end of the Easter term.
 - (b) It was necessary because of the limited time factor that the areas of investigation be readily accessible by road.
 - (c) Unskilled enumerators were being used. It was necessary therefore that the enumeration be as simple as possible.
- (iii) Melanose disease was selected not because it is the most important disease of grapefruit in Trinidad, but because:
 - (a) It was the most informative one complying with the requirements and limitations of the survey.
 - (b) Melanose, as distinct from certain other citrus diseases, gummosis for example, can be easily and positively identified by an examination of the ^{fruit} point.
 - (c) The severity of melanose incidence is important to the Trinidad citrus industry as melanose infected grapefruit may be rejected for export. As the Trinidad Department of Agriculture had no reliable information on the extent and severity of melanose infection, the information resulting from a sample survey of melanose on grapefruit could be of considerable value to grapefruit producers and the Department of Agriculture.

(d) The presence of melanose on citrus fruit sold on the local market does not appreciably affect the value of the fruit. However, depending upon the degree of melanose infection, citrus fruit may not be accepted for the higher-priced export market. As very little citrus fruit, other than grapefruit, is exported from Trinidad, the melanose investigations were confined to export producers of grapefruit.

(iv) A frame for a citrus survey was available in the form of a list of all the current members of the Co-operative Citrus Growers Association in Port-of-Spain. This organisation is responsible for the marketing of all grapefruit exported from Trinidad.

(v) The survey was based on direct personal observation by the enumerators, thus avoiding the more time-consuming "question and answer" type of survey.

Prior to the choice of melanose disease on grapefruit for a sample survey, several other categories of Trinidad agriculture were mentioned. In all cases these categories had limitations which militated against their choice as a suitable sample survey for the post-graduate survey team. A sample survey on "the commercial production of bananas" within certain areas of Trinidad was suggested. Dr. Jolly reminded the survey team that it would be very difficult to establish a list of commercial banana producers for a survey frame. A number of backyard producers are known to be irregular commercial producers.

A further suggestion was that a survey be carried out investigating "the number and distribution of livestock on peasant holdings" with particular reference to the purposes for which the livestock are kept. The lack of a suitable frame, plus the fact that the investigations would involve exhaustive questioning and interrogation of peasant farmers, made this suggestion unsuitable.

A survey designed to investigate "fertiliser practices on sugar cane plantings" was mentioned. This was rejected on the grounds that such a survey would be applicable to only the large estates as the peasant cane farmer does not use artificial manures to any extent.

Also there is a large amount of information of a current nature on the subject of fertiliser practices on sugar-cane in Trinidad.

"Rice production in Trinidad" was a further alternative. This was not practicable as the rice crop would have already been harvested before the survey team could commence the field investigations at the beginning of the Christmas vacation in mid-December.

"Land Tenure in Trinidad" was also mentioned as a possible survey choice. Dr. Jolly reasoned, that an investigation along these lines would be very time-consuming and could not be completed within the time available to the post-graduate team.

The specifications of a suitable frame should define clearly the scope and extent of the survey and the categories of sampling material involved. Thus when making a frame it is most important to remember that only those units specified and contained in the frame should be sampled. When making a survey of farms in a particular area, for example, only those farms that occur in the frame should be investigated.

For the citrus survey the frame was a complete list of the current members of the Co-operative Citrus Growers' Association, Port-of-Spain. The list was supplied by secretary of Mr. Gillan of the Co-operative Citrus Growers' Association. The frame contained the names of 275 members, all thought to be export producers of grapefruit. In addition for each member the frame also contained the name of his estate, and its approximate location and acreage of citrus.

2.3. Defects of a Frame.

A survey frame is subject to five forms of defects which can lead to inaccurate or misleading results.

The defects may be:

(a) Incompleteness.

May result from inaccurate information regarding some of the units listed in the frame.

2. THE FRAME.

2. 1. The Survey Frame.

A frame is defined as a list of sampling units in which at least one recognisable characteristic is available for every unit of the population to be sampled. In the sampling of a human population for example, (with households as sampling units,) there must be available a list of all households, and the list must be such that any household selected from it can be unambiguously located. In such cases the list of households would be the frame.

Other frames suitable for the sampling of human populations include lists of individuals in a population; lists of towns, villages, farms, town plans, maps of rural areas; results of a census.

The specifications of a suitable frame should define clearly the scope and extent of the survey and the categories of sampling material involved. Thus when using a frame it is most important to remember that only those units specified and contained in the frame should be sampled. When making a survey of farms in a particular area, for example, only those farms that occur in the frame should be investigated.

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2. 2. Defects of a Frame.

A survey frame is subject to five forms of defects which can lead to inaccurate or misleading results.

The defects may be:

(a) Inaccuracy.

May result from inaccurate information regarding some of the units listed in the frame.

For example a citrus estate of 200 acres to be listed as only 30 acres.

(b) Incompleteness.

Certain units or individuals not listed in the frame.

If one or more of the estates marketing export citrus is missing from the export producers list then the frame is incomplete for the purposes of the citrus survey.

(c) Duplication.

When certain individuals or units are included more than once in the frame.

(d) Inadequacy.

A frame is inadequate when it does not cover all the categories of the material which one wishes to include in the survey.

(e) Out-of-Date.

The information provided by a frame, although it be accurate, complete and free from duplication, may be unsuitable for the survey if the information is out-of-date. It is realised (that it is rarely possible) to get a frame in which the information is right up-to-date. Providing the frame information is relevant, it is desirable to have a frame as up-to-date as possible. Although the perfect frame would in many cases improve the accuracy of the survey results, it is usually considered hardly worthwhile, going to the extra expense and inconvenience of completely revising and checking a frame prior to sampling to ensure that the frame has no defects. It is important however, that the defects be reduced to a convenient minimum.

In actual practice, frames do suffer to a greater or lesser extent from some or all of the listed defects. Therefore it is necessary at the outset of the survey to make some investigations regarding the frame, particularly the administrative machinery by which the frame has been constructed and is kept up-to-date.

The citrus survey frame was on the whole rather accurate and quite suitable for the purposes of the survey. Several inaccuracies regarding estate acreages were present in the frame, but as these inaccuracies were automatically discovered and corrected as the survey progressed they did not invalidate the survey results. The defects of the citrus survey frame are discussed more fully under section "Survey Evaluation".

Information is usually required quickly and with accuracy in many types of surveys, because of their cost and the need for prompt action. The alternative is to conduct a more detailed survey which is usually more expensive and takes longer to complete. In the case of agricultural surveys, the need for quick and accurate information is particularly important. In the tropics, where the growing season is long and the crops are often perishable, it is essential to have a reliable survey of the land and its resources. The survey of the citrus industry in the tropics is a good example of this. The survey was conducted in 1957 and 1958 in the island of Ceylon. The survey was conducted in a number of districts, including the Kandy, Nuwara-Eliya, and Uva districts. The survey was conducted by a team of experts, including the author, and was supervised by the Director of Agriculture. The survey was conducted in a number of stages, and the results were reported to the Government. The survey showed that the citrus industry in Ceylon was a major source of income and employment. The survey also showed that there were a number of problems which needed to be solved in order to improve the industry. These problems included the need for better irrigation facilities, the need for better pest control measures, and the need for better marketing facilities. The survey also showed that there was a need for more research into the citrus industry in the tropics. The survey was a valuable contribution to the knowledge of the citrus industry in the tropics, and it provided a basis for the development of policies and programs to improve the industry.

2.2. Survey of Land.

Sampling is simply the collection of part of an aggregate of material to represent the whole. The selected set of units or portions of the aggregate is the sample, and should be selected in such a way that it is representative of the whole aggregate.

Usually material to be sampled consists of a number of variable units. In the sampling of such material, whatever procedure of selection is used the sample should be considered to be exactly representative of the whole, only in the chance selection of an equal proportion of one or more units of variable units.

3. SAMPLING AND ITS APPLICATION.

Mention was made in the introduction of this report of the increasingly important role of sample surveys in socialological and agricultural fields. Intensive economic planning and development is a common feature in many countries today. Before economic development can be planned efficiently, vital statistics and information regarding food production, population, rates of change in the countries economy, must be supplied. Such information is usually required quickly and with a minimum of expenditure. Complete surveys, because of their cost and lengthy duration are often impracticable. The alternative is to conduct sample surveys.

Sample surveys can be (introduced) into agriculture in the tropics in a number of ways. K. E. Hunt in Statistics for Colonial Agriculture states that sample surveys are practicable in the Colonies for estimating the acreage and production of a few important crops grown in a territories where the growers freely welcome investigation of their crop. The food crop survey of 1956/57 also demonstrates the value of sample surveys in the tropics. A further example is cited of J. W. Purseglove's land use survey in areas of Kabale, Kigezi District, Uganda. The land-use survey showed that the area was very over-populated and soil-fertility was declining. Population pressure on the land was relieved by resettlement of approximately 30% of the population in new areas.

3. 1. Theory of Sampling.

Sampling is simply the selection of part of an aggregate of material to represent the whole. The selected set of units or portion of the aggregate is the sample, and should be selected in the belief that it is representative of the whole aggregate.

Usually material to be sampled consists of a number of variable units. In the sampling of such material, whatever processes of selection are used the sample cannot be considered to be exactly representative of the whole, owing to the chance selection of an undue proportion of one or more kinds of variable units.

Hence estimates of the aggregate based on a sample of units are liable to error. Whether or not a sample will give totals and averages which are sufficiently representative of the aggregate for the purpose in view will depend of course on the magnitude of the errors introduced.

The errors, the occurrence of which is inevitable, are termed random sampling errors of the results. Provided a statistically sound process of selection is used, the random sampling errors can be calculated from the variability observed between units in the sample. The simplest way of decreasing the magnitude of the random sampling errors and so increasing the accuracy of the sample is to increase the size of the sample. Other things being equal, the random sampling error is approximately inversely proportional to the square root of the number of units included in the sample. But in a finite population the random sampling error is also directly influenced by the $1 - f$ factor, the complement of the sampling fraction.

A further source of error in selection is the error due to bias. For example, an investigator asked to select by eye an average yielding tree from each row of trees in a grapefruit field. Such a sample would be of little value as it may well be biased. That is the selection of all the trees may be affected by similar errors. In each case the investigator may have been biased towards higher-than-average yielding trees.

Other ways in which bias may be introduced in selection are:

- (i) Bias in enumeration.
- (ii) Substitution. In a house-to-house survey, for example, the next house may be taken if there is no reply from the first house.
- (iii) Conscious or unconscious bias in the selection of a "random" sample.
- (iv) Failure to cover all of the chosen sample.

Bias is almost impossible to eliminate completely even when employing the most vigorous forms of selection. It is therefore a constant component of error.

Unlike random sampling errors which tend to decrease as the size of the sample increases, errors due to bias do not decrease in a large population as the size of the sample increases.

Bias cannot be statistically estimated. As it is apparent that fully objective conclusions cannot be drawn from a sample in which the possibilities of large bias exist, it is equally obvious that a primary objective of any sampling scheme must be the elimination of all sources of bias. It is only by adherence to strict random selection methods, and by ensuring that only the selected sample is investigated in the enumeration, is it possible to minimise or avoid bias in the sampling process.

As it is important to eliminate errors due to bias, it is also important to minimise the random sampling errors. Random sampling errors are a function of the size of the sample, and the variability of the material composing the population, and hence the sample. It has been mentioned already that an increase in the size of the sample decreases the random sampling errors. The accuracy obtained is influenced by that part of the variability of the selected units contributing to the sampling errors. There are, however, certain restrictions that can be incorporated in the sampling scheme. These restrictions allow a reduction in the variability per unit of the sample unaccounted for, and therefore attributable to the sampling errors. The restrictions while imposing some degree of restriction on fully random sampling do not introduce bias into the sampling process. It follows that the size of sample required for a given degree of accuracy can be reduced accordingly.

Restrictions in Sampling:

- (i) Stratification.
- (ii) Utilising supplementary information.
- (iii) Variable sampling fraction.
- (iv) Multi-stage sampling.

Stratification is the simplest form of restrictive sampling. In a stratified sample the population is divided into groups or strata, such that the units of each stratum are more homogeneous than those drawn from different strata.

Each stratum in a stratified population is independently random sampled. A simple example of stratification would be in a survey of dairy farms where the number of cows on the farm was used as a basis for stratification.

Stratification besides increasing the overall accuracy of the population estimates, allows adequate representation of the divisions of the population which are of interest.

Since in stratified sample only variation between the units within strata gives rise to sampling errors, greater accuracy in the overall population estimates is possible as the population is sub-divided into strata for certain similarities between units of the population within the respective strata. Within each stratum then, the number of units selected should provide a more representative sample of the total population than if selected directly as a random sample from the total population.

Supplementary information is information which is derived from sources other than the sampling scheme, or from a more extended sample than that on which information on the main characters is collected. If the information be of a quantitative character, and is available for all of the units of the population, then it may be used as a basis for stratification, (or for the adjustment of an unstratified sample by stratification after selection.

A variable sampling fraction is simply the sampling of different strata at different intensities. This refinement of random sampling allows more intensive sampling for greater accuracy, of the more important, or more variable fractions of the population.

Yates (1953) states that a more important application of the variable sampling fraction is to material stratified into size groups. In such material the various quantitative characteristics of the units under investigation of ten have within-strata standard deviations which are roughly proportional to the mean sizes of the units in the different size groups. The sampling fraction should be taken about proportional to the mean sizes. If quantitative characteristics very highly correlated with size of unit are under investigation, the ranges of the size groups may give good estimates of the relative within-strata standard-errors.

In multi-stage sampling a degree of flexibility is introduced into the sampling scheme, as sampling is carried out in progressive stages. The population is regarded firstly as consisting of a number of first stage sampling units, each of which contains a number of second stage units. Similarly the second stage units may contain third stage units.

The first stage in sampling is to select the first stage units. These are usually selected by random or stratified sampling. A sample of second stage units is then selected from each of the selected first stage units. The methods of sampling may be the same as, or different from the methods employed in selecting the first stage units. Similarly further stages of sampling units may be employed. Multi-stage sampling for example could occur in a survey of dairy farms in an area. The dairy farms might be the first stage units and the dairy cattle on the farms might be the second stage units.

The procedure of sampling in progressive stages makes it possible to use at various stages the natural different components of the population as sampling units. Furthermore where the survey is concerned with a large area or population, it is possible by multi-stage sampling to concentrate the activities of the survey and thus reduce the cost per unit surveyed.

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3. 2. SAMPLING SCHEME FOR THE CITRUS SURVEY.

Before it is possible to select the most suitable sampling scheme for a survey, it is necessary to consider and examine, inter alia, the salient factors of the nature, scope, purpose and cost of the survey. These factors determine to a greater or lesser degree the choice of sampling scheme depending upon the degree of accuracy required. The availability or not of, supplementary information, and the amount of preliminary planning and organisation necessary are further factors that warrant consideration in the choice of the sampling scheme.

3. 2. 1. Preliminary Investigations.

In the early stages of the citrus survey planning it was necessary for the survey team to conduct prerequisite preliminary field investigations. The object of the field studies was to gather information on the nature and variability of the material under investigation, and to be cognisant of some of the problems likely to be encountered in the actual field side of the survey organisation.

The first stages in the preliminary investigations involved:

- (i) The recognition of melanose disease in the field.
- (ii) The levels of melanose infection necessary for grapefruit to be unacceptable for export.
- (iii) Field investigations to examine the distribution of both fruit and melanose on the tree.
- (iv) A visual appraisal of the average size and shape of grapefruit trees on Trinidad estates, and the approximate number of fruit per tree.
- (v) Plotting on a map of Trinidad the approximate location of all the citrus estates included in the survey frame.

(1) In pursuance with the above objectives, the survey team first accompanied Mr. Spence, Plant Pathologist at the Centeno Central Experiment Station, on a visit to the St. Augustine Nursery. At the Nursery, grapefruit trees heavily infected with melanose disease were examined.

Mr. Spence thoroughly explained the symptoms, methods of infection, and transmission of the disease. It was noticeable that the symptoms of melanose infection were much easier to recognise on the fruit than on the leaves. Various other markings on the leaves tended to mask the symptoms of melanose disease.

The next phase in the planning was to make exploratory investigations on a number of estates, and also to visit the Co-operative Citrus Growers' packing house in Port-of-Spain, to familiarise ourselves with the system of grapefruit grading at the packing-house. To expedite these investigations the survey team was divided into three parties; York, Myers and MacLean in one party, Amazigo and Barrie in the second party, and Alexander in the remaining party.

- (i) York, Myers and MacLean visited five estates in the Caroni-Montserrat area.

The planting design and lay-out of the estates, plus the general shape and size of the trees, amount of pruning, and the distribution of fruit on the trees was studied.

- (ii) Amazigo and Barrie first revisited the grapefruit field at the St. Augustine Nursery to examine the general distribution of melanose on infected trees.

The Co-operative Citrus Growers' Association in Port-of-Spain was then visited where the system of grapefruit grading was closely observed. Samples of grapefruit showing varying intensities of melanose infection were given to Amazigo and Barrie, for the purposes of the survey, by the Manager of the packing house. The samples were divisible into two categories:

- (a) Those grapefruit that were still acceptable for export owing to a not-too-severe melanose infection. It was estimated that the maximum incidence of melanose on fruit still acceptable for export was between 80 - 100 spots per square inch. If the spots were large then the number was proportionately lower.
- (b) Those fruit that were unacceptable for export because of too-severe melanose infection.

All members of the team later examined the samples closely to ensure that each member was readily able to distinguish between acceptable and unacceptable fruit.

(iii) Alexander and Barrie plotted on a trace map of Trinidad the approximate position of the estates listed in the survey frame.

Although the plotted estates gave an island-wide distribution, the main concentrations of estates occurred around the Sangre Grande-Talparo area, Santa Cruz-Maracas Valley area, San Fernando-Caroni area, and the Erin-Siparia area.

(iv) Alexander, the statistician of the survey team was appointed to stratify the population of estates, stratifying for both size and rainfall.

(a) The size strata were designated as:

- 0 - 10 acres in area.
- 10.1 - 100 acres in area.
- over 100 acres in area.

The respective estate citrus acreages were obtained from the frame.

(b) The rainfall strata were:

- estates with less than 100" rain per year.
- estates with more than 100" rain per year.

Table I. shows the specifications for each stratum.

TABLE I.

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

Size stratification was decided upon ^{because} as it was assumed that general estate management practices would be proportionately better on the large estates.

Stratification for rainfall was selected as both Mr. Spence and other Officers of the Trinidad Department of Agriculture were of the opinion that melanose incidence was less in the higher rainfall areas. The average annual rainfall was used for the rainfall stratum. Alexander included on the map of Trinidad showing the approximate estate locations, the "100 inch" isohyet, thus differentiating the plotted estates for rainfall.

From the preliminary estate visits and the second visit to the St. Augustine Nursery, it appeared evident that both the distribution of fruit on the tree and the incidence of melanose on the tree was rather uniform over the tree. The number of fruit on the tree was fairly closely correlated with the size and vigour of the tree. Although the size of the trees varied, it was apparent that fruit examination from the ground would be possible in most cases. Pruning was evidently restricted to the removal of dead or debilitated wood.

It was decided by the team at this stage of the planning to base the survey investigations for melanose on a visual examination of the fruit only. The symptoms for melanose being much more discernible on the fruit than on the leaf, particularly for the inexperienced investigator.

The next step in the preliminary planning was to carry out pilot surveys to assess approximately how much time would be required per operator per tree in the actual enumeration for melanose incidence. For this purpose it was decided to select one estate at random from each of the three size-strata. The estates selected were:

	Frame	Estate No.	Owner	Citrus Acreage.
i)		181	R. Fredericks	4 acres.
ii)		12	G. Stollmeyer	85 acres.
iii)		43	Dr. K. Inniss	123 acres.

The pilot survey was carried out on the following lines:

- (i) On arrival at the estate, a sketch map showing the location of fields and roads within the estate was made.
- (ii) In each field the trees were sampled using a sampling fraction of 1 in 50. The respective number of each sample tree was ascertained from a given list of random numbers supplied to each investigator.

- (iii) A "3-row" counting technique was used in an endeavour to reduce the amount of walking within fields, and so decrease the time of enumeration. The technique was to sample three rows of trees concurrently, but to count the trees in the middle row only of each three rows of trees. Any tree misses in either of the outside rows were disregarded, but tree misses in the middle row were taken into account. Thus actual trees only, and in the middle row only, were counted.
- (iv) In the estates of over 100 acres it was agreed that the time factor would allow only one in three of the fields on the estates to be sampled. The choice of fields was left to the individual investigator. It was stressed, however, in the interests of the survey planning, that investigators select fields with as much variation as possible. For example, a clear field and a weed overgrown field, or a flat field and a hillside field.
- (v) The starting point for tree counting was designated as the first three rows in the corner of the field nearest to the investigators' point of entry into the field.
- (vi) A letter after each random number indicated the appropriate sampling position for each tree. The sampling positions were determined by random selection.
- At the appropriate position on the tree, the ten fruit nearest to eye level were selected for examination. Each fruit was graded into one of the three categories, namely:
- (a) No melanose present.
 - (b) Melanose present, but the fruit still acceptable for export.
 - (c) Melanose present, but the fruit unacceptable for export because of too much melanose on the fruit.
- (vii) An approximate estimate, to the nearest "100" fruit, was made for the number of fruit on each tree sampled.
- (viii) The final condition for the pilot survey was that two fields only were selected for sampling on each estate, and that the sampling time be restricted to half-an-hour for each field. The object ..

The object of this proviso was to determine approximately how many trees per hour, and hence how many acres per hour, an enumerator could be expected to examine.

(ix) The pilot survey teams were:

- (a) Alexander and MacLean to G. Stollmeyer's Estate, Santa Cruz.
- (b) York and Myers to R. Frederick's Estate, Maracas Valley.
- (c) Amazigo and Barrie to Dr. K. Inniss's Estate, Talparo.

Each team was supplied with a letter of introduction from Dr. Jolly, stating the purpose of the survey and the nature of the investigations.

Results of the Pilot Survey.

Team	No. trees examined in one hour.
Alexander and MacLean	12.
York and Myers	12.
Amazigo and Barrie	9.

In the case of Amazigo and Barrie the fields examined were on hillsides and were very much overgrown with weeds. These factors probably accounted for the fewer trees examined.

From the pilot survey results the team concluded that:

- (i) One enumerator could be expected to sample six acres per hour - that is examine 12 trees.
- (ii) The "3-row" counting scheme was very satisfactory and would expedite the field work of the citrus survey investigations.
- (iii) A sampling fraction of 1 in 50 for the selection of trees was convenient and statistically satisfactory.

3. 2. 2. The Survey Sample.

In determining the most suitable sampling scheme for the citrus survey, the team considered firstly, the nature, scope and purpose of the survey and secondly, the information resulting from the preliminary investigations and pilot survey, and stratification of the frame on the basis of rainfall and citrus acreage.

- (i) Stratification of the frame of 275 estates for size and rainfall, gave a distribution of estates as shown in Table 2.

Table 2.

Acreage	R A I N F A L L		Total
	Below 100"	Over 100"	
0 - 10	67 estates	38 estates	105
10.1-100	123 "	35 "	158
Over 100	8 "	4 "	12
Total	198 "	77 "	275

The reasons for citrus acreage and rainfall stratification were explained in section 3. 2. 1.

- (ii) The number of estates in each stratum as shown in Table 2 may be substituted by the total estate acreage for each stratum. See Table 3.

Table 3.

Acreage	R A I N F A L L		Total
	Below 100"	Over 100"	
0-10	303 acres	280 acres	583
10.1-100	3803 "	1052 "	4855
Over 100	1582 "	595 "	2177
Total	5688 "	1927 "	7615

In the frame, seven estates did not have any listed acreage. Mr. Allan was able to ensure the team, however, that three of the estates were under 10 acres, and the remaining four were between 10 and 100 acres. The respective stratum estate average was given to each of the seven estates for the purposes of compiling Table 3.

- (iii) From table 3 it was possible to calculate for each size stratum:
- (a) The number of estates in the stratum as a percentage of the number of estates in the frame.
 - (b) The total acreage of the respective stratum as a percentage of the frame acreage. See Table 4.

Table 4.

Acreage.	No. of Estates in Stratum as % of Frame	Total Stratum Acreage as % of Frame Acreage
0 - 10 acres	38%	8%
10.1 - 100 "	58%	63%
over - 100 "	4%	29%
Total	100%	100%

- (iv) The following observations were evident from an analysis of Table 4:
- (a) The 0 - 10 acres strata contained a large proportion of the estates but a small percentage of the overall acreage.
 - (b) More than half of the estates and almost two-thirds of the frame acreage was in the 10 - 100 acres strata.
 - (c) A very small percentage of the estates, but almost one third of the frame acreage was comprised by the estates over 100 acres.
- (v) With reference to the overall totals, the 1 - 10 acres and 10.1 - 100 acres strata - comprised approximately 96% of the number of estates in the frame. The 10.1 - 100 acres and over 100 acres strata accounted for 92% of the frame acreage. As stated earlier the technical object of the survey was to investigate the incidence and severity of melanose disease on grapefruit. Hence to ensure that a fairly representative picture be obtained it was important that as wide a range of grapefruit plantings as possible be investigated.

By doing so the survey team would get an overall picture of the incidence of melanose on grapefruit. Furthermore, as export producers only were being investigated, it was apparent that acreage distribution rather than estate distribution was the more important criterion to be considered in devising a suitable sampling scheme. From this it follows that more intensive sampling was warranted within the 10.1 - 100 acres and over 100 acres strata for the selection of estates. As those strata comprised 92% of the frame acreage the more intensive sampling for estates would ensure a proportionate acreage representation in the survey sample of the estates within those strata.

Bearing in mind the above considerations, plus the information from the preliminary field investigations and pilot survey, the survey team devised the following sampling scheme:

- (i)
 - (a) 1 in 10 of all the estates in the 0 - 10 acre strata;
a sampling fraction of 1 in 50 for the trees on the selected estates;
all the grapefruit fields on the estate were sampled.
 - (b) 1 in 5 of the estates in the 10.1 - 100 acres strata;
a sampling fraction of 1 in 50 for the trees on the estate;
all the grapefruit fields on the estate were sampled.
 - (c) All the estates in the over 100 acres strata were sampled;
a sampling fraction of 1 in 150 for the trees on the estate;
all the grapefruit fields on the estate were sampled, and not 1 in 3 of the fields as in the pilot survey.
- (ii) On each tree sampled ten fruit were selected at random and examined for the incidence of melanose. Each fruit was graded into the appropriate category as follows:
 - (a) No melanose present.
 - (b) Melanose present but the fruit acceptable for export.
 - (c) Melanose present but the fruit unacceptable for export, because of too severe melanose infection.

- (iii) For each tree sampled an estimate was made of the approximate number of fruit on the tree. The estimation was to the nearest "100" fruit. For example, 270 fruit would be recorded as 3.
- (iv) Within the estates random sampling was used for the selection of the sample trees. For this purpose, Alexander prepared a list of random numbers suitable for a sampling fraction of 1 in 50. On each tree the ten fruit nearest to eye-level at the appropriate position on the tree were examined. The appropriate sampling position on the tree was predetermined by assigning to the four sides of the tree the positions A, B, C, and D, respectively, as illustrated in Appendix 6, instruction 7. The position A was the side of the tree facing the examiner on his line of approach up the row. Moving around the tree to the right were positions B, C, and D respectively.

Examination of the fruit was at eye-level as it avoided the necessity of transporting unwieldy ladders or of enumerators climbing grapefruit trees. The latter expedient would not have been favoured by estate managers or owners. Examination of the fruit higher on the tree was not necessary as the preliminary investigations had shown that melanose was rather uniformly distributed on infected trees.

As the over 100 acres strata contained only 12 estates of the frame total of 275 estates, and as the 12 estates comprised 29% of the frame acreage it was decided that all of the 12 estates be sampled. Thus with a sampling fraction of 1 in 1 for the estates in the over 100 acres strata, and hence no sampling errors for between estate sampling, it was considered unnecessary to sample as intensively within estates as for the 0 - 10 acres and 10.1 - 100 acre strata. The pilot survey had indicated that more variation could be expected between estates rather than within estates, and between fields rather than within fields on the estate. The less intensive sampling fraction for the over 100 acres strata complied with the limitations of the survey team as regards the limited time available for enumeration.

Using a sampling fraction of 1 in 150 rather than 1 in 50 meant in fact that only one third of the total acreage of the over 100 acres strata was sampled as compared with the more intensive sampling of the remaining strata.

The random sampling within each stratum for the first stage units, the estates, gave an estate distribution as shown in Table 5.

Table 5.

Acreage	R a i n f a l l		S. F.	
	Under 100"	Over 100"	f'	f''
0 - 10	7 estates	4 estates	1/10	1/50
10.1 - 100	25 "	7 "	1/5	1/50
over 100	8 "	12 "	1	1/150
Total	40 "	23 "		

S.F. = Sampling fraction, and f' and f'' are the sampling fractions for the selection of estates and trees respectively.

Appendix 1, is a duplicate of the citrus survey sample estates.

Substitution of the estate numbers in Table 5 by the total estate acreages for each stratum gave an acreage distribution for sampling as shown in Table 6.

Table 6.

Acreage	R a i n f a l l		Total
	Under 100"	Over 100"	
0-10	31 acres	14 acres	45
10.1- 100	748 "	211 "	959
Over 100	528 "	198 "	726
Total	1307 "	423 "	1730

Analysis of the citrus survey sample reveals that:

- (i) The survey sample consisted of 63 estates selected from a frame total of 275 estates. *? No*
- (ii) The survey sampling acreage was approximately 1730 acres selected from the frame acreage of approximately 7615 acres.
- (iii) Analysis of the sampling scheme for the citrus survey reveals that the sampling scheme included the restrictions of:

(a) Stratification.

Citrus acreage and average rainfall were both used as a basis for stratification.

(b) Multi-stage Sampling.

The aggregate of sampling material was divided into three stages of sampling units. The estates, trees and fruit being the first, second and third, stage sampling units respectively.

(c) Variable Sampling Fraction.

A variable sampling fraction was used for the:

(1) Selection of estates within size strata;

1 in 10 for 0 - 10 acres.

1 in 5 for 10.1 - 100 acres.

1 in 1 for over 100 acres.

(2) Selection of trees within estates;

1 in 50 for 0 - 10 acres.

1 in 50 for 10.1 - 100 acres.

1 in 150 for over 100 acres.

The sample survey of citrus was therefore based on a stratified, multi-stage sampling scheme, employing a variable sampling fraction.

Means for this scheme not entirely clear

4. MELANOSE DISEASE.

Citrus production is the fourth largest primary industry in Trinidad, following sugar cane, cocoa and coconuts respectively in order of economic importance.

The successful commercial production of fruit-crops in the tropics, as in temperate areas, requires that the marketable produce be of the highest possible quality. This applies particularly to areas such as Trinidad where the success of the industry is reliant on a favourable export market. The consumers' preference for fruit of attractive appearance and good quality, and his willingness to pay a premium for it is the primary reason for the growers endeavour to produce clean and attractive fruit.

Conditions and factors beyond the control of the grower are sometimes responsible for some of the lowering of the grade of grapefruit. But a greater number of the factors reducing the quality and appearance of the fruit, and consequently its grading and value, are controllable blemishes - caused by insects and diseases. Of these melanose disease in citrus is one of the more important in Trinidad. Melanose infection of citrus permanently mars the appearance of the fruit as the disease blemishes cannot be washed off or removed from the fruit, without damage to the surface of the fruit.

In 1957, Dr. A. F. Camp, a visiting citrus authority from the United States Department of Agriculture, inspected a number of Trinidad citrus groves. Dr. Camp's subsequent report stated, inter alia, " a rapid survey here indicates that there should be possibilities of greatly increasing production, and at the same time getting a much higher percentage of shippable fruit." Dr. Camp commented on the disfigurement of fruit and loss of young foliage in a number of groves. This damage appeared to be as a result of melanose infection.

Whilst in Trinidad Dr. Camp visited a number of citrus estates but did not carry out either a sample survey or census of melanose disease incidence on citrus.

4. 1. CAUSE OF DISEASE.

Melanose is caused by the fungus, Diaporthe citri (Fawe) Wolf. All commercial varieties of citrus are liable to attack, but grapefruit appears to be more susceptible than oranges. Infection results from the spores of the fungal pathogen germinating and attacking the younger parts of the grapefruit plant.

Two types of spores are produced: sexual spores, produced in small, flask-shaped perithecia, and borne on decaying twigs and branches on the ground; and asexual spores produced in pycnidia and borne on dead wood on the tree. Spores of the asexual stage are the chief source of infection. The spores are produced and liberated in large numbers and under favourable moisture conditions germinate and start the infection in the young, tender growing parts.

Spore dissemination is mainly by free-water dripping, spattering or washing from the fruiting areas. When strong winds accompany rains, Florida experience has shown that water laden with spores may be blown 20 - 30 feet from the sporulating area. Moisture is necessary for the germination of the spores and the development of the disease. Given frequent rains, heavy dews or fogs, fruiting bodies on dead wood may continue to infect growing tissues for as long as they remain susceptible. Infection of susceptible tissues occurs within 36 hours after the spores have been deposited, but spots do not become visible until 4 - 7 days later.

Citrus fruits and foliage are susceptible only whilst they are young and tender. Once the young leaves harden, about 2 - 3 weeks in good growing weather, they are safe from infection. Fruits are susceptible when first formed, but become progressively resistant with age. Grapefruit are immune once the fruit is more than 2 - 2½ inches in diameter. With respect to the age of the tree, melanose generally increases in severity with advancing age and declining vigour.

In general all factors which tend to decrease tree vigour and cause an accumulation of dead wood tend to intensify the severity of melanose infection.

4. 2.

S Y M P T O M S.

Melanose attacks the foliage, twigs and fruit of citrus trees. On leaves the first visual symptom is the appearance of minute, round pinpricks which become larger, sunken and dark-centred with yellowish holes. As leaves age the spots become raised, giving rise to a sand-papery effect. The spots vary in size from mere dots to $1/32$ inch in diameter. The lesions may appear on either surface of the leaf. With age the holes are lost. In cases of severe attack, leaves may become twisted and otherwise distorted, lose their green colour and drop prematurely from the tree.

Twigs exhibit a characteristic dotting or spotting. The raised marks appear dull and dark in colour. If the infection is heavy, the twigs are killed but the pathogen continues to grow on them and produce spores. The disease is usually not found on older branches, because as the bark grows and sloughs off on the outside, the marks of the disease disappear.

It is on the surface of the fruit where it appears as small crust-like, yellow to dark brown or black spots that melanose is most serious. The spots may vary from $1/100$ - $1/16$ of an inch in diameter. The surface of the fruit may be spotted abundantly with the small spots arranged in characteristic streaks, rings, bands or irregular groups. "Tear -stain" melanose results from infections initiated by the washing of spores over fruits by rain drops or dew. In heavy infections the surface of the fruit is covered and cracks and splits occur to give the fruit an unattractive appearance. This roughness, which is persistent, serves to distinguish melanose from surface stains caused by anthracnose, or from smoother russetting produced by must mites or "corkiness" of scab.

The blemishes caused by melanose infection cannot be washed off the fruit. If they are scraped away the underlying tissues are injured. The fruit is made unsightly and its grade is very much reduced.

4. 3.

C O N T R O L.

Experience in Florida and Australia has demonstrated that successful melanose control is based on a combination programme of spraying and pruning.

Spraying with copper sprays to prevent infection and removal of dead wood to eliminate the sources of infection. In Trinidad, apart from the pruning of dead wood in some citrus estates no direct control measures for melanose disease are practised.

The accepted control is to apply a single copper spray, one to three weeks after fruit setting. As it is difficult to coat the dead wood successfully with copper, as the spores are ejected from the closed pycnidia through any coating of copper, the aim of spraying is to apply a copper coating to the new leaves and fruit to prevent infection from germinating spores. Attendant advantages of copper spraying are that it assists in the control of corky-scab of citrus, and of lichens, and possibly greasy spot of citrus.

The use of copper sprays may warrant follow-up spraying with insecticides to combat the build-up of scales and mites that often follows the use of copper sprays.

5. FIELD WORK ORGANISATION.

Preparation for the survey field operations involved the:

- (i) Location and mapping of estates.
- (ii) Preparation of field record sheets.
- (iii) Estimated duration of the survey.
- (iv) Preparation of instructions for enumerators.
- (v) Pre-survey briefing of enumerators.

5. 1. LOCATION AND MAPPING OF ESTATES.

The team's experience in the preliminary field investigations and pilot survey had shown that some difficulty could be expected in locating various estates drawn in the sample. Although the approximate estate location, for example, Sangre Grande, was listed in the frame, it was not always sufficient for the ready location of the estate. Team members often found that the estate had changed hands. It was not uncommon also to find that the estate owner was commonly known by a different name to that listed in the frame. These irregularities applied mainly to the smaller estates, particularly these in the 0 - 10 acres strata. With these considerations in mind it was decided to locate and map as many as possible of the 63 estates in the survey sample prior to the commencement of enumeration.

The mapping entailed drawing a map of the estate plus adequate directions for locating the estate. Instructions for locating the estate included the names of the main access roads, plus the mileage as shown on the nearest mileage post to the estate. Each map showed the demarcation and shape of fields within the estate, and the access roads for each field. The maps also indicated for enumerators the position at which enumeration was to begin in each field.

The estate maps were intended, without entering into too much detail, to provide adequate information for an enumerator on being given the map to locate the estate and sample the fields accordingly. As the survey enumeration was limited by time it was obviously desirable that the sample estates be located and mapped before it was time to begin enumerating.

The survey team was able to locate and map 44 of the 63 estates in the sample before enumeration began on the 16th December. The remaining estates were located by York, who was specifically assigned to this task, and the other members of the team during the early part of the field work.

The subsequent value of the estate maps in expediting the enumeration is fully discussed in the section of this report entitled "Survey Evaluation". However, the procedure of locating and mapping the sample estates prior to beginning enumeration is strongly recommended for future surveys of a similar nature to the citrus survey.

5. 2. PREPARATION OF FIELD RECORD SHEETS.

The recording of the field data was facilitated by issuing the enumerators with simple field record sheets. Specimens of the record sheet are shown in appendix 5.

The record sheet contained two columns, entitled "Tree No. and Row". Each of these columns was divided into three columns, L, M, and R, respectively. The letters represented the left-hand, middle and right-hand tree rows respectively, as required for the "3-row counting" technique illustrated in Appendix 6. Each of the three columns contained a list of random numbers in the ratio of 1 in 50. The random numbers in each column indicated the respective numbers of the trees for sampling in the corresponding tree rows for a 1 in 50 sampling fraction. The random numbers were prepared by Alexander from lists of random numbers recorded in Yates, (1953). A suffix letter, either A, B, C or D, appeared after each random number to indicate the appropriate sampling position for the tree as illustrated in Appendix 6, instruction 7.

The record sheet contained 52 random numbers, which were sufficient for the sampling of approximately 25 acres of grapefruit, if using a sampling fraction of 1 in 50. The same form of record sheet, and hence the same random numbers, was used for all of the sample estates.

In addition to the above columns, two columns entitled "Category" were also included in the record sheet. The category columns were divided into three columns, N, PA and PU respectively for recording the number of fruit in each category on each tree.

The three categories were:

- (i) No melanose, column N.
- (ii) Melanose present but the fruit acceptable for export, column PA.
- (iii) Melanose present but the fruit unacceptable for export, column PU. Appendix 5 is an example of a record sheet showing category recordings.

The remaining columns on the record sheet were entitled "Crop Estimate (100's)". The number of fruit on each sample tree was estimated and recorded to the nearest "100" fruit as shown in Appendix 5.

At the top of the record sheet the following information was required:

- (i) The name of the enumerator.
- (ii) The number of the estate as shown on the survey frame, and the number of the field as shown on the estate map.
- (iii) The date of sampling.
- (iv) The times when sampling commenced, and was completed.

A separate record sheet was used for each field within an estate. The demarcation of fields was left to the estate owners or managers. During the course of the pilot survey and the estate mapping the team members soon realised that a ready demarcation of estates into clearly defined fields was not always possible. To overcome this problem it was decided that the estate maps demarcate the fields as indicated by the estate managers. Hedges, roads within the estate, age of the trees, drainage channels, and citrus plantings other than grapefruit, all served in various instances to demarcate fields.

5. 3. ESTIMATED DURATION OF ENUMERATION.

Post-graduate students accompanied by the various members of the survey team in the capacity of supervisors, acted as enumerators for the citrus survey.

The number of enumerators required per day was estimated on the basis that one enumerator could be expected to sample six acres per hour, as indicated by the pilot survey studies.

Allowing for an eight-hour day, it was estimated that an enumerator would not be enumerating for more than six hours a day. The extra two hours being allowed for travelling time to and from estates and within estates.

The total sampling acreage was approximately 1730 acres. As an enumerator was expected to sample six acres per hour it was estimated that approximately 300 man-hours would be required for enumeration. Apart from the members of the survey team, thirty-one post-graduates were available for enumerating. This meant approximately ten hours fieldwork for each enumerator. It was assumed therefore that each enumerator would be required for two days only to complete the survey enumeration.

It was decided that for the purposes of adequate supervision it would not be practicable to have more than about 15 enumerators per day. The scarcity of suitable transport also ^{precluded using} ~~initiated against~~ too many enumerators in the field on any one day. To facilitate transport arrangements MacLean was detailed to ask all intending enumerators to advise him as to which days they preferred to be available for enumerating. All enumerators were asked to designate three days in order to avoid over-lapping of preferences, and also in the event of the survey requiring more than two days work per enumerator.

MacLean also enquired from those enumerators ⁿ ~~owning~~ ^{using} a motor-car, whether the vehicle would be available for the transport of enumerators, and on what days it would be available.

5. 4. INSTRUCTIONS TO ENUMERATORS.

To acquaint enumerators with the field aspect ^{side} of the citrus survey, Myers was detailed to prepare a list of simple instructions for the guidance of enumerators. Appendix 6 is a specimen of the "Instructions to Enumerators".

The instructions explained quite clearly what the enumerators were required to do on locating the specified estates. The "3 - row" counting technique was explained and diagrammatically illustrated. Adequate instructions were given for tree sampling and fruit grading. A partly completed record sheet was included in the instructions for the guidance of enumerators.

Finally each enumerator was instructed to keep a log book in which to record his time of departure from, and return to the College each day, and the number of miles travelled. This last instruction was to enable the survey team to calculate the total time involved in the course of the survey, and the total mileage travelled.

Although the instructional notes were rather brief they did contain the categorical information to allow the enumerators to be fully cognisant of their duties in the field. It was realised prior to the preparation of the instructions to enumerators, that enumerators are not necessarily as interested in a survey as the survey organisers themselves. Hence long and detailed instructions may tend to be ignored or confused, whereas short, concise instructions can be referred to quite readily. The subsequent experience of the citrus survey showed quite clearly that the prepared instructions, although brief, were adequate for the guidance of enumerators. This information may be of value in future survey planning particularly where it is not convenient to give the enumerators close supervision in the field.

5. 5. PRE-SURVEY BRIEFING OF ENUMERATORS.

The final stage of the preliminary planning for the citrus survey was the pre-survey briefing of enumerators. This was done on the 13th December at a meeting of all intending enumerators, and the survey team. Dr. Jolly officiated as Chairman.

Amazigo first addressed the meeting. He dealt with the application of sample surveys in agriculture, citing the citrus survey as an example. Brief mention was then made by Amazigo of the theory of sampling, the selection of a suitable frame and the planning and organisation involved in a sample survey. The latter part of his address dealt with the frame and the sampling scheme for the citrus survey.

For the actual instructions as to the method of enumeration, and the duties of the enumerators in the field, Barrie explained and discussed the points listed on the "Instructions to Enumerators" sheet. Prior to Barrie's address, a sample of the field record sheet and a copy of the "Instructions to Enumerators" was given to each intending enumerator.

Samples of grapefruit from each of the three categories, N, PA and PU respectively, were passed around the meeting for inspection. The meeting was also advised that letters of introduction to estate managers and owners would be available for all enumerators. The letters introduced the bearer and explained the purpose of the survey. As all the owners of estates drawn in the sample had previously been informed by post of the proposed visit to their estate, the letters of introduction were rarely required during the course of the survey.

Several reasons may be advanced for the efficiency of the field operations. There is little doubt that the value of the preliminary field investigations and pilot survey contributed to a large degree. Information and practical experience from the early investigations by the team members allowed them to foresee many of the problems that could be expected when conducting a sample citrus survey on an extensive scale. Dr. Jolly's guidance in this regard also influenced the team to give greater consideration to matters which, although they seemed of minor importance at the survey planning stage, assumed greater importance during the actual enumeration. A particular example was the use of the "E-row" counting technique for tree sampling. During the pilot survey the respective trees in the three rows were counted. Although this system of counting was practicable, the modified "E-row" counting proved to be considerably faster and simpler. There is little doubt that the more complicated counting system would have confused the enumerators and increased the duration of enumeration.

The preliminary mapping of estates also aided for efficiency in the field investigations. Supervisors were able to proceed directly to an estate and detail enumerators to the respective fields without having the inconvenience of first familiarizing themselves with the estate layout. During the mapping operations the survey team, whenever possible, forewarned estate managers of the impending visit of an enumerating team. In all such cases permission was given for the enumerating team to proceed straight ahead with enumeration without first making a courtesy call on the estate managers. Much valuable time was saved in this respect.

PART B. SURVEY FIELD OPERATIONS.

6.1. INTRODUCTION.

The survey enumeration proceeded very smoothly and was at all times ahead of the planned schedule. Enumeration began on the 16th December and was completed on the 20th December. Except for the 17th December, a day of heavy and continuous rain, no unforeseen circumstances arose to interrupt the planning and carrying-out of the field operations.

Several reasons may be advanced for the fluency of the field operations. There is little doubt that the value of the preliminary field investigations and pilot survey contributed to a large degree. Information and practical experience from the early investigations by the team members allowed them to foresee many of the problems that could be expected when conducting a sample citrus survey on an extensive scale. Dr. Jolly's guidance in this regard also influenced the team to give greater consideration to matters which, although they seemed of minor importance at the survey planning stage, assumed greater importance during the actual enumeration. A particular example was the use of the "3-row" counting technique for tree sampling. During the pilot survey the respective trees in the three rows were counted. Although this system of counting was practicable, the modified "3-row" counting proved to be considerably faster and simpler. There is little doubt that the more complicated counting system would have confused the enumerators and increased the duration of enumeration.

The preliminary mapping of estates also made for fluency in the field investigations. Supervisors were able to proceed directly to an estate and detail enumerators to the respective fields without having the inconvenience of first familiarising themselves with the estate lay-out. During the mapping operations the survey team, whenever possible, forewarned estate managers of the impending visit of an enumerating team. In all such cases permission was given for the enumerating team to proceed straight ahead with enumeration without first making a courtesy call on the estate managers. Much valuable time was saved in this respect.

The survey planning involved fairly extensive travelling throughout the island, particularly in the grapefruit producing areas. The resultant familiarity of communications by the team members also contributed to the smoother efficiency of the field work. Supervisors familiar with certain areas were able to proceed with or direct enumerators to those areas without undue delay. During the mapping of estates the different members of the survey team tended to concentrate on certain localities and so became familiar with the access roads in those areas. Alexander and MacLean concentrated mainly on the Sangre Grande - Manzanilla - Toco region; York and Myers on the Maracas Valley - Santa Cruz area and the Erin - Siparia region; and Amazigo and Barrie on the Arima - San Raphael - Talparo region. However, at no stage was it intended that the individual team members be assigned to specific localities as was the case with the 1956/57 Food Crop Survey in Three-Counties of Trinidad.

The practical experience of the citrus survey does suggest that the successful planning and conducting of sample surveys of a similar nature would be improved by sound preliminary organisation. Organisation based on sound exploratory field investigations, pilot surveys and familiarisation with the survey area.

6. 2. D A I L Y P L A N N I N G.

The daily field work programme was planned on a day-to-day basis, except for the detailing of enumerators who were usually given two days notice as to what day they would be required for enumeration. MacLean was detailed to assign and notify the required number of enumerators and car owners each day from the information previously supplied to him by the enumerators. Refer section 5 . 3.

Each supervisor would elect to sample a specified list of estates each day. The number of estates that could be sampled on any one day, by any one team of enumerators was dependent largely upon the size of the estates and the proximity of the estates to one another.

After each days field work, each supervisor would record on the survey sample the estates sampled that day. The supervisors would then meet to decide the programme of field work for the following day.

In the case of a number of small estates in an area, sometimes two supervisors would accompany one car of enumerators. Experience soon showed that it was usually not possible for one supervisor to supervise satisfactorily the sampling of more than one, or perhaps two, estates concurrently.

For the first two days of enumeration, York was detailed to locate and map sample estates not already mapped. Other members of the team also assisted in this respect whenever there were unlocated sample estates in the areas in which the supervisors were operating.

On some of the very small estates, supervisors sometimes found it convenient to sample the estate, rather than map it and then send enumerators for the sampling. Enumeration by supervisors in such cases avoided the necessity of re-visiting the estate and so contributed towards lessening the time of enumeration for the survey.

6. 3. D A I L Y R O U T I N E.

An early start was aimed at each day. Most cars usually managed to leave the hostel by 8.00 a.m. Before leaving the hostel it was the duty of each supervisor to ensure that he had provided:

- (i) A packed lunch for each enumerator.
- (ii) A sufficient number of record sheets.
- (iii) The maps of the estates scheduled for sampling on that day.
- (iv) Grapefruit samples of each category.

On reaching the estate, the usual procedure was for the supervisor to assign one enumerator to each field indicating the position in the field to start tree-counting as specified by the estate map. Sometimes in the case of large fields, two enumerators were assigned to the one field. Enumerators were advised to make quick counts of the fruit numbers on several trees before they began enumerating, in order that they would have a better idea of the approximate crop number on the sample trees.

It was not intended that enumerators count the fruit on the sample trees but simply make an eye-estimate to the nearest "100" fruit.

Prior to the beginning of the enumeration the survey team members had intended to supervise concurrently the sampling on two or more estates. This procedure was soon found to be impracticable and was discontinued. It was noticed that estates were sampled more quickly and efficiently when supervisors remained with the enumerators. Usually the supervisors themselves were often able to assist with enumeration. For about their first hour in the field enumerators often became confused with the tree-sampling, particularly in irregularly shaped fields. The presence of a supervisor helped avoid delays and further confusion in such instances.

As each enumerator completed the sampling of a field he reported back to the supervisor and handed in his record sheet for the completed field. A separate record sheet was required for each field on the estate. It was the duty of the supervisor to note on the top of the record sheet the sampling fraction for the trees on the estate, for the guidance of enumerators.

On several estates the "3-row" counting was not possible, as the grapefruit was sometimes planted around the perimeter of orange fields. Usually the grapefruit would be either as single or double rows. Either single row or double row counting, whichever was the more convenient, was used in such cases.

In no single instant was it necessary to re-visit an estate for sampling purposes. Hence follow-up visits, a common and usually expensive feature of a sample survey, were not necessary for the citrus survey.

PART C. ANALYSIS OF DATA.

7. 1. NOTATION.

The notation adopted for the data analysis was similar to that given by Yates (1953, 6. 2).

A "super bar" denotes a mean value, e.g. \bar{y} is the mean of a number of values of "y".

A "sub-bar" denotes an estimate e.g. \underline{N} denotes the estimated number of trees in a stratum.

The following symbols were used in the notation:

- f' , working sampling fraction for first stage units.
- f'' , " " " " second " "
- g' , raising factor for first stage (= $1/f'$).
- g'' , " " " " second " (= $1/f''$).
- n' , number of sample estates in a stratum.
- n'' , " " trees sampled on an estate.
- \underline{N} , estimated number of trees in a stratum.
- \underline{N}_2 , " " bearing trees in a stratum.
- x , crop estimate in "100's" of sample trees.
- \underline{X} , estimated crop yield in "100's" of a stratum.
- y , estimated number of fruit in "100's" for trees in a particular category.
- \underline{Y} , estimated number of fruit in a particular category, in a stratum.
- r , ratio of y/x .
- \bar{r} , mean ratio of y/x .
- $\underline{\bar{r}}$, estimated value of $\underline{Y}/\underline{X}$.
- S' , summation of values over first stage units.
- S'' , " " " " second " "
- u' , number of estates in a stratum possessing a given attribute.
- u'' , number of sampled trees on an estate 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 possessing a given attribute in the sample.
 \underline{p}' , proportion of trees possessing a given attribute in a stratum.
 \underline{p}'' , proportion of trees possessing a given attribute in an estate.
 \underline{q} , equals $1 - \underline{p}$.
 \underline{q}' , equals $1 - \underline{p}'$.
 \underline{q}'' , equals $1 - \underline{p}''$.
 λ', S' , a factor of the variance due to first stage sampling.
 λ'', S'' , a factor of the variance due to second stage sampling.
 \underline{V} or $\underline{Var.}$, an estimated variance.
S. E., estimated sampling error.

7. 2. T A B U L A T I O N.

For the 1956/57 Food Crop Survey a system of clip-card recording was used for tabulating the survey data. Clip-card recording is recommended by Jolly (1950) for isolated small surveys and research projects. It offers the distinct advantages of facilitating the systematic arrangement of large amounts of data, by suitable coding, onto a limited number of small cards. The condensing of pertinent data in this form allows for more convenient storage and ease of reference. A further advantage is that a large number of comparisons can be made without the inconvenience of tabulating results for each comparison.

For the citrus survey the field record sheets were used to tabulate the survey data. Several reasons may be advanced for this preference.

Firstly for the citrus survey there was not the same volume of detailed, assorted information for tabulation. In the Food Crop Survey a number of crops were investigated, there being 19 - food crops recorded in the results. In addition the fertiliser practices, cultivation methods and avenues of consumption and marketing in connection with these crops were investigated. At the conclusion of the enumeration, therefore, the survey team was faced with a voluminous amount of information for tabulation and

analysis. It is in such cases that the use of clip-cards for data tabulation can be put to great advantage. By comparison the citrus survey was concerned with one crop only and the survey investigations were limited to two factors only, namely, the incidence of melanose disease, and the estimated crop yield. For each unit in the sample therefore, there were two sets of observations; the category assessments and the crop estimates. Stratification of the survey sample for rainfall and estate size allowed for comparison between strata. There would have been no distinct advantage therefore, in using clip-cards for the citrus survey as the amount of information on each unit was small and the number of comparisons limited.

A further factor favouring the choice of the record sheets was that in no case had the right-hand side of the field sheet been used for data recording in the field. None of the sampled estates contained fields large enough to require more than the left-hand columns of random numbers for tree sampling. Hence the "category" and "Crop Estimate" columns on the right-hand side of the record sheet were used to tabulate the data recorded in the respective columns on the left-hand side of the record sheet, as shown in Appendix 5.

Before the data was analysed, therefore, the category assessments for each tree were multiplied by the crop estimate for that tree to give an estimate of the number of fruit in the various categories. These figures were entered as "100's" of fruit in the corresponding right-hand columns. The advantages of this form of tabulation were twofold. Finally it was considered that there was less likelihood of making simple mistakes when tabulating the data on the same sheet than when transferring data from one sheet to another. It was also a simple matter to keep a check of the crop estimate (x) totals for each field, as recorded on the left-hand side, against the corresponding category estimate (y) totals on the right-hand side. For the purposes of a ready check, the total of the category estimates for any one field was equal to the total of the crop estimates for that field. The specimen record sheet in Appendix 5 demonstrates the simple method of checking.

Although the system of tabulating the survey data on the record sheets proved both convenient and satisfactory for the citrus survey, it would not be practicable for a sample survey containing a large amount of detailed and assorted data for analysis. The system of data tabulation used for the citrus survey would thus have limited application in agricultural surveys. For sample surveys containing a large amount of detailed information, clip-card recording would be more convenient and satisfactory for data tabulation.

7. 3. COMPUTATION.

Quantitative and qualitative analyses were carried out for each stratum. For the analyses, each member of the survey team was assigned one particular stratum for analysis. The writer was assigned stratum 5. In this section of the report therefore, it is intended to refer mainly to the quantitative and qualitative analysis of stratum 5. For analysis of the remaining strata, reference is made to the respective reports of the other members of the survey team, as follows:

Team member	Stratum No.
Amazigo	1.
Myers	2.
MacLean	3.
Alexander	4.
York	6.

7. 3. 1. Quantitative Analysis.

In the quantitative analyses it was necessary to estimate:

- (i) Number of fruit (\underline{N}) in the stratum;
- (ii) Number of fruit (x) in "100's" on the trees at the time of the survey;
- (iii) Number of fruit (y) in the categories, N, PA and PU;
- (iv) Proportion of fruit (\bar{r});

with their sampling standard errors.

The population estimates and their standard sampling errors were thus built up stratum by stratum.

As all the estates in stratum 5 were sampled the sampling fraction was 1, i.e. $f' = 1$, and $g' = 1$, and the estates behaved as separate strata. There were, therefore, no sampling errors between estates. But as the sampling fraction for the selection of trees was 1 in 150, i.e. $f'' = 1/150$, sampling errors were estimated from the variation between trees within estates.

(i) Estimated number of trees (\underline{N}) in the stratum.

$$\underline{N} = g' g'' S' (n'') \dots\dots\dots(1)$$

$$\text{Var. } (\underline{N}) = 0. \quad \text{as } f' = 1 \dots\dots\dots(2)$$

(ii) Estimated number of trees in a particular category in the stratum (\underline{Y}).

$$\underline{Y} = g' g'' S' S'' (y) \dots\dots\dots(3)$$

Variance (\underline{Y})

$$\underline{V} (\underline{Y}) = \frac{(1 - f')}{n'} S'^2 + f' \cdot \frac{(1 - f'')}{n' n''} S''^2 \quad \text{Yates, 7.17.} \dots\dots\dots(4)$$

As the number of trees sampled per estate, n'' , was not constant, n'' was substituted by \bar{n}''_o , where

$$\bar{n}''_o = S' (n'') - \frac{S' (n''^2)}{n' - 1} \quad \text{Yates, 8.11.}$$

S'^2 and S''^2 are obtained from the analysis of variance table which may be written as:

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

By substitution as seen in Alexander's report, the above formula for $\underline{V}(\underline{Y})$ may be resolved to:

$$\underline{V}(\underline{Y}) = (g'g'')^2 \left((1-f') n' \bar{n}''_0 A + f' (1-f'') n' \bar{n}''_0 B \right) \dots (6)$$

$$= (g'g'')^2 (\alpha A + \beta B) \dots (7)$$

where $\alpha = (1 - f') n' \bar{n}''_0$.

and $\beta = f' (1 - f'') n' \bar{n}''_0$.

The formula, $\underline{V}(\underline{Y}) = (g'g'')^2 (\alpha A_y + \beta B_y)$ was used in strata 1, 2, 3, and 4, as the estates sampled were under 100 acres in area.

In strata 5 and 6, $f' = 1$,

hence $1 - f' = 0$.

and $\alpha = 0$.

The $\underline{V}(\underline{Y})$ then becomes,

$$\underline{V}(\underline{Y}) = (g'g'')^2 (\beta B_y)$$

$$= g''^2 \beta B_y \dots (8)$$

Thus the variance of \underline{Y} is obtained by evaluating βB_y and then multiplying by the square of the overall raising factor.

The same general formulae apply for the calculation of \underline{X} and $\underline{V}(\underline{X})$. B_y and B_x are the between trees mean squares.

(iii) Estimation of \bar{r} . (For strata over 100 acres).

In each estate:

$$\bar{r} = S''(y) / S''(x) \dots (9)$$

(11) For the stratum:

$$\bar{r} = S' S'' (y) / S' S'' (x) \dots \dots \dots (10)$$

\bar{r} is used in the formula for the calculation of Q since \bar{x} is not known for the estates or the stratum as a whole. Yates 7.9.

Q is the pooled estimate of variance.

$$Q = B_y - 2 \bar{r} B_{xy} + \bar{r}^2 B_x$$

B_{xy} is the between trees mean product.

$$\text{Then } S^2_q = Q / S' (n'' - 1)$$

$$V(\bar{r}) = S' (n'') / (S' S'' (x))^2 S^2_q \dots \dots \dots (11)$$

$$S.E(\bar{r}) = \sqrt{V \bar{r}}$$

7. 3. 2. Qualitative Analysis. (Estates over 100 acres).

The aim of the qualitative analysis was to determine the proportions of units possessing given attributes together with their sampling standard errors.

7. 3. 2. 1. EXAMPLE COMPUTATIONS.

(i) Estimation on a single estate for the proportion of trees bearing fruit in one particular category.

$$\underline{p}'' = u'' / n'' \dots \dots \dots (12)$$

$$V(\underline{p}'') = \underline{p}'' q'' / n'' \dots \dots \dots (13)$$

where $q'' = 1 - p''$, and ignoring $(1 - f'')$ since f'' is small ($f'' = 1/150$).

(ii) Estimation for the stratum of the proportion of trees in one particular category.

$$\underline{p}' = S' (u'') / S' (n'') \dots \dots \dots (14)$$

$$V(\underline{p}') = S' V(\underline{p}'') \dots \dots \dots (15)$$

(iii) Estimation for the stratum of the number of trees in one particular category.

$$\underline{U}'' = \underline{N}_2 \cdot \underline{p}' \dots\dots\dots (16)$$

where \underline{N}_2 = estimated number of bearing trees at the time of the survey.

$$\text{S. E. } \underline{U}'' = \underline{N} \cdot \text{S.E. } (\underline{p}') \dots\dots\dots (17)$$

(iv) Estimation of the proportion of estates in a stratum possessing a given attribute.

$$\underline{p} = \underline{u}' / \underline{n}' \dots\dots\dots (18)$$

as $f' = 1$, there are no sampling errors between estates,

$$\text{hence } \underline{v} (\underline{p}) = 0 \dots\dots\dots (19)$$

7. 4. EXAMPLE COMPUTATIONS.

An example of both the quantitative and qualitative analyses is included in the appendix. Appendix 3 is the quantitative computation sheet for category N, and appendix 4 are the qualitative computations for category N. For "example computations" of the remaining strata reference is made to the respective reports by the other members of the survey team.

7. 4. 1. QUANTITATIVE COMPUTATION SHEET.

A quantitative computation sheet was compiled for each of the three categories, N, PA and PU. The same form of sheet and the same general formulae were used for category N. See Appendix 3.

For each category the \underline{N} , \underline{Y} , \underline{X} , and \bar{r} values were determined. \underline{N} and \underline{X} being constant for each category.

The additions for the sum of squares for the between and within estate variances, were self-checking with the total sum of squares. The correction factor for the mean (C.F.M.) and the mean square were determined in the conventional manner.

$$\text{C.F. for } y = \frac{\left(\sum S' S'' (y) \right)^2}{S' (n'')}$$

$$\text{M. S.} = \frac{S . S}{d . f.}$$

7. 4. 2. QUALITATIVE COMPUTATION SHEET.

Qualitative computations were made for each of the categories, N, PA, PU, N + PA and PA + PU. For each category, the number of trees in that category was estimated. The same form of computation sheet and the same general formulae were used for each category, as illustrated in Appendix 4.

The values of "u" and "n" were obtained from the field record sheets.

With both the quantitative and qualitative computations and analyses, it was intended that a complete check be made of each of the stratum analyses. Unfortunately the limited time factor did not allow a complete check of each team member's computations, by another member of the survey team. Alexander, however, was able to check each of the stratum analyses sufficiently to ensure that no apparent gross errors were present in the quantitative and qualitative computations.

7. 4. 3. ADDITIONAL ANALYSES.

From the stratum quantitative and qualitative analyses, Alexander made the following assessments, with their sampling standard errors, for each stratum:

- (1) The estimated percentage of fruit of the total \underline{X} , in the categories N (Y_n), P A (Y_{pa}), and P U (Y_{pu}) respectively. Appendix 2, Tables 11, 12, and 13.

(ii) The estimated percentage of trees of the total \underline{N}_2 bearing fruit in category N or P U only.

Appendix 2, Tables 14 and 17 respectively.

(iii) Estimated percentage of trees bearing any diseased fruit (categories P A + P U) of the total \underline{N}_2 .

Appendix 2, Table 15.

(iv) Estimated percentage of trees bearing acceptable fruit only, (N + P A), of the total \underline{N}_2 .

Appendix 2, Table 16.

(v) From the quantitative and qualitative analyses, Alexander calculated for:

a) the size strata.

b) the rainfall strata, and

c) the frame

with their respective sampling errors, the:

a) Estimated numbers of trees, \underline{N} .

b) Estimated number of bearing trees, \underline{N}_2 , at the time of the survey.

c) Estimated total number of fruit, \underline{X} , in 100's.

d) Estimated number of fruit in categories N (\underline{Y}_n), P A (\underline{Y}_{pa}) and P U (\underline{Y}_{pu}) respectively.

e) Estimated number of trees bearing fruit in categories N or P U only.

f) Estimated number of trees bearing acceptable fruit only. (N + P A).

g) Estimated number of trees bearing any diseased fruit. (P A + P U).

The full results of all the calculations in section (v) are shown in tabled form in Appendix 2.

PART D. RESULTS OF THE SURVEY DATA ANALYSIS.

All estimates, with their percentage sampling errors, of the survey results are recorded in tabled form in Appendix 2.

8. 1. ESTIMATED FRUIT AND TREE NUMBERS.

- (i) At the time of the survey the members of the Co-operative Citrus Growers' Association were cultivating approximately 232,000 (S.E. 6.53%) mature grapefruit trees.
- (ii) The under 100" rainfall strata contained approximately 178,000 (S.E. 8.33%) trees of the total in (i).
- (iii) Of the estimated total of grapefruit trees in (i), approximately 217,000 (S.E. 7.15%) were bearing fruit at the time of the survey, and carried a total crop of approximately 65,570,000 (S.E. 5.43%) grapefruit. The overall crop average was therefore in the vicinity of 300 fruit per tree.
- (iv) The average yield per tree was significantly higher in the under 100" rainfall strata, where 170,950 (S.E. 9.44%) trees carried an estimated crop of 54,365,000 (S.E. 6.53%) fruit, or approximately 320 grapefruit per tree. In the over 100" rainfall strata, 46,050 (S.E. 5.14%) trees carried an estimated 11,205,000 (S.E. 7.85%) fruit, or approximately 240 grapefruit per tree.
- (v) Stratum 3 (10.1 - 100 acres and under 100" rainfall) contained an estimated at 107,500 (\pm 14,450) trees of the estimated total, or approximately 46% of the total.
- (vi) The total percentage sampling errors for \underline{N} , \underline{N}_2 , and \underline{X} respectively for the two rainfall strata (under 100" and over 100") are in all cases below 10% for the results. However, the percentage sampling errors (S.E.) for \underline{N} , \underline{N}_2 and \underline{X} respectively for the size strata, are on the whole larger than those for the rainfall strata.

The percentage S.E. for the 0 - 10 acres stratum were 12.37%, 14.97% and 22.93% for N, N₂ and X respectively. The high percentage S.E. for various results will be discussed in more detail in section 9.1.

8. 2. ESTIMATION OF MELANOSE INCIDENCE AND SEVERITY.

(i) Table 6 gives for the two rainfall strata, the estimated percentages of fruit in each category of the stratum total.

Table 6.

Category	Under 100"	Over 100"
N	42.84 (S.E. 1.77%)	80.03 (S.E. 1.89%)
P A	41.35 (S.E. 0.51%)	19.37 (S.E. 3.56%)
P U	15.81 (S.E. 2.59%)	0.60 (S.E. 15.0%)

The high percentage of fruit with no melanose (category N) in the over 100" rainfall stratum is evident. Similarly the percentage of unacceptable fruit (category P U) is very low.

(ii) Table 7 gives for the three size strata, the estimated percentages of fruit in each category of the stratum total.

Table 7.

Category	0 - 10 acres	10.1 - 100 acres	Over 100 acres
N	35.66 (S.E. 18.64%)	38.80 (S.E. 4.59%)	72.21 (S.E. 0.03%)
P A	56.76 (S.E. 7.86%)	45.84 (S.E. 2.53%)	15.79 (S.E. 0.06%)
P U	7.11 (S.E. 8.30%)	15.36 (S.E. 4.04%)	12.00 (S.E. 0.16%)

The increasing percentage of fruit with no melanose with increasing size of estate is evident from Table 7.

(iii) Table 8 gives the estimated percentage of the stratum total, of the number of trees in each stratum bearing acceptable fruit only, (categories N and P A combined).

Table 8.

Acreage	Under 100"	Over 100"	Totals	% S. E.
0 - 10	71.43	91.66	76.62	7.58%
10.1 - 100	68.78	96.08	74.98	2.45%
over 100	70.43	98.35	80.39	3.32%
Totals	71.32	96.83	76.73	
% S. E.	2.07%	4.65%	1.96%	

The appreciably higher percentage of acceptable fruit in the over 100" rainfall strata as compared with the respective under 100" rainfall strata is quite conclusive.

(iv) Table 9 gives the estimated number of trees in each stratum bearing unacceptable fruit only. (category P U).

Table 9.

Acreage	Under 100"	Over 100"	Totals	% S.E.
0 - 10	Nil	Nil	Nil	-
10.1 - 100	7175	Nil	7175	16.14%
over 100	2263	Nil	2263	5.21%
Totals	9438	Nil	9438	
% S.E.	12.33%	-	12.33%	

No trees bearing unacceptable fruit only were recorded in any of the over 100" rainfall strata.

(v) Table 10 gives the estimated percentage of the stratum of fruit in category N (Y_n), for each stratum.

Table 10.

Acreage	Under 100"	Over 100"	Totals	% S.E.
0 - 10	30.24	58.00	35.66	18.64%
10.1 - 100	37.86	52.28	28.80	4.95%
Over 100	60.90	94.34	72.21	0.03%
Totals	42.84	80.03	49.19	
% S.E.	1.77%	1.89%	0.07%	

The dual effect of high rainfall and to a lesser degree, increasing estate acreage, in giving a higher percentage of fruit with no melonase infection is clearly shown in Table 10.

(vi) The rather consistently high percentage sampling errors for the 0 - 10 acres strata are evident throughout the results. Reasons for such consistently high sampling errors in these strata (0 - 10 acres) will be discussed in more detail in section 9.1. The remainder of the percentage sampling errors, and particularly the totals, are generally below 10%, which indicates a fairly high degree of accuracy, and would be acceptable for most sample surveys that were not concerned in recording highly accurate and precise information. Surveys conducted by governments and other organisations are quite often satisfied with results in which the percentage sampling errors do not exceed 15.0%.

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9. SURVEY EVALUATION.

9. 1. ANALYSIS AND CONCLUSION.

Before a valid interpretation can be drawn from the results of the citrus survey, it should be realised that the results are specifically applicable to the 1957/58 cropping season only. Rather unusual seasonal conditions, in the nature of a lower than average rainfall for both the 1957 wet season and the succeeding dry season, prevailed throughout the 1957/58 grapefruit season. At the time of the citrus survey the general concensus of opinion among export grapefruit producers was that the seasonal conditions for the 1957/58 crop were extremely favourable and that disease incidence appeared to be less than usual. These observations were justified by the subsequent record grapefruit crop handled by the Co-operative Citrus Growers' Association, and the lower than normal incidence and severity of melanose disease reported by the Citrus Growers' Association.

i) The first conclusion drawn from the results is that melanose is not at present a serious disease of grapefruit in Trinidad. Of the total number of fruit, (X), approximately 83% in the under 100" rainfall strata, and 99.4% in the over 100" rainfall strata, was judged as suitable for shipment. If the percentage of shippable fruit is considered in relation to the size strata, then approximately 92% in the 0 - 10 acres strata, 85% in the 10.1 - 100 acres strata, and 88% in the over 100 acres strata was considered suitable for export.

ii) A second conclusive feature of the results was that the incidence of melanose was much lower in the higher rainfall areas. In the under 100" rainfall strata, approximately 43% of the fruit was free of melanose infection, whereas approximately 80.0% of the fruit in the over 100" rainfall strata was free of melanose. Further, no trees were recorded as bearing unacceptable fruit only, in the over 100" rainfall strata.

In the under 100" strata 9,438 (S.E. 12.33%) trees were recorded as bearing unacceptable fruit only.

iii) The estimated yield in the under 100" strata was 320 fruit per tree, which was significantly higher than the estimated yield of approximately 240 fruit per tree for the over 100" strata. No between-strata comparisons or observations were made on the general size and quality of the fruit.

iv) Examination of the complete tabled results as shown in Appendix 2, reveals that, with a few exceptions, the percentage sampling errors were below 10.0%. Closer inspection reveals that the majority of the percentage S.E. above 10%, were attributable to the two 0 - 10 acres strata, namely stratum 1 and 2.

A number of components of variation contributed to a greater or less degree, to the high percentage sampling errors often recorded for stratum 1 and stratum 2. Firstly, for both strata $n' - 1$ was small and $1 - f'$ was large. In stratum 1, six estates were sampled, and in stratum 2, four estates were sampled. Hence the degrees of freedom were 5 for stratum 1 and 3 for stratum 2. The sampling fraction for both strata was 1 in 10 for the estates, so that $1 - f' = 0.9$. The lower the $1 - f'$ value, the less variation between estates, until $f' = 1$, then $1 - f' = 0$, and no variation between estates.

In stratum 1 the survey team was unable to locate two estates drawn in the sample. Results for these estates were substituted for from the results of two of the sampled estates in stratum 1. Similarly, substituted results were used for one unlocated estate in stratum 2. The reasons for, and the validity of these substitutions will be discussed more fully later in this section. However, the substituted results did mean that in stratum 1 only four different sets of values were available, although for the purposes of computation and analysis, results from six different estates were available. Similarly in stratum 2, three sets of different values, and not four, were available.

For stratum 1 and stratum 2, n was usually very small. The small number of observations per estate thus contributing to higher second stage variation. The high second stage sampling errors are reflected as a component of second stage variation in the first stage variation.

v) Stratum 5 (under 100", over 100 acres) was recorded as having a higher percentage of unacceptable fruit than any other stratum. Such a high percentage was due largely to one estate which contributed 28% of the fruit in the stratum of which 65% was unacceptable for export. Thus the high sampling errors in stratum 5 for the estimated number of trees bearing any diseased fruit (categories P A & P U) are due mainly to one large estate.

vi) A further component of sampling error, particularly for the quantitative (\underline{X}) and (\underline{Y}) estimates, were the estates in which all the fruit had been picked prior to enumeration. In such instances tree counts (\underline{N}) were recorded for the estate. The crop estimates (\underline{X}) and category assessments (\underline{Y}) were recorded as nil. Estate numbers 89, 170 and 262 in strata 1, 2, and 4 respectively, were recorded as having no fruit at the time of the survey. The only way in which it would be possible in future citrus surveys to avoid having sample estates in which the fruit had been picked, would be to alter the time of the survey. It would appear that November is the ideal month to conduct a citrus survey in Trinidad to investigate melanose or similar diseases. Very little picking is done in November. Hence it was due to a fault in the timing of the survey, that the 1957/58 survey team recorded three estates in which all the fruit had been picked at the time of the survey.

vii) A number of the smaller estates drawn in the sample were not enumerated as the survey team was unable to locate the estates. Although numerous enquiries were made in the respective districts as to the whereabouts of the unlocated estates, there remained nine unlocated, small estates at the completion of the field work. For the purposes of enumeration the unlocated estates were recorded as "no responses".

However, as it was due purely to chance that the estates were not located, it was decided that for the purposes of computation and analysis, a more reliable estimate would be obtained by substituting the "no responses" by the results of sampled estates in the same stratum. The substitute estates to be drawn at random from the respective strata. The reason for substitution was based on the assumption that the unlocated estates did exist, and it was through insufficient information regarding the location of the estates and not through a defect in the frame that the estates were not located. Substituted results were used for the following:

<u>Unlocated Estate</u> No.	<u>Stratum</u>	<u>Substitute Estate.</u> No.
32	1	232
79	1	275
278	2	231
101	3	50
142	3	61
158	3	61
168	3	137
243	3	51
291	3	203

viii) A defect of the survey frame was that the estate acreage recorded on the frame did in some cases differ greatly from the actual field acreage of grapefruit. The frame acreage as recorded was approximately 7,300 acres. The 7,300 acres were sampled in the belief that the majority of the 7,300 acres consisted of grapefruit plantings. However, taking into account the normal spacings for grapefruit plantings in Trinidad, the average number of trees per acre is approximately 90. Thus the actual acreage of grapefruit at the time of the survey was approximately 2,600 acres (survey estimate of approximately 232,000 trees). The acreage planted to oranges therefore was considerably more than expected, and the acreage under grapefruit was considerably less than expected.

For example, in strata 5 and 6, it was found on several estates listed as having more than 200 acres of grapefruit, that at least half of the acreage consisted of orange plantings. In such cases the estates were still regarded as having more than 100 - acres of grapefruit and were sampled accordingly, $f' = 1$ and $f'' = 1$ in 150. The reason for size stratification in the first place was based on the assumption that management practices on the larger citrus estates would be proportionately superior to the smaller estates.

Estate No.180, in stratum 3, was found, on mapping, to contain more than 100 acres of grapefruit instead of 31.50 acres as listed in the frame. Estate No.180 was thus transferred from stratum 3 to stratum 5, increasing the number of estates in stratum 5 to 9. The transfer of estate No.180 from stratum 3 did not invalidate the sampling scheme for stratum 3, as it reduced the total number of estates in stratum 3 from 123 to 122 and the sample from 25 to 24 estates, for a 1 in 5 sampling fraction as before. Due to a further minor defect in the frame the number of estates in stratum 5 was restored from 9 to 8. The mapping operations revealed that the two estates Nos. 167 and 176 in stratum 5 were incorporated in one estate. The two listed were in fact one estate only and were sampled accordingly.

ix) Examination of table 1, appendix 2, reveals that the 0 - 10 acre strata (strata 1 and 2) contained an estimated 31,000 ($\pm 15,164$) trees. On a proportionate basis therefore, the 0 - 10 strata estates are of fairly minor economic importance to the Trinidad citrus industry as they contain approximately 12% only of the total production. However, during the preliminary field investigations, considerable time was involved in locating the smaller estates. In the writer's opinion, proportionately more time than the importance of the results from the small estates warranted. High sampling errors were also a feature of the results for stratum 1 and stratum 2. Should it be considered necessary to reduce the sampling errors for the 0 - 10 acres estates, then for future surveys it is suggested that a more intensive sampling fraction for the selection of estates would give lower percentage sampling errors between estates.

Perhaps a sampling fraction of 1 in 5, rather than 1 in 10.

Although a lower sampling fraction for the selection of estates would give lower sampling errors, it would increase considerably the time and cost of the survey. It is extremely doubtful if the greater accuracy of results for the 0 - 10 acres estates would justify the added cost of the survey. Alternatively it is suggested that rather than have 0 - 10 acres, and 10.1 - 100 acres strata, that the size strata be 0 - 25 acres and 25.1 - 100 acres, and that both strata be sampled with the same intensity, possibly 1 in 5. On the basis of size distribution of the estates in the frame, minor importance of estates under 10 acres, and the desirability of minimising the sampling errors, the latter suggestion for an alternative size stratification would appear preferable to the sampling scheme followed in the citrus survey. The purpose of the survey and the degree of accuracy required would of course be the determining factors in the selection of a similar or modified sampling scheme.

x) Sampling errors due to faulty enumeration must occur in surveys of the nature of the citrus survey, where unskilled investigators are used for enumerating. However, in the case of the citrus survey, errors of enumeration were judged to be low as they were in the main "self-cancelling errors". Where one enumerator may err towards over-estimation of crop estimates, another could quite possibly err towards under-estimation of same. Similarly for the category assessments the sampling errors were judged to be "self-cancelling" errors. There was no evidence in the field to suggest that enumerators were all biased in the one direction regarding their investigations.

xi) The efficiency and limitations of the frame and the sampling of the citrus survey may be summarised as follows:

1. The frame used, although it was the only one available for citrus survey, proved to be very satisfactory for the selection of the sample, since:

- (a) it was adequate for the scope of the survey as it included all citrus producers who marketed their produce through the Co-operative Citrus Growers' Association, Port-of-Spain.
 - (b) No follow-up survey was needed. Follow-up surveys are an important consideration in any survey as they often appreciably increase the cost of the survey.
 - (c) although several "no-responses" were recorded in the enumeration, it was possible to substitute results for the non-responses without invalidating the results of the survey, and
 - (d) minor defects in the frame were adjusted without invalidating the sampling scheme or the results of the survey.
2. The sampling scheme for all strata, with the possible selection of the 0 - 10 acres strata was satisfactory. A modified and more practicable sampling scheme for the smaller estates has been suggested.
 3. Stratification for both rainfall and plantation size was completely justified in the light of the survey results for melanose incidence and severity.
 4. The methods of tabulation, computation and analysis of data, were not unnecessarily detailed or complicated, but allowed the ready-checking of computations and results, and estimation of the percentage sampling errors between and within estates.
- xii) The citrus survey achieved three main objectives:
1. Firstly, it has furnished valuable information on an important aspect of one of Trinidad's principal commercial crops. Disease incidence and severity, particularly of any disease directly concerning the export prospects of a crop, is an important phase of cash-crop agriculture in any country.

The survey information regarding melanose disease of citrus in Trinidad is pertinent information which ^{could} be of direct value to the Trinidad Department of Agriculture and the Co-operative Citrus Growers' Association.

2. Secondly, the citrus survey has provided information, which should be of value in the planning and conducting of similar surveys in Trinidad by students and staff of the Imperial College. Such information should facilitate the more efficient planning and carrying out of similar surveys.
3. The third achievement of the citrus survey is that it has given each member of the survey team valuable practical experience in the planning, conducting and analysis of a sample survey. Experience of this nature could prove to be of real value to the individual members of the team in their capacity of agricultural officers in various Territories.

It should be noted, however, that for the efficient planning and evaluation of surveys, the services of an experienced statistician are very necessary for guidance in the survey organisation and analysis.

xiii) In the introduction of this report, mention was made of the general application and value of sample surveys from the aspects of convenience and quickness, limited cost, accuracy of results and greater ease of data analysis as compared with complete surveys. Provided a suitable frame is available, a sample survey can be planned. Electoral and parish registers, town plans, maps, lists of households, farms or villages, may at one time or other be used as a frame for a sample survey. The following suggestions for sample surveys, are made in the belief that a sampling scheme somewhat similar to that of the citrus survey could be used.

1. A sample survey conducted to investigate the incidence of malaria in children in a primitive native community. If the community included only a lowland coastal region, stratification for age of the children is suggested.

If a highland area was also included in the community stratification for altitude as well as age is suggested. Malaria could be diagnosed by an external examination of the size of the spleen. In areas where an annual census was taken, the village census books would constitute a suitable frame. The villages could possibly be the first-stage sampling units, and the children the second-stage sampling units.

Similarly the incidence of other diseases in backward native communities could be investigated. Diseases such as scabies, leprosy and hookworm, could be investigated over large areas by means of a sample survey.

2. A sample survey investigation of one or more cultural practices in peasant crops. In some Territories, it is compulsory by law for all cocoa growers to be registered with the local government authority, particularly in countries where Swollen Shoot disease of cocoa is not present. The registered list of growers would therefore provide a suitable frame for any investigations regarding the management and production of cocoa in those areas.
3. Providing a suitable frame is available a sample survey could be undertaken to investigate the incidence and severity of Red Ring disease of coconuts in Trinidad.

	Man-days	Cost
Preliminary investigations	176	28.70
Survey	700	114.00
Investigation	100	157.30
Total	976	300.00

9. 2. TIME AND COST OF SURVEY.

1. (a) Total time of enumeration
 - 108 hours, 35 minutes.
- (b) No. of trees examined = 915.
- (c) Overall average sampling time
 per tree = 7.12 minutes.
- (d) Average sampling time for
 1 in 50 sampling = 6.48 mins./tree.
- (e) Average sampling time for
 1 in 150 sampling = 7.62 mins./tree.

2. No. of man-days for enumeration.

Date	Man-days.
Monday 16th December	24
Tuesday 17th "	20
Wednesday 18th "	17
Thursday 19th "	14
Friday 20th "	<u>10</u>
Total	<u>85 man-days.</u>

3. Mileage travelled during Survey.

	Mileage	Cost
Preliminary investigations	178	26.70 dollars.
Mapping	763	114.43 "
Enumeration	<u>1841</u>	<u>262.65 "</u>
Total	<u>2782 miles</u>	<u>403.78 dollars.</u>

10.

R E C O M M E N D A T I O N S .

In the light of experience gained from the citrus survey, the writer feels that the following recommendations may be of value to teams planning and conducting surveys of a similar nature in subsequent years.

1. Should the survey require an examination of the fruit on the tree, then November is the most suitable time for enumeration.
2. Thorough preliminary investigations, and if possible, pilot surveys, are very important for the efficient planning of the survey.
3. An accurate and up-to-date frame helps to simplify, the planning of the survey and the analysis of the survey data.
4. In future surveys of a similar nature it would be desirable to allow more time for the training of enumerators. Should it be possible, a pilot survey for enumerators should accrue for more accurate enumeration.
5. Supervisors should familiarise themselves thoroughly with the survey area and access roads.
6. Ensure that the sampling scheme be as simple as possible. A slightly modified sampling scheme has been suggested in the body of the report for future citrus surveys.
7. An analytical method which embodies ready checks in the computation and analysis of data is recommended.

11.

S U M M A R Y.

1. An account is given of a Sample Survey of Citrus in Trinidad.
2. The survey was undertaken by a team of six post-graduate students of the Imperial College of Tropical Agriculture during 1957/58 academic year.
3. The objects of the survey were:
 - (a) to investigate the incidence and severity of melanose disease on grapefruit, and
 - (b) to provide an exercise in statistical sampling.
4. The frame used was a list of the current members of the Co-operative Citrus Growers' Association of Trinidad.
5. A stratified, multi-stage sample with a varying sampling fraction was taken.
6. Enumeration was by direct observation and examination.
7. Quantitative and qualitative analyses were carried out and sampling errors were calculated.
8. The survey as a whole, and the results were discussed, and recommendations were made.

12. ACKNOWLEDGEMENTS.

The writer wishes to express his thanks to Dr. A. L. Jolly, Lecturer in Economics, Imperial College of Tropical Agriculture, for the guidance and encouragement he has given the survey team during the course of the Sample Survey of Citrus; and to Mr. G. E. Hodnett, Statistician to the Regional Research Scheme, for his help and advice concerning the statistical aspects of the survey.

Thanks are also due to Mr. F. Allan, Co-operative Citrus Growers' Association, Port-of-Spain; and to Mr. J. Spence and Mr. Hosein of the Central Experimental Station, Centeno.

Finally, the writer wishes to acknowledge the co-operation of the remainder of the survey team.

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CITRUS SURVEY SAMPLE.

No.	Name of Owner	Name of Estate	Location of Estate	Acreage in Citrus
<u>STRATUM 1. (0 - 9.9 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
<u>STRATUM 2, (0 - 9.9 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
287	R. L. J. Pierre	Good Hope	2 $\frac{1}{4}$ Mile Post, Cunapo Southern Road.	6.25

CITRUS SURVEY SAMPLE.

No.	Name of Owner	Name of Estate	Location of Estate	Acreage in Citrus
<u>STRATUM 3. (10 - 99.9 acres, below 100" Rainfall)</u>				
5	F. A. Agostini Ests. 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, Tunapuna.	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 Ests. Ltd.	Corsica	Brasso	22.80
101	Est. of A. G. de Caires		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

CITRUS SURVEY SAMPLE.

No.	Name of Owner	Name of Estate	Location of Estate	Acreage in Citrus
<u>STRATUM 3. (= 10 - 99.9 acres, below 100" Rainfall)</u>				
203	David Satnarinesingh	Terdant Vale	Chin Chin Road, Cunupia.	26.00
214	Ramsood Maharaj	Liverpool	Chin Chin Road	14.00
243	Ramnarine Mahabir	La Hope	Montserrat Ward	26.00
253	Koorban Ali	Mount Pleasant	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
<u>STRATUM 4. (10 - 99.9 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

CITRUS SURVEY SAMPLE.

No.	Name of Owner	Name of Estate	Location of Estate	Acreage in Citrus
<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 Expt. Station	Central Expt. Stn.	Piarco	107.00
167)	Nariva Cocal Ltd.	Las Hermanas	San Raphael	100.50
176)				140.00
180	Palo Seco Estates Ltd.	Cyrnos	Siparia & Palo Seco	131.50
<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	239.00

APPENDIX 2.

MELANOSE SURVEY - RESULTS (1)

1. Estimated Number of Trees (N)

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

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

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

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

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

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

	Under 100" Rainfall	Over 100" Rainfall	TOTALS	% S.E.
0 - 10 acres	21,780 ± 9,051	10,150 ± 5,464	31,930 ± 10,541	33.01%
10.1 - 100 acres	125,225 ± 21,088	12,025 ± 2,408	137,250 ± 21,225	15.46%
Over 100 acres	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 P A in 100's. (Yna)

	Under 100" Rainfall	Over 100" Rainfall	TOTALS	% S.E.
0 - 10 acres	43,780 ± 9,605	7,050 ± 5,363	50,830 ± 11,000	21.64%
10.1 - 100 acres	151,300 ± 29,274	10,875 ± 5,406	162,175 ± 29,770	18.36%
Over 100 acres	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.	13.75%	35.23%	12.91%	

6. Estimated Number of Fruit in Category PU in 100's. (Ypu)

	Under 100" Rainfall	Over 100" Rainfall	TOTALS	% S.E.
0 - 10 acres	6,490 ± 1,979	300 ± 243	6,790 ± 1,994	29.37%
10.1 - 100 acres	54,225 ± 14,918	100 ± 232	54,325 ± 17,961	33.06
Over 100 acres	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.

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

8. Estimated Number of Trees bearing any Diseased Fruit.

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

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

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

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

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

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

	Under 100" Rainfall	Over 100" Rainfall	TOTALS	% S.E.
0 - 10 acres	30.24 ± 2.31	58.00 ± 15.40	35.66 ± 6.65	18.64%
10.1 - 100 acres	37.86 ± 1.65	52.28 ± 6.69	38.80 ± 1.12	4.95%
Over 100 acres	60.90 ± 0.24	94.34 ± 0.09	72.21 ± 0.02	0.03%
TOTALS	42.84 ± 0.76	80.03 ± 1.52	49.19 ± 0.36	
% S.E.	1.77%	1.89%	0.07%	

12. Estimated Percentage of Fruit in Category PA (Ypa) of the total (X)

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

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

	Under 100" Rainfall	Over 100" Rainfall	TOTALS	% S.E.
0-10 acres	9.01 ± 0.75	1.71 ± 0.58	7.11 ± 0.59	8.30%
10.1 - 100 acres	16.39 ± 2.79	0.43 ± 0.41	15.36 ± 0.62	4.04%
Over 100 acres	17.91 ± 0.03	0.37 ± 0.03	12.00 ± 0.02	0.16%
TOTALS	18.81 ± 0.41	0.60 ± 0.09	13.21 ± 0.27	
% S.E.	2.59%	15.0%	2.04%	

14. Estimated Percentage of Trees bearing Fruit in Category N only of the total (N₂)

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

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

	Under 100" Rainfall	Over 100" Rainfall	TOTALS	% S.E.
0 - 10 acres	100.00 ± 0.00	50.00 ± 34.60	88.12 ± 8.22	9.33%
10.1 - 100 acres	71.22 ± 5.12	60.78 ± 14.53	70.07 ± 4.84	6.91%
Over 100 acres	54.88 ± 29.20	20.33 ± 14.50	42.55 ± 19.47	45.78%
TOTALS	69.76 ± 7.04	35.40 ± 9.45	73.47 ± 8.69	
% S.E.	12.83%	26.69%	11.83%	

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

	Under 100" Rainfall	Over 100" Rainfall	TOTALS	% S.E.
0 - 10 acres	71.43 ± 6.84	91.66 ± 6.92	73.62 ± 5.58	7.58%
10.1 - 100 acres	68.78 ± 1.95	96.08 ± 2.51	74.98 ± 1.84	2.45%
Over 100 acres	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%	

APPENDIX 8.

MAP OF TRINIDAD SHOWING LOCATION OF ESTATES
IN THE SAMPLE

10° 40' N.

10° 10' N.

61° 0' W.

61° 31' W.

Port-of-Spain
I.C.T.A.

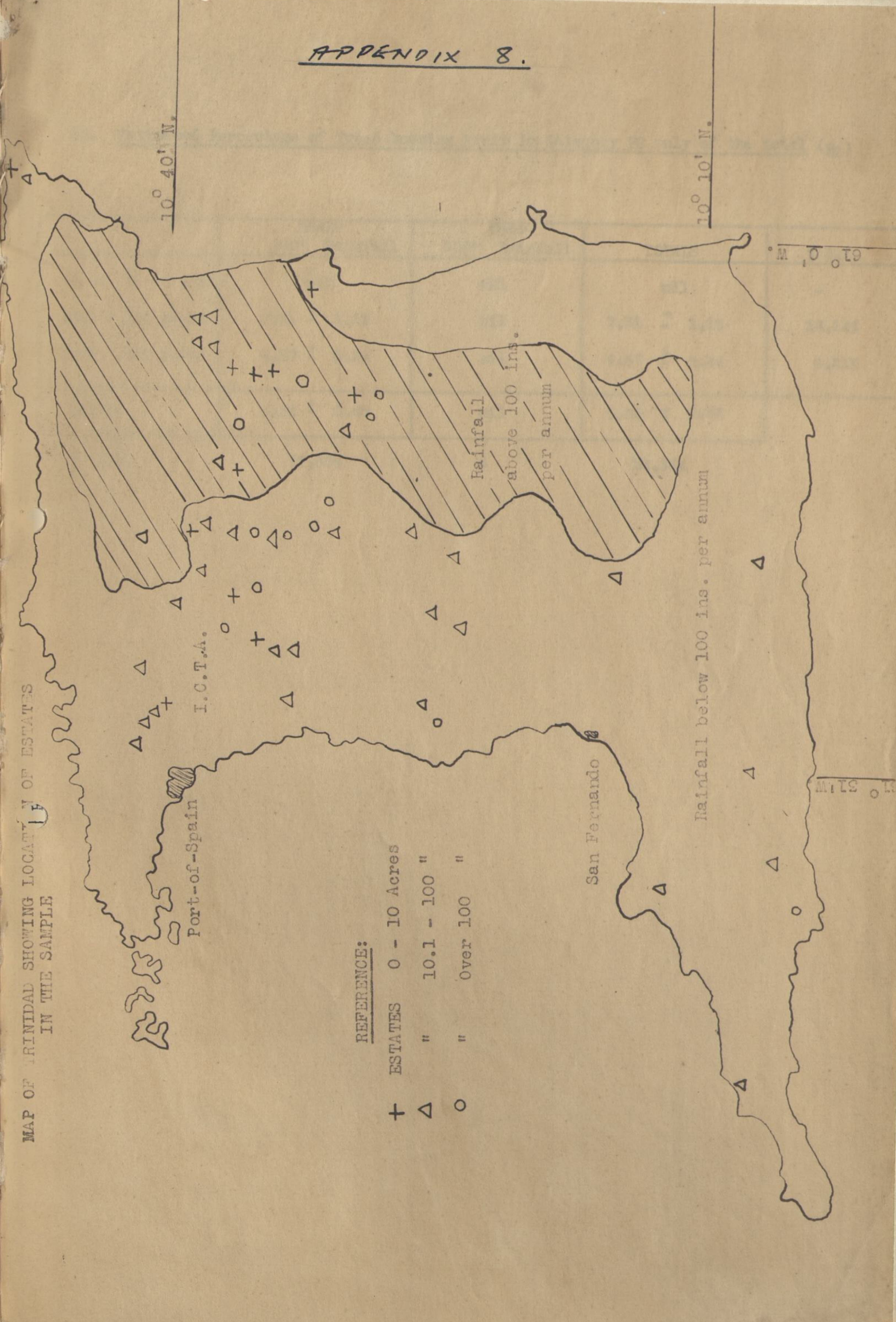
San Fernando

REFERENCE:

- + ESTATES 0 - 10 Acres
- Δ " 10.1 - 100 "
- " Over 100 "

Rainfall
above 100 ins.
per annum

Rainfall below 100 ins. per annum



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

	Under 100" Rainfall	Over 100" Rainfall	TOTALS	% S.E.
0 - 10 acres	nil	nil	nil	-
10.1 - 100 acres	7.31 ± 1.13	nil	7.31 ± 1.13	16.14%
Over 100 acres	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%

APPENDIX 3.
MELANOSE SURVEY.

COMPUTATION SHEET (1) APPENDIX 3
 x = crop estimate (100's).
 y = No. of fruit without melanose (100's).

STRATUM: 5. $n' = 8, g' = 1, g'' = 150, (g'g'')^2 = 22,500, \bar{n}''_o = 38.63, n'\bar{n}''_o = 309.04, \alpha = 0, \beta = 307.80.$

ESTATE	n''	$h''-1$	$S''(y)$	$(S''(y))^2/n''$	Diff.	$S''(y^2)$	$S''(x)$	$(S''(x))^2/n''$	Diff.	$S''(x^2)$	r	$S''(x).S''(y)/n''$	Diff.	$S''(xy)$
31	78	77	9.3	1.11	5.38	6.49	240	738.46	82.54	821	0.04	28.62	- 4.92	23.7
33	23	22	65.1	184.26	39.83	224.09	67	195.17	41.83	237	0.97	189.64	40.06	229.7
37	83	82	165.1	328.41	164.32	492.73	216	562.12	103.88	666	0.76	429.66	96.44	526.1
43	12	11	40.5	136.68	22.69	159.37	50	208.34	37.66	246	0.81	168.75	26.95	195.7
73	32	31	58.4	106.58	108.46	215.04	98	300.13	109.87	410	0.59	178.85	97.35	276.2
165	44	43	128.6	375.86	166.28	542.14	156	553.09	96.91	650	0.83	455.95	108.65	564.6
167	9	8	23.9	63.46	8.19	71.65	28	87.12	10.88	98	0.85	74.36	8.34	82.7
180	47	46	81.6	141.67	33.63	175.30	84	150.13	31.87	182	0.97	145.84	32.36	178.2
Total	328	320	572.5	1338.03	548.78	1886.81	939	2794.56	515.44	3310	5.82	1540.41	405.23	2076.90

$S' (h''^2) = 18,884$

C.F.M.	13,448	999.26		999.26		2688.17		2688.17		1638.95		1638.95
S. S:	5,436	338.77	548.78	887.55		106.39	515.44	621.83	- 32.71	405.23		708.05
d. f.	7	7	320	327		7	320	327		7		320
M.S.	776.57	$A_y = 48.40$	$B_y = 1.72$			$A_x = 15.20$	$B_x = 1.61$		$A_{xy} = -4.67$	$B_{xy} = 1.27$		
Var.	0-			12,619,800				11,881,800				

Est. Totals: $\underline{N} = 49,200 \pm 0.$ $\underline{Y} = 85875 \pm 3,552.$ $\underline{X} = 140850 \pm 3,447$

$\underline{r}^2 = 0.3721$

$- 2 \underline{r} = - 1.22.$

$Q = 0.759681.$

$S^2 q = 0.002374$

$\frac{S' (n'')}{(S' S'' (x))^2} = 0.0000372$

$\text{Var. } \underline{r} = 0.0000000883128.$

$S.E. \underline{r} = \pm 0.000297.$

u'' = number of trees sampled with no melanose.
(category N).

STRATUM: 5. $n' = 8, f' = 1, f'' = 1/150.$

Estate	n''	$n'' - 1$	u''	\underline{p}''	\underline{q}''	$V(\underline{p}'')$
31	78	77	0	0.00	1.00	0.000
33	23	22	20	0.87	0.15	0.005
37	83	82	51	0.61	0.39	0.003
43	12	11	3	0.25	0.75	0.016
73	32	31	3	0.09	0.91	0.003
165	44	43	28	0.64	0.36	0.005
167	9	8	4	0.44	0.56	0.027
180	47	46	39	0.83	0.17	0.003
Total	328	320	148	3.73	4.27	0.062

$\underline{N}_2 = \underline{49,200} \pm 0.$

$\underline{p}' = \underline{0.4512} \pm 0.062.$

$\underline{U}'' = \underline{22,199} \pm 3050.$

S.E. $\underline{U}'' = 3001.2$

APPENDIX 5.

MELANOSE SURVEY

Enumerator's Name: _____ Estate & Field No.

..... Date

Recording Times: Commenced Completed

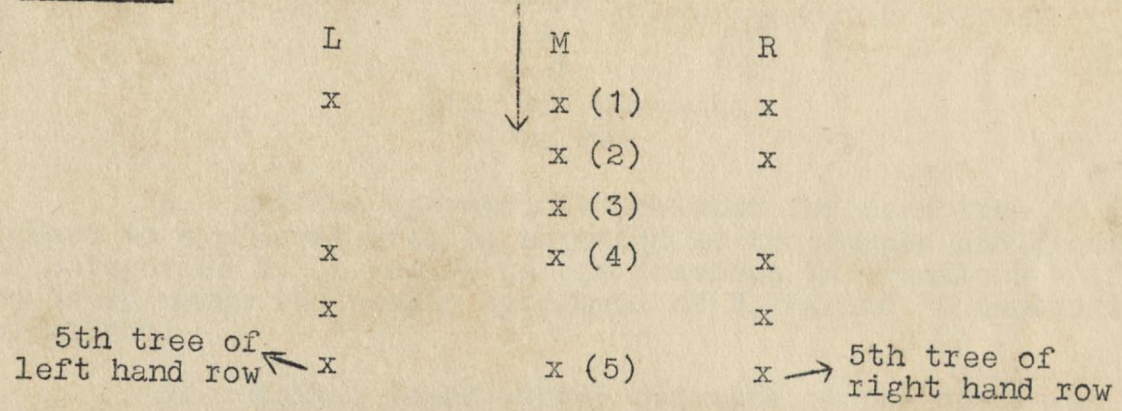
Tree No. & Row			Category			Crop Estimate (100's)	Tree No. & Row			Category			Crop Estimate (100's)
L	M	R	N	PA	PU		L	M	R	N	PA	PU	
37A			6	3	1	4			446C	2.4	1.2	0.4	
		39C	7	3	0	5	458D			3.5	1.5	0.0	
	48B		5	4	1	4		483A		2.0	1.6	0.4	
		80B	4	3	3	3		485B		1.2	0.9	0.9	
81D			5	2	3	6	522C			3.0	1.2	1.8	
	94A		TOTAL =			<u>22</u>			533A	<u>12.1</u>	<u>6.4</u>	<u>3.5</u>	
		102A						542D	TOTAL = <u>22</u>				
130C								572D					
	141D						576B						
	158C							592C					
		167D						614B					
195B								626C					
	201B						648A						
		206C						651A					
245A							652D						
	254A							681B					
278D								712A					
		283B						718D					
		302A					735C						
	333D						755B						
348C								757C					
	370C							776D					
392B							816A						
		397D						836B					
425A								838C					
	445B						860D						

MELANOSE SURVEY

Instructions to Enumerators:

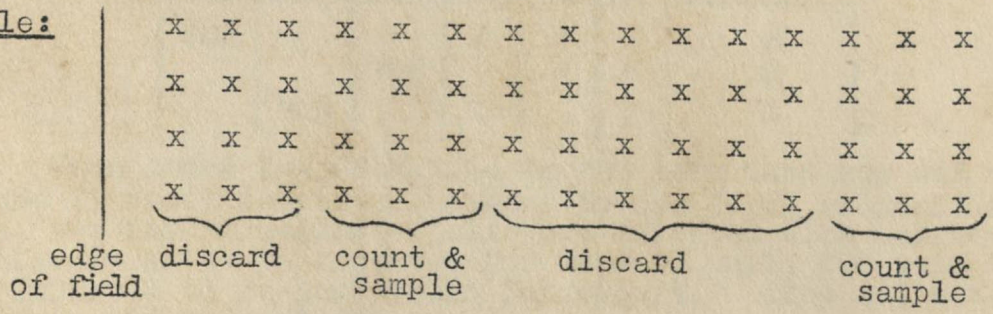
1. Enumerators will be provided with (a) maps clearly demarcating those fields in the estate that are included in the survey, (b) a combined record sheet and list of random numbers - the latter indicating those trees to be sampled within each field, (c) specimen samples of N, PA and PU categories for 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:



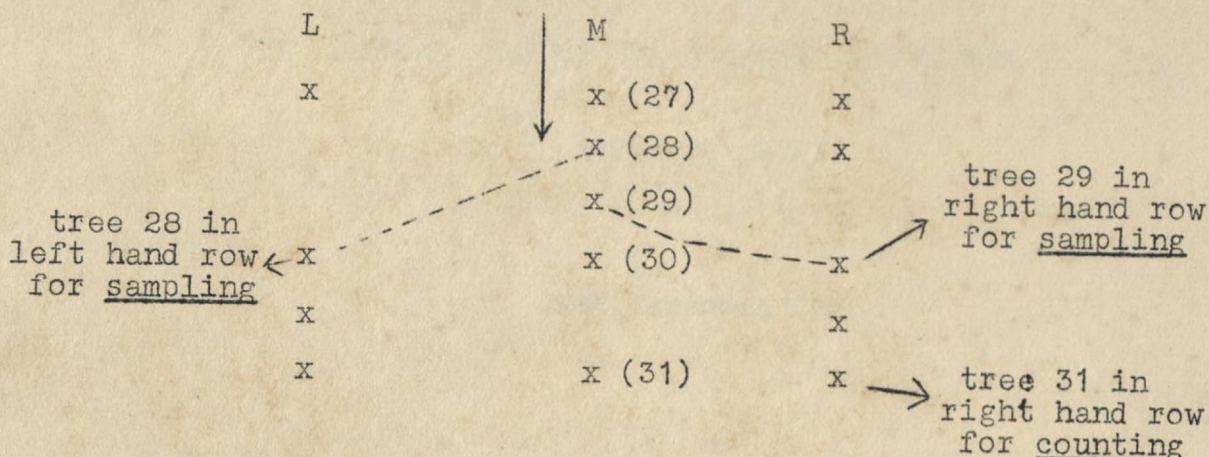
5. In the case of larger estates (those estates concerned will be indicated to the enumerators) this "3-row counting" technique will be somewhat modified and only 3 adjacent rows within each nine rows will be counted and sampled. Thus enumerators will disregard the first three rows (at the edge or boundary 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:

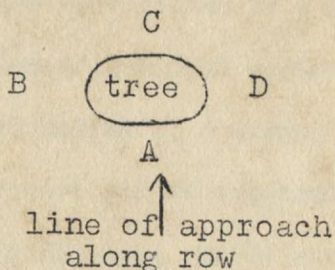


6. Counting is commenced at the tree indicated on the map and is continued along the middle row (of each 3 rows) until the first (lowest) number on the list of random numbers provided is reached. Random numbers are printed in three columns, each of the columns from left to right representing the left, 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			2	6	2	2
		72C		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.

C

O

APPENDIX 7.

P

Y

THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE,

TRINIDAD, B.W.I.

10th December, 1957.

TO WHOM IT MAY CONCERN.

The bearer of this letter is a postgraduate student of the Imperial College of Tropical Agriculture who, under my supervision, is participating in a survey of Melanose disease of grapefruit. The surveyor is required only to inspect selected trees for the disease; he is not required to pick fruit or remove any other material.

I should be grateful if you would afford him facilities for making his inspection of your grapefruit trees.

Signed: A.L. Jolly
(Lecturer in Economics).