A Note on

COFFEE RESEARCH IN SOUTH INDIA

by

W. WILSON MAYNE

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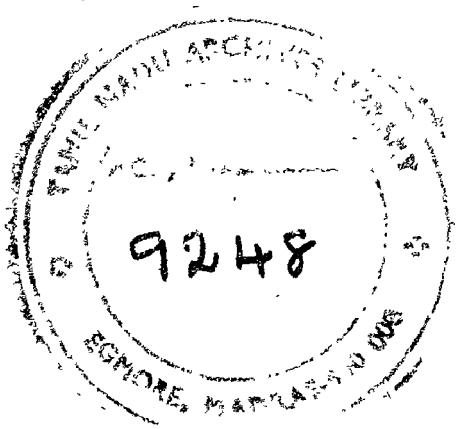

Preface

This memorandum consists of that part of a report submitted to the Indian Coffee Board on the organisation of coffee research in South India, dealing with the initial programme of work recommended for the research organisation. The remainder of the report dealt with the details of the staff, buildings and land required to carry out the technical programme.

I believe that the successful development of a research organisation in the service of an industry requires the careful planning of the lines of work to be undertaken. In the past, industries have frequently decided to undertake research, determined the amount of money they will spend on it and appointed a staff without any clear idea of what work they wish the organisation to carry out ; sometimes indeed without any clear conception of the possibilities and limitations of research methods. The results, while not always unsuccessful, depended far too much on the personalities and predilections of the staff appointed. There is still a great deal to learn about the special problems of organising research services and far too little thought has been given to the conditions for success. One of the important conditions is to ensure that the resources available are adequate to tackle the questions the industry requires investigated. This may demand the limitation of the investigations undertaken, or the provision of larger resources for the research. This obviously requires careful planning before embarking on any research programme.

The need for planning may be misunderstood—it does not mean the setting up of a cast-iron frame, limiting research to preconceived ends. It does mean the clear and detailed formulation of the problems to be studied and of the initial stages in their investigation. The results obtained in these initial stages will themselves determine the further development of the work, always with the guidance of the formulation of the problems originally drawn up. The plan is dynamic, not static, constantly under review and modified by the influence of its own development. In other words it has the unity of a developing organism rather than of a machine.

Such a plan would in no way limit the methods of approach to the solution of the problems and it would

recognise that the solution to some of them demands investigations of the type which might be regarded as falling within the sphere of ' pure ' science. In my opinion this distinction between ' pure ' and ' applied ' science has been over-emphasised and the essential unity of all scientific work, neglected. Whether the investigation of a problem is undertaken to satisfy an intellectual curiosity or to solve a practical problem, the methods of approach must be the same—the same technique, the same standards of rigorous proof and the same breadth of vision.

A second condition also requires some emphasis—the necessity of seeing the work of a scientific organisation as an integral part of the working of the industry. It has been said " any modern technical enterprise requires, or in any event has resulted in a high degree of specialisation of function " but " expertness is not an end in itself and (that) each skill is only part of the unity of knowledge necessary to do the job of developing and conserving resources " (D. E. Lilienthal ' TVA ' Penguin Books 1944). These remarks can be applied equally to a research organisation. It is of great importance to the success of the application of research to production that the industry should be looked at as a whole, not only by the research workers but by the actual producers. This implies that the place of the research organisation should be clearly understood as a vital and important part of the industry and not as a rather expensive luxury added on to it. This will require a change in attitude on the part of many producers who still regard the scientific worker in industry as some one to be called in, in times of trouble, but who can be ignored at all other times, and on the part of some scientific workers who tend to ignore all aspects of industry except those which appeal to their particular technical interests.

Within the scientific organisation, the same essential unity of effort must be encouraged and maintained. An attempt has been made in the memorandum to consider the work from the point of view of the individual production problems to be solved, rather than from the point of view of the specialist studies required for the solution of production problems. This approach will make heavy demands on the Director and require the utmost co-operation of the research staff, but in my view, it represents the central problem facing the staff and the Board's Research Committee.

Finally, it must be always remembered that the application of the scientific method to the problems of an industry makes demands not only on the research worker, but also on the producer. It is not sufficient for an industry to consider that by providing funds for the maintenance of a group of scientific workers, all it then has to do is to sit back and wait for the results to accrue in the form of simple formulæ for manures or disease control measures or fool proof instruction for this or that estate operation. Full advantage of the research organisation can only be secured if every producer realises that the application of research results to production demands a real understanding of the recommendations in relation to the individual circumstances of his property. As a rule, the results of research are generalised and, especially in biological research dealing with highly variable material and a wide variety of environmental conditions, require adaptation to meet individual cases. This adaptation must remain largely the responsibility of the individual estate owner or manager. It is incumbent on every producer to make an effort to acquire a scientific habit of mind and a sufficient acquaintance with the fundamentals of the sciences concerned with crop production to enable him to appreciate the place that technical advances made by research workers can play in the business of production and the adjustments which may be necessary to meet the circumstances of his individual property. The existence of such skilled management will not only ensure a rapid incorporation of research results in practical production but will act as an immense encouragement to the research workers.

Research work can only flourish in a favourable environment and that environment is not only a matter of adequate staff remuneration, security of employment and suitable equipment and resources, essential as these are. It will reach its full value only if it finds an atmosphere of critical appreciation and understanding amongst those whom the research is intended to serve. It is certain that the full flowering of the marriage of research and production will not be attained until a scientific outlook is widely diffused among producers. When this happens we can expect gains in productive efficiency and in the well being of all connected with the industry which will surpass anything so far experienced. I hope that this memorandum may do something to assist in bringing about such developments which will make the research organisation of the

South Indian coffee industry not only a source of economic strength to the industry and through it, to the country, but also an example of the fruitful union of research and production upon which I believe the prosperity of all industry rests.

In conclusion, I should like to pay a tribute of thanks to those producers and other research workers, mainly in the service of the Mysore Department of Agriculture, contacts with whom have made it possible for me to prepare this memorandum and assisted in developing my views of the effective application of research to production.

7th August 1946. W. WILSON MAYNE

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I. INTRODUCTION

The scheme of work for a research organisation to deal with the problems of a productive industry falls into several distinct, but overlapping spheres. In the first place, the organisation should become the repository of knowledge of the technique of production in the industry it serves; secondly, it should investigate the difficulties of production with a view to providing solutions for them; thirdly, it should examine the existing methods of cultivation with a view to their improvement; and finally it must endeavour to convey the results of its work and its critically sifted experience to the widest circle of practical producers, in a form which will encourage them to incorporate them in their systems of management.

Both the Management Committee and the staff must realise that the function of a research institute cannot and must not be limited to the experimental investigation of production problems. It must include the accumulation of knowledge of the coffee industry by observation, so that the problems can be seen in their true relation to the whole productive process, and that producers can feel confident that the research officers understand the industry they are serving. It must also devote thorough attention to the problem of presentation of results of both experiment and observation in a form which will reach and influence the producer.

This emphasis on the threefold nature of the work of the research organisation is based on the fact that in the past there has been much good research done on agricultural and horticultural crops which has either failed to affect production or has been an inordinately long time in reaching the producer, from the neglect of the first or the third of the main branches of work outlined above.

Plenty of attention has been directed to the problem of conveying the results of research to the producer, but the importance of the research worker being thoroughly acquainted with the whole technique of production has not been so frequently considered. It is especially important in the case of specialised crops, such as tea, coffee and rubber, since upon the producers' confidence that the research worker does understand his problems, depends to a high degree the extent to which the results of research can influence the production technique. The agricultural research workers who have influenced agriculture most have been precisely those who understood the farmer's business best.

The logical order of these activities is (*i*) knowledge of the industry, (*ii*) investigation of its problems, and (*iii*) dissemination of the results of research and observation. Naturally this order is only a logical one, since both the first and second groups of activities will in practice proceed simultaneously. For the purposes of discussion, however, it is considered desirable to consider in some detail, how the research organisation can set about attaining that breadth of knowledge of the industry, which will enable it to play its full part in developing the industry.

Turning to the investigational activities, these may be grouped into those investigations designed to solve problems connected with the normal cultivation systems practised on the best managed properties; those investigations designed to solve problems of rehabilitating poor coffee; and those designed to create an improved system of management based on new strains of plants and planting systems modified to secure the highest degree of efficiency.

Thus, fair to good areas of existing coffee present problems which require solution and which must be tackled within the limits of the existing management system in so far as these cannot be changed without a more or less complete renovation. Such problems as manuring, disease control and pruning demand investigation within the limits of existing coffee stands. A little lower in the scale of efficiency are estates of low average yield, demanding the investigation of means of improvement, but also raising the question of how far improvement can be secured without a replanting programme. Finally there is the question of the best methods of rehabilitating the vast areas of worn out coffee and of reopening abandoned and semi abandoned

coffee estates which offer opportunities for radical changes in the planting material used and in the lay out of plantations with an eye to the new problems of labour supply and costs and the new methods of soil management, disease control and plant training which research has already provided and will continue to provide in the future.

The third group of activities is concerned with bringing the results of research to the grower. While the coffee industry is in a better position to make use of the written word than many other agricultural industries, it is clear that ability to read and even a high standard of education and culture, is no guarantee that the bearing of the printed results of research on experience will be readily appreciated. The fact is that the weighing of evidence of a scientific character is not commonly a product of the ordinary educational system and this is partly responsible for the often slow spread of well established technical results among educated producers. It is therefore a matter of some importance to consider the methods of presenting the results of the work of the organisation in some detail.

In dealing with the technical programme, every attempt will be made to keep these three main aspects of the work in clear view.

II. THE RESEARCH ORGANISATION AND THE SYSTEMATISATION OF COFFEE MANAGEMENT METHODS

The coffee industry in South India consists of some 4,500 holdings ranging in size from an acre or so, to 1,000 acres and the total production divided by the total acreage indicates a yield level of well under 200 lbs. of dry coffee per acre, even in a reasonably good year. The maximum average yield of *arabica* coffee in South India under the best management at present is probably about 700 lbs. per acre, while *robusta* may reach 1,000 lbs. per acre under similar circumstances. Looking at the problem in terms of yield of dry matter per acre, the yield compares very unfavourably with tea, whose average yield in South India is now about 600 lbs. per acre and is barely as good as the average yield of rubber, a crop at the limit of its geographical range in South India.

There are doubtless many factors involved in this very low average yield, many of which hardly come within

the normal field of a research institute. Nevertheless, the problem demands a scientific investigation and the research organisation cannot avoid the responsibility of tackling the problem, merely because some factors are financial, economic and sociological. It is certain that the problem cannot be wholly solved by the research organisation alone, but it is equally certain it cannot be solved without it. My own views on the problem have been outlined in a pamphlet entitled " The Agricultural Problem of South Indian Coffee " published by the U.P.A.S.I. in 1942. I believe this to be a fair statement of the general nature of the problem, although there may be argument about details.

The question is how this fundamental problem can be tackled by the research organisation to provide a better " documented " case than could be produced by a single individual drawing mainly on experience. In my view, the first task of the research organisation should be in the nature of a survey of the industry, but this survey should be an intensive and not an extensive one. Rightly conducted it should prove not only of the utmost value to the research officers themselves but should define the lines of research more clearly and provide the basis for a sound body of knowledge of efficient coffee management.

The Board is now in possession of the yields of coffee estates for a number of years and it should prove relatively simple to select representative samples of " poor," " average " and " good " estates in relatively homogeneous districts. As an example, estates might be selected on the basis of yield in the wet zone of North Mysore, in the dry zone of North Mysore, in the Saklespur area, in North Coorg, in the Suntikoppa area, in South Coorg, in the Shevaroys, in the Coonoor-Kotagiri area of the Nilgiris and in the Pulney area for *arabica*, and in the North Mysore wet area, South Coorg and Malabar Wynaad for *robusta*. On this basis and with the co-operation of the owners, these ' samples ' would be subject to a detailed survey by the technical staff. Such a survey would include a study of the soils both in the field and the laboratory, the nature and composition of the shade, the incidence of diseases and pests, the age and condition of the coffee bushes and the agricultural procedure followed in recent years. Due allowance would have to be made for difficulties of labour during the war years.

A procedure of this type has been followed in connection with the cacao industry in Trinidad, which from an economic point of view has many illuminating parallels with the coffee industry in India. Useful material on the methods employed will be found in the reports of the Cacao Research Scheme in that island and in the pages of " Tropical Agriculture." Much of the methods and experience there can be adapted to a similar coffee enquiry.

Such an investigation would involve all the staff and the details of the methods employed would require working out in full consultation, so that the various enquiries would dovetail together to form as complete a picture as possible. The aim is to study selected samples as intensively as possible and the developments in sampling technique which have played a big part in British agricultural research in the war years could doubtless be fully utilised in arriving at representative samples.

There is a danger in surveys of this kind that the aims may be lost sight of, unless they are very carefully formulated. It is anticipated that such a survey will provide answers to the following questions :

1. Is low yield primarily a matter of climate, soil or plant condition, or is it primarily financial and economic ?

2. How do cultural practices differ on " low ", " medium " and " good " yielding estates, and to what extent are they responsible for low yield levels ?

At the same time, it should indicate to what extent improvement can be brought about merely by modifications of management methods or whether complete replanting or some other form of rehabilitating is a necessary prerequisite of a return to economic production. In this connection, useful guidance can be secured from Shepard's work in Trinidad, recorded in a series of studies entitled " Cacao Industry of Trinidad ", " Some Economic Aspects " published between 1932 and 1937 by the Imperial College of Tropical Agriculture.

As a result of this survey, the research organisation will be in possession of a mass of data on management methods which will form the basis for its general advisory work. This will be supplemented by the observations of the staff in the course of advisory visits for a variety of

special purposes to estates. At a very early stage, the technical officers should all learn to make accurate observations according to a defined plan which can be recorded for the use of the whole organisation. It should be possible for the entomologist to record in general but accurate terms the nature of the soil, the shade composition and the disease position in an estate to which he may be called on an entomological enquiry, and for the chemist to record generally the incidence of say borer, or green bug on an estate whose soil he is examining.

This is very important, since no problem—plant pathological, entomological, chemical—can be considered without reference to the whole environment in which it occurs. A chemist, who doesn't know one shade tree from another, an entomologist who does not recognise soil erosion or signs of defective drainage or a botanist who cannot recognise a borer beetle, is no use to a research organisation in the service of an agricultural industry.

If careful observation, possibly assisted by some general schedule of features to be recorded, is regulary carried out, the organisation will rapidly accumulate a store of knowledge of the industry which will be invaluable and will be constantly available to keep the research work in proper perspective and to strengthen advisory work of all types. This store of knowledge will be the soil on which the research work can grow.

III. THE RESEARCH PROGRAMME

While the survey outlined in Chapter II might logically precede the formulation of a research programme, coffee research is not starting at this stage from nothing and past experience and past research clearly indicate a wide range of problems upon which investigation must continue or must be initiated with the greater resources now to be made available. It may be that an intensive survey may reveal new problems not previously suspected but it is unlikely that they will exceed in importance those of which previous workers and coffee growers are well aware. In fact, there are more problems than any reasonable sized research organisation can possibly tackle and the main question is that of selection.

In the various sections which follow, it is proposed to outline the problems which I consider most urgent and the

lines which seem to me the most profitable to pursue. It may be found necessary to select still further to keep the work within the capacity of the staff, but it is hoped that the relative priorities will be clear enough to permit such a selection without undue difficulty. In any case, it always has to be borne in mind that exceptional circumstances may demand alterations in programmes to cope with some unexpected threat to the industry. Such alteration should however only be made after the most careful consideration by the research staff and the experimental sub-committee which should be set up by the Research Committee.

It is of course natural that much of the work to be dealt with in the succeeding sections is the continuation of work which is already in progress, or developments from it. Obviously, the activities of the new expanded organisation will grow naturally out of the work which has been done by the Mysore Experimental Station and the U.P.A.S.I. staff in the past, while at the same time offering an opportunity of reviewing the work done up to date.

Considerable thought has been given to the question of how the research programme should be dealt with in this plan. Two main approaches are possible—the planning of the work of each division of the research organisation, or the definition of the major problems and indicating the part to be played by the research divisions. On the whole the second method seemed the more desirable, in that it will emphasise the essential unity of the research organisation and the paramount importance of co-operation in solving the principal problems. No problem is exclusively chemical, plant pathological, entomological or botanical and solutions demand joint endeavours. The problems are more important than the divisions, which are really matters of academic convenience.

The main problems which are dealt with are as follows:—

1. The problem of manuring coffee and its relations to shade, spacing and soil management.

2. The problem of the management of the coffee bush and its effects on blossoming and fruit set.

3. The problem of disease control in coffee with special reference to spraying and pruning.

4. The problem of insect pest control, in particular, of coffee stem borer, green bug in *arabica* and shot hole borer in *robusta*.

5. The problem of improving the type of coffee grown, in respect to yield, disease and pest resistance and quality.

6. The problem of establishment of replantings and the rehabilitation of poor coffee.

7. The problem of improving the preparatory processes to ensure uniformity and good quality.

Each of these seven main problems affect both *arabica* and *robusta*, and it is important that the needs of the latter crop are not overlooked, since evidence is growing that full advantage of its productivity and vigour is not at present being taken.

So far, work has been in progress touching all these problems, but the results are very uneven. The most substantial results from a practical point of view have been in connection with disease control. Technically very substantial progress has been made in connection with the control of borer and with the improvement of coffee types, but their effects on practice have so far been limited; in the first place, from apathy and economic difficulties and in the second, because the technical progress is still not sufficient for widespread practical adoption. The most serious lack of progress lies in the first problem—the manuring of coffee—though in my view, insufficient weight has been given to the considerable body of negative evidence, indicating that the application of fertilisers to mature coffee under South Indian condition has little direct influence on crop production.

It will be noted that throughout the discussion of this technical programme, the major emphasis is on the careful laying down of field experiments, on sound statistical principles. Much time and effort have been wasted in laying down experiments in which the developments of modern experimental technique have been ignored. It cannot be over-emphasised that if a trial of any kind is to be undertaken, the extra trouble in conducting it on a sound statistical basis will be amply repaid and will avoid frequent disappointments. The specialised services of the Imperial Council of Agricultural Research will be available to

assist in the selection of suitable experimental designs, but it is important that all the research officers should understand the application of modern statistical technique to the laying down of experiments and the interpretation of results.

IV. THE PROBLEMS OF MANURING AND SOIL MANAGEMENT

I am starting from the position that the coffee industry requires guidance on the utilisation of fertilisers more than almost anything else. The present outline is not intended as a plan to be followed slavishly but as a broad design, indicating how the whole work of the research organisation is inter-related in tackling problems of this kind.

Experience so far of laying out manuring experiments on established coffee estates has been almost uniformly disappointing. It is quite clear that the problem can only be approached by planting areas of coffee to fit an experimental design and not by imposing an experimental design on established coffee. In the first place, therefore, an experimental design to tackle the fundamental question of the role of the major plant nutrients must be drawn up. For such an exploratory task, the $3\times3\times3$ factorial design is probably the best. Such a design permits the testing of Nitrogen, Phosphoric Acid and Potash at three different levels, alone and in all possible combinations.

In the laying out of this and other experiments, there are certain desiderata essential to success. The size of plot must be so adjusted to give the utmost economy of area, consistent with a satisfactory level of accuracy and with the accommodation of a suitable shade plan which will permit each individual plot to constitute a shade unit. Experience with adult established coffee in South India indicates that a plot size much less than 100 trees gives very high figures for error, but work done by Gilbert in Tanganyika on younger coffee indicated that 20 tree plots were adequate. If a suitable area of young coffee is available it would be desirable to initiate a study of plot size of the usual type for both *arabica* and *robusta* on the model of Gilbert's work. The importance of using plots of coffee which also form units of shade design cannot be overemphasised as it is possible that many of the unsatisfactory results from manuring experiments in the past may have been due to complications introduced by shade heterogeneity. Taking into consideration, all the information

and experience at present available, a plot size of about 100 trees is recommended, although it seems likely that this could be reduced under the system of planting for experimental purposes now proposed. In estimating the area required for experiments on manuring cultivation, spraying, etc., an ultimate plot size of 1/10th acre per plot has been used.

The next point to consider is that fertilisers may exert quite different effects on coffee during its formative years from those during its adult productive years. Provisions must therefore be made for a series manured from the first year of planting and for a series in which manuring is deferred until full bearing is reached. Alternatively, the whole area could be manured in the formative years and discontinued in one series, when adult production was attained.

To cover these points in the main experiment it will be necessary to have four $3\times3\times3$ blocks, totalling 108 plots of 1/10th acre, *i.e.*, about 11 acres.

This stage of the work will require the co-operation of the Agronomist, the Chemist and an experienced planter, whose advice in deciding on a shade plan would be essential.

The next question would be a decision on the planting material to be employed. While in the interests of uniformity, vegetatively propagated material would undoubtedly be preferable, work on vegetative propagation has not reached a stage in India when such a course would be practical on the scale required. At this stage, the Botanist might be able to provide seed of a type of reasonable uniformity from his resistant selections, which could be used and the main plots could be sub-divided for comparison of Kent's and the selection. If this proved too cumbersome, an area at Balehonnur might be laid with $3\times3\times3$ blocks, two involving the selection and two a commercial Kent, to provide a repetition of the main experiments and to compare the selection with the Kent, but manuring all blocks either from the first year, or from attainment of maturity.

The actual plantings would be made from as uniform young plant materials as possible from nurseries raised under the most efficient conditions and large enough to dermit rigorous selection. The area to be planted would,

of course, have to be completely cleared. The chemist would be concerned with a full study of the soil in the experimental area at the beginning of the experiment and arrangements would be made for periodical re-examinations to study any changes following the differential treatments.

Before the actual planting, the whole staff of the station would need to confer on the records which must be kept. Much more is required than the mere recording of yields, if nothing is to be missed. The following list of points which can be considered of importance is illustrative rather than exhaustive.

1. Growth of the coffee plants—girth increases, shoot growth, leaf and shoot characters, attainment of topping height.

2. Blossoming—time of first blossom, amount of blossom, presence of abnormal blossom.

3. Fruit setting—percentage of blossoms setting fruit, amount of bean abnormality, physical characters of beans, (size, weight, etc.) quality and ultimate chemical composition.

4. Disease and Pest incidence—variations in attacks of *Hemileia vastatrix*, *Corticium koleroga*, *Coccus viridis*, *Xylotrechus quadripes*, etc.

5. Shade growth—girth increments, branch spread, amount of loppings (in the case of loppable shade) attainment of topping height (in the case of permanent shade).

6. Weed flora—nature of the weeds and their density.

The list is formidable, but all these features might be influenced by manuring, and the team of workers will have to decide on the type of records to be made, the sampling methods to be employed, and the type of samples required for laboratory study. The actual responsibility for carrying out the field recording will rest primarily on the Agronomist but other members of the staff will have to co-operate either directly or through their departmental recorders at certain periods.

The idea behind this design is to subject an area planted and brought into bearing under the highest standards of coffee husbandry but treated differentially with

fertilisers to the most complete and intensive study that staff and funds will permit.

In spite of the disappointing response to manuring in experiments on established coffee, I think the existing series of trials on estates under the "Quality Scheme" should be continued, together with the artificial shade trial at Balehonnur. This latter experiment has been rather disappointing up to date, but I consider that before its abandonment, a careful investigation should be made of the reasons for its poor performance. If the investigation indicates that the position is irremediable, then the experiment should be abandoned and the area diverted to other uses. In addition a mature coffee manuring experiment in a form similar to the trials already in progress on estates might be laid out at the field station after a careful survey to try and secure, by removal of shade if necessary, as uniform plots with reference to shade, as possible. I do not consider, however, that the annual submission of samples for testing is worth continuing, though if differential effects with respect to quantity begin to appear, then samples might again be prepared for quality valuation.

By extension from this main study directed to fertiliser response, two lines of work present themselves,—the interaction of shade and fertilisers and the interaction of spacing and fertilisers.

The study of shade by field experiment is beset with enormous difficulties. In the first place, there is little doubt that experiment with unshaded *arabica* is of little value in South India, but it should be possible to experiment with degrees of shading by varying the shade composition of large plots. The necessity for large plots rests on the need to minimise border effects, but there could be no objection to sub-dividing the main plots to study various interactions of manuring and spacing. The following design is purely suggestive but might form the basis for the study of this difficult problem. A shade unit of $\frac{1}{2}$ acre is utilised and three levels of shading, determined by the number of shade trees per unit, replicated say six fold. This will require 10 acres, each replication consisting of $1\frac{1}{2}$ acres and allowing for borders. The $\frac{1}{2}$ acre unit will be divided into three spacings, allowing 1/6th acre per spacing, and the spacings again divided into two halves, one given a basic fertiliser dressing and the other unfertilised. The

total number of ultimate plots will be 144. It is admitted that the lay out is complex and there are many difficulties but the problem is a fundamental one. No coffee producing country in the world plants coffee as closely as South India, and it is doubtful whether any country has a lower average yield per acre. It is not suggested that these are cause and effect, but it is mentioned as illustrating the need for investigation of this very difficult problem. Moreover, with increasing costs of labour, it is important to investigate any improvement which will render the problems of management simpler and which are likely to reduce the labour requirements. Wider spacing may be expected to reduce spraying costs and facilitate the use of light machinery in some areas. Similar considerations are involved in the study of tree training methods to be discussed in the next chapter.

The details of carrying out such an experiment are subject to an infinite variety of modification. The following appears to me a workable scheme. Initially the whole area would be uniformly planted with dadaps and thinned uniformly during the first four or five years in accordance with the best estate practice. Semi-permanent shade (*Grevillea*) and permanent shade (*Ficus spp., Bischofia, Eugenia*) would be planted at different distances, according to the final shade design and the dadap stand at five years would be adjusted to that design to give three degrees of density. This experiment too would have to be subject to close observational study, along lines similar to those suggested for the fertiliser response experiment.

It would be highly desirable for a member of the staff to visit Tocklai to see the shade experiments carried out there and to discuss with the Officers of the Indian Tea Association the problems involved in experiments involving variations in shade density.

Special attention would be devoted to disease and pest observations and of course standards of disease and pest control would have to be as uniformly high as possible, so that any differences would reflect the effect of the treatments in the presence of control measures.

Green manuring might be adopted as standard throughout for as long as the planting distances would permit and estimates of the quantities of green material produced

would be made for each treatment. Studies on weed development would also form part of the detailed studies.

The question of green manuring raises an important field of work in connection with the use of bulk manures and composts, and their relation to cultivation. This subject could also form part of a relatively complex experiment. Practical experience generally agrees that bulk materials give marked responses on coffee, but it does not necessarily follow that turning them into compost is the most efficient means of utilisation. The work done at Tocklai on tea manuring has suggested that the application of the materials of which compost is made may give as good if not better results than the prepared compost. Mulching has also proved of immense value in coffee cultivation and in East Africa has been the major achievement of research in increasing production. The use of these materials is also intimately bound up with cultivation since the question of the incorporation of organic matter or not is still insufficiently studied in connection with permanent crops. Furthermore, recent work on cultivation of temperate soils has indicated a radical change of views and the subject merits further attention in the tropics.

The following is offered as illustrative of a suitable type of experiment, but it can, of course be modified in a variety of ways. It is suggested in the first place for trial on mature coffee, but could be adapted with suitable modifications to a new planting. This should be done eventually, but would give place in the first two or three years to the two main experiments described above.

The main treatments would consist of three cultivation systems—(i) No cultivation, (ii) Annual forking after application of manures, and (iii) A trenching or renovation pitting system. Each of these would consist of $\frac{1}{2}$ acre plots, replicated six times. Each $\frac{1}{2}$ acre would be divided into 1/10th acre plots to carry each of five treatments—(i) Compost at 5-10 tons per acre, (ii) Artificials with the same main fertiliser elements as the compost, (iii) The raw materials of compost at the same rates as used for compost manufacture, (iv) Plain green material at 5-10 tons per acre, and (v) Control. Such an experiment would require about 10 acres of land.

This experiment should provide valuable information on the effects of cultivation, mulching and turning in

manures. It would afford an opportunity for studying the influence of these treatments on root distribution and the soil characteristics, such as the soil moisture and nitrogen variation through the year.

These three experiments could be regarded as the basic work on soil and shade management. Naturally they could be varied in an infinite range of combinations, but the above outline seems to me a reasonable choice of experiments in the first instance.

So far these experiments have been considered only from the point of view of *arabica* coffee. The question remains as to whether they should all be repeated for *robusta*. I think they should, but possibly the order of importance is not the same. It seems to me that the immediate problem in *robusta* is that of spacing and shading and that manuring can be left for later investigation. I would therefore suggest that to begin with a fertiliser trial with *robusta* should be deferred, until the experiments outlined below are well under way.

These suggestions for field experiment can be summarised as follows :—

A. At the Field Station.

New Planting.	1.	Fertiliser experiment ..	11 acres
	2.	Shading and spacing experiment (*robusta*) ..	10 ,,
	3.	Shading and spacing experiment (*arabica*) ..	10 ,,
	4.	Fertiliser experiment for *robusta*	11 ,,
Old Coffee.	1.	Soil management experiment	10 ,,
	2.	Established coffee area for 5 × 5 manuring experiment	3 ,,

B. At Balehonnur.

	1.	Prepare land for fertiliser experiment	11 ,,
	2.	Investigate the artificial shade and manuring experiment with a view to deciding its future.	
	3.	Continue the compost *vs.* artificials experiment already in progress.	

If the preparation of the thirty acres for planting at the Field Station should prove too heavy a task in the first year, the *arabica* shading and spacing experiment might be deferred.

C. Co-operative Experiments.

1. Continue the manuring experiments already in progress under the " Quality Scheme."

During the first year, the main tasks will fall on the field managers, the chemist and the Agronomist who together will have to fit the experiment lay out to the land selected, after a careful survey of the available area. Once this is done, the problem becomes purely one of practical planting—clearing, lining, pitting and planting, preferably with basket plants carefully selected for uniformity.

At this time, the chemist should survey thoroughly the soil of the experimental areas, to afford a basis for the later following of any changes brought about by the differential treatments.

Once the plants are in the field, the recording work will begin, although at first it will be on a limited scale and will only reach its full activity after five or six years. Some records will only require to be made at long intervals, others will need to be annual. This recording work will fall mainly on the Horticultural Division, with the assistance of the Plant Protection Division. It has already been pointed out that standards of disease and pest control must be the highest attainable, in order to eliminate as far as possible any disturbance from these factors.

No mention has so far been made of laboratory work in connection with this problem, beyond that involved in the soil survey of the experimental areas. On the whole, laboratory work will develop naturally from the field experiments, but the following lines of investigation for the Chemical Division should be taken up as time permits.

1. *Plant Injection.*—The striking work of Roach at East Malling on diagnosing nutritional deficiencies in fruit trees should be developed for coffee, both for studying the effects of the main nutrients and also for exploring the part played by minor elements. The importance of this investi-

gation lies in the possibility—made almost a probability by the negative results of so many coffee manuring experiments—that the response is masked by shade interactions. The direct injection of nutrients may reveal effects which can only be detected with difficulty or not detected at all in field experiments. The results of this work will undoubtedly assist in the interpretation of field experiments on fertilisers and indicate possible new avenues of approach to the practical problems of the optimum nutritional requirements of the coffee plant and the means of realising them.

2. *Foliar Diagnosis.*—The analysis of plant parts for the detection of nutrient deficiencies has also been largely developed in recent years and should also be explored in connection with coffee problems. Its main importance will arise after the manurial experiments have been in progress for some time, but the preliminary work can be readily commenced on material from the "Quality Scheme" manuring experiments which have already been in progress for a number of years.

3. *Soil Changes.*—The Chemical Division will also have to undertake the laboratory investigation of the soil changes which occur under the different modes of soil management in the experiments on this question. Such studies will involve both physical and chemical studies.

V. THE FIELD MANAGEMENT OF THE COFFEE BUSH

Ultimately, coffee yields depend upon the yields of the individual bushes. This may appear a truism but it is clear that there is often a tendency to regard coffee in terms of acres rather than bushes, and the amount of attention to individual bush behaviour has been rather limited in South India. It must be emphasised, however, that the investigation of the management of the coffee bush must start from a thorough knowledge of individual bush behaviour. The lines of approach therefore must follow lines similar to those developed in pomological research. Problems of pruning and training must therefore be tackled by the detailed recording of the individual coffee bush under varying treatments and larger scale field trials developed gradually.

The first task of the Agronomist in this connection should be the detailed study of suitable groups of normal

adult coffee, both *arabica* and *robusta*. The main purpose of this study is to familiarise this officer and his staff with the detailed growth response of the two species and to permit the working out of recording methods for the investigation of various methods of tree management. Some work of this nature has been done by the writer on *arabica* coffee, and if it is not possible to provide a written account of the work, the basic data and an outline of the recording methods used will be made available to the research organisation. It must be borne in mind that this work is of a preliminary nature, designed in the first instance to provide knowledge, upon which the solution of practical problems can be based.

The attack on practical problems will not need to await the outcome of this exploratory work, but its results can be made use of in improving the nature of the data collected, as the field experiments develop.

The practical problems which require investigation in the first instance are :

A. Pruning of existing single stem coffee.

B. Comparison of single and multiple stem systems.

These are all problems of management of existing coffee, though the second one is also applicable to the development of new plantings or replantings, but will be dealt with here for convenience.

A. Pruning of Existing Single Stem Coffee.

(*i*) *Arabica*.—While, many books give details on the training of young coffee—topping, centring, " herring bone " pruning of primaries, etc.,—these details are of little value in dealing with the average tangle of secondary, tertiary and higher order shoots, which represents the average crown of an adult coffee bush in South India. Few planters have succeeded in systematising pruning in South India, and no detailed studies have been made of the actual reactions to pruning. An experiment at Balehonnur, involving different degrees of pruning as judged by the weight of wood removed indicated that best results in terms of crop were secured with light pruning, but no attempt was made then to describe the nature of the wood removed in this type of pruning, so that it would be possible to give instructions in the art of pruning which could be readily followed.

At present, the U.P.A.S.I. Scientific Department has a pruning experiment in progress in South Coorg which is of an exploratory nature and should be continued under the aegis of the new organisation. In this experiment, an attempt has been made to systematise to some degree, the type of wood removed, at two levels of pruning carried out at two seasons—dry weather and monsoon. It is also associated with detailed studies of sample trees to investigate the growth response and fruit setting behaviour under the different treatments. There is also an experiment on pruning and spraying under the "Quality Scheme" at Balehonnur, but it is somewhat doubtful whether this need be continued as it is important that more land should be available there for the selection work, and it is unlikely that much further information will be obtained from it.

When the Field Station is available, the experience gained in the Coorg experiment should be utilised for the institution of a new experiment covering the same problem, although the results of the present experiment may indicate desirable modifications in treatments and in recording methods.

Assuming that the same essential design is utilised for a pruning experiment at the new station as that at present in progress in South Coorg, an area of mature coffee of about 2 acres will be required.

The existing experiment and any similar experiment laid down at the Field Station will afford material for studies by the Horticultural, Plant Protection and Chemical Divisions. The first will be primarily concerned with the effect of the treatments on growth, fruit bud differentiation and fruit set. Jointly with the Plant Protection Division, it will be possible to study any effects of the treatments on the bean diseases, such as Black Bean and on the incidence of it leaf and shoot diseases and insect pests. With the Chemical Division, studies could be made on the influence of pruning on grading, quality and bean composition.

From the practical point of view, the questions asked of an experiment of this type may be summarised as follows :

1. Does suitable pruning increase the average crop ?
2. Does it even out successive crops and afford a means of reducing irregular bearing ?

3. Does it permit economy of spraying materials ?

4. Does it reduce the incidence of any diseases or pests ?

5. Does it influence grading and quality of the produce ?

Other questions which may lead to further developments are :

1. If pruning increases the actual average crop, does it result from increased blossom bud production or from improved setting ?

2. Does pruning affect the blossoming under unfavourable blossom shower conditions and if so, how ?

(*ii*) *Robusta.*—Practically nothing is known about the best pruning system for *robusta* coffee in South India, or indeed whether any pruning is required at all. In fact, it is doubtful whether studies of pruning of existing *robusta* stands should be initiated until some basic information on growth behaviour has been collected and until the training systems have been more thoroughly tested. On these grounds it is considered that studies directed to devising *robusta* pruning systems should await on detailed growth studies and on training system trials. On the basis of the results of these studies, it should be possible to decide on the lines upon which *robusta* plant management should be developed.

B. Training Systems.

(*i*) *Arabica.*—The training of coffee bushes in South India has been almost entirely standardised on the single stem system, usually with an intermediate topping height at about 3 feet and a final height of about 5 feet. There is however, an urgent need for the study of the multiple stem system under South Indian conditions. This system has attracted considerable attention in East Africa with distinctly promising results. The preparation of suitable field experiments to study this training system is an early necessity. An experiment of the type in progress at the Tanganyika Coffee Experiment Station would serve for the initial exploratory work. This consists of three treatments —single stem, three stemmed multiple stem and three

stemmed Agobiada system. The method raises questions of spacing and of transforming from one system to the other, but in the first instance the trials should be made with at initial new planting. It would be essential to include a trial of spacing in combination with the training system since it is probable that the usual South Indian spacing distances will be too close for success with the multiple stems. The following is a suggested design for an experiment at the Field Station to study this problem. The main treatment would consist of three spacings,—say 6′ × 6′, 8′ × 8′ and 10′ × 10′ in the case of *arabica*—replicated six times and each main treatment sub-divided into three training systems, giving a total of 54 ultimate sub-plots of say 1/10th acre each, which with borders would involve about 6 acres.

The treatments would be expected to affect the following main factors :

(*a*) Yield per acre
(*b*) The set of the blossom
(*c*) The quality of the product
(*d*) The incidence of diseases and pests
(*e*) The economics of disease and pest control
(*f*) The soil cover

and these various factors will require attention from the Plant Protection and Chemical Divisions as well as the Horticultural.

It is probable that the question of the incidence of diseases and pests and the related one of the economics of their control will play a large part in determining the relative value of the training systems under investigation, and the Plant Protection Division will have to be very closely concerned with the study of these experiments.

It must be understood that it is not sufficient to judge the value of the treatments merely by the yield obtained ; efforts must be made to find the reasons for the differences since it may then be possible to adapt or modify the treatments to arrive at the most efficient method of management. This is in fact a matter of general application to experimentation with a permanent crop—yield differences alone are not sufficient to judge whether a given treatment may be of value, unless the reasons for the differences can be

ascertained. For instance, if two treatments gave the same final yield, it is not impossible that the yields are arrived at in different ways and a choice might need to be made of the least exhausting treatment physiologically, *e.g.*, a yield obtained from a high percentage set of the blossom would be less physiologically exhausting than a similar yield obtained from a much larger flowering and poorer setting.

(*ii*) *Robusta*.—The study of training systems is probably more important in the case of *robusta* than in the case of *arabica*. The position of *robusta* as a very suitable small holders' crop indicates the desirability of exploring the simplest management methods. So far in South India the general tendency has been to manage *robusta* along the same lines as *arabica*, but there is growing evidence that the management of *robusta* needs distinct methods. An early experiment on spacing and training, essentially using the same layout as for the *arabica* experiment, but using planting distances of say 8′, 10′ and 12′, is suggested.

The remarks already made under *arabica* about the type of information which should be collected apply equally to *robusta* with such modifications as are made necessary by the difference in the disease and pest problems.

The field experiments proposed in this connection may be summarised as follows :

1.	Preparing for the training/spacing experiment (*robusta*)	6 acres
2.	Preparing for the training/spacing experiment (*arabica*)	6 ,,
3.	Laying down a mature *arabica* pruning experiment	2 ,,

All these would be laid down at the Field Station, but it would be desirable, if possible to repeat the *robusta* experiment at Balehonnur. Of the two training/spacing experiments, I think the one with *robusta* should be given priority, if circumstances make this necessary.

Laboratory work in this field is limited, but the experiments will provide material for the laboratory study of fruit bud differentiation and the development of the fruit. The latter investigation is essential for the elucidation of the problem of Black Bean and related defects. Material

for the investigation will of course be drawn from both the pruning and training trials and from manuring experiments, and the results should afford the data on which control of the defects can be devised, or at the worst, the means of forecasting the conditions under which such troubles are likely to occur. The laboratory side of this work could be carried out best by the Plant Protection Division in close association with the Horticultural Division, which will be mainly responsible for the field recording of fruit set.

VI. DISEASE CONTROL

In South India, coffee is notable less for the variety of diseases to which it is subject, than for the importance of two or three fungus diseases which have largely influenced the history and management methods of the crop. The principal diseases are Leaf Disease, *Hemileia vastatrix*, Black Rot, *Corticium koleroga* and Die Back associated with, but only doubtfully caused by *Colletotrichum coffeanum*. Previous work has established that an economic control of all these diseases can be secured by Bordeaux spraying.

It is in the field of disease control that the greatest progress has been made, and the work of the plant pathologist is now mainly that of refinement. As far as the field experimental work is concerned, this can pass largely under the control of the Horticultural Division, which is primarily concerned with field experiments.

In this field, it is especially important to consider the experiments already in progress before detailing any fresh work. At Balehonnur, a series of three demonstration plots involving no spray, a spray in September and a spray in May and September and covering about $2\frac{1}{2}$-3 acres has been maintained under the same treatments since 1931, and records have been collected from them twice a year since September 1931. This demonstration area should be maintained and the records continued. A full note on the details of the recording will be prepared and submitted later as it is not necessary to go into details of this purely technical aspect of a single experiment here.

Also at Balehonnur, a new experiment laid out last year to study anew the problem of adhesive spreaders and strength of spray should be continued for four or five years.

It need not be a permanent experiment and the land can be held in reserve for later use by the Botanical Division.

Under the "Quality Scheme," the experiment at Balehonnur on spraying and pruning has already been mentioned and the suggestion made that it should be given up. Certainly as far as Balehonnur is concerned—and a very large area of coffee in South India elsewhere—unsprayed *arabica* coffee is no longer a subject for experiment.

In Coorg three experiments to study season of application and strength of spray mixture on private estates should also be continued to provide six years data, after which their future should be reviewed.

The problem now to be considered is in what further directions, research on disease control by spraying should be developed. In view of the progress already made, the question of trails over all the major coffee areas in South India to discover the limits of the economic usefulness of spraying arises acutely, but it is proposed to defer consideration of this question to a later chapter on co-operative experiments with estates. Here, consideration will be limited to work appropriate to the experiment stations.

In the first place, it is my opinion that the most serious lacuna in our knowledge of spraying lies in what may be called the mechanics of application. Along with this, is the possibility of improvements on the fungicide already in use. A wide range of experiments on the mechanics of application can be visualised, but I should place first the question of pressure of the application and the design of the nozzle. A suitable initial experiment to explore this field might be developed on the following lines,—three pressures with three or four nozzle types would be tested under field conditions using a motor sprayer and a standardised hose system and a standardised volume per tree. Such an experiment would best be conducted with main plots treated with one nozzle type and sub plots for each pressure. Assuming, 6 replications of 4 nozzle types combined with three pressure levels and ultimate plots of about 1/10th acre, an area of about 8 acres would be required. Accurate methods of recording disease intensity have been worked out, and yield records together with the time required to spray the plots with a given nozzle and a given pressure would afford a measure of the relative economic value of

treatments. Further lines of investigation would follow from this experiment, according to the results obtained. This experiment would be laid down at the Field Station, but might well be duplicated at Balehonnur.

A number of new fungicides have come on to the market in recent years and the number is not likely to decrease. These new materials and the requests of their manufacturers for the organisation of trials can easily become embarrassing, and it is necessary to establish some policy in respect of them. A satisfactory field trial, which alone can decide the suitability of a fungicide involves considerable land, time and materials, and there should be some weeding out of fungicides presented for trial in order to restrict full field trials to those which show definite promise. The principle should be established that no fungicide should be submitted to full field trial until it has shown a reasonable efficiency in small scale trials. The working out of small scale trial methods should be taken up at an early stage by the plant pathologist. A possible method, which has been given a preliminary trial is to select pairs of healthy leaves on bushes in the field at a time when leaf disease is at a minimum, and dip one member of each pair in the fungicide under trial and the other in a standard Bordeaux. The leaves are then left to natural infection and observations made at intervals to see the results. An investigation of such a method from a statistical point of view, should enable a satisfactory system to be worked out.

Proposals have been made by the Imperial Mycologist for the testing of fungicides and it is recommended that the coffee research organisation should play the important part its experience of fungicides warrants, in this work. I understand that two fungicides have been especially noted for test-Perenox and Fermate. Some work has already been done on the former and the results, while not indicating any notable superiority over Bordeaux, certainly warrant further trial. It is suggested that an experiment involving two strength of Bordeaux, two of Perenox and two of Fermate be laid down at an early date. This would involve 36 plots or roughly four acres, using a standard method of application approximating to normal working methods. This experiment should be duplicated at both the Field Station and Balehonnur.

The question of the use of adhesive spreaders is already under fresh investigation in the experiment at Balehonnur. Early work did not indicate any special value from these additions, but it was considered desirable to re-examine the question with the use of improved experimental designs and observational methods. For this study too, small scale studies along the lines indicated for the preliminary evaluation of fungicides, could be investigated.

There is one other feature of disease control by spraying which it would be worth studying and that is the refinement of spray timing. A suitable design would consist of three spray timings relative to the blossom before the South West Monsoon—say 20 days after blossom, 40 days after and 60 days after—combined with three timings after the monsoon, commencing with the first break in the weather after 15th August, and continuing with, say 25 days and 50 days later. This scheme replicated 4 times to give 36 plots and covering about four acres would provide valuable evidence in defining the most favourable spray time relative to weather. This could well be repeated at Balehonnur.

Summarising these field experiments, we arrive at the following :

At the Field Station

1. The study of the mechanics of spraying on adult coffee .. .. .. 8 acres
2. The study of new fungicides .. .. 4 ,,
3. The refinement of spray timing .. 4 ,,

At Balehonnur

The same series of experiments .. .. 16 acres.

As far as mechanics of spraying are concerned, it seems probable that the technique most suitable for Leaf Disease control, will be equally adapted to Black Rot control. It is already well established that the timing for the best control of Black Rot is as close to the onset of the South West Monsoon as possible and the studies on timing will be limited to the problems of Leaf Disease control. The study of fungicides should be primarily directed to Leaf Disease, but any opportunity presenting itself for tests against Black Rot on private estates in areas where Black Rot is serious could be made use of, and this question will be discussed more fully in connection with co-operative experiments.

The observational work involved in the experiments proposed will be heavy, but not, I think, beyond the capacity of the organisation. The observational methods in use, which are highly sensitive, are very simple and comparatively unskilled assistants can carry them out. Nevertheless it must be borne in mind that it may not be possible to carry out observational records in all the experiments every year, and it will be for the staff to find out what are the limits of this kind of work. Here, as in many other cases, the limiting factor will be the size of the recording staff available rather than the size of the technical staff.

There are no other fungus diseases of coffee in South India which require extensive field experiments for the investigation of control measures. Root diseases occasionally cause local trouble, but their importance is not such as to warrant large scale investigation. Most of such problems will fall within the sphere of advisory services and full use can be made of the extensive work done on the same problem in rubber and tea.

The problem of Black Bean and related defects has already been dealt with, and the part to be played by the plant pathologist considered in connection with the management of the coffee plant.

In the laboratory, apart from work on Black Bean and in connection with advisory work, the main problem is that of inheritance of resistance to *Hemileia vastatrix* strains which will have to be carried on in co-operation with the Botanical Division. A good deal of work has already been done on this subject and the technique has been worked out and reduced very largely to routine. There is, however, an urgent necessity for a more complete exploration of the number of strains of *Hemileia vastatrix* present in South India and an estimation of their abundance in the various coffee areas. This should form one of the main laboratory studies of the plant pathologist.

The work on plant injection would also provide material for laboratory studies on the relations of nutritional conditions to *Hemileia vastatrix* infection and development. While this work is of great academic interest, it should give place to studies on the strains of the fungus and the inheritance of resistance which are vital to development of the breeding work.

As opportunities offer, the plant pathologist could take up an investigation to clear up the role of *Colletotrichum coffeanum* in Die Back, which is still not entirely settled. However, as field evidence is clear that Die Back is largely associated with defoliation by other diseases, this is not an urgent problem from a practical point of view.

The plant pathologist will also touch the work on pruning in that it seems likely that the " carrying over " of sporulating pustules of *Hemileia vastatrix* through the dry weather is an important factor in initiating attacks in the following season. This matter will involve field observations of the usual type.

Robusta presents at present no serious disease problems. The plant pathologist should, however, maintain the records already being made at Balehonnur and on an area of *robusta* in South Coorg to study whether susceptibility of *robusta* to *Hemileia vastatrix* is on the increase, or whether new strains capable of attacking *robusta* are developing.

VII. INSECT PEST CONTROL

The insect pest problems of coffee are, like the disease problems, more notable for severity and importance of two or three insects rather than for a large variety. Only three pests have ever reached a level of importance to form prominent elements in a research programme, the rest being readily dealt with in the ordinary course of advisory work.

The principal insect pest of *arabica* is the stem borer (*Xylotrechus quadripes*) and a great deal of work has been carried out on it. The position at present is that existing knowledge *properly applied* could generally be relied upon to keep this pest at a level which would not warrant any control measures other than the rigorous elimination of attacked plants. A considerable amount of work has been done on insecticidal or ovicidal stem washes and the work done, both by the Entomologist at Balehonnur and the U.P. A.S.I. officer at Sidapur, should be critically examined. Trials by cage methods should be continued with the most promising methods already tried and with the new insecticides, D.D.T. and Gammexane. The major task of the entomologist should be the systematisation of a satisfactory cage technique for the study of stem washes. Satisfactory

field trials are very difficult to carry out to test treatments against borer and it is only after a preliminary sorting of treatments in cage tests, that they should be carried into the fields. Such field trials will not in the ordinary way be possible on the experiment station and it will be necessary to find areas on private estates where borer incidence is high enough to offer possibilities of differential effects of a size large enough for significance.

The problem of effective experimental design for borer control is a difficult one and the methods already used should be critically examined with the assistance of a statistical specialist.

The studies both at Sidapur and at Balehonnur on the seasonal distribution of emergence should be continued, with a view, if possible to establishing the relation of emergence to weather conditions. The studies to clear up the limits of the life cycle should also be continued until a clear statement of the position can be given. The former work, will assist in assuring the efficient use of insecticidal or ovicidal stem washes or stem rubbing, if these show sufficient promise to warrant their general recommendation.

While this work should be continued, I must express my view that borer control is more a matter of the efficient adoption of the advice already widely disseminated by the Mysore Agricultural Department and the vigorous enforcement of Pest Acts, than of any new control measures likely to result from further research.

The entomological section will be concerned with the experiments on manuring, spacing, shade, pruning and training in ensuring that present methods of borer control are thoroughly carried out and in observing whether the borer succeeds in defeating the control more in certain treatments than in others. At present, the control measures recommended are the regular and thorough inspection of bushes and timely destruction of attacked plants throughout the coffee on the experiment stations and regular stem rubbing prior to the borer flight season or seasons.

The next important pest is Shot Hole Borer of *robusta*. A considerable amount of work has been done on the life history and seasonal sequence of this pest at Balehonnur and it is to be hoped that this will be published in due course. From field experience of this pest, it seems likely

that the main sphere for further investigation of this pest will lie in a study of its incidence in the spacing, training and manuring experiments. The application of tree injection technique to modify the nutritional condition of trees might be useful in investigating the influence of the nutritional status of the tree on the establishment and multiplication of the insect. A search for strains of *robusta* resistant to this insect should be planned as part of the general programme for the improvement of *robusta* planting material.

Most of the work on this pest will be of a fairly straightforward nature in the first instance, mainly directed to studies of field populations and their fluctuations under different cultural conditions. It will require the elaboration of field recording methods suited to the insect under investigation.

The third insect pest or group of pests is represented by the scale insects, of which green bug is the most important. At present they are only locally serious pests but there is always a chance that a severe outbreak may develop, especially in connection with young replantings on which they can do serious harm. Very thorough work on this group of insect pests was done by Dr. Kunhi Kannan of the Mysore Department many years ago, but there is still scope for studies on the seasonal sequence of the pest in relation to weather and the part played by predators and parasites in maintaining it under control. Its importance in some of the North East Monsoon districts—the eastern Nilgiris and the Shevaroys—would warrant a re-examination of the position.

A series of tests of insecticides, including the newer types, in comparison with the fish or honge oil soaps in use at present should also be undertaken. These tests should be first on a laboratory scale or semi field scale. Field trials of the ordinary type are rarely practicable since the attacks are rarely sufficiently uniform over a large enough area for the purpose.

Summarising the programme for the entomologist, the following are the main lines of work :—

1. The continuation of steam borer emergence studies to discover the relation between emergence and weather.

2. Completion of studies on the duration of the life cycle.
3. Cage studies of insecticides and ovicides in comparison with controls and stem rubbing.
4. Study of suitable technique for field trials of insecticides, etc., which offer promise in cage trials.
5. Population studies of Shot Hole Borer of *robusta* under varying cultural and nutritional conditions in field experiments and by tree injection.
6. Exploratory studies with the dust insecticides, especially Gammexane and D.D.T.
7. Search for *robusta* types resistant to Shot Hole Borer.
8. Small scale tests of insecticides against green bug.
9. Population studies of scale insects on coffee in relation to weather and to parasites and predators.

Work on stem borer is limited to certain seasons only and the same remarks apply to some extent to scale insects. It should prove possible to tackle 1, 2, 3 and 4, 6 and 8 at once. The work under (5) will only arise when the appropriate field experiments on *robusta* are well under way, and when the technique of tree injection applied to coffee has been worked out, a task in the first place in the hands of the Chemical Division. Work under (9) should be taken up as opportunity offers.

This section cannot be concluded without reference to the problem of nematode worms attacking coffee. Although the organisms are animals, the work on nematode worms attacking plants usually falls to plant pathologists except in such large institutes as can afford a nematologist.

The present position with respect to this pest is that it has been identified in four or five localities as a major cause of loss of young plants in replantings and control measures have proved ineffective although losses can be reduced by the utmost care in the planting. Apparently *robusta* is tolerant of attack and it is possible that where affected areas are limited a solution may be found by the use of grafts on resistant stocks.

In the meantime, it is difficult to suggest any really promising line of investigation. In my own opinion, a great deal more work is required on the ecology of these nematodes to discover, if possible, their inter-relations with the soil conditions, plants and other soil organisms. This seems pre-eminently the type of problem which could be most effectively prosecuted with the assistance of the Universities. A great deal of basic work in field zoology and in taxonomy is required, which falls within the field of pure research. The nematodes of the west forest soils of South India are a practically unexplored field offering problems of great interest to zoologists, and it is suggested that the possibility of interesting a University Department of Zoology in the subject should be explored at an early date.

The tea industry in Ceylon is concerned with the same pest attacking tea and close contact should be established with the workers there. Some of the recent tests there suggested that some tea plants are more resistant than others to the nematode attack. Studies with material supplied by the Botanical Division could well be initiated along similar lines for coffee, and this might open a new line of approach to the problem.

VIII. THE IMPROVEMENT OF PLANTING MATERIAL

There can be no question that the most efficient and in the long run, the most economical means of improving the productive capacity of an agricultural industry lies in the planting of the best possible plants. Experience has shown that in any planting of seedlings, there are variations in vigour, yield, disease resistance and other characters and that many of these are inherited, so that by selection and further propagation, strains of plants can be developed superior to the general bulk from which they were selected. As far as I am aware this approach to the problem of improving the planting material in a seedling crop has never failed, although, of course, the degree of success is variable.

The value of this approach to the problem of coffee improvement was recognised at an early date and a definite attempt to tackle it was laid down in the technical programme for the Balehonnur Station twenty years ago. The programme then suggested has been very closely adhered to, with such modifications as the development

of the work has made desirable, and the new organisation inherits a large mass of valuable material with which to continue and extend the work. In order to follow the recommendations for further work, it will be desirable to recapitulate briefly the methods which have been adopted in this work in the past. Since the problems are not identical for *arabica* and *robusta*, each species will be dealt with separately.

(*a*) *Arabica.*—It was obvious at a very early stage in the attempt to select improved coffee types in South India, that a primary requirement for high yield was resistance to *Hemileia vastatrix*. This is well illustrated by the fact that in the course of a study of a selection family of which roughly half the members were susceptible and the other half resistant, it was found that the average yield of a random sample of the resistant plants was over $3\frac{1}{2}$ times that of a similar sample of susceptible plants. This average was for a period of six years from the maiden crop in the fourth year.

It was well known that many estates possessed individual plants which showed a high degree of resistance to *Hemileia* and while it was also known that many of these were poor croppers or gave a poor outturn of good coffee, it was considered that among them, it should be possible to find useful parent material. Search was made over a large number of estates and seed from individual selected plants was transferred to Balehonnur and families raised and planted in observation blocks. As soon as these became old enough the plantings were examined and selections made. These selections were then allowed to self-fertilise and the self-fed progeny were planted out for further study. From many thousands of plants, the number of mother plants eventually considered worthy of further study were reduced to little more than a dozen, and the major portion of the work has been carried out on the progeny of not more than half that number.

These selections and their self-fed progeny have also provided material for hybridisation both among themselves and with other strains to attempt the introduction of desirable characters absent from the original selections.

It can be said that it is possible now to provide seed which will give plants resistant to the common strains of

Hemileia vastatrix and with the possibilities of yields without spraying as good or better than those secured from Kents with the help of spraying. The major drawback with these selections at present lies in the quality of the produce in the sense that the grade percentages are often unfavourable owing to deficiencies in the larger sizes and excesses of triage and empty beans. In addition, there is a tendency to somewhat greater variability in the vegetative characters of the individuals in the sowings.

The next stages of work are determined by these facts. The major immediate need is a detailed tree by tree study of the best families already established at Balehonnur with a view to finding plants which give a crop of good quality with respect to size and uniformity, along with a good record for quantity and resistance to disease. Such investigation should be on a broad basis and include the examination of other characters as well, in the hope that there may be relations between the desirable bean characters and other more easily observed features. Some work on this has already been done but it has been hampered by shortages of recording staff. Everything should, for the time being, give place to this examination of the best existing families on an individual plant basis.

The selections made within these families should be multiplied by seed and by vegetative means on as large a scale as possible. If whole families are found which give a good quantitative yield and reasonable uniformity, seed of similar origin should at once be incorporated in regular comparative experiments both at Balehonnur and the Field Station. A suitable design for, say, six selections, would be a randomised block design of 6 fold replications, of 1/10th acre plots using Kents coffee, sprayed, as the control. The selections would be unsprayed.

As soon as possible, such material should be used for trials on estates, using a standard experimental design which will permit of easy comparisons of performance in different coffee zones.

Further hybridisation work should await this examination of the existing material. When that examination has been completed, a decision can be made on what further work is necessary to continue the process of improvement. In my view, the time is ripe for a very thorough study of

the material available before further extensions of hybridisation are undertaken.

It must not be lost sight of, that the aim of this work is to distribute seed to the grower which will give him a stand of coffee better than he can grow at present. The decision to distribute seed must be made with the greatest care. There are dangers in the too hasty distribution of seed on the one hand and also in too long a delay in distributing it because reasonably sound material is not quite up to the degree of perfection the breeder has in mind. The problem is much more difficult in a permanent crop than it is in an annual crop where the change from one improved type to a better involves no questions of capital outlay.

It is appreciated that a certain amount of seed has already been distributed and careful attention should be given to the performance of these earlier distributions which should all be visited and studied by the staff of the Botanical Division. If the reports are favourable, further distribution of the same material can be contemplated and arrangements considered for the commercial production of the seed in question under close control of the research organisation. There should be three stages in the field trial of promising material. First, the trial on a sound statistical plan of the principal promising lines isolated, both on the experiment stations and in co-operation with interested planters ; second, the distribution of the types which come through the statistical trials satisfactorily for what may be described as " sample " planting, and third, the arrangements for commercial distribution when a demand has been created, on the basis of performance. At the second stage, it is important to emphasise to the planters co-operating any limitations which may be inherent in the material. Thus, it might prove advantageous to distribute seed which, while satisfactory for the production of a stand of disease resistant plants, would give rise to plants which could not themselves be relied upon to breed true for this character. It will be necessary to take action to prevent seed being distributed as Station Selections, which has not been produced under the supervision of the Botanical Division. No seed should be distributed in future, unless it is known that it can be relied upon to come reasonably true for resistance to the common strains of *Hemileia vastatrix*.

To summarise the main lines of work requiring immediate attention :

1. The thorough study on a tree to tree basis of the best existing material with special reference to the quality of the beans produced, and the fixation of disease resistance characters.

2. The establishment of suitable field experiments to give a sound comparison of the best selections with the present commercial material normally used for planting.

3. The review of the planting already established from seed distributed in earlier years with a view to deciding how far these types can be recommended for commercial development.

If the results of the first line of work are successful in isolating one or more strains with desirable crop qualities, a considerable area should be planted up with seedling material with a view to selecting the highest yielding types, which can afford the basis for still better strains in the future. We can visualise the lines of progress as follows—we know that if we can get a strain or strains of coffee breeding reasonably true for resistance to the common strains of Leaf Disease with a crop capacity equal to the ordinary commercial seed at present available, and with a crop quality approximately similar, a substantial step forward has been made, since ordinary commercial seed never realises its full crop capacity on account of disease, even with the help of spraying. To improve upon this still further, it will be necessary then to select within the improved type for the maximum yield. This work can only arise after the work outlined under (1) above.

Turning now to laboratory work, two lines of advance present themselves. It has been clear for some time that a cytological investigation of the material available in the selection areas might throw considerable light on some of the abnormalities of the beans, which play such a big part in reducing the value of otherwise promising selections. It is suggested therefore that a programme for the study of the chromosome complex of coffee should be initiated. This is a problem for which the help of a University Botanical Department might be sought, and offers possibilities for fruitful co-operation between the Board's research organisation and the Universities. It is certain that a more thorough knowledge of the development of the essential floral organs will help to avoid wasteful effort in the breeding and

selection work, and indicate the most promising lines to follow up.

The second problem is that of disease resistance. It has already been pointed out that *Hemileia vastatrix* exists in a number of distinct strains, which however do not differ in appearance. It has also been found that while many of the selections already made are resistant to the strains of the disease at present common, and therefore appear resistant in the field, other strains exist, to which these selections are not resistant. With the passage of time, and the extended planting of such 'resistant' coffee strains, the disease strains to which these plants are susceptible may become common and the result will be a " breakdown " of resistance, such as occurred with Kents. To meet this threat and to develop coffee strains with a wider range of resistance, it will be necessary to study the mode of inheritance of resistance to the various strains and to seek coffee types which carry resistance to all the strains likely to be met with. This work has already been touched upon in connection with the programme for the plant pathologist, but it is elaborated here, because on this problem, both the plant pathologist and the botanist will have to work very closely together. The method of study has already been worked out and the actual testing work will be largely routine. It may prove the best way to tackle this problem if the plant pathologist concentrates on the study of the strains of *Hemileia vastatrix* and the establishment of strain differentials, providing stocks of pure strains to the Botanical Division, which will use them for inheritance studies.

As opportunity offers, the Botanical Division should attempt to work out the mode of inheritance of the various commercial characters of value to the producer. Most of these are likely to be determined by a large number of genes and the best practical approach is by straight selection, but where there are cases, as in disease resistance, where inheritance is governed apparently by a few genes, a knowledge of the mode of inheritance will afford valuable short cuts in seed production.

The collection of coffee types should continue, so that the Station may possess a collection as comprehensive as possible of material which may prove of value as the breeding work develops. I do not think, however, that the time is yet ripe for the diversion of effort to work on interspecific

hybridisation and chromosome modification by chemicals or radiation. This work offers interesting possibilities but should come in at a later stage. The present position of coffee selection demands the completion of a great deal of work based on older techniques before the newer ones can be profitably employed. In no field of work is it easier to get lost than in the field of plant improvement by selection and hybridisation and it is important to proceed step by step, attaining certain limited objectives and then moving on to the next stage.

(*b*) *Robusta*—The problems of *robusta* selection differ in several respects from those of *arabica*. In the first place, there is no overriding disease susceptibility problem to concern the selectionist and although the need to search for resistance or tolerance to shot hole borer exists, it does not occupy the same predominant position as the need for resistance to *Hemileia* in *arabica*. Secondly, the normal commercial plantings of *robusta* are far more heterogeneous than *arabica* plantings, and probably offer greater scope for direct selection. Thirdly, *robusta* appears to be, in the overwhelming majority of cases, self sterile, so that the method of self-pollination for sorting out types is not applicable.

Robusta selection work has not progressed as far as the *arabica* work, but it has been in progress both at Balehonnur and Sidapur.

At Balehonnur, pre-occupation with *arabica* problems has limited the work on *robusta* largely to the laying down of observation blocks from individual selections made on estates either by visiting officers or by estate managers and the selection of seed bearers on the basis of their performance in the observation blocks. No progeny trials from the selections have been reported. At Sidapur, through the co-operation of the Consolidated Coffee Estates Ltd., a block of $2\frac{1}{2}$ acres of *robusta* has been harvested on an individual bush basis for six years and a dozen plants have been selected as " mother trees " on the basis of their yield, and progeny tests have been commenced, though no yield data are at present available. Recently, selection work has been extended to a number of estates in order to widen the scope of the work.

The main task in *robusta* is to continue this work both at Sidapur and at Balehonnur. The progeny resulting from

free pollinated mother plants should be studied with reference to yield and bean type, and any promising material should be subjected to statistically sound trials along the same lines as those suggested for *arabica*, normal commercial *robusta* seed being used for comparison. The good selections should be multiplied vegetatively and the cuttings or grafts planted in such a way as to facilitate the production of seed from approved parents. The question of work on vegetative propagation will be referred to below.

The development of controlled crosses between proved mother trees should form an early subject for trial, and if the results are encouraging, investigations should be carried out to make the production of such seed possible on a substantial scale. This could probably be secured by the development of isolated seed gardens built-up from pairs of vegetatively propagated clones which were compatible. It is not known whether the self sterility of *robusta* is associated with any considerable degree of intersterility between different strains, but this point will obviously require investigation.

These studies on the various progenies raised as a result of selection will of course include the investigation of tree habit, reaction to diseases and pests, and to climate as well as yield outturn and the size and quality of the beans. The possibilities of correlation between crop characters and easily observable vegetative characters should also be kept in mind.

The type of work outlined is only limited by staff and land. The remarks on seed distribution made in connection with *arabica* apply equally here and need not be further elaborated.

Laboratory work on *robusta* would include cytological studies which could be conducted along with the similar investigations with *arabica*, but apart from this, there is little work required in the laboratory, beyond that associated with the study of bean characters.

IX. VEGETATIVE PROPAGATION

Several references to the need for vegetative propagation in connection with the breeding and selection work have already been made, but it was considered desirable to defer consideration of this subject to a separate section since it touches both research and practice at a number of points.

A considerable amount of work has been done at Balehonnur on vegetative propagation which has shown that coffee can be propagated both by cuttings and by grafting. Progress in large scale adoption of vegetative propagation of coffee has been very much more considerable, however, in East Africa and Java, and it is desirable that work on this subject should be speeded up and extended in India.

Before giving details of the lines of work to be followed, it is desirable to outline briefly, the scope for vegetative propagation in coffee production so that the scheme for work can be understood.

Vegetative propagation can be immediately useful for three purposes, (i) to increase the number of individual plants derived from selections, (ii) to provide uniform material for field experiments, which will permit the reduction in the area of land required and (iii) to study the possibility of replacing rapidly " off type " plants in coffee stands by top working. The first of these can be met both by grafting and by cuttings ; the second would probably best be met by cuttings, and the third involves the problem of top working. Primarily, this work is to facilitate research and experiment, but the third might find commercial application.

The question of the general use of vegetative propagation in commercial production offers room for differences of opinion. As long as coffee is planted as close as it is at present, the problem of providing the required numbers of vegetatively propagated plants for substantial plantings appears almost insuperable, though it must not be lost sight of, that improvements in technique might well alter the position. If however, the studies of training and spacing, point to the value of wider planting, the use of vegetatively propagated material might prove of great value, especially since use could be made of good selections, which may not have reached the stage of providing reasonably uniform seedling stands.

In cases where, as is frequent in *robusta* stands, there are many " passenger " plants, it would seem possible that top working might form a quicker and cheaper means of raising the average yield than replacing such plants by new seedlings or cuttings. Similar methods might be useful in *arabica* in dealing with small percentages of disease susceptible plants in stands predominantly disease resistant.

The first task therefore is a thorough review of the work on vegetative propagation so far carried out (a) by cuttings, (b) by grafts on seedling root stocks and (c) by top working. This review should concentrate on the techniques so far tried and where statistically valid trials have not been laid down, such trials should be made. With this work, investigation should be extended to techniques so far not tested adequately, in particular the use of propagating frames along lines similar to those developed so effectively in East Africa. Some work has been begun on this aspect of the problem at Sidapur in connection with *robusta*, but it has been so far only ancillary to the selection work.

As soon as it is considered that a sufficiently satisfactory technique has been worked out, a field trial involving cuttings, grafts on seedling rootstocks and seedlings should be laid down. In preparation for this, suitable plants should be immediately prepared for the production of scion material. What is required is the selection of a single plant, either a commercial Kent, or from a family which breeds reasonably true for disease resistance. This plant should be immediately propagated by cuttings or grafts, without, however, destroying the whole cropping head of the plant. Possibly half the primaries could be cut away to secure material for propagation, while leaving adequate crop wood for the production of seed. The vegetatively propagated plants should be treated so that they can be relied upon to produce an abundance of material for vegetative propagation on a scale adequate for a statistically sound trial. For a trial such as that envisaged a minimum of 800 cuttings and 800 grafts developed in one season would be required. These planted along with 800 seedlings from the same parent, would afford material for studying the time required to come into bearing, the variability of grafts, cuttings and seedlings and the yields of each kind of plant. The crucial point is that the grafts and cuttings should be genetically uniform.

At the same time, an investigation of the economics of the operation should be instituted. Efforts should also be made to establish plots of all the best selections of *arabica* consisting of single clones both as cuttings and as grafts and of all the best selections of *robusta* consisting of pairs of clones to ensure pollination. A start has been made on such plantings at Balehonnur, but they should be extended as soon as possible.

In the work of investigating technique, a complete study of the value, if any, of growth promoting substances should be included. It will also be necessary to bear in mind that different individual coffee plants may differ in their ability to root, or to make sound graft unions, and trials of technique must be designed with this possibility in view. The development of the investigation of vegetative propagation will of necessity be considerably influenced by such variations if they appear. A search should be made among the labour for workers who are especially adept at this kind of work. Vegetative propagation is very much an art, and a knowledge of the technique alone is not sufficient for a high degree of success.

If the problem of an efficient and reasonably cheap mode of vegetative propagation can be solved, it will be possible to utilise much of the good selected material now available, without having to wait for the development of seed supplies of a sufficient degree of uniformity for commercial use. Even if large scale commercial plantings are not possible, small areas might well be developed by small holders if interest is aroused by the demonstration of what can be done with two or three thousand such plants. For seed production, vegetatively propagated seed gardens may prove of considerable value. The progress made in the vegetative propagation of tea in the last few years offers considerable encouragement to the coffee grower.

Turning now to the question of top working, it is suggested that a review of the work done in this field should be carried out and the trials already in progress continued and systematised. If feasible, an area of coffee of which the individual plant yields are known should be converted to an experiment to test the value of this method of improvement. This could be done both for *arabica* and *robusta*. A suitable type of experiment might consist of the following design; the area should be divided into suitable plots, one series would be left untouched, another top worked on, say, 20 per cent of the poorest yielders, and a third, thinned to remove 20 per cent of the poorest yielders and the vacancies replanted with selected seed. Presuming a lay-out of an 8 fold randomised block of 100 trees per plot, 2,400 plants would be required and 160 trees would be top worked in one series and replaced by selected seedlings n the second.

The work on vegetative propagation suggested can be summarised as follows :—

1. A critical review of the work so far done combined with the institution of statistically valid trials of the most promising technical methods including the use of propagating frames which have proved successful in East Africa.

2. The institution of field experiments to compare cuttings and grafts with seedlings. An eightfold replication of three treatments in randomised blocks of 1/10 acre plots would require about $2\frac{1}{2}$ acres for each experiment. Experiments of this kind should be laid down for both *arabica* and *robusta.*

3. The investigation of the possibilities of improving yield per acre by top working poor yielders with better quality scions. This is probably more applicable to *robusta* than to *arabica* at present, but it might be useful in *arabica* for dealing with offtype plants in seedling plantings of selections which may be less uniform than present commercial seedling plantings. A field experiment suited to investigate this problem along the lines suggested would require about 3 acres of bearing *robusta,* preferably of which the individual tree yields have been recorded for two or three years.

Most of this work would be centred at Balehonnur in the first instance, but parallel work could be carried out at the Field Station and any work already in progress on private estates could be incorporated in the programme.

X. THE PROBLEM OF REHABILITATION OF POOR COFFEE

It is certain that much can be done for poor coffee by the utilisation of existing knowledge, which should be made available through advisory services and propaganda. As results of investigations on manuring, soil management and disease control accrue, this advisory service will grow in ability to help growers. At the same time, it is clear that much coffee cannot be made a profitable economic proposition with the existing coffee bushes and shade stands and the industry will need advice on the best methods of dealing with such problems. The first step in investigating this problem will lie in the intensive survey already suggested in Chapter II.

In the meantime however, certain lines of work will require investigation, since apart from the question of rehabilitating poor areas, problems of replanting will arise in connection with the extension of new selections. On this account I consider that some attention should be given to the problems involved in replanting. Here, as in so many cases, the possible variations which can be tried are numerous and selection is necessary. Three possible treatments suggest themselves as worth study in the first place—clean clearing, thinning shade and clean clearing old coffee, and thinning shade and thinning coffee to leave say 25 per cent of the best plants in the area. These three treatments could be carried out on one acre plots replicated three times, involving 9 acres.

The acre plots could be sub-divided into two treatments involving the presence and absence of green manure hedge plants, these again sub-divided to compare basket and bed plants and finally sub-divided to compare pit sizes. This would give 108 ultimate sub-plots of 1/12 acre.

The main comparisons have been suggested with a view to exploring the cheapest ways of conversion. There are many growers who will be nervous of the complete cessation of income and the capital outlay involved in complete clearing and replanting. The thinning of shade instead of its complete removal is designed to investigate a reduction in initial costs, while the thinning of the coffee is to explore the maintenance of some income during the conversion period. Experience reported in the pamphlet "The Agricultural Problem of South Indian Coffee" suggests the desirability of a trial of this conversion method. The subsidiary comparisons are to compare methods which have been employed with success, as in the case of the use of hedge green manures, or upon which there are differences of opinion, as in the case of the relative merits of bed and basket plants. The study of pit size is suggested in view of interesting results obtained in Kenya with large pits.

It may be objected that the best way to replant is obviously to make a clean sweep, and this may be true, but until the relative merits have been established by experiment, it would be difficult to deal with the type of problem which is certain to arise in advisory work, when economic factors obtrude themselves. It is of the utmost

importance in an experiment of the type suggested that careful cost data should be kept throughout so that the economics of the methods can be clearly set out. Such an experiment could probably be laid out at the Field Station. It must be emphasised that this design is purely suggestive and could be modified in a number of ways. Possibly a simplification would be necessary in the interests of keeping the work within reasonable limits and this could be secured by omitting the pit size comparison, which would permit the reduction of the number of ultimate plots to 56. It is considered, however, that the main plots should not be less than one acre in extent. Alternatively the pit comparisons could be replaced by weeding trials, including a test of chemical weed control with one of the new weed control chemicals to which so much publicity has recently been given.

Consideration might be given to an experiment to test the effect of burning against clearing without burning, but there would be practical difficulties involved in burning comparatively small areas required for a field trial of the usual type. Such a problem has been tackled in rubber in Ceylon (Murray, R.K.S., Rubber Research Scheme (Ceylon) Quart. Circular 3 and 4, Nov. 1934) and experience there might assist in laying down trials for coffee on this important point.

Many other modifications can be visualised, but the type of experiment outlined above would, I consider, provide evidence of very great value in advisory work and in assisting in the replacement of old stands of coffee with new selections as the material becomes available from the Botanical Division. This work will fall mainly on the field managers and the Horticultural Division.

XI. THE PREPARATION OF COFFEE FOR THE MARKET

The preparation of coffee offers a considerable field for investigation and is closely linked with the question of quality. This is, therefore, an appropriate point at which to consider the future of investigation into the problem of coffee quality. In so far as Indian coffee will again come on to the European market it will be essential to maintain—or regain—the reputation for quality for which it was famous. It is suggested that as far as quality is affected by agricultural management, the field experiments already outlined will provide material for submission to tasters or teams of tasters from time to time as circumstances

suggest. In general, field treatments should be allowed to act for several years, before it will be necessary to consider submitting samples for quality evaluation, but in the meantime, it would be useful to explore further the establishment of the reliability of the taster, by submitting series of parallel samples for tasting and using a score card for reducing reports to a numerical basis suitable for statistical study, along lines similar to those already followed in connection with the " Quality Scheme."

It is suggested that the research organization should study carefully the work done in this connection in Kenya, and the closely parallel work done on tea by the Indian Tea Association Station at Tocklai and the Ceylon Tea Research Institute. By the pooling of experience, it should be possible to arrive at some degree of standardisation of methods for the evaluation of beverage quality.

Along with trials of the technique of evaluating quality, it would probably be worth continuing to submit suitable samples from the best selections as part of the study of such material.

Turning now to the problems of preparation, the most important are probably those associated with fermentation and drying. The former, of course, is only applicable to plantation coffee, but drying problems arise with both plantation and cherry, and in my view, are the more important of the two. I would suggest, therefore, a careful investigation of the drying process, including studies of artificial drying on a laboratory scale both by heat and air currents, and of sun and shade drying. The main question to be answered is whether the present methods of drying which are largely dependent on the vagaries of the weather and take up considerable time and space, can be improved upon with a view to shortening the time, and turning out a uniform product without damaging the intrinsic quality of the bean, or increasing the cost of preparation.

In the first place, samples from various experimental drying methods could be submitted to local panels for their views on the effects on appearance of the product, and if a satisfactory standardisation of tasting trials can be worked out, samples can be submitted to the tasters. Although this work would appear to be comparatively simple, there

are many difficulties in securing satisfactory material for study of different treatments, since a few bad beans, or damaged beans may alter the whole character of a sample, quite independently of any treatment applied to it.

The problem of fermentation and its possible influence on quality has already received attention from the Quality Research Scheme, and a number of trials have been made on the possibility of yeasts in the fermenting vats influencing the quality of the product, on the effect of the time the parchment remains in the fermenting vat, and on the value of fermentation under water. Associated with the fermentation is the problem of foxiness. In my view, the last problem is of some importance and worthy of investigation, and this will imply a study of the fermentation process and the organisms associated with it.

It is suggested that the Chemical Division should undertake an investigation on this subject as time permits. In the course of such a study the part played by yeasts and other organisms in the process will be studied and the results reported in 1945 on the influence of certain yeasts on the speed of fermentation can be followed up. When the fermentation process has been worked out, a fresh approach to the question of whether it influences quality can be taken up.

I do not regard the work on preparation as pressing as work dealing with increased yield per acre. The present position of the coffee industry is such that the most important problem is one of increased production per acre, rather than refinements in preparation. Work on this subject of preparation presents many points of interest but it should, I think, at this stage, be subordinated to the work outlined in earlier sections.

It is convenient also to remark at this point that I do not consider an extensive investigation into the biochemical basis of quality would be justified at this stage. Experience in tea has convinced me that such a study should be developed on a co-operative basis by a number of countries interested in coffee, in the same way as it has been organised for tea. There are too many problems of greater urgency which require solution, and which are more appropriate to a research organisation devoted to a very small fraction of the world's production. The possibility of interesting a University in the problem is, however, worthy of keeping

in mind, and the research organisation could well provide suitable material for various phases of such an investigation.

XII. CO-OPERATIVE EXPERIMENTS ON ESTATES

The problem of the extent to which use can be made of co-operative experiments on estates is an acute one. There is a number of problems which cannot be adequately solved by experiments on the Experiment Stations alone and it becomes necessary to consider how experiments can be organised on private estates, and what are the conditions for success. Experience with such co-operative experiments is variable, but given certain conditions, they can be valuable both to the research worker and to the participating estate. There are however risks to be faced, the most serious of which is loss of interest on the part of the estate. I may say at this point, my own personal experience has been happy in respect of co-operative experiments, but I realise that other workers have not always been so fortunate.

As a general rule estate experiments should be simple. Any experiment on an estate means extra work for the management, and if the design is complex this extra work may easily form an excuse for its abandonment. Normally speaking, estate experiments should be derived from station experiments which have indicated specific points for wider trial, and which have already produced results attracting the interest of growers. Exceptions to this are experiments on disease and pest control or to deal with specific local problems brought up by the estates themselves, and in which it is to be expected that they will have a direct and pressing interest.

Apart from experiments arising from individual estates' problems, the most important consideration in organising co-operative field experiments is the interest of the estate managers in the problem to be investigated. This demands frequent contacts between the research workers and planters so that there will be ample opportunities for informal talks on work in progress and the possibilities of the value of estate trials. Care must be taken by the research worker not to " force the pace " but to try and rouse a real interest in the problem so that the actual desire to experiment will develop naturally in the planter's mind. It will be found that some planters have special interests in particular problems, interests of which advantage can be taken.

Once an estate has agreed to undertake an experiment the details should be fully discussed and the plan of work and the part to be played by the research organisation and the estate respectively clearly laid down in writing. Whatever happens the research staff must do their full part in maintaining interest in the experiment by regular visits and by keeping the estate management fully informed of all developments in the experiment.

Much can be done by taking advantage of discussions among planters, by encouraging them to try out their ideas with the help of the research organisation in organising critical trials. This brings into prominence a major difficulty—explaining to the grower why a critical trial demands the relative complexity of replicated plot experiments. On this question, I consider the research organisation should take a firm stand. No trials on estates, except of treatments which are well known to produce large differences, should be carried out on a co-operative basis unless they are statistically sound. This of course does not apply to " sample " planting in connection with selections referred to on (PAGE 42). It is true that the statistically sound trial, even for a simple experiment is more tedious and complex than the single plot comparison, but its results have a definite validity, which can never be the case with the results of single plot trials, which except in isolated special cases, must always contain an element of uncertainty.

While recommending a firm attitude to this question of estate trials, I must emphasise that at the same time, the research organisation should give the most earnest consideration to the problem of explaining to the producer the fundamental reasons for this attitude. This forms part of the general question of the research worker taking the producer fully into his confidence. This particular work will fall especially on the Director and on the advisory officer and it will not be easy. I feel sure, however, that time spent in devising non-technical expositions of the reasons for the forms which investigations take will amply repay the effort.

As far as immediate action on estate co-operative experiments are concerned, the existing series should be maintained, *viz.*, the co-operative manuring trials under the " Quality Scheme ", and the time and strength of spray,

pruning and *robusta* selection experiments in progress in Coorg. In addition, there are certain lines of work which can best be developed by co-operative experiments if suitable co-operators can be secured.

The first of these is spraying, and this is probably the one type of experiment where single block trials would probably be sufficiently convincing in the majority of areas, where a comparison of sprayed against unsprayed coffee is required. I am convinced that over 80—90 per cent of the *arabica* coffee area in South India requires protection against Leaf Disease and that the provision for this protection is more important than any other treatment, including manuring. To bring this home forcibly to the producer, it is necessary to have a series of trials of spraying of the nature of demonstration plots. The demonstration plots at Balehonnur referred to above (PAGE 28, 29) are completely convincing to any unprejudiced observer and similar plots should be laid down wherever spraying has not been adequately tried throughout South India under the ægis of the research organisation in association with the local agricultural department staff wherever possible. This work should perhaps be more accurately described as development rather than experiment, but it can well be mentioned here.

In connection with spraying, it would be desirable to extend the "time and strength of spray" experiment design now in use in Coorg, to other areas, especially the North East Monsoon areas. Experiments of this type in the Shevaroys, Pulneys, and East Nilgiris would help to place knowledge of Leaf Disease control on a wider basis. For the purpose of these trials, some simplification could be secured by omitting the trial of strength of spray and concentrating on the timing. For this type of experiment it would be necessary to secure the co-operation of planters already convinced of the value of spraying and interested in improving its efficiency on their estates.

It is possible also that tests of new spray materials and of new machinery could be arranged of private estates when need arises. The problem of testing of new machinery is an important one which will require careful consideration in consultation with manufacturers and manufacturers' agents and a regular system of procedure drawn up. This problem has arisen in connection with tea manufacturing machinery in Ceylon and their policy will deserve study.

The need for the development of co-operative trials in connection with insect pests has already been dealt with in Chapter VII and needs no further comment. In these cases, the special feature is the necessity of securing areas where the insect pests occur at a level severe enough to offer a reasonable chance of differential effects from treatments. As a general rule, it is not so difficult to secure assistance in conducting experiments against pests or diseases which constitute an obvious menace to the crop, as it is for trials of variations on cultural practices or new selections.

As far as manuring trials are concerned, apart from those already in progress, I consider that co-operative experiments should await some more definite results from the experiment station experiments, when it should be possible to reduce co-operative trials to simpler forms than can be done in the present state of our knowledge.

The testing of selections in replicated trials will undoubtedly present difficulties on private estates. The tendency will often be for the grower to wish to proceed at once to the 'sample' plot (PAGE 42), but it is desirable to start a new selection with critical tests in a variety of localities. The securing of co-operation for these trials will require the utmost tact and education of the grower, to stimulate his interest and his appreciation of the problem. A few well conducted trials of this type will be of immensely greater value than haphazard tests not suited to critical examination.

In connection with rehabilitation experiments (Chapter X) the most fruitful source of assistance will probably be found among the larger producers with " problem areas " rather than among the smaller ones with low yielding properties. An attempt to arrange a few rehabilitation experiments of a simplified form on private estates, especially near centres where many owners of less efficient properties could readily see the work, would be of great propaganda value. The value of work on a larger property influencing the methods of the smaller grower in the vicinity is too well known to need further remark.

It may prove possible to develop experiments on other problems—pruning, spacing, preparatory methods, etc.—in special cases where a definite interest has been aroused, but it seems to me that the fields in which progress is both

possible and desirable with this kind of trial, are spraying insect pest control, varietal testing and rehabilitation methods.

It ought to be made clear at the outset that all results of co-operative trials must be freely available to all producers.

XIII. COLLECTIONS, RECORD & LIBRARY

In addition to the research projects, each research division should form a centre for the collection of material likely to be useful in advisory work. The plant pathologist will build up a herbarium and museum of coffee and shade tree diseases, including ones which at present may be of negligible importance. The entomologist will develop a collection of insects associated with coffee and shade trees and this will be interpreted broadly. The botanist will be responsible for the herbarium, which should concentrate in the first instance on the shade tree, green manure and weed flora, but can be extended as opportunity offers. In addition, a collection of living green manure and shade trees should be built up which, suitably planted, could provide material for observations on their usefulness. The need for a collection of coffee species and varieties has already been mentioned and a substantial nucleus is already available at Balehonnur. The living plant collection will be a matter for the Botanical and Horticultural Divisions and it would probably be best to establish the shade and green manure collections at the Field Station. In connection with shade trees, it is suggested that at both stations a regular system of phenological observations should be established to study the time of leaf fall, refoliation, and flowering of the most important shade species. These records maintained over a period of years and related to the meteorological data are likely to prove both of considerable use to coffee growers and of no little scientific interest. The labour involved is small and can easily be arranged along with the meteorological recording.

Both stations should maintain standard meteorological records on the same lines as those at Balehonnur at present. At the same time microclimatic records should be maintained within the coffee, similar to those also kept at Balehonnur. These will be of especial value and importance in connection with the spacing and training trials, and in work on shot hole borer, but have a bearing on every field problem of the crop.

Much help in this work will doubtless be available from the Agricultural Meteorology organisation at Poona and full advantage should be taken of its specialised knowledge and experience.

The maintenance of records is of the utmost importance and very careful thought should be given to the methods adopted. Every research officer and institute has its own methods and such experience should be freely drawn upon. The main records will be those of the field experiments. All records for each experiment—observational data, yield records, operations carried out, etc.—should be brought together in one record book, which for safety should be duplicated, one being kept at Balehonnur and the other at the Field Station.

In the case of the selection work, each important family should have its own record book, again, in which all information should be recorded. The principle should be that the required information can be readily turned up and that all the relevant information is kept together.

The records of projects solely the concern of a single officer will naturally depend on the actual worker and the nature of the problem under investigation, but all such records should be placed in a permanent form so that in the event of staff changes, all the information can be obtained by a succeeding officer.

Another type of record is that of estate visits and these should be prepared as far as possible on a standard system and filed and indexed so that an officer following up a specific problem can readily find all observations on that problem which have accumulated as a result of estate visits.

The Chemical Division will in the course of time collect analytical data on soils from many estates and a standard system for recording information about soils will be required. In this case in particular, care should be taken that the system adopted fits in with the general system recommended for the Indian soil survey.

Finally, arrangements should be made for a classified card index of information bearing on the coffee industry, which should be added to by all the staff. The method I employ for my own use is simply to record on a card (or sheet of stout paper 8″ × 5″) the reference or source from

which the information is derived and to give a summary of the contents of the paper, a quotation if that suits the purpose, or the gist of the discussion, if the information is verbal. The note is then classified at the head of the sheet, usually including a main head, and two subheads. Thus a reference dealing with coffee pruning in Uganda might be headed. "Coffee. Pruning. Methods in Uganda," followed by the reference in the literature, and a short note on the main points. In the event of an interesting point cropping up on some specific subject in the course of a discussion, such as a desirable mode of managing a particular shade tree, the heading might be "Coffee. Shade,—Management of Grevillea," followed by a reference to the estate or planter from whom the information was derived, and an abbreviated account of the method, and if necessary a reference to a fuller account recorded in files of lengthier notes. This system has proved of great value in advisory work and is more useful, with but little increase in bulk, than a simple bibliography. This type of card index should be maintained by the advisory officer as part of the library facilities, but each technical officer should be responsible for providing material for this index, within his own field. Such a card index can be improved by the use of the decimal or similar system of indexing as used in "Horticultural Abstracts" and similar journals.

It is not suggested that this is the only or the best way of dealing with the problem of building up a readily available body of information upon which the staff can draw for the purposes of advice and research, but it is one which has been found useful in fulfilling one important function of a research organisation,—the provision of advice based on the widest acquaintance with the available knowledge.

A few words on the question of library facilities is appropriate at this point. I do not know how far the present library at Balehonnur will be made available to the new organisation, but there is a useful nucleus available there which can be added to as time goes on. The problem of library facilities for a comparatively small institution is not easy and it is essential that arrangements be made so that the organisation can draw upon the resources of a well furnished Central Library when required. At the same time every attempt should be made to utilise the resources available as efficiently as possible to build up a library

covering the main fields of work of the institution. No attempt will be made here to detail the composition of the library but it is considered desirable to make a few remarks on journals. The most important journals for the organisation are the abstracting journals and the following should be available from the beginning—Horticultural Abstracts, Soils and Fertilisers, Plant Breeding Abstracts, Review of Applied Mycology, Review of Applied Entomology (Series A), Chemical Abstracts, Biological Abstracts and The Experiment Station Record. These will suffice to keep the research workers in contact with world progress in their respective fields and to enable them to secure the full papers if necessary. In order to enable officers to keep in touch with the general stream of scientific thought the organisation should also secure, " Nature," " Current Science " and possibly the American journal " Science." In addition the main journals touching tropical and plantation agriculture should be available. Each division should have at least one journal in its own field, *e.g.*, " Phytopathology " and the " Journal of Economic Entomology " in the Plant Protection Division, " Journal of Genetics " in the Botanical Division, " Journal of Pomology and Horticultural Science " in the Horticultural Division and " Soil Science " and " The Biochemical Journal " in the Chemical Division.

This is only intended to give a general idea of the basic needs of a library with respect to journals if the staff are going to be up to date in the developments affecting their work. Nothing is more discouraging to the research worker than isolation from the literature of his subject.

I consider that the library should be in charge of the advisory officer and library rules should be the minimum necessary for the care of the books.

Technical staff should be encouraged to become members of specialist societies and if necessary financial help should be forthcoming. Facilities should also be provided for attendance at technical conferences within reasonable limits. The success of a research scheme of the type under consideration rests to a considerable extent on the mental alertness of its technical staff.

XIV. ADVISORY WORK AND PUBLICATION

The work of the research organisation does not end with the solution of technical problems. The results have to be

conveyed to the producer in a form which he can understand and in a way which will convince him of their utility. There are also other important aspects of the relations between the producer and the research worker which must be thought out and given their due place in the organisation.

In the first place, the research organisation must bring the services it can offer to the notice of the producer. It must create in the minds of the producer, the realisation that the research organisation exists for his assistance and that any enquiry made will be promptly and thoroughly dealt with. This can be done partly by printed circulars and by personal contacts, and use can be made of the press and the wireless. By these means, growers should be told in a simple way, what the research workers are trying to do and in what way they can assist them. The industry requires to be made conscious of the services available to it. The best and most fruitful means of developing this consciousness is by personal contacts and all technical officers should at a fairly early stage be given the opportunity to contact growers by carefully designed tours, to familiarise them with the conditions under which the crop is cultivated and the people who cultivate it. Full use in arranging these tours and contacts should be made of District Planters' Associations, with whom close and friendly relations should be established. Meetings of such Associations afford useful occasions for discussing the work in progress, and securing assistance in co-operative experiments. All such Associations should be asked to send the research organisation notices of their general meetings.

Most of this kind of work will fall on the Director and the advisory officer, but, subject to the requirements of their principal duties, the research officers should be given occasional opportunities to tour. The amount of touring will require to be carefully worked out. It is considered that specialist officers' touring, after they have had reasonable opportunities of visiting the main coffee areas in the early years should normally be restricted to the investigation of definite problems in the field or to the supervision of co-operative experiments within their sphere of study. In designing tours, tours of long duration should be avoided as far as possible since after a certain time the touring officer loses the power to get a clear mental picture of conditions in areas passed through. In my view, a general tour of 10—14 days is the maximum that can be undertaken

without risk of confusion of impressions. Careful tour diaries are of course essential.

The advisory officer will naturally spend more time in touring and in contacting growers and it will be necessary for him to be acquainted in fair detail with the work going on in the research divisions and to be responsible for the formulation, under the Director, of the advisory policy of the organisation. This is especially important in the case of problems where knowledge is scanty. For example, the commonest problem in advisory work is the question of manuring and growers will frequently ask the organisation to recommend a manure mixture or manuring programme. In the present state of our knowledge of coffee manuring in South India the answer to such an enquiry presents an almost insoluble problem and the organisation will have to decide on the best answer *with our present knowledge*, until such time as experimental data offer a sounder basis for advice.

A flow of enquiries to the research organisation from estates should be encouraged as they are a useful indication of the interest in the research work and help to keep the workers in touch with problems and trends of development. The analysis of the type of problem referred to the organisation at intervals will often reveal valuable information on such matters as the fluctuation in importance of various pests and diseases and the attitude to manuring and pruning. Normally all enquiries should go to the Director and from him to the advisory officer unless they deal with some technical matter which requires the special attention of one or the other research officer. Where the enquiry can be dealt with on the basis of the established advisory policy of the organisation, the reply will normally be drafted by the advisory officer but it would be desirable that the specialist officer concerned should see such reply before despatch. In many cases a general discussion by the whole senior staff of enquiries received and draft answers to them would be of advantage and could form an item in the regular but informal, staff meetings which can do so much to weld the individual specialists into a unified team.

I would emphasise the importance of the most careful consideration being given to every enquiry and the avoidance of anything in the nature of a stock answer, except in the few obvious cases where a stock answer will meet the case.

Often, it will be necessary to call for more information from an estate, and this should always be done if a sound reply requires it. The reputation of the organisation will largely depend on the careful handling of estate enquiries. If this is done, and advice given is sound, the support and encouragement of growers for the research work will be assured.

All correspondence in connection with enquiries from estates should be filed independently of other correspondence and I am inclined to think this is best done on the basis of the estate, since it is then possible to follow over a period of years the type of enquiry raised and the results of advice of a given property. The alternative method is by the subject of the enquiry, but I prefer the ' estate ' method, provided a subject index is maintained.

For general advice and information, full use can be made of publications since the vast majority of coffee growers are literate. Material for publication may be of the nature of general instruction, of warning, of results of research or of appeal for information, and in general will need to be made available in English, Kanarese and Tamil. A careful distinction in composition and style must be made between material for the grower and that intended for a technical audience. The question is how written material should be distributed is of some importance. The usual methods are by leaflet or bulletin, by a periodical or in the pages of the Press. I think that in the first instance, the leaflet and bulletin is the best, although in the course of time, a regular periodical might be published. If the existing Board's Bulletin could be printed attractively, the research organisation could provide material for it, although it is not easy for a comparatively small staff to keep up a regular supply of material of uniform value. The pages of " The Planters' Chronicle " would of course be open to the research organisation but this publication only reaches a proportion of growers.

It is suggested that there should be four types of published matter—notes, circulars, bulletins and technical papers. Notes would consist of short items of interest to growers suitable for the Press and other journals likely to reach them. For instance, certain weather conditions might warrant a spray warning in connection with *Hemileia* control, a warning of an impending increase of severity

of green bug or borer, or a new disease or insect pest might require an early warning to growers of its possible appearance in their area, or a small piece of *ad hoc* investigation might be of general interest, but hardly justifying the larger circular. In the case of pest and disease warnings, use could also be made of the broadcasting system.

A circular would be a rather larger publication of perhaps 3 or 4 pages dealing with some matter of interest arising out of the research or advisory work. If similar enquiries are received from a number of estates, the matter would obviously be of general interest and could well form the subject of a circular. Every attempt should be made to make such circulars attractive in form and well illustrated. If graphs or diagrams are used, careful thought should be devoted to their form in order to convey easily the information to be imparted. A study of the circulars of the U.S.A. Department of Agriculture would be of great help in devising attractive publications.

The same remarks apply to bulletins, which are really only more elaborate publications dealing with some larger subject of general interest or with the results of an experiment or investigation. It must be emphasised that it is generally unwise to try and combine in one publication a technical communication and an account of work for the planter. I think this type of bulletin should be used initially for a complete description of each major experiment with photographs of the lay out, a popular account of the reasons why it has been undertaken and the type of information it is likely to give to the grower.

The technical communication will normally be published in an appropriate technical journal and should be a full account of a completed investigation. All specialist officers should write up their results in technical papers suitable for publication, even if they are not actually published. At the same time the publication of technical progress reports, interim notes and short papers of a fragmentary nature should be discouraged. This is not to suggest that technical papers should be lengthy, but that publication should be generally restricted to finished investigations which have given a definite addition to knowledge, even though it be a negative result. There is far too much fragmentary material published in India at present, which would more appropriately form part of accounts of a completed investigation.

There is a great need in the industry for a planting handbook, or series of hand-books dealing with the various phases of coffee management. The organisation should keep this need in mind and attempt to secure the assistance of suitable planters in preparing, in collaboration with the staff, suitable hand-books for the instruction of young planters and as reference books for the older.

The question of annual reports is a vexed one. It is obvious that the Board has a right to expect annual reports of the work in progress, yet the annual report can only occasionally contain the results of a finished piece of work and to secure the whole history of an experiment may require the turning up of half a dozen such reports. The annual report should never be regarded as a medium for publishing results of investigations though they will of course be noted therein. I consider the annual report should be strictly confined to a statement of work done and in progress in each division with a general introduction by the Director on the policy and trend of developments. It would be desirable to prepare a more elaborate report, say, every five years to review the work of the organisation, as has been done from time to time by the Mysore Department of Agriculture for Balehonnur. I would reiterate, however, that every completed piece of work which has an interest to the coffee grower should appear as a separate circular or bulletin, or as an article in a journal if it is eventually decided to publish one.

In time, though not in the early stages of development it should be possible for the organisation to arrange short courses of instruction in special aspects of coffee production such as pruning, grafting, spraying, etc., should a demand exist. If any schemes for training planters are developed the coffee research organisation should be prepared to play a part. The amount of work of this nature which could be undertaken with the staff planned at present would be small, and should not be allowed to prejudice the research work.

Close liaison must be established with the agricultural departments of the coffee producing areas so that the district agricultural officers posted to coffee districts will be fully conversant with the advisory policy of the coffee research organisation and will be in a position to give advice on this basis in the course of their normal duties. It would

be impossible and undesirable for the research organisation to supply a staff of district officers to work alongside the ordinary agricultural officers and every effort must be made to work through them. I consider the close and friendly co-operation between commodity research institutes and agricultural departments is of vital importance. This can be secured by personal contact, by the arrangement of technical conferences and possibly by a regular cyclostyled circular letter to agricultural officers in coffee districts. The advisory officer of the research organisation should be enabled to contact all such officers regularly.

Conferences on the application of research to coffee production can serve a useful purpose, and could be arranged from time to time through District Planters' Associations. Visitors to the stations would always be welcome, but in the interests of the regular work, advance notice of visits should normally be required and definite days announced as those most suitable for visitors. Occasional field days are useful, but in view of past experience, numbers should be limited at any one time.

In concluding this section, it may once again be emphasised that the development of advisory services and the establishment of the closest relations with the coffee grower are extremely important and must never be lost sight of. When the coffee grower turns regularly and naturally to the research organisation for help and advice, it will have become an essential part of the industry, not likely to be abandoned or starved of the funds necessary for its continuance.

XV. CONCLUSION

It must be emphasised that while I am satisfied that the items of work recommended for priority are sound ones, the details of experiments are subject to modification according to the land available, its topography and the results of further thought and consideration by the technical officers appointed to carry out the work, and the experimental sub-committee which I recommend should be set up by the research committee. They can both look to various specialists in other services for further help and guidance in connection with such problems as statistical design for field experiments, agricultural meteorology and so on.

I think that the problems outlined for investigation can lead to results which properly applied will raise the economic

position of the coffee industry in South India, and assist the prosperity of the areas in which it is situated.

APPENDIX

SUMMARY OF TECHNICAL PROGRAMME.

These experiments can be begun as soon as the Field Station is available, and those which are asterisked, as most suitable for duplication at Balehonnur can be commenced as soon as the organisation begins to function. The experiments in Group I are given priority over those in Group II.

B. BOTANICAL DIVISION.

Work on these field experiments are largely contingent on the observational work to isolate the best selection lines and the establishment of the best methods of vegetative propagation. The asterisked trials should be duplicated at both stations, but this does not exclude the duplication of the others at the Field Station when opportunity offers.

C. FIELD EXPERIMENTS ALREADY IN PROGRESS TO BE CONTINUED.

3. *Observational Laboratory Work.*

This excludes the observational work directly arising from Field Experiments.

A. HORTICULTURAL DIVISION.

Pages.

2. Study of fruit bud development and fruit differentiation (Jointly with Plant Protection Division) .. 27–28 & 32–33

B. CHEMICAL DIVISION.

1. Nutritional Studies by Plant Injection and Foliar analysis 22–23
2. Coffee Soil Characteristics 15–18
3. Studies on Drying Coffee 51–53
4. Studies on Fermentation (with co-operation of the plant pathologist). 52–53
5. Organizing testing trials 51–52

No. 2 will arise in connection with the sample survey in the first instance.

C. PLANT PROTECTION DIVISION.

i. *Plant pathologist.*

1. Small scale testing of fungicides .. 30–33
2. Studies on strains of *Hemileia vastatrix* 33–34
3. Studies on Black Bean and related defects (in co-operation with the Horticultural Division) .. .. 27–28 & 32–33
4. Nutritional factors in *Hemileia* infection (in co-operation with the injection studies of the Chemical Division) 33–34
5. Studies on the etiology of Die Back .. –Do.–
6. Observational studies on the progress of *Hemileia* on *robusta* .. .. –Do.–

ii. *Entomologist.*

1. Coffee Stem Borer—
   (*a*) Cage studies with ovicides .. 33–36
   (*b*) Seasonal distribution of emergencies .. .. .. –Do.–
   (*c*) Completion of life history studies .. .. .. –Do.–
2. Shot Hole Borer—
   (*a*) Field studies on seasonal incidence of attack 35–38
   (*b*) Nutritional factors in attacks (in co-operation with the injection studies of the Chemical Division) .. .. –Do.–
   (*c*) Possibilities of insecticidal dusts 36–38

3. Green Bug— Pages.

(*a*) Trial of insecticides 35–38

(*b*) Seasonal studies on green bug and its parasites and predators. —Do—

4. Nematodes—

(*a*) Study of the possibility of varietal resistance or tolerance in pot tests (in co-operation with the Botanical Division) 38–39

D. BOTANICAL DIVISION.

1. Detailed studies of main selection families with a view to improving quality of produce 38–41

2. Examination of existing selection stands on estates 41–42

3. Continuation of selection and hybridisation studies on *robusta* .. 44–46

4. Studies of inheritance of resistance to *Hemileia* (in co-operation with the plant pathologist) 41–44

5. Study of *robusta* sterility 44–46

6. The cytology of *Coffea* spp. (possibly in co-operation with a University Department of Botany) .. 41–44

7. Study of Vegetative Propagation .. 46–49

4. *Co-operative Experiments.*

The development of co-operative experiments will proceed gradually and no regular plan can be laid down. The items mentioned here are those which can only be handled by estate co-operation.

1. Field trials of stem borer control methods 33-34,35, 36,55-58

2. Field trials on green bug control .. —Do—

3. Demonstration plots of effects of spraying in areas where spraying has not been widely adopted .. 54–57

4. Field trials on spray timing, especially in North East Monsoon districts .. .. —Do—

5. Field trials of selections as suitable material becomes available .. 41–42 & 55–85

5. *Co-operation with Universities or other Academic Institutions.* Pages.

There are many problems in the solution of which University Institutions could be of assistance, but the following are the most obvious.