Study Group 1

THE EVALUATION AND UTILISATION OF GENETIC RESOURCES IN TROPICAL ROOT CROPS.

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The genetic resources available in the field of tropical root crops include not only germplasm of the species involved, but also the body of information concerning each species, and the trained personnel capable of best utilizing such materials and information. The adequate utilization of these resources could best be stimulated by developing better systems of communication. When plant breeders and geneticists are better informed, they are more able to make rational decisions concerning programmes and objectives.

To facilitate communication, the Study Group recommends the establishment of a Tropical Root Crops Newsletter. The proposed newsletter would contain address lists of persons working on the genetics or breeding of such crops, periodic bibliographies of recent papers, lists of stocks or materials available for exchange, periodic summaries of the status of particular crops and short, informative research noted.

It is also suggested that the newsletter serve as the publication of a Root Crop Development Cooperative. The organisation would serve not only to publish the annual letter, but would also serve to coordinate efforts to establish and maintain germ plasm collections. In addition, the possibility is visualized of the growth of this organization into a Root Crop Society.

In order to organize such a Cooperative, an organizing committee should be constituted. The current study group has asked Dr. Jorge Leon, Inter-American Institute of Agricultural Sciences, Andean Zone, Apartado 478, Lima, Peru, to act as temporary chairman. Volunteers to serve on such a committee include :

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In addition, other volunteers for this committee are needed, and interested persons are advised to contact Dr. Jorge Leon.

It is proposed that the committee organize and present a newsletter within one year of its beginning. Until the committee can develop a standard policy, contributions intended for the newsletter should be sent to Dr. Leon. Contributions most appreciated at the present time include names, addresses, and programmes of persons working with root crops and lists of plant materials available for exchange.

Naturally, the organising committee will be concerned with developing a sound financial backing for the proposed Cooperative and Newsletter. Until an adequate study of financing can be managed, the study group proposes that any persons interested in participating in the Root Crop Development Cooperative and/or receiving the annual Tropical Root Crop Newsletter, contribute one dollar U.S. to the temporary chairman.

The study group also recognizes that certain current collections of root crops are in danger of extinction. We recommend that sincere efforts be made to preserve these until the Root Crop Development Cooperative is in a position to aid in their maintenance.

The volunteer committee earnestly seeks suggestions and advice from interested persons, especially during the crucial early phases of this proposed project.

Study Group 2

THE USE OF PHYSIOLOGICAL PARAMETERS IN ROOT CROP BREEDING

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General Remarks

The committee was able to consider the use of physiological parameters in improving the production of tropical root crops, only in the most general sense. We believed that there was too little knowledge available on which to base concrete recommendations for a sophisticated breeding programme. Generally, the selection, improvement and general agronomic techniques concerning tropical root crops such as sweet potato, cassava, yam, and the aroids are relatively poorly developed and understood in comparison with cereals, fibre crops and even the temperate root crops such as the edible Solanum potato. Also, the degree of understanding and progress towards adequate levels of production vary in different areas of the tropical world. Accordingly, we make the following suggestions on an approach to the problem, recognising that some of our suggestions have already been implemented and the desired result achieved with some crops, in some regions e.g. sweet potatoes in the Southern United States and Solanum potatoes in Venezuela. It is our feeling that the experience gained in such regions should be utilized as far as possible in other regions — climatic, economic and other factors permitting.

Basic Work

An important pre-requisite of any breeding programme is the collection and classification of the main varieties of the area, in order to select the most promising ones from existing material. Collection of cultivars from regions of similar climate, but with longer experience and more advanced breeding programmes, should also be made and the cultivars evaluated under local conditions.

Concurrently with the initial collection, classification and selection of cultivars steps have to be taken to improve the general agronomy of the species, recognising the major disease and insect pest problems.

The major requirement for improving agronomic practice is the definition of the factors limiting the yield of the chief varieties in the local environment and hence identification of the areas where significant responses to treatment may be obtained.

Studies along these lines should indicate whether:

1 the problem of improving production is essentially one of management such as manipulation of the environment to suit the species, by altering date of planting, rate of planting, fertilizer application and other agronomic practices.

2 the problem is one of breeding a new cultivar to suit the environment, as illustrated by resistance to disease or changes in growth pattern etc.

3 a combination of both factors.

It is suggested that growth-analysis techniques be used at this stage, with particular reference to the development of the leaf surface and of the storage organ, throughout the normal growing season. When this basic information is satisfactorily documented one can then proceed to the next major step in the programme.

We shall assume that the basic work indicated that this step calls for plant breeding.

Breeding Programme

As a basic premise, we agree that the ultimate objective of a breeding programme is to maximize the ability of the plant species to contribute food for man. This objective, in a very broad sense, can be achieved in two ways, namely:

1. by improving the performance of the plant species within the environment in which it is destined to be grown.

2. by improving the nutritional value of the edible portions of the plant.

The degree of sophistication of the agriculture and of the consumer in the region concerned will dictate the relative importance of the two factors. Thus, shape, size and colour of tuber, consistent with a "grade standard," may have greater relevance in some areas than nutritional value in itself.

The most difficult problem facing us is to define in unambiguous terms, the objective of the plant breeding programme. A clear and concise definition of objective, implies a ready determination of the essential parameters of the breeding programme. In our opinion, the plant physiologist has a vital role to play in such a definition.

Role of the Plant Physiologist

We envisage at least a four-stage involvement of the physiologist in the definition of the breeding programme, as follows:

1. To identify the physiological parameters which are basic to the yield potential of the species.

2 To determine those factors which are inhibiting the species in the expression of its maximum potential.

3 To assist the plant breeder in establishing the range and sources of variation which exists for those particular parameters, in order that he may determine their heritability.

4 To provide the plant breeder with simple techniques of measuring relevant parameters in individual plants in segregating populations, and hence of selecting effectively for improvement.

An increase in the yield of the economic portion of a species will most likely be achieved by selection for an increase in edible plant material in relation to the total dry matter, whilst increasing the total dry matter. The area of responsibility of the physiologist is to provide the basis for this selection.

Physioiogical determinants of Yield

We do not feel that we should attempt here to enumerate physiological parameters that might be used in a breeding programme. It is suggested that these should be worked out for individual crops and if necessary for particular environmental conditions. We draw attention, however, to two ways in which this problem can be investigated. These are :

1. The analysis of the contribution to yield in a high-yielding variety compared with a low-yielding variety.

2 Consideration of the factors which have been previously found to be important determinants of yield in other more thoroughly investigated crops.

The physiological explanation of yield can be investigated by the physiologist using growth analysis techniques. So far there have been few investigations of this type and these have been done mainly on temperate crops. Before definite recommendations can be made to the plant breeder, there is need for more growth analysis investigations on tropical root crops.

In temperate crops, the important contributory factors to high yield are :

1. early establishment of a large leaf area.

2 maintenance of leaf area near the optimum level for as long as possible.

3 maximum diversion of dry matter into the economic portion of the crop.

Leaf efficiency as assessed by net assimilation rate does not seem to be a very important attribute although differences in the net assimilation rate are found between varieties and especially with age within the one variety.

Although similar factors are no doubt involved in yield determination of tropical root crops it is felt that the differences between the temperate climate and the tropical climate and indeed between the wet tropics and the dry tropics are so great, that separate investigation is required with particular reference to the tropical environment.

It is also certain that there will be physiological parameters other than already mentioned which are very important in particular areas. Examples could be dormancy, obtaining tubers of the correct physiological state at planting, obtaining varieties which will tuberize with high levels of nitrogen nutrition, and so forth.

The Tropical Environment

It is suggested, that breeding programmes and agronomic trials should be supported by climatological records of pertinent aspects of the environment especially soil moisture deficit (from rainfall and evaporation estimates) and potential transpiration and temperature.

It is also felt that great advantages in production may be derived, in some tropical climates, from growing more than one crop in any year. The accurate documentation of annual climatic variations with an aim to fulfilling this possibility is therefore recommended.

Quality

Quality has not been a major consideration in our discussions because we feel that quality is largely determined by local preference. Quality considerations are important, however, and must be related to the utilization of the product.

Tropical root crop quality, for human and animal consumption, for processing and for manufacturing new products such as starch should be taken into consideration in breeding programmes, whenever this is possible. This may be achieved without being the primary objective of the programme by making routine records of the following characteristics of all promising varieties :

1. size, shape of roots and colour of skin and flesh
2. chemical composition of roots
3. keeping quality of roots
4. cooking quality of roots

In conclusion, we recommend that careful consideration be given to the conditions for which new varieties are to be produced. The variety for a subsistence agriculture may not at all be suited to a sophisticated cultivation system. A wet season variety may also require altogether different characterisics from a dry season variety.

We recommend that, in areas concerned with these crops there should be teams consisting of agronomists (or horticulturists), plant physiologists, and plant breeders to explore the more important crop in the region in the detail necessary for adequate understanding of the relevant issues. Inter-Regional collaboration should be actively encouraged.

Study Group 3

ECONOMIC AND AGRONOMIC FACTORS LIMITING LARGE SCALE ROOT CROP PRODUCTION

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General

Large scale root production is defined as a large acreage unit of farm land devoted to a given crop rather than a large total production of a root crop due to the sum of production of many small farm units. Large scale root production in this report will be based on mechanization of as many field operations as possible rather than the use of hand labour, inasmuch as future indications in many parts of the world reveal a shortage of cheap available labour for such agricultural crops.

Procedure

A questionnaire covering the main possible limiting factors, both agronomic and economic, which can limit large scale root crop production was circulated among the 23 countries represented by our symposium delegates. The results of these questionnaires were tabulated on the IBM Computer to give a fairly comprehensive picture of factors which might limit root crop production.

Preliminary Results

A preliminary scanning of the data indicates that limiting factors to large scale root crop production are more economic rather than agronomic. Sufficient land appears to be available for mechanization in most countries. However, further information and experience is needed in the proper machines for planting and harvesting mechanically.

The economic limitations are apparently based on prices of the product, lack of markets (local and export), seasonality of production, and lack of information of cost of production of the various agronomic phases of mechanizing the root crops. The lack of proper marketing facilities and apparently large mark-up in price between farm price and retail price was indicated in a majority of the countries.

A large group of countries indicated the possibility of processing of root crops (especially cassava) as a means of making the mechanization of root crop production economical. However, more information is needed as to actual feasibility in the particular crop and country.

Study Group 4

IDENTIFICATION OF AREAS NEEDING FURTHER ELUCIDATION IN DISEASE OCCURENCE ON TROPICAL ROOT CROPS

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The opinion has often been expressed that tropical root crops are largely free of diseases and pests. We consider this idea to be an erroneous one and attribute this error largely to an insufficient awareness of the problems which exist. Indeed, the lists of diseases and pests reported on tropical root crops are short in comparison to those on most other cultivated crops. A brief and incomplete examination of the literature indicates that some 16 fungi have been associated with root rots and necrosis of the above-ground parts of **Manihot esculenta.** Several fungi have been associated with diseases of **Colocasia esculenta, Xanthosoma sagittaefolium, Dioscorea** species and **Maranta arundinacea.** In addition, bacterial, virus and nematode diseases are known to occur on most of these crops. Many of the virus diseases are transmitted by aphids and white flies, and several other insect pests are known to cause damage to the aerial and under-ground parts of these root crops.

In general, very little work has been done on tropical root crops and therefore information is limited on several aspects of root crop production. It is, perhaps, not altogether insignificant that **Ipomoea batatas,** the root crop which has been studied most extensively, also has the largest number of recorded problems. There are at least 30 fungal diseases, 7 virus diseases, 3 nematode diseases, and 7 major insect pests of this crop.

Let us now examine some of the factors in root crop production which particularly favour the development of diseases and pests.

1 Root crops are all vegetatively propagated. They thus provide excellent reservoirs for viruses and other pathogens.

2 The economic parts of these crops are underground and thus are liable to direct attack by soil fungi, bacteria, nematodes and insects.

3 The location and methods of harvesting the economic parts of these crops facilitate wounding thus providing ready avenues of ingress for pathogenic organisms which may cause considerable damage in storage.

4 The long duration of growth and the growing season (wet) of most tropical crops are likely both to enhance the incidence of disease and to render control measures difficult and expensive.

Undoubtedly, diseases and pests are limiting factors in the production of tropical root crops. However, we feel that the information available is insufficient to permit us to assess fully the magnitude of the problem. Perhaps one of the most important factors contributing to this dearth of information, particularly in the Caribbean area, is related to the system of producing these crops. Until very recently, root crops were produced almost exclusively by small farmers and backyard farmers in small plots. Under such a system, plants may genuinely escape disease and pest damage, or their susceptibility may go unnoticed principally because of the small acreages involved. Invariably, the incidence of disease and pests increases as the acreage of a particular crop is increased. It should, therefore, be reasonable to expect that with the contemplated increased emphasis on the production of tropical root crops, little known and previously unknown diseases and pests will become evident, as in the case of **Colletotrichum** disease of **Dioscorea** which now is present in the West Indies.

In view of the problems outlined above the study group concerned with the pathology and entomology of tropical root crops considers it extremely difficult to isolate specific areas needing further elucidation. Indeed, this study group considers that the entire field stands in need of elucidation and agrees that careful consideration should be given to the following points:

1. The personnel engaged in research on diseases and pests of tropical root crops are far too few to cope effectively with the present and potential problems.

2. The group recognises the need for greater emphasis on research, and strong support for the development of departments in the sciences of entomology and plant pathology in tropical countries.

3 With the present limited number of personnel engaged in research on diseases and pests of tropical root crops every effort should be made to encourage co-operative ventures such as seminars, symposia and exchange of bibliographical complications. In the opinion of the group the importance of such activities cannot be over-emphasised.

4 Exclusion of pathogens and pests that are not present in given areas is an extremely valuable aid in combatting diseases and pests. Adequate attention should therefore, be given to quarantine regulations and measures, both on a regional and territorial basis, to avoid the introduction of new diseases and pests.

5 Programmes for the improvement of tropical root crops by breeding and selection should include screening for resistance to diseases and pests as a major objective.

6 Increased attention should be given to the efficient use of modern chemical, biological and cultural control measures, e.g. disease-free planting material, crop rotation and field sanitation.

Study Group 5

THE FUTURE OF ROOT CROPS AS A SOURCE OF CARBOHYDRATES

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It is clearly important but also extremely difficult to assess the future position of the tropical root crops as a source of carbohydrate. Their importance in human diets will depend upon the interaction of three factors:

1 the costs of producing root crops compared with competing staple foods — notably the cereal crops;

2 the extent to which the farm level price is increased by costs of distribution and processing; and

3 the extent to which the farm level price is increased by costs of distribution and processing; and

3 consumer preferences which determine the quantities consumers are prepared to buy at various prices. The future demand for starchy roots as livestock feed will depend essentially on their comparative cost as the energy component of livestock rations.

There appear to be large differences in the extent to which the tropical roots are able to compete on a cost basis with other sources of carbohydrates. Under traditional systems of farming they are capable of giving yield per acre of product and of calories that is high relative to the alternative crops available. They are also capable of giving relatively high yields per man-day, although yams tend to be relatively demanding in their labour requirements whereas manioc is particularly cheap to produce.

They are, of course, large local variations in yields and production costs depending on the root crops, the variety grown, and the technology used. In addition, there appear to be rather striking regional differences in the relative costs of the root crops and competing staple foods. In tropical Africa, the root crops, and again manioc in particular — tend to be the cheapest sources of food calories in the humid and subhumid areas where they thrive. The situation is very different in the West Indies. Price data indicate that local root crops are about as costly on a weight basis as imported cereals which means that in terms of calories they are something like three times as expensive. The foregoing price comparison applies to the retail price of fresh roots and therefore is in part a reflection of the rather high costs of transporting, storing, and handling the root crops because of their bulky and semiperishable nature. There is also a tendency for fresh roots to be relatively more expensive in urban centres in Africa, presumably for the same reason. But in a number of African cities at least one processed root product — manioc meal or **gari** — is the cheapest source of food calories.

Judging by the experience of the last half century and more in the West Indies, there is a strong tendency for consumers to shift from root crops to rice and wheat products as they come to rely increasingly on purchased food. This shift has been possible because of fairly high foreign exchange earnings from sugar and other exports that have provided the foreign purchasing power for very heavy reliance on imported cereals. In fact, apart from farm households that still subsist mainly on their own production, the root crops have become primarily a vegetable food that adds variety to the diet rather than a staple food. It seems likely that at present the local root crops compete much more with imported Irish potatoes than with the imported cereals.

Although imports of wheat products, and in some countries rice, have increased sharply in tropical Africa, food imports have not as yet become highly important In a few instances there appears to have been a tendency for growing demand in urban areas to be satisfied by imports rather than expanding the flow of indigenous roots and other staple foods, but that appears to be the exception rather than a dominant feature as in the West Indies. Although it is certain that total demand for food will grow rapidly with the growth of population and rising per capita income the effect of this on the root crops is uncertain. Total and per capita consumption of root crops in tropical Africa will no doubt continue to increase for some time until incomes rise sufficiently to permit a substantial shift to preferred foods — initially wheat production or rice and eventually high cost but preferred items such as meat and dairy products. In the West Indies growth of demand associated with population increase may for a time, offset the trend toward declining per capita

consumption that will probably continue. The view was advanced that efforts to promote consumption of local root crops, for example popularizing new techniques of production or introducing processed products with the transport and handling characteristics of the West African **gari** or Brazilian farinha da mandica might slow or even reverse the trend toward declining consumption. But this is highly speculative, and it is understandable that, from the demand point of view replacing imported "Irish" potatoes by local production is receiving much attention.

The statement is subject to many qualifications. Even more important than the time limitation under which the committee operated is the lack of reliable information concerning consumer preference in various areas, comparative costs of production and comparative cost of handling, storing and transporting of roots and cereals and of the different roots.

The committee was unable to get information on Latin America and Asia in making its recommendations and does not feel equipped and competent to formulate statements on the future of root crops as a source of carbohydrates for these areas. This study group would like to draw on the knowledge of people in these areas by

1. asking delegates from these areas their views and

2 by corresponding with experts based in these areas.

Study Group 6

ROOT CROPS AS PRIMARY SOURCES OF CARBOHYDRATE

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This Report aims to identify areas where more work is required to increase the utilisation and processing of tropical root crops, and, to show ways of promoting international cooperation in this field.

A. The major tropical root crops, arranged in diminishing order of knowledge as primary sources of carbohydrate are the sweet potato, the cassava, the yam and the edible aroids. The Study Group dealt with the following specific areas of the study of these crops.

1 The need for more information on dry matter quality with respect to utilisation of tropical root crops as foods and feed stuffs.

There is a need for large scale processing and a greater availability of tropical root crops as foods and feed stuffs.

(a) The Study Group noted the widespread importance of cassava as a food which grows under a wide variation of ecological conditions. For example, in India, in the State of Kerala where the Cassava averages over three million tons per year, semiprocessed cassava as chips have been used to help break a recent famine in the State of Behar. Satisfactory results are reported with the use of cassava and nutritive supplements to feed poultry and cattle in some parts of the world. This crop could be encouraged in tropical countries as a replacement for the expensive imported animal feed stuffs such as oats and maize. Through cottage industries in India the cassava is available in forms such as fried chips. The methods already in use have solved the problems of detoxification and of preserving the cooked cassava. Sun-dried chips can be stored for as long as six months. Cassava starch and glucose from the cassava are already in use in the United States, India and elsewhere. However, the cassava has perhaps an even greater future as a milled flour with properties useful for incorporation in bread manufacture and in other industries.

(b) The sweet potato is apparently the second world source of carbohydrates from tropical root crops. Although there are efforts to promote the use of yellow fleshed varieties high in carotene content the greater demand in some areas is for the white fleshed potato. And it is likely that this will continue until sociologists and economists encourage a change. Meanwhile, in Puerto Rico efforts are being made to improve white fleshed varieties for canning. Sweet potato cultivation for foods and feed stuffs should be encouraged in the tropical lowlands in place of less well adapted crops like the Solanum potato. It is hoped that the more extensive production of this crop could reduce the cost of production.

The sweet potato is already available in canned, chip and flake forms in the United States of America. Yams and edible aroids can be processed by the same equipment now used to process the sweet potato, provided the economic problems are solved. More attention should be paid to the quality of starch derived from these root crops to meet a specific culinary need. For instance, more studies should be done in relation to the texture required for the important West African yam food called "fu-fu," and "Poi" which is derived from the taro of the Pacific Islands.

(c) Compared to the cassava and the sweet potato, there is much less data available on yam and the edible aroids which are however grown largely as home garden vegetables in many countries. More of these root crops might be grown profitably in rotation with staples where they are now not grown in the tropics. They are highly accepted everywhere, and there may be surprisingly good returns from researches on the domestication of some of the less well-known yams (**Dioscorea spp.**) and edible aroids, (**Xanthosoma** and **Colocasia spp.**).

(d) The existence of toxic **Dioscorea species** should be noted. They are used in an emergency as famine relief food, but with cultivation on a larger scale they should find more extensive useage as foodstuffs after processing which includes detoxification.

2 There is an urgent need for more information on proper handling and storage of all tropical root crops to extend their period of availability.

3. **Root crops as raw materials for industrial processes:**
There is a lack of information to determine whether the four main tropical root crops (sweet potato, yam, cassava and aroids) are interchangeable as raw materials for processing for industrial use.

(a) Starch manufacture for the paper and textile industry from cassava and from sweet potato is already carried out in Mexico, East Africa and elsewhere. Glucose, alcohol and other products are also being obtained in India from the cassava. Inter-disciplinary teams of economists and horticulturists would consider in some cases the need for small factories and for plantations of tropical root crops to take the place of other starchy crops now grown only with difficulty.

(b) It is unlikely that yams and the edible aroids would in general be useful raw materials in industrial processes because they are grown mainly as food stuffs at greater cost than the cassava.

4 **The preparation of a monograph on traditional culinary methods used for tropical root crops in order to increase their utilisation:**
There is need to collect data on indigenous methods of use and preservation of tropical root crops. A working party drawn from participants at this symposium should collect recipes and socio-economic data relevant to the conditions under which the foods are prepared by traditional methods from tropical root crops, from country to country.

B. Another major recommendation of the Study Group is establishment of regional and international cooperation and regular consultation amongst workers in the field of tropical root crops utilisation. It recommends that support for this work should be actively sought from already established International institutions such as the Food and Agriculture Organisation of the United Nations, the Inter-American Institute of Agricultural Sciences of the O.A.S., and other interested organisations.

Study Group 7

THE SCOPE FOR IMPROVEMENT OF DIET THROUGH INCREASES IN THE NUTRITIVE VALUE OF TROPICAL ROOT CROPS

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It has been well established during this Symposium that dietary habits, scarcity of grains, and the availability and production potential of root crops in many regions of the tropics demand that tropical roots play a major role in supplying a large proportion of the daily food intake of millions of the world's population. The great advantage of these roots over other crops that can be produced in the tropics lies in their potential for supplying extremely large quantities of utilizable calories per unit of land area. This basic advantage, and the economics of commercial production require that primary emphasis in root crop improvement be given to increasing yields of edible roots.

Generally in areas where root crops supply the major portion of the daily food intake, protein and more specifically amino-acid deficiencies and under-nutrition are widespread. It is generally accepted that the protein quality and nutritive value of most tropical roots are very low; however, complete and accurate chemical and nutrient analyses for a wide range of genetic materials are not available to allow us to assess the improvement in nutritive value that might be possible from an intensive breeding and selection programme.

On the basis of these findings we would suggest that:

1 Any attempt to improve the nutritional level in certain tropical areas must involve some consideration of increasing and maintaining an adequate supply of total calories. This would indicate that major emphasis should be placed on measures designed to increase yield per unit area and to increasing total production. Selection of varieties for yield characteristics and improved agronomic practices would allow rapid progress to be made in increasing caloric availability.

2 Concomitant with selection for high yield; protein, amino acid, vitamin, mineral and toxic principle composition should be obtained for all available genetic materials. This will establish the feasibility and scope for improving the nutritive value of these tropical roots. It is recommended that arrangements be made for establishing standard procedures collecting, drying, handling and labelling of samples and that some institution be selected which has the capacity and is willing to undertake the analysis, compilation and distribution of these data.

3 Because of the low nutritive value indicated, the economics and feasibility of associated cropping of root crops with legumes should be investigated with a view to supplying a more balanced diet.

4 Studies be undertaken to investigate possibilities of incorporating dehydrated forms of these roots into acceptable, enriched food preparations and to assess the value of leaves of these crops as human food.

5 Possibilities be explored for increasing the utilization of roots and the leaves of these plants in stock feeds in order to increase the supply of dietary animal protein, and to reduce competition between livestock and humans for other food sources.