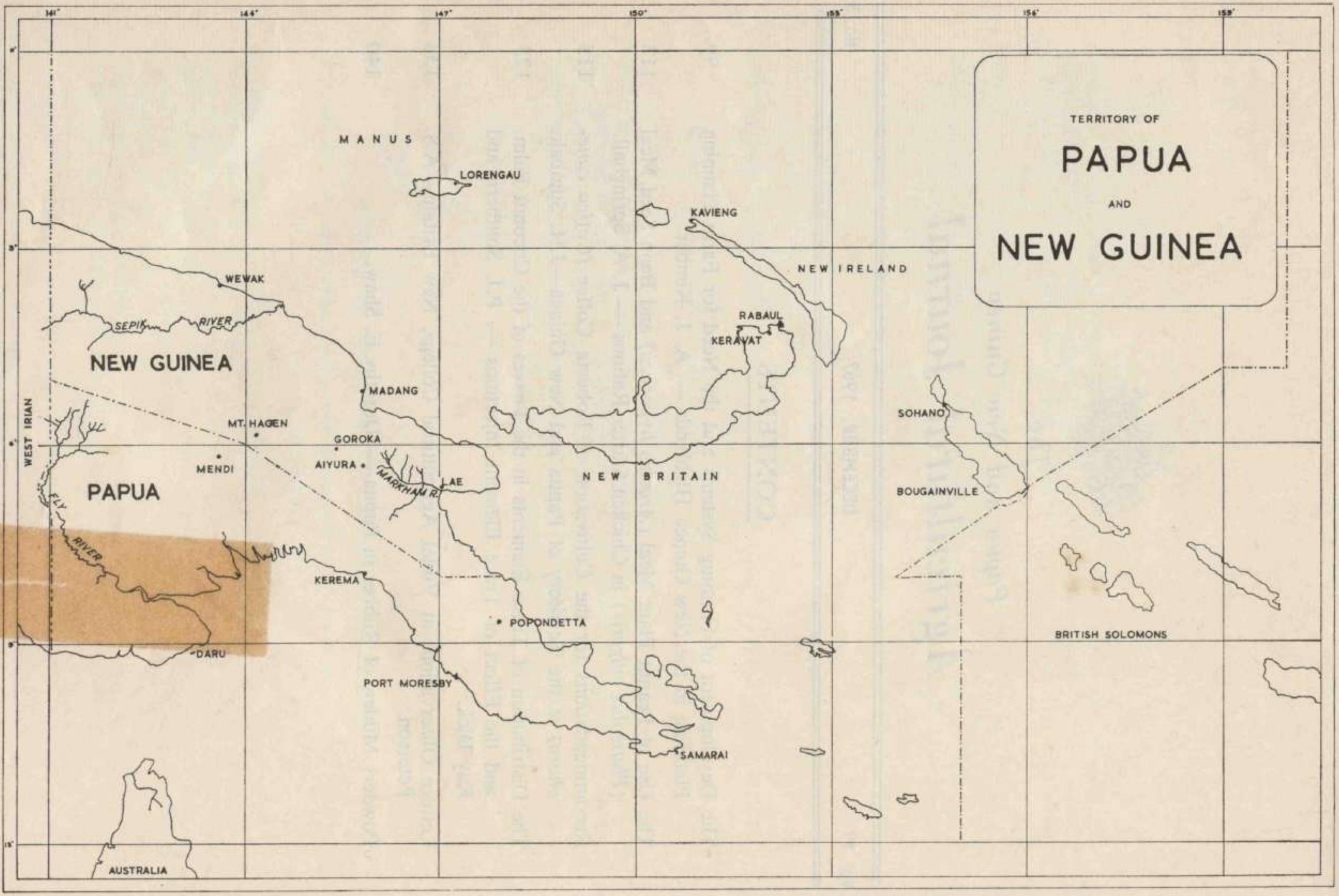
The

Papua and New Guinea

Agricultural Journal

Vol. 19 DECEMBER, 1967 No. 3

CONTENTS


TERRITORY OF
PAPUA
AND
NEW GUINEA
141°
144°
147°
150°
153°
156°
159°
MANUS
LORENGAU
KAVIENG
NEW IRELAND
RABAUL
KERAVAT
WEWAK
SEPIK RIVER
NEW GUINEA
MADANG
WEST IRIAN
MT. HAGEN
GOROKA
MENDI
AIYURA
MARKHAM R.
LAE
NEW BRITAIN
SOHANO
BOUGAINVILLE
PAPUA
FLY RIVER
KEREMA
POPONDETTA
BRITISH SOLOMONS
DARU
PORT MORESBY
SAMARAI
AUSTRALIA

THE DEVELOPMENT OF FARMING SYSTEMS AND THE NEED FOR FARM PLANNING IN THE NEW GUINEA HIGHLANDS

A. J. KIMBER*

ABSTRACT

Cash agriculture is becoming more diversified in the New Guinea highlands. In addition to cattle grazing and the coffee, tea and pyrethrum industries there are opportunities for other forms of agriculture, particularly in the form of annual crops which may be used as food for man and livestock.

The desirability of raising living standards, discussed elsewhere in detail, is assumed. A brief assessment is made of the effects of cash agriculture on the subsistence economy and the emergence of farming systems in the Highlands. However, the development of more viable farming systems depends on a number of factors and after discussion of these, suggestions are made to assist this trend.

INTRODUCTION

THE development of farming systems in under developed countries is an obvious way of helping to solve economic pressures amongst people changing over from a subsistence to a cash economy.

Subsistence agriculture in Papua and New Guinea is in fact a system of land rotation (Barrau, 1958; Newton, 1960). The length of the rotation depends on how much land the individual has available. In many lowland areas of Papua and New Guinea it is a long enough period for the bush to regenerate to high secondary forest. However, rarely if ever in Papua and New Guinea would the rotation be long enough to allow regeneration of a climax forest. Alternatively, the rotation may be over a short period (less than ten years) so that trees may have little time to establish and the land remains permanently under grass, particularly if burning is practised. This is the usual pattern in the New Guinea highlands.

Within this system of land rotation, according to custom and locality, various systems of subsistence cropping may be carried out during the continuous cropping of one area. The Orokaiva people of Inonda take off only one crop (Crocombe et al., 1963) but the Chimbu people of the New Guinea highlands use at least three different rotations, often combined with mixed cropping (Barrie, 1956).

In this discussion of developing farming systems for the New Guinea highlands, it is taken for granted that the system of bush fallow rotation, though admirable for the conditions under which it is still being practised, is inadequate to meet the modern developments of cash cropping and increasing population. Gourou (1958) says that if the standard of living of tropical peoples is to be raised, then the system of shifting cultivation (or bush fallow rotation)* must be abolished because it is incompatible with a high standard of living.

The question becomes one of finding more efficient ways of using the land available so that the range of agricultural produce can be diversified and produced in excess to promote cash incomes. This article is mainly concerned with conditions in the New Guinea highlands where cash agriculture is becoming more diversified. Development is proceeding

* Agronomist, Highlands Agricultural Experiment Station, Aiyura.

* Many authors distinguish between the two. Generally the former is carried out over very large areas often under no particular system. The latter adheres to a definite time interval between when a garden is cropped, rested and cropped again.

in such a way that in addition to cattle grazing and the coffee, tea and pyrethrum industries there are opportunities for other forms of agriculture, particularly in the form of annual crops which may be used as food for man and livestock.

THE EFFECTS OF CASH AGRICULTURE ON THE SUBSISTENCE ECONOMY

The immediate effects of cash cropping and animal husbandry on subsistence agriculture in the New Guinea highlands have been as follows:-

(a) A tendency towards a more sedentary agriculture. Coffee gardens for example, induce people to remain at the one village site. The fallow period between subsistence crops has been shortened, with the result that the land immediately around the village is used most of all.

(b) With increasing cash income, mainly from coffee and the sale of fresh vegetables and meat, some food is now being purchased, as well as cooking utensils, clothing and building materials. Subsistence garden areas have been reduced compared to former times. This is the first real step toward a cash or partly cash economy because it stems from the realisation that it takes less effort to support a family by growing a cash crop with a relatively high return and then purchase food, than trying to grow all the family's food needs, which involves a very high labour input.

(c) A process has been set in motion whereby increased wealth within the community means that higher economic goals have been set and improved methods of agricultural production can be applied which before may have been too costly to people with little or no cash income. An example of this is in the Goroka Valley where returns from coffee production are being invested in livestock (McKillop, 1966). Indeed, in the Goroka Valley some individual farmers now have the means to invest in the hiring of tractors or the purchase of rotary hoes, etc.

(d) The introduction of grazing animals has meant that some fallow areas have been utilised whereas before they were lying idle as part of the traditional bush fallow rotation. About 75 per cent. of the Goroka Valley, for example, is at present unused grass land (McKillop, 1966).

(e) A joint effect of cash cropping and animal grazing has been the movement towards the changing of traditional forms of land tenure. The old system appears satisfactory for the subsistence agriculture it supports, but those people who are engaging in more intensive crop/animal production involving capital investment are pressing for a more secure tenure of their land, often on an individual basis. This process in lowland areas has been accelerated by the example of the Administration, which purchases land from the people and then subdivides into small-holdings. One would expect the same catalytic effect in the Highlands, particularly in areas close by Administration land resettlement schemes.

THE EMERGENCE OF FARMING SYSTEMS

In the Western Highlands District, settlement of land under Administration control is being carried out at Nondugl, Kindeng West and Kondepina. The farm size is usually eight to ten acres. Tea is being established as a first avenue of income and this is based, as with cocoa, rubber and coconuts in land settlement areas in the Papua and New Guinea lowlands, on the concept of family labour units.* It is thought that the area of tea which the average family could handle (that is a family with one and a half labour units available each working day of the year) would be two or three acres, including labour for subsistence requirements.

One model farm is being developed in the Western Highlands and one at Aiyura in the Eastern Highlands. It is hoped that settlers will use many of the ideas being demonstrated. Around the boundary of the farms trees of a local species of *Casuarina* have been planted in a single line at close spacing. These are rapid growers and will be thinned as they grow and used as a source of fire-

* *Department of Agriculture Stock and Fisheries Circulars* Nos. 2, 7 and 9 of 1963. These are standard plans and budgets which may be modified to suit local conditions.

wood and building materials because of the often chronic shortage of firewood in grassland areas. *Casuarina* is planted in bush fallow rotation systems in the Highlands for subsequent use as firewood and terracing of steep hillside gardens (Barrie, 1956). The farms are being planted with three acres of tea (one acre in each of the first three years). An area of about one acre is allowed for home site, tea nursery, a few citrus trees and minor subsistence crops such as maize, taro, sugar cane, bananas and pineapples, leaving about four acres available for other activities. It is considered that by introducing cattle into the land resettlement schemes this remaining land could be used at little extra labour cost to the farmer. This would be preferable to growing sweet potato haphazardly for subsistence. Rather should sweet potato be included in a rotation, with the possibility of building up a regular supply to plantations and to local markets. In addition to cattle, a substantial cash income may be possible for more advanced settlers growing fresh vegetables supplying coastal markets.

Apart from the land settlement schemes there has been little evidence of the emergence of farming systems in the Western Highlands. The development of the coffee and pyrethrum industries by indigenous farmers in this area is as yet in its infancy.

There is no doubt that farming systems are beginning to develop in the Goroka Valley of the Eastern Highlands. These are small scale systems using a combination of subsistence/pigs (with all pig food being grown on the farm) or subsistence/cattle. Coffee may or may not be included in either system. The standard of livestock management is variable and is sometimes quite high, especially in the case of the pigs.

Plate I.—A small intensive pig project in the Goroka Valley. (Photo R. F. McKillop).

Plate II.—A mixed crop garden of corn (*Zea mays*) and sweet potato (*Ipomoea batatas*) to be used for sale and for pig feed. (Photo A. J. Kimber).

Pig projects in the Goroka Valley are being developed along intensive lines, that is with a minimum of grazing, mainly because of the internal parasite problems involved if improved breeds of pigs are grazed (*Plate* I). Houses are of bush material and/or sawn timber, usually with a roof of corrugated iron. All projects have cement floors and provision for a water supply (usually from a race) to facilitate daily cleaning. The economics of the projects, particularly in regard to labour, are uncertain. The usual practice is to feed the pigs with sweet potato tubers and leaves growing close by, occasionally supplemented with greens (*Plate* II). Some individuals are beginning to plant soybeans in an effort to raise the protein level of the ration. The pig projects are not farms, demarked on the ground as such, largely because of the indigenous land tenure system. However the various activities reflecting the working of a farming system are present.

There are now 352 head of cattle in 38 projects in the Goroka Valley (*Plate* III). Each project has a night paddock of at least five acres. In many recent projects this area is 20 to 30 acres and in one case 100 acres. The fenced area on cattle projects is in excess of 500 acres and is increasing at the rate of 20 to 25 acres each week (McKillop, 1966). For cattle McKillop states that fencing and livestock should be under individual ownership, which is not always the case, and that the fenced area could form the nucleus of a future family farm.

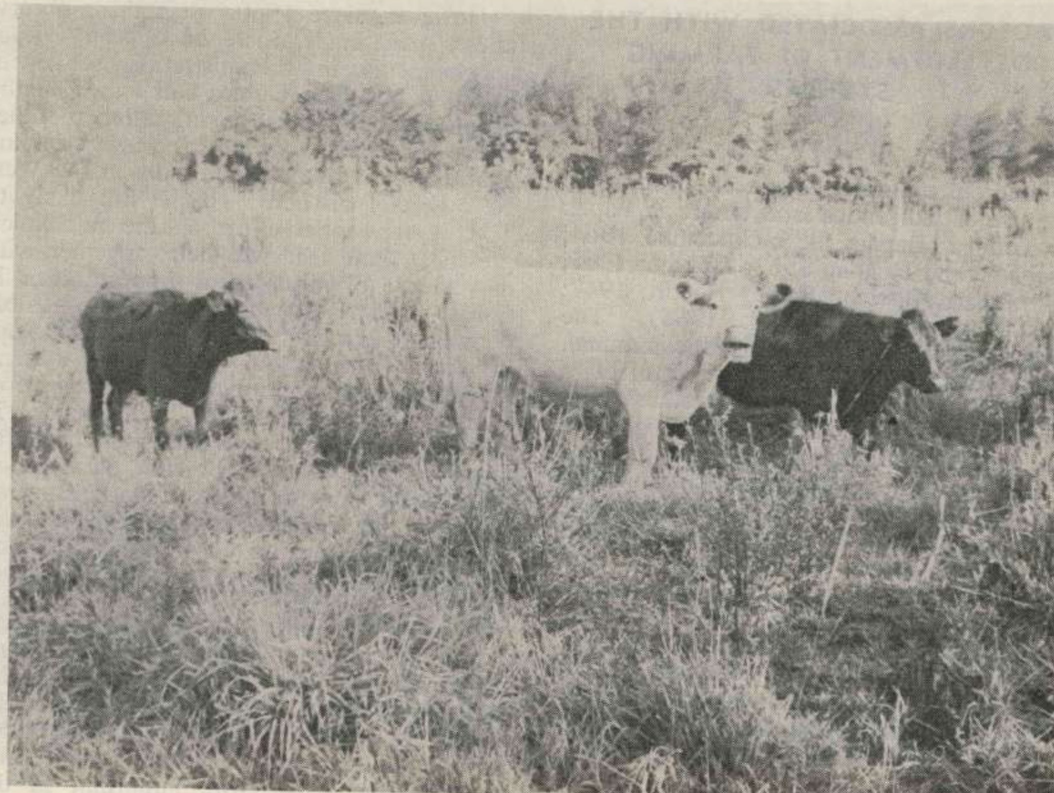


Plate III.—Cattle on a typical project in the Goroka area. Pasture of a stand of *Setaria sphacelata* (Photo A. J. Kimber).

All pig and cattle projects in the Goroka Valley are sound attempts at good husbandry practices, but they are largely feeling their way, not only because of the transition involved for the indigenous farmer himself, but also because of the lack of critical information on the associated crop and pasture production. Basically, for the cattle projects, there is need for information on how best to establish an improved pasture on these smallholdings, which are quite hilly and without machinery. For the pig projects, in view of the relatively high standard of management adopted, there is need for work to be carried out on suitable crops that can be utilised for pig feed. In time one might visualize specialised feed producers supplying pig farmers. This would be one way of overcoming the present high costs and would seem to be even essential if individual farmers are to expand.

In view of the high cost of purchase of eggs, there is considerable scope for poultry as a sideline for some farming systems, if not for specialised production. Importing feed to the Highlands makes the profit margin in poultry farming small, even in competent hands, so the answer appears to be in feeding locally grown material. It would be possible, for instance, to incorporate a small intensive poultry house on a settler's block and grow the feed for the poultry in rotation. The problem of finding balanced cheap rations has been solved (Ross and Springhall, 1965) and it remains to find out how to grow the required feedstuffs intensively.

FACTORS ASSOCIATED WITH THE DEVELOPMENT OF FARMING SYSTEMS

Land Tenure

Numerous examples have been given in the literature of indigenous land tenure in Papua New Guinea (Barrie, 1956; Crocombe, 1964; Crocombe and Hogbin, 1963; Jackson, 1965; New Guinea Nutrition Survey Report, 1947; Rimoldi, 1966; van Rijswijk, 1966). The usual unit of land ownership is communal. The community may be in the form of a tribe, a village, a family or some other social group. Individuals have various rights to land, such as cultivation, hunting and harvesting certain trees etc., by virtue of their membership of the community. Inheritance patterns vary and may be patrilineal, matrilineal or bi-lineal. Although inheritance of land is often on an individual basis, the sale or transfer of what may be called economic areas of land usually becomes an affair of the community. This is especially so in many parts of the Highlands where fragmentation of land ownership is a problem in developing farming systems.

Taking the country as a whole, Papua and New Guinea is in the fortunate position that the introduction of cash cropping, combined with the prevailing subsistence agricultural pattern, has not created any serious land shortages for food production. There are certain areas where shortage of land is evident, as for example in the Gazelle Peninsula, the Chimbu district and someareas of the Sepik district. Generally the New Guinea highlands are more densely populated than other areas, an example being the Chimbu district, the most populous of all, where the density is about 60 per square mile (population census, 1966. The density on arable land would be much greater than this and so Montgomery (1960) concludes that in the Upper Chimbu Census Division cash cropping should not be allowed to supplant subsistence agriculture because of the interference which would occur with the food needs of the people. Accordingly, he says, the economic potential of the Upper Chimbu is poor.

However, since 1960, when these observations were made, there have been various developments in Administration settlement in Papua and New Guinea and some Chimbu people will in future be migrating to other areas where leasehold land for cash cropping has become available, especially in the West New Britain district. This is not likely to have a substantial effect on the population pressure, though it will help, together with movement to employment opportunities in towns, industrial developments and possibly permanent employment on large plantations instead of the present recruitment system. Apart from migration there is the example of Kenya where statements were made in 1946/47 of how every African area there was grossly overpopulated, but later thoughts on the subject are much more optimistic because of the development of land resettlement and farm plans allowing for a much more efficient use of available land (Brown, 1957).

At present over 97 per cent. of the land in Papua and New Guinea is held under indigenous tenure. Not all of this is arable, but it represents the greatest potential for agricultural development in the country. Land consolidation is therefore important in the development of farming systems. Apart from the purchase of land by the Administration for subsequent subdivision and leasing as smallholder blocks, there is now opportunity for the consolidation of indigenous land into economic areas of secure tenure (Land Tenure Conversion Ordinance, 1963) (*Plate* IV). Perhaps the most encouraging sign is that in certain areas of Papua and New Guinea, such as the Northern district around Popondetta and Kokoda, land tenure conversion to individual blocks has become highly desired by the people. However, advantages such as these, when they occur in the Highlands, need to be followed up by new farming techniques, otherwise there will be a tendency towards continuous cropping and subsequent rapid depletion of nutrients and loss of viable soil structure. These problems are even more pressing in the Lowlands where the clearing and burning of forest results in rapid leaching of nutrients and yields are likely to decline after the first one

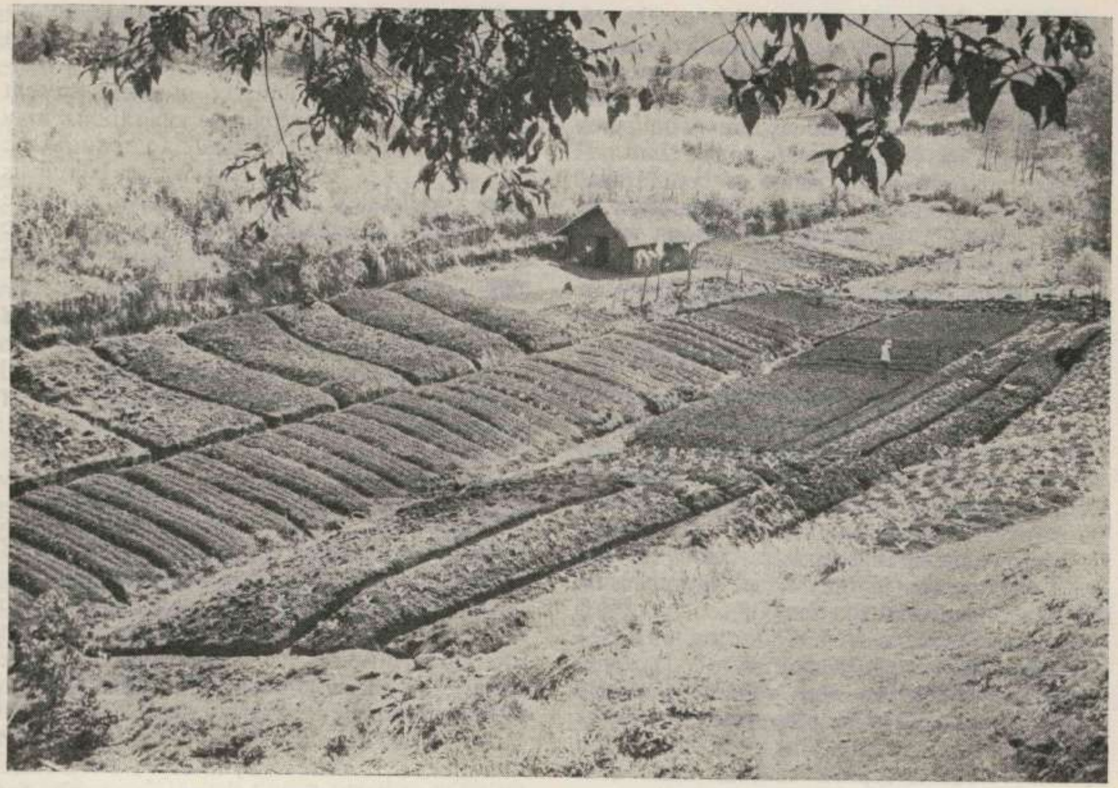


Plate IV.—An indigenous market garden, near Goroka, on land owned by a single individual. (Photo A. J. Kimber).

or two crops *(Department of Agriculture, Stock and Fisheries, Annual Reports,* 1956-64). Conversion of land to individual title is not encouraged in heavily populated araes because consolidation into what would be sub-economic araes would be valueless and would therefore create an unfavourable impression from a landowner's point of view.

It is not known if a system of land tenure based on individual title will overcome all or most of the impediments placed on agricultural development by traditional tenure systems. However, in the author's experience in the Northern and West New Britain districts, it does at least provide an initial stimulus to cash cropping on an individual basis. The advantages and disadvantages have been summarised by Brown (1957).

Size of Holding.

This will depend on the type of farming programme envisaged. In lowland areas, on Administration settlement schemes, the acreage of land that a man and his family can handle is reasonably well established for such crops as cocoa, rubber and copra.* Size of holding is designed according to the crop plus an extra quite substantial area of land, to allow for future development and subsistence. A similar situation exists for the Administration tea settlement schemes in the Highlands.

* *Department of Agriculture, Stock and Fisheries Circulars* Nos. 2, 7 and 9 of 1963. These are standard plans and budget which may be modified to suit local conditions.

In land tenure conversion schemes size of holdings can be fairly well controlled, but it can vary according to the number of people who have an interest in the particular area to be subdivided. Individual titles would not be granted on sub-economic areas, but because of the extending range of commercial agriculture in the Highlands information is now needed on yields of the various crops under local conditions so that realistic plans and budgets can be prepared and minimum economic areas determined.

Machinery.

Up to the present time the increasing income of most indigenous farmers has been from expansion of areas planted to perennial tree crops. There is a need for diversification, particularly as tree crops are a long term investment and alternative quick return cash crops mean that farmers can withstand price fluctuations in the former more easily. In this connection the use of machinery is particularly relevant. Whitehead (1962) describes various applications of Japanese machines which are often unique in design and Phillipson (1962) and Boshoff (1961) advocate the use of walking type tractors on farms. Boshoff reports that in trials conducted in Buganda prior to 1958, the conclusion was that because of their unreliability, the effort required to operate them, the limited range of accessory implements and the lack of skill of the operators, these machines would not be suitable for use by African peasant farmers. However, subsequent trials led to the conclusion that two types of walking tractors tested would be satisfactory, but certain conditions would have to be fulfilled before they could be economically employed. These included the following:

(a) On the smaller farms the machines would have to be occupied in alternative productive work such as weed control in coffee, water pumping, coffee hulling and transport, thus making up for the restriction in farm size. Alternatively, contract work could be undertaken.

(b) A technique would have to be developed for the training of farmers so that machines would be sufficiently and efficiently utilised and maintained.

This type of tractor may provide an attractive alternative to the use of tractor drawn machinery to many farmers in the New Guinea highlands, particularly at their present stage of development where operations may not be sufficiently large scale to require the use of a large tractor and where labour is often unreliable. They would also be more practicable on hillside farms and could be used for a variety of purposes similar to those mentioned.

An alternative to the ownership of machinery by individual farmers would be to use contract tractor operation. This would ensure perhaps a more efficient use of machinery.

Credit and Labour.

Stent (1962-63) lists four pre-requisites which must be met for any rationalisation of peasant agriculture to be successful. Among them he considers that farmers must have financial assistance available to them. Credit for family farming has been important in the pattern of development of Administration settlement areas in Papua and New Guinea (Cheetham, 1963). Agricultural loans can be obtained from the Papua and New Guinea Development Bank and terms are usually for the development of a minimum economic area, or what is estimated to be such, for one farmer using family labour for the various crops concerned. This has applied mostly to the lowlands settlement areas on Administration leasehold land and so far loans have not been granted for the tea settlement areas of the Highlands.

However, apart from the family labour concept, the Administration is ready to give those who have demonstrated their ability opportunity, in the form of loan monies, to develop their interests beyond that which can be handled by family labour. Despite the fact that many settlers are not suitable as employers of labour, there are indications that the more competent indigenous farmers can both employ labour and use machinery. Examples can be found of settlers on settlement blocks in the Popondetta, Gazelle Peninsula and Cape Hoskins areas employing extra labour in addition to carrying out the development programme undertaken with their loan monies. Some have been granted extra loans.

In these settlement areas, however, extra labour is often paid for out of private finances or it is employed at no immediate cost to the settler under the terms of indigenous social structures. One can envisage the same pattern occurring in the settlement areas of the New Guinea highlands where labour is more plentiful. It may become useful also in areas of tenure conversion where it is not so important that loans be granted because farmers, though they may be considered "settled" on blocks, particularly if they build their houses on them, cannot be considered as being "resettled" in foreign areas and they will, therefore, already have subsistence gardens and a house. Loans for development can be granted to such individuals, provided they have demonstrated their ability, but any tendency to associate automatic credit with tenure conversion would be detrimental to the aims of the latter.

Before extra loan monies can be granted, however, it is important to the development of farming systems that accurate records of the performance of labour be obtained. Clayton (1960) lists three possible methods of recording labour:

(a) By observing and timing randomly chosen individuals as they work on their normal farm tasks. Although sometimes difficult to assess, this method when spread over an adequate number of individuals can be quite accurate.

(b) By operating a farm plan and system with a controlled labour force. This means data are relevant to the particular plan but can be expensive. It is nevertheless possible to separate different parts of the system, for example a small piggery or a small vegetable growing project and apply the findings elsewhere.

(c) Recording labour spent on stock and crops over a long period, but within the setting of a farm system.

Each of these methods is already being used in the New Guinea highlands. Observations are being made under the conditions of (a) in the Western Highlands where settlers are at the moment planting tea and subsistence gardens. In regard to (b) records are being kept by staff supervising the demonstration settlement blocks, one in the Western Highlands at Nondugl and one in the Eastern Highlands at Aiyura. Recording has begun along the lines of the third aspect at Aiyura and with certain crops, especially coffee and sweet potato, has been going on for some time. When records are more complete it will be possible to compare the results of the three methods.

The Problem of Fertilizing and Rotations.

As knowledge of the farming potential of the Highlands increases, land can be utilised more intensively, but in the meantime it will be necessary to adopt systems which can be readily applied and improved upon as experience and experiment suggests. Wakefield (1948) points out that it is impossible to improve soil fertility by trying to find ideal crop and crop/grazing rotations without the use of fertilizers. It may be possible to maintain and improve soil structure, use crops less demanding on the soil, add nitrogen through legumes and increase yields after grass fallow but all the time soil reserves are being depleted and must eventually be replaced.

If the emerging farming systems discussed previously in the section *'The Emergence of Farming Systems'* are to become more viable, the question becomes one of deciding whether systems more intensive than bush fallow rotation can be applied under the circumstances. It is necessary to be aware of the basic changes that occur from an agronomic point of view:-

(a) because the farmer becomes sedentary, lengthy bush fallow is eliminated and the rotation is speeded up,

(b) a variety of new crops is grown to suit commercial conditions. This does not mean that subsistence crops are eliminated, but rather they become a relatively minor part of the farming system,

(c) the old concept of allowing time for the release of nutrients from soil minerals to restore the fertility of the soil and for control of disease and insect pests disappears and is replaced by more productive methods.

In the New Guinea highlands generally the large areas of grassland are usually thought to have arisen from frequent cultivation, often combined with the practice of burning for hunting and preparation of food gardens, preventing the regeneration of forest trees. This often leads to the conclusion that the soil fertility cannot be high since deep rooting forest trees have not been present to recover leached minerals from greater depth and the accumulation of organic matter under forest has not taken place. Adherents of this idea would further state that soil fertility and presumably structure under these conditions must be gradually declining. This is supported by the fact that the people do not usually leave their food gardens in the one place for more than three years before moving to a new site.

On the other hand it is commonly acknowledged that grassland areas give a good yield of most crops. Especially is this so with sweet potato in the second and subsequent croppings and it is thought at Aiyura to be due to the first cropping helping to mobilise soil nutrients after the grass fallow. In addition, tentative results of soil exhaustion and crop rotation trials at Aiyura (*Department of Agriculture Stock and Fisheries, Annual Reports,* 1956-64) indicate the possibilities of continuous cropping on some grassland soils. The soil exhaustion and crop rotation trials are sited predominantly on a black to brownish-grey light to heavy loam up to 16 in. deep, with a dark-grey to grey clay-loam sub-soil down to as deep as 38 in. and subject to a periodic water table. Though this soil structurally responds well to cultivation, it would not be regarded as first class. The variety of sweet potato used in these trials was inadvertently changed about 1961, when the higher yielding variety Akaio was substituted for the less productive though popular Gonimi. This however, has not altered the fact that it is possible to continuously cultivate a grassland soil, since current yields in the rotation trial (20,000 lb./acre) compare well with local village plantings and in the exhaustion trials are still economic, though variable (about 16,000 lb./acre).

However, the question may be asked, why do subsistence farmers themselves not cultivate for longer periods? In addition, why do they cultivate steep slopes, unless it is because more favourable areas are quickly depleted? The cultivation of steep slopes, however, is commonly given over to sweet potato because this crop requires better drainage conditions than can usually be found on the flatter valley floors. Further, there are social customs and spiritual beliefs prompting many people to rotate their land. An example of shifting due to insect pests and not soil fertility decline is of the Orokaiva people of Inonda village in the Northern District of Papua (Crocombe and Hogbin, 1963).

Many farming systems in other developing countries are based on the value of crop and grazing rotations as a means of maintaining soil fertility. Such systems are often used because of the impracticability of applying fertilizers under the local conditions of costs and lack of knowledge by farmers. The basic factor in developing farming systems in the New Guinea highlands at the moment is to ensure that productivity does not decline through more intensive land use. This involves aiming at the conservation and improvement of the nutrient and structural status of soils. The use of a grass fallow is practical for farming systems because it is cheap and conservative. Moreover, other experimental work has shown that in many tropical areas soil fertility and hence crop production can be maintained at an adequate level (Jameson and Kerkham, 1969; Kerkham, 1947; Martin and Biggs, 1937; Pereira, Chenery and Mills, 1954) by the inclusion of a grass fallow, with or without grazing. The crop rotation trial at Aiyura supports the contention that fairly conservative systems based on grass and/or legume fallow might reduce depletion of soil reserves to the level where fertilizing may not become critically important for some time. The time factor will depend on soil type and inherent soil fertility and will vary from soil to soil. It seems also in the New Guinea highlands where cattle are incorporated into systems of farming that grazed fallows or ley pastures would improve soil structure after cropping. Generally speaking, there are good prospects of recommending farming systems for indigenous people who have little or no knowledge of the use of fertilizers. However, the use of fertilizers by more progressive farmers should be encouraged.

The traditional background amongst New Guinea highlanders is one of mixed cropping. This raises the question as to whether this should be continued or replaced by pure stands in rotation. The best possibilities for inter-cropping are where machinery is not used for harvesting and this perhaps is a sound approach for small scale farmers at the moment who are growing their own pig feed and perhaps in the future, poultry feed. Results from Tanganyika (Evans, 1960) indicated that over a wide range of populations inter-cropping maize and sorghum with groundnuts generally leads to greater overall crop production per acre than growing the crops in pure stands. This was found so in two years of different rainfall, one favourable, the other unfavourable, and in two araes where soil fertility was contrasting.

In the Eastern Highlands of New Guinea coffee has so far been the means by which people have accumulated some money for investment in other forms of agriculture, at the same time retaining their interest in coffee. The mulching of coffee is one method of utilising material which may otherwise be inefficiently used. Schindler and Fraser (1964) demonstrated the superiority of mulching over clean weeding and cover crops in coffee shaded with *Albizia sp*. They concluded that labour requirements for mulching were very high, but that the yield increases obtained in the third and fourth years more than compensated for the extra cost involved and the advantage could be expected to continue. They recommended that a yearly application of six tons of elephant grass mulch per acre, whether in a single or in two applications, would be sufficient to give a worthwhile return. Alternatively any other material easily obtained would be useful. In this regard the use of maize stover for mulching material is of particular interest, as reported by Mehlick (1966). Under New Guinea highlands conditions maize is of only minor importance in the subsistence diet, so the grain could perhaps be used as a cash crop for supplying pig or poultry farmers, or alternatively for the farmer's own pigs or poultry. Another consideration would be a sorghum variety capable of producing both grain and mulching material, since this too may be useful as a cash crop supplying feed to pig and poultry projects (McKillop, 1966).

SUMMARY AND CONCLUSIONS

It has been shown that the traditional subsistence economy of the Eastern and Western highlands of New Guinea is being greatly modified and that if the standard of living of the people is to be raised, then this change is desirable. However, if improvements are to continue, consideration must be given to the consolidation of and the granting of individual rights to land as quickly as possible in areas where population pressure is not too great. In overpopulated areas it is probably necessary that there be some evolution of rights within the traditional system and some outward movement of population so that remaining individuals will have rights to economic blocks, before tenure conversion would be desirable. The more widespread use of credit by competent individuals is also desirable.

In the Western Highlands, apart from the relatively new coffee and pyrethrum industries, there are possibilities of developing farming systems in Administration settlement schemes. These include tea as a permanent cash crop, but sufficient land remains on each block for other activities such as cattle grazing. It may be possible for more advanced farmers to get extra income from high return annual cash crops grown in rotation with grazing on grass fallows or ley pastures.

In the Eastern Highlands, returns from the indigenous coffee industry are now being invested in cattle and pig projects. Certain farming systems have been initiated, especially in the Goroka Valley, and these will, under their own momentum and with proper guidance, develop into more definite systems on land consolidated into individual tenures.

The ultimate in farming systems is to have all relevant information available so that accurate budgets may be prepared, either partially or on a whole farm basis. This is necessary so that realistic proposals can be made by farmers to obtain credit. Before this is possible, critical information on certain crops is required and the following are some suggestions:

(a) Selection of crops suitable for the growing of pig and poultry feed, perhaps with the residues of some being used for the mulching of coffee. Possibilities include sweet potato, maize, sorghum, soybeans and groundnuts.

(b) Methods of cultivation. For the small scale producer, mixed cropping may be more productive than growing one stand crops. Selection of varieties needs to be carried out and establishment of optimum planting distance concurrently with fertilizer requirements. There are also possibilities of large scale production of these crops in the not too distant future, perhaps using mechanical preparation, planting and maintenance and using hand labour for harvesting.

(c) Investigations into methods of growing fresh foods such as potatoes, beans, peas, cabbage, strawberries etc.

(d) Investigations into labour and capital inputs relative to yield of all crops.

(e) Investigations into suitable species for ley pasture under Highlands conditions.

It is important that farming systems be allowed to develop with a certain amount of flexibility to allow for variations in climate, markets and preferences of individual farmers. There is a need for some systems to be organised (as for example when indigenous farmers do not understand supply and demand situations) but because of the overall picture in the Highlands of little land shortage there is opportunity to develop these systems as the agricultural knowledge of the people regarding cash cropping becomes greater. Thus simple rotations at first may be best, adopting sound agronomic practices, yet at the same time being able to be fitted in with the capabilities of the people. It would be legitimate to use up some of the soil reserves, as long as it is done conservatively, until economic conditions are such that they can be replenished with artificial fertilizers.

(Accepted for Publication, September, 1967.)

ACKNOWLEDGEMENTS

The author would like to express appreciation to the following:—Mr. A. W. Charles, Chief of Division of Plant Industry, whose suggestions have been incorporated in the article; Professor B. R. Watkin, Professor of Agronomy, University of Manawatu, New Zealand, who suggested improvements in the manuscript; Messrs. M. Belfield and R. McKillop, District Agricultural Officers respectively at Mount Hagen and Goroka, for arranging transport and accommodation during visits.

REFERENCES

BARRAU, J. (1958). "Subsistence agriculture in Melanesia. Bernice P. Bishop Museum, Hawaii, *Bul.* 219.

BARRIE, J. W. (1956). "Population-Land investigation in the Chimbu Sub-District." *Papua and New Guinea agric. J.* 11 : 45-51.

BOSHOFF, W. A. (1961). "The performance of single axle tractors on peasant coffee farms in Uganda." *E. Af. agric. J.* 27 : 77-84.

BROWN, L. H. (1957). "Development and Farm planning in the African areas of Kenya." *E. Af. agric. J.* 23 (2).

CHEETHAM, R. J. (1963). "The development of indigenous agriculture, land settlement and rural credit facilities in Papua and New Guinea." *Papua and New Guinea agric. J.* 15 : 67-78.

CLAYTON, E. S. (1960). "Labour use and farm planning in Kenya." *Emp. J. Exper. Agric.*, 28 : 83-93.

CROCOMBE, R. G. (1964). "Communal cash cropping among the Orokaiva." *Australian National University New Guinea Res. Unit Bul.* No. 4.

CROCOMBE, R. G. AND HOGBIN, G. R. (1963). "Land, work and productivity at Inonda." *Australian National University New Guinea Res. Unit Bul.* No. 2.

.... "The Erap mechanical farming project." *Australian National University New Guinea Res. Unit Bul.* No. 1.

Department of Agriculture, Stock and Fisheries Annual Reports, (1956-64). Govt. Printer, Port Moresby.

EVANS, A. C. (1960). "Studies of intercropping. 1. Maize and sorghum with groundnuts." *E. Af. agric. J.* 26 : 1-10.

JACKSON, G. (1965). "Cattle, coffee and land among the Wain." *Australian National University New Guinea Res. Unit Bul.* No. 8.

JAMESON, J. D. AND KERKHAM, R. K. (1960). "The maintenance of soil fertility in Uganda. 1. Soil fertility experiment at Serere." *Emp. J. exper. Agric.*, 28 : 179-192.

KERKHAM, R. E. (1947). "Grass fallow in Uganda. 1. Grazing during the fallow period. " *E. Af. agric. J.* 13 (1).

Land (Tenure Conversion) Ordinance, (1963). Territory of Papua New Guinea.

MCKILLOP, R. F. (1966). "Changing farm patterns in the Goroka Valley, Eastern Highlands District. *"Department of Agriculture, Stock and Fisheries Newsletter* 8, 2: 53-56.

.... "A Highlands pig industry?" *Department of Agriculture, Stock and Fisheries Newsletter* 8, 4: 147-151.

MARTIN, W. S. AND BIGGS, C. E. J. (1937). "Experiments on the maintenance of soil fertility in Uganda." *E. Af. agric. J.*, 2 : 371-78.

MEHLICK, A. (1966). "Production of maize for grain and mulching material." *Kenya Coffee*, Mar. 66: 105-109.

MONTGOMMERY, D. E. (1960). "Patrol of Upper Chimbu Census Division, Eastern Highlands." *Papua and New Guinea agric. J.* 13 : 1-9.

New Guinea nutrition survey expedition report (1947). *Department of Territories, Canberra.*

NEWTON, K. (1960). "Shifting cultviation and crop rotations in the tropics." *Papua and New Guinea agric., J.* 13 : 93-130.

PEREIRA, H. C., CHENERY, E. M. AND MILLS, W. R. (1954). "The transient effect of grasses on the structure of tropical soils." *Emp. J. Exper. Agric.* 22 : 148-160.

PHILLIPSON, A. (1962). "Machinery for the small farm. The small tractor." *World Crops* 14 : 510.

RIMOLDI, M. (1966). "Land tenure and land use among the Mt. Lamington Orokaiva." *Australian National University New Guinea Res. Unit Bul.* No. 11.

ROSS, E. AND SPRINGHALL, J. A. (1965), "Feeding poultry in New Guinea." *Territory of Papua and New Guinea publication.*

SCHINDLER, A. J. AND FRASER, R. R. (1964). "Cover crops, mulch or clean weeding for coffee (*Coffea arabica*) in the highlands of New Guinea." *Papua and New Guinea agric. J.* 17 : 39-47.

STENT, W. R. (1962-63). "The rationalization of peasant agriculture." *Papua and New Guinea agric. J.* 15 : 111-122.

VAN RIJSWIJK, OLGA, (1966). "The Silanga settlement project." *Australian National University New Guinea Res. Unit Bul.* No. 10.

WAKEFIELD, A. J. (1948). "The groundnut scheme." *E. Af. agric. J.* 13 (3).

WHITEHEAD, G. (1962). "Machinery for the small farm. The small tractor in Japan." *World Crops*, 14 : 53.

THE USE OF PEANUT PLANT MEAL ("ARACHIS HYPOGAEA") AND BEAN SEED MEAL ("PHASEOLUS VULGARIS") IN CHICKEN STARTER RATIONS

J. A. SPRINGHALL*

ABSTRACT

Various levels of peanut plant meal were substituted in a maize/soybean ration and fed to chickens from hatch to 19 days of age. When compared with a maize/soybean ration containing a similar crude protein level of 21 per cent., it was found that peanut plant meal included in the ration in concentrations of 10 and 20 per cent. did not alter the growth rate of the birds significantly, and that concentrations of 30, 40 and 50 per cent. depressed growth.

Chickens fed 5, 10 and 15 per cent. of bean seed meal either raw or cooked, when compared with chickens fed a maize/soybean meal ration, were not significantly different in weight. At a concentration of 20 per cent. a growth depression occurred.

INTRODUCTION

THE use of peanut plant meal in poultry growing and laying rations has previously been reported by Springhall (1967). Since that report, further trials have been undertaken to determine the use of this material in chicken starter rations.

Bean meal has been included in poultry rations previously (Heuser, 1955). It has been suggested that it is better to cook beans before feeding them to poultry. As beans are available in the Territory of Papua and New Guinea, their ability to support growth of poultry at various levels was investigated.

MATERIAL AND METHODS

Peanut plant meal was prepared similarly to that already described by Springhall (1967).

A quantity of bean seeds, *Phaseolus vulgaris,* was obtained. Half the material was fed raw and the remainder was boiled then dried. The analysis of the test ingredients is shown in *Table* 1.

Table 1.—Analysis of ingredients.
(Expressed as grams per 100 grams, on an air dry basis).

Material.	Crude Protein.	Ash.	Fat.
Peanut Plant Meal	16.6	8.2	20.5
Bean Seed Meal	20.6	2.7	3.5

The composition of the rations is shown in *Table* 2. The vitamin and mineral premixes were composed similarly to those previously described by Springhall (1967).

Meat strain chickens were obtained from a commercial hatchery. The birds were then selected at random, weighed, wing banded, and placed in groups of 10, into pens in an electric brooder unit which had wire floors. Two groups were allotted to each treatment.

The experiment was conducted from hatching to 19 days of age. Body weights were recorded on the 12th and 19th days. Feed and water were provided *ad libitum* and continuous lighting was supplied.

* Senior Lecturer in Animal Husbandry, Veterinary School, University of Queensland.

The composition of the control and experimental rations is shown in *Table* 2. All the experimental rations were compounded by substituting the test material for a portion of maize and soybean meal at the levels indicated. All test rations were calculated to contain 21 per cent. crude protein by adjusting the quantities of maize and soybean meal in the control ration to compensate for the added ingredient. No attempt was made to balance the energy content of the rations. The materials were hammermilled before using.

Statistical treatment of the data consisted of the analysis of variance (Snedecor, 1964) and the multiple range test (Duncan 1955, Kramer 1956).

RESULTS AND DISCUSSION

The results of the feeding trial using peanut plant meal are shown in *Table* 3.

At 19 days the birds receiving the rations containing 10 and 20 per cent. peanut plant meal were not significantly different in weight from those on the control ration. However, at higher concentrations, (30, 40 and 50 per cent.), the body weights were not as great as those of the birds receiving the 10 and 20 per cent. rations.

The feed conversion followed a similar pattern, namely that 10, 20 per cent. and control rations were slightly better than the 30, 40 and 50 per cent. group.

Table 2.—Composition of Peanut Plant and Bean Seed Meal Starter Rations (%).

Ingredient.	Control.	Experimental Rations.									
Maize	64.3	56.1	48.0	39.8	31.7	23.5	60.7	57.1	53.5	49.9
Soybean Meal (50%)	30.4	28.6	26.7	24.9	23.0	21.2	29.0	27.6	26.2	24.8
Peanut Plant Meal	—	10	20	30	40	50	—	—	—	—
Bean Seed Meal	—	—	—	—	—	—	5	10	15	20
Dicalcium Phosphate	4	4	4	4	4	4	4	4	4	4
Salt	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Vitamin and Mineral Premix	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Total	100	100	100	100	100	100	100	100	100	100

Table 3.—Mean body weights of birds fed rations containing graded levels of peanut plant meal.

Group.	Per cent. Peanut Plant Meal.	19 day weight (g) Mean of 2 replicates.	Feed Conversion.	Mortality per 20 birds
1	0	211	1.9	0
2	10	200	1.8	1
3	20	196	1.7	0
4	30	166	2.0	0
5	40	141	2.2	1
6	50	123	2.3	0

Table 4.—Mean body weights of birds fed graded levels of raw and cooked bean seed meal.

Group.	Per cent. Raw Bean Meal.	19 day weight (g) mean of 2 replicates.	Feed Conversion.	Mortality.	Per cent. cooked Bean Meal.	19 day weight (g) mean of 2 replicates.	Feed Conversion.	Mortality per 20 birds
1	0	211	1.9	0	0	211	1.9	0
2	5	203	1.7	0	5	186	1.9	0
3	10	194	1.9	1	10	195	1.9	1
4	15	183	2.0	0	15	179	1.9	0
5	20	163	2.2	0	20	160	2.2	0

From the results of this trial in which peanut plant meal was compared with a maize/soybean ration it is suggested that peanut plant meal should not be included in poultry starter rations in concentrations greater than 20 per cent. of the ration.

The cooking of the bean meal did not significantly improve the growth rates at any level fed (PK.01). From the results obtained it is suggested that the optimum levels of bean meal should not exceed 15 per cent. in starter rations, when compared with a maize/soybean meal ration.

SUMMARY

1. Chickens fed 10 and 20 per cent. peanut plant meal for 19 days did not have significantly different growth rates from those fed a maize/soybean ration. It is suggested that concentrations greater than 20 per cent. be not used in chicken starter rations.
2. Chickens fed 5, 10 and 15 per cent. bean seed meal for 19 days did not show significantly different growth rates. Similar levels of cooked bean seed meal produced similar results. If this material is used for young chicks, it is recommended that the amount included in the ration be not greater than 15 per cent., when compared with a maize/soybean meal ration.

ACKNOWLEDGEMENTS

This project was financed by the Rural Credits Development Fund. Thanks are due to Miss L. Hardy, B.Sc., for the feed analysis and Mr. I. S. Burgess, Q.D.A.H., for statistical and technical aid.

(Accepted for Publication, September, 1967.)

REFERENCES

DUNCAN, D. B. (1955). Multiple Range and Multiple F. Tests. *Biometrics,* 11: 1-42.

HEUSER, G. F. (1955). Feeding Poultry, John Wiley and Sons, Inc., New York.

KRAMER, C. Y. (1956). Extension of Multiple Range Tests to Group Means with Unequal Numbers of Replications. *Biometrics,* 12: 307-310.

SNEDECOR, C. W. (1964). Statistical Methods. 6th Edition, Iowa State College Press, Ames, Iowa.

SPRINGHALL, J. A. (1967). Peanut Plant Meal an Ingredient for Poultry Growing and Laying Rations. *Proc. Aust. Poultry Sci., Conference, Surfers Paradise,* 205-213.

RECOMMENDATIONS FOR THE CULTIVATION OF ROBUSTA COFFEE (COFFEA CANEPHORA) IN THE TERRITORY OF PAPUA AND NEW GUINEA

J. H. SUMBAK*

ABSTRACT

Recommendations are given for planting and processing of robusta coffee under Papua and New Guinea conditions. Use of the 'Besuki' strain is advised. Details are given of nursery practices, shade establishment and maintenance, spacing of both coffee and shade trees in relation to the pruning system to be adopted, transplanting, field maintenance, different methods of pruning, harvesting, pulping, fermenting, drying, hulling and grading. Brief notes are given on the more common pests and diseases.

INTRODUCTION

THESE notes have been prepared as a guide to the cultivation of robusta coffee under Territory conditions. Recommendations are based on overseas findings as well as experimentation by Department of Agriculture, Stock and Fisheries' officers in both the Lowlands and Highlands.

In the past robusta coffee has received little attention in comparison with arabica coffee grown in the New Guinea highlands. Some of the findings on arabica coffee are applicable, usually in a modified manner, to robusta coffee, while others are completely inapplicable. Nursery techniques and field planting methods are similar for both crops, while light requirements and pruning systems tend to differ.

The articles included in a list of literature consulted at the end of this paper are well worth studying.

GENERAL

Robusta coffee, *Coffea canephora,* has been grown in the Territory since the turn of the century. Prior to the Second World War, there were a number of substantial plantations in New Britain and Bougainville and some in the Popondetta area. These were neglected during the war. At present there are a number of holdings in the vicinity of fifty acres each around Cape Rodney in Papua, as well as several near Lae. Substantial acreages of indigenous plantings occur in the Milne Bay district and the Sepik district and to a lesser extent in parts of the Northern district.

Prices for the last few years have been relatively stable, and there is a reasonable demand for this type of coffee in Australia. Robusta coffee is used in blends of ground coffee as well as soluble coffee extracts for instant coffees, for espresso-type coffee and in chicory mixtures.

Cultivation of robusta coffee can be carried out over a variety of soil types and climatic conditions. It appears to favour light soils but can do reasonably well on heavier soil types. It has been grown successfully up to 1,700 ft. or more in the Mullins Harbour area of Milne Bay. Robusta coffee noted at about 5,000 ft. at Aiyura in the Eastern Highlands has a much slower growth rate. A rainfall of at least 70 to 80 inches, relatively well distributed, is desirable, although dry periods of up to two or three months can be withstood on most soil types. Robusta coffee is tolerant of heavy rain and can tolerate standing water for days.

Unfortunately no accurate figures on robusta coffee yields under Territory conditions are available. From observations at

* Agronomist, L.A.E.S., Keravat, New Britain.

Keravat, yields in the vicinity of 1,000 lb. dry beans per acre could be obtained with proper attention.

PLANTING MATERIAL

Over the years numerous introductions of robusta coffee have been made but unfortunately records are scanty. Pre-war plantings, some of which are still in existence, are very variable especially with regard to coffee bean size. Uniformity in bean size, as well as suitable liquoring qualities, are important to manufacturers.

With this in mind a Javanese strain of robusta termed 'Besuki' was introduced by the Department of Agriculture, Stock and Fisheries from Indonesia. This strain is reputedly high yielding as well as producing a large even-sized bean. In quality it is good and has at times commanded premium prices. It is recommended and distributed by the Department of Agriculture, Stock and Fisheries. It should be noted that although 'Besuki' seed produces progeny that are relatively uniform, 'off-types' are still common, as robusta coffee is an outbreeder. Plants displaying abnormalities should be eliminated as soon as they are detected in the field. 'Off-types' commonly have small crinkly leaves associated with poor, if any, fruit production, while others have exceedingly small cherries.

Limited supplies of 'Besuki' seed are available from the Lowlands Agricultural Experiment Station at Keravat. In most lowland districts, seed gardens of twelve selected clones have been established at Agricultural Extension centres and some are now producing seed.

NURSERY PRACTICES

Seed must be sown as soon as possible after receipt. Germination trials at Keravat showed that after two months storage, viability was much reduced. Viability of three to four month old seed was very low and five month old seed did not germinate. Seed planted at half an inch depth germinated quicker than seed planted at one inch depth, but the ultimate germination rate of the latter was greater (Jamieson 1963).

Germination beds consisting of fine, loose soil worked to a depth of at least three inches should be used. Seed should be planted on a two inch square and at a depth of one inch. Any broken or abnormal seed should be culled.

Germination will take from three to seven weeks depending on age of seed as well as on the moistness of the seed bed and the soil temperature. Seed beds must be kept reasonably moist but excessive wetness will inhibit germination as well as causing fungal attack. Collar rot (or damping off) caused by a fungus can be especially damaging under excessively moist conditions. The fungus attacks between time of germination and the appearance of the plant above ground level. A small dead spot forms at the base of the stem at the point of contact with the ground and spreads until the whole stem is encircled. The stem collapses and the plant dies. If it seems likely that this fungus will cause considerable trouble, the following treatment should be adopted: drench seedbed with 4 lb. copper oxychloride dissolved in 100 gallons of water immediately after planting. Repeat treatment at weekly intervals.

Shade over seedbeds should be relatively heavy. *Leucaena leucocephala* formerly known as *L. glauca*) is a very suitable nursery shade. Other shades such as *Gliricidia maculata* or *Erythrina,* as well as a number of temporary shades such as *Crotalaria* or *Tephrosia,* might be used. Artificial covers of bamboo slats, kunai or coconut fronds are also satisfactory.

Once seedlings in germination beds have reached the fully expanded cotyledon (seed-leaves) stage, they can be transplanted either to a nursery bed or to polythene bags as described below.

Traditionally seedlings are transplanted to a nursery bed on an eight inch by eight inch spacing. Seedlings are grown in this nursery, preferably to the five or six pairs of leaves stage or somewhat larger, before they are field planted. Nursery beds should consist of loose, friable soil well worked to a depth of eighteen inches and should have a water supply handy in case of any dry spells. Four or five weeks prior to anticipated field planting, seedlings should be 'root-pruned' or 'root-snapped' if planting in a sod is to be used. The aim is to prevent the formation of a 'bench-taproot' and also to stimulate seedlings into producing a multitude of new feeder roots. Bench-rooting occurs when tap-roots which are excessively long are bent at transplanting with the result that they grow sideways instead of downwards. Insecure anchorage as well as a restricted feeding area are the result.

Root pruning entails inserting a spade into the ground to its full depth about four inches from the base of the seedling and tilting backwards until a snapping sound is heard. The earth is then firmed down around the plant again.

When planting in sod (this is desirable but can be expensive and inconvenient), all roots extending outside the sod should be pruned away. If seedlings are not sod planted any excessively long tap-roots should be pruned and care taken to avoid bending tap-roots when transplanting.

A second method which is convenient and causes a minimum of shock at transplanting has been used with success at Keravat. Seedlings at the fully expanded cotyledon stage are transplanted to perforated polythene bags (as used for cacao) which are filled with good, rich soil (any 'bush' soil is generally suitable). Seedlings then develop to the five or six pairs of leaves stage when they are ready for field planting. It is important not to delay transplanting much past the five or six pairs of leaves stage as polythene bage will restrict full rooting. Polythene bags must be removed when field planting as they are quite resistant to decomposition and hence will limit the spread of roots. The tap-roots should also be pruned.

Regardless of whether seedlings are planted into nursery beds or polythene bags, it is necessary to water at least for a week after removal from the germinating beds.

Nursery plantings must be timed so as to have seedlings at the appropriate stage for field planting at the onset of the wet season in areas where definite wet and dry seasons are usual. It will take from five to seven months from planting of seed to the five or six pairs of leaves stage.

Careful screening of seedlings before transplanting to polythene bags as well as before field planting is necessary. Any slow germinating seedlings should be discarded. As a rule, provided seed of the same age is used and planted at the same depth, it is best to discard seedlings that germinate more than three weeks after germination is first observed. In addition, seedlings with abnormal leaf characteristics or colouring should be culled.

SHADE AND SPACING

The most common and probably at present the most suitable shade for robusta coffee is *Leucaena leucocephala*. Almost all of the Territory's robusta coffee is grown under this type of shade. *Gliricidia, Erythrina* and *Albizia* have been experimented with but all have disadvantages by comparison with *Leucaena*. *Gliricidia* has an unruly branching habit and also tends to be susceptible to wind damage. However, it does better than *Leucaena* in wetter situations and is more tolerant of sulphur deficiency. *Erythrina* is a relatively fast growing shade but has the distinct disadvantage of losing its leaves during the dry season. *Albizia* grows to a large tree and necessitates thinning which can result in mechanical damage to coffee trees.

Shade can be established from either seed or seedling stakes. The latter method is preferable as it provides a quick shade and is usually cheaper.

Shade From Seed.

Seed should be inoculated with the appropriate strain of Rhizobium, a bacterium which induces nitrogen-fixing nodules on the roots of *Leucaena,* unless it is known that this is unnecessary in a particular area. Inoculum is not necessary in many areas of the Gazelle Peninsula and lower Markham Valley where satisfactory nodulation is ensured by sufficient inoculum in the soil. Inoculum can be procured by writing to the Director, Department of Agriculture, Stock and Fisheries, Konedobu.

Spectacular responses have been shown in different sections of the Gazelle Peninsula, New Britain, to sulphur fertilizer, especially on old kunai land subject to frequent burning. Stunted *Leucaena,* about three years old and still only waist high, has greened up within two weeks of sulphur application and has provided adequate shade within about six months. Applications of about 1 lb. of flowers of sulphur to each 100 ft. row of *Leucaena* are recommended where necessary. As sulphur deficiency has been observed in the Popondetta area, these results might well be applicable to that locality if difficulty in establishing *Leucaena* is encountered.

Leucaena seed should be sprinkled at a rate of eight to ten seeds per foot about a quarter of an inch below the surface along proposed shade rows. From five to fifteen pounds of seed per acre will be needed depending on the efficiency of the labour and the shade spacing adopted.

Shade from Stakes.

To provide seedling stakes, a nursery should initially be prepared. One acre of nursery should provide stakes for at least fifty acres of shade. Seed, inoculated if necessary, at a rate of eight to ten per foot and at a depth of a quarter of an inch should be sown in rows about a foot apart. Germination takes four to five days under good conditions.

Stakes are ready for field planting when they are approximately half an inch thick at the base, usually after three or four months. Stakes are cut off about three inches below ground level and planted at a depth no more than one inch (this is important) below the original level.

Shade Requirements.

For coffee seedlings shade at transplanting should be relatively heavy as grass competition will be reduced with adequate shade. Field planting should be possible within about six months of planting stakes.

If it appears likely that permanent shade will be inadequate at time of transplanting, temporary shade such as *Crotolaria anagyroides* or *Flemingia congesta* can be sown in the vicinity of the planting holes. As soon as permanent shade is adequate, temporary shade can be removed.

The degree of shade necessary will depend largely on the environment and will change with the age of the coffee. Areas subject to frequent heavy cloud will need less shade than sunnier areas. Soil fertility will also play a part in determining what shade intensity is needed.

Broadly speaking, shade will control a plant's growth rate if other factors are not limiting. The less the shade, the greater the plant's potential growth rate and hence the greater the demand for nutrients. If these nutrients cannot be adequately supplied, (either through the soil being inherently poor or grass competition being severe), the plant's physiology is upset, leading to leaf chlorosis and dying back.

Under Territory conditions and with traditional systems of maintenance newly planted seedlings require a relatively high level of shade, certainly more than older trees which are substantially self shading.

At Keravat, seedlings planted in full sunlight survive but are very chlorotic and stunted. Experience in the Milne Bay area has shown shade to be essential even in areas such as the Sagarai valley which are characterised by a heavy cloud cover. Recent experimentation has shown that seedlings can be successfully established under conditions of very light shade provided nutrition requirements are satisfied—in this case elimination of weed competition through clean weeding sufficed. As a general rule, however, it would be safest to establish coffee under relatively heavy shade and thin shade later after seedlings are well grown.

Shade and coffee spacings will depend on pruning systems adopted (these are discussed later). Recommendations are made for the arch or Agobiada system of pruning and a single stem system involving rotational stumping.

Arch or Agobiada Pruning.

A ten foot triangular spacing allowing 502 trees to the acre seems adequate for this system of pruning.

Shade should be planted initially in rows 10 ft. apart and 3 ft. apart within rows. This will enable two rows of coffee to be established between rows of shade (taking rows at right angles to the base line so that the coffee is seen as planted in rows 5 ft. apart with a 17 ft. 4 inch spacing within rows). At this stage there will be roughly one coffee tree to three shade trees.

As the coffee develops shade should gradually be thinned. The following programme is suggested:-

1. Six months after transplanting remove alternate shade trees within rows, to leave 6ft. spacing within rows.
2. Twelve months after transplanting remove alternate shade trees within rows, to leave 12 ft. spacing within rows.
3. Eighteen months after transplanting remove alternate rows of shade trees, to leave 20 ft. apart with a 12 ft. spacing within rows.
4. If after twenty-four months coffee trees are of good appearance and showing little sign of chlorosis, alternate shade trees within rows could be removed to leave rows 20 ft. apart with a 24 ft. spacing within rows.

In approximate terms the original three shade trees to one coffee seedling at transplanting should be thinned to only one shade tree to five coffee trees.

For high yields a relatively low level of shade is required. However, unless the soil is extremely fertile additions of fertilizer, usually a nitrogenous type, will be necessary.

Single Stem Pruning with Rotational Stumping.

An eight foot triangular spacing giving 785 trees to the acre would be suitable. The closer spacing is used as the lateral spread of single stem trees and is considerably less than that of trees pruned to an arch system.

Shade should be planted initially in rows 8 ft. apart and 4 ft. apart within rows. Two rows of coffee can be grown between rows of shade (taking rows at right angles to the base line so that coffee is seen as planted in rows 4 ft. apart with a 13 ft. 10 inch spacing within rows).

The following thinning programme is suggested:-

1. Six months after transplanting remove alternate shade trees within rows, to leave 8 ft. spacing within rows.
2. Twelve months after transplanting remove alternate shade trees within rows, to leave 16 ft. spacing within rows.
3. Eighteen months after transplanting remove alternate rows of shade trees, to leave 16 ft. row spacing with trees 16 ft. apart within rows.
4. If after twenty-four months trees are of good appearance and colour remove alternate trees within rows to leave rows 16 ft. apart with trees in rows 24 ft. apart.

Considerations of shade and fertility are as given above for arch pruned trees.

Thinning of Leucaena.

Unless *Leucaena* is thinned in the correct fashion, it can become rather troublesome. Cutting out without previous or subsequent poisoning will result in profuse suckering. Spraying the tree bases with a mixture of 2,4,5-T (such as Shell Weedkiller 'B') and diesel distillate is an extremely efficient method of thinning *Leucaena*. A concentration of ¼ per cent. 2,4,5-T active ingredient is adequate (about 3 pints of 2, 4, 5-T 30 per cent. concentrate per 44 gallons diesel distillate). There is no need to 'frill' the bark.

For old *Leucaena* (stem diameter of more than about 3 inches), a ½ per cent. solution is recommended.

PLANTING

Preparation of planting holes three or four months prior to the anticipated time of transplanting is generally recommended. These holes should be at least 18 x 18 x 18 inches. Three or four weeks before planting, they should be refilled with *top soil only* and a small mound formed to allow for settling. Holing is of special importance in heavy soils.

Timing of nursery preparation should be such that seedlings are ready for field planting at the beginning of the wet season.

The following points are worth noting:

1. Transplant at a young stage, i.e. the five or six pairs of leaves stage, to minimise transplanting shock.
2. If seedlings are grown in polythene bags, prune the tap-roots and *remove bags*. When transplanting in sod, prune away any roots extending beyond the sod.
3. Plant on cool, cloudy days into a moist soil.
4. Be certain that the level of planting is slightly above the surrounding level so as to avoid waterlogging.
5. Ensure that roots exposed when plants are lifted from the nursery are kept moist until field planting is completed.

MAINTENANCE

As robusta coffee has a swallow root system, any competition from associated plants, particularly grass, greatly restricts development.

At the transplanted seedling stage, shade will restrict grass development. Ring weeding as well as periodical general slashing must, however, be carried out. Mulching in the proximity of the seedlings is also very desirable and will suppress weeds for an extended period.

A number of grasses can be used successfully for mulch. Giant kangaroo grass (*Themeda gigantea*), Kunai (*Imperata cylindrica* or wild sorghum *(Sorghum spp.)* can be utilised. Elephant grass (*Pennisetum purpureum*) has been specially grown for mulching because of its high yield per acre. It should be thoroughly dried out before use or it will root from the stems. Once established it is very hard to eradicate.

Experiments at Keravat have clearly demonstrated the importance of weed control. Coffee grown in experimental plots which were kept clean weeded reached the same stage of development about fourteen months after field planting as coffee grown under field conditions, with periodical ring weeding and grass slashing, for about twenty-four months.

Chemical weedicides such as 2,4-D with dieselene and Dalapon with water have been used successfully overseas for weed control. Territory experience, however, does not allow any definite recommendations to be made for chemical weed control in robusta coffee plantings.

PRUNING

At present there is no single pruning system that can be described as best for robusta coffee.

Pruning systems at present utilised are briefly described as follows:-

Single Stem System.

This system, although commonly used, is by no means ideal for robusta coffee. In classical single-stem pruning the main stem is topped at four and a half to five feet. Laterals touching the ground, as well as varying numbers of other laterals on the main stem, are removed to allow more light penetration and a better general air circulation. Secondary branches on the laterals are also thinned and eventually secondaries are trained to take the place of primary laterals. Fruiting gradually progresses down the laterals and then onto the secondaries and the tertiaries. Single-stem pruning requires a considerable amount of skill as well as time.

Single-stem pruning of the classical type is not really applicable to robusta coffee for the following reasons:-

(i) The growth rate of robusta coffee is very rapid and it is difficult to form an adequately shaped bush. Secondary branching generally does not occur.

(ii) Robusta coffee flowers on the current year's growth and flowers only once at the same site. Flowering on one lateral is usually restricted to one year. The result is that laterals usually only produce for one year. Topping will therefore limit fruiting sites quickly and will produce an umbrella shaped tree which has a productive life of only a few years unless regenerated.

Multiple Stem Systems.

Capping System—Several uprights, usually three or four, are encouraged with the idea of training each as a separate stem. Although secondary shoots often appear on transplants as a matter of course, capping soon after transplanting in order to induce sucker production is recommended. Capping involves cutting off the stem above the last pair of leaves.

Once the stems have reached the flowering stage, interlacing laterals at the centre of the tree should be removed to permit better light penetration and air circulation. This, combined with the weight of developing fruit, will bend the stems outwards and leave them more or less separated from each other. A stage will come when these stems will have to be topped to facilitate picking. Topping at between eight and ten feet is recommended. In the 'topped' condition a stem will bear a worthwhile crop for only three years at the most. This means that regeneration is necessary by systematically removing one stem a year and replacing it. After the first year of bearing, one stem is stumped and a basal shoot encouraged (usually before stumping), the next year another stem is stumped and so on. Theoretically this appears sound but successful replacement of stumped stems can be difficult. New shoots are usually excessively shaded by other stems as well as by neighbouring trees, frequently resulting in a weak spindly stem.

The Agobiada System—This type of pruning is one of the most commonly used with robusta coffee in the Territory. A main stem is allowed to grow to a height of two and a half to three and a half feet and then bent over in an arch and fixed to the ground by means of a forked stick or heavy gauge wire. As a consequence a large number of orthotropic (upright) shoots are formed. Four or five of these are selected as far apart on the bent stem as possible and are allowed to develop as separate stems. Restricted pruning is conducted to facilitate light penetration and air circulation between laterals of the different stems. Volunteer suckers are also periodically removed. A rotational system of stumping and rejuvenation is applied. Topping at a height of between eight and ten feet is recommended. Again difficulties are met in getting replacement stems away successfully. Stems are often weak and spindly, with long internodes and hence fewer fruiting sites. They often suffer wind damage as well as breakage under the weight of developing fruit.

A newer system used mainly with arabica coffee in some Central American countries and Hawaii utilises closely spaced single-stem trees which are stumped rotationally The plantation is planted in blocks each consisting of four closely spaced rows. On the first year after harvest, row one is completely stumped and a new shoot is encouraged, next year row three is stumped, then row two and finally row four.

Close spacings are used to encourage high early yields as well as to minimise grass growth. As trees are stumped every fourth year, reduction in yield owing to crowding will not be great. In any case, low yields per tree are more than compensated for by high tree numbers per acre. Heavy fertilizing and no shade is generally utilised.

This system is relatively cheap as grass maintenance is at a minimum and virtually no pruning is required except for periodic removal of suckers.

Experimental plots at Aiyura utilising such systems are promising.

Unfortunately little work has been done in robusta coffee with similar systems. It is probable that modifications would be needed. While proven recommendations cannot be given, the following method of cultivation should be successful:-

1) Divide plantation into blocks of four rows at about eight foot spacing.

2) Establish shade as previously recommended, plant coffee and prune on a single-stem system, i.e. top at about eight feet (this will take about two years under field planting under good conditions), as well as removing any secondary growth (mostly basal suckers).

3. After the first worthwhile harvest stump row no. 1. Allow one regenerated shoot to come away on each tree. There should be enough light to permit the formation of a sturdy stem. Next year stump row no. 3, in the third year stump row no. 2, and in the fourth year, row no. 4.

4) Thin shade gradually as previously indicated.

Experimental work is needed to see whether fertilizing and lower levels of final shade are warranted.

HARVESTING

Ripe cherries ready for harvest are usually a dark red colour, but colour varies from area to area. At Keravat ripe cherries are a bright red, while in Milne Bay they are usually pink. In the Sagarai Valley ripe cherries turn yellow and have only streaks of pink colouring.

A ripe cherry will split and eject its beans if pressed gently between thumb and finger. It takes only a little experience to select ripe cherries.

Unfortunately all cherries at a node may not ripen at precisely the same time and a mixed sample will result if the entire cluster is picked. This should be avoided if possible as it results in an uneven product.

Frequency of harvesting will vary greatly from place to place. Coffee stumped and rejuvenated at Keravat in March, 1964, was harvested in May, August, November of 1965, and January, February, April, June, July, August and October of 1966. There is no definite harvesting season at Keravat. In the Milne Bay area the main pick is between May and August, with a peak in June-July. There is, however, a little picking all year round. Harvesting in Indonesia is continuous.

Cost of picking will depend on the crop as well as cultural variables such as spacing and pruning systems and the quality of labour. At Keravat the average picker harvests seventy-five pounds of cherries per day while the best labourers pick up to one hundred and thirty pounds per day.

PROCESSING

An efficient system of collecting and transporting cherries to the factory is essential.

The morning pick should be pulped as early as possible in the afternoon and placed in fermenting vats, while the afternoon pick should be pulped separately and placed in separate vats. The morning pick should not be held for processing with the afternoon pick, as ripe cherries left unpulped for any period of time will start fermenting and detrimental flavours and bean discolouration may develop.

Coffee cherry for pulping is placed in a receiving vat full of water above the level of the pulper. On agitation, unripe cherries as well as over-ripe cherries float to the top—they should be removed and treated separately if the amount warrants it, or alternatively discarded. Cherries then pass through the pulper which removes the fleshy covering and releases the beans (normally two to a cherry). Adjustment of the pulper can be critical. If the adjustment is even slightly out, mechanical damage to beans may result. Broken beans are liable to develop off flavours and unsightly stains during fermentation.

As cherry size will vary considerably, it is always likely that a certain amount of crop will be lost despite careful pulper adjustment. If losses are considerable, grade cherries before pulping.

After pulping, the beans, still enclosed in the parchment skin, pass into fermenting vats where they remain until all the mucilage covering the skin has disappeared. There are different methods of fermenting.

Fermentation in water is the commonest method. The process is complete when a handful of beans no longer feels slimy and slippery but gritty when rubbed. Time for fermentation depends on the amount of coffee as well as the dimensions of the fermenting vat. For robusta coffee the time will vary usually from twenty-four to thirty-six hours.

Other fermenting systems involve 'dry' system fermentation for a specified period followed by completion of fermentation in water.

If desired, fermentation can be by-passed by removing coffee mucilage with caustic soda, which takes about fifteen minutes and has no adverse effect on the product. One pound of caustic soda is sufficient for two hundred pounds of freshly pulped coffee (i.e. approximately four hundred pounds of cherries). The calculated amount of caustic soda is mixed with water and added to the pulped beans, which are agitated for about fifteen minutes, by which time all the mucilage is removed. Excess alkali is of no benefit.

On completion of fermentation, beans are thoroughly washed with clean water. Insufficient washing can lead to a poor product.

Coffee may be sun dried but in the Territory mechanical drying will usually be necessary. Partial sun drying followed by mechanical completion of drying may be used. With sun drying, the beans must be protected from sudden showers. Sliding roof driers are convenient. Sun drying takes a minimum of nine days to reduce moisture content to the required eleven to thirteen per cent. If a bean 'gives' when bitten it is insufficiently dried.

Mechanical drying is necessary in many areas where high rainfall and a resultant lack of sunshine render sun drying impossible. Most cocoa driers can be adapted to coffee drying quite easily. At Keravat both coffee and cocoa are dried simultaneously on a Universal drier. Rotary driers are quite successful.

Some authorities recommend high initial drying temperatures (about 85 degrees C. or 185 degrees F.) and then, about six hours later, a reduction to 75 degrees C. (167 degrees F.). Others recommend lower temperatures throughout.

Once the coffee is dried it is ready for hulling and polishing. If a time lag of several days occurs between completion of drying and hulling, a quick re-drying may be necessary. The hulling process consists of removing the parchment skin (loose outer covering of the bean) and the silver skin or testa which in the case of robusta coffee adheres firmly to the bean.

There are a number of makes of machine available for pulping and hulling. Most are satisfactory.

Grading of hulled coffee for broken beans and traces of silver skin is recommended as uneven samples are frowned upon by buyers.

PESTS AND DISEASES

Robusta coffee is relatively free from serious pests or diseases.

The following pests sometimes occur:-

Mealybugs (*Planococcus* spp. and others) can be a minor problem. Heavy infestations reduce effective leaf area in mature trees and limit growth in seedlings. They are associated with ants which can be a nuisance at harvest.

Scale Insects can also be a minor pest. Green scale *(Coccus viridis)* is quite common, occurring more in overshaded areas and often in association with mealybugs.

Ants, both 'Kurakums' (*Oecophylla smaragdina)* and 'fire-ants' *(Solenopsis geminata*], are common on robusta coffee. 'Fire-ants' culture mealy bugs and scale insects as well as making picking exceedingly difficult where infestations are heavy. A high volume spray of 0.2 per cent. dieldrin and about a 1 in 80 emulsion of white oil will control ants, mealybugs and scale insects. Alternatively dieldrin could be applied separately as a spray to the trunks of the coffee bushes. A concentration of white oil any higher than 1 in 80 should not be used as it may cause leaf burn.

Coffee Stem Borer (*Zeuzera coffeae*) larvae can cause damage by burrowing through main stem and also lateral branches. Limbs may be killed. Serious outbreaks are rare.

Caterpillar Damage — damage to new foliage and flowering buds occurs on occasions. Loopers are generally responsible.

Cacao Army Worm (*Tiracola* sp) has been responsible for damage on coffee in the Wau area.

The following are some diseases of robusta coffee in the Territory.

Pink Disease, caused by a fungus (*Corticium salmonicolor*). This condition is seen as whitish threads over young limbs and a pinkish crust on older wood. It is usually associated with high humidity, often as a result of excessive shade. It can be controlled by pruning away infected branches and, if the outbreak warrants it, spraying with fungicides such as copper oxychloride or Bordeaux mixture before the branches are pruned in order to kill any spores on the surface. All pruned material should be burnt.

Thread Blight, caused by a fungus (*Pellicularia koleroga*). The fungis appears on the underside of leaves and on fruit as white silvery threads eventually causing a brown rot of leaf or stem. It is often prevalent during the wet season and especially under heavy shade. For control, reduction of shade may be necessary. Pruning of diseased parts should be carried out and all prunings burnt.

White Thread Blight *is another* fungal condition caused by a species of *Marasmius* or *Corticium*. It can be controlled by reducing shade and pruning of infected parts.

Root Rots are all fungal diseases. The most common are caused by species of *Fomes*. Symptoms consist of a fairly sudden wilting of the leaves, sometimes within a few days. The leaves turn brown and the tree dies. Affected trees should be dug out. All root material *must* be removed and burnt as the root rot fungi can exist for long periods on dead root material.

If *Leucaena* or other shade is thinned it should be poisoned or pulled out entirely so that it will not serve as a host for the root rotting fungi.

(Accepted for Publication, October, 1967)

REFERENCES

ANON (1956) "The removal of coffee mucilage by means of caustic soda." *Papua and New Guinea agric. J.* 11: 52.

BARRIE, J. W. (1956). "Coffee in the Highlands." *Papua and New Guinea agric. J.* 11: 1-29.

BARRIE, J. W. (1959). "Coffee practices in Central America, the West Indies and Hawaii." *Papua and New Guinea agric. J.* 12: 9-19.

COLE, K. S. (1960). "Robusta coffee in south-east Papua." *Papua and New Guinea agric. J.* 12: 168-179.

JAMIESON, G. L. (1963). "The preparation and germination of Besoeki coffee seed". *Papua and New Guinea agric. J.* 15: 138.

SHAW, D. E. (1962). "Diseases of coffee in the Territory of Papua and New Guinea." *Papua and New Guinea agric. J.* 15: 1-6.

THE DISTRIBUTION OF TRACE ELEMENTS IN THE LEAVES OF THE COCONUT PALM, AND THE EFFECT OF TRACE ELEMENT INJECTIONS

P. J. SOUTHERN AND KAY DICK

ABSTRACT

A study was made on the distribution of manganese, iron, copper, zinc and boron in the leaves of coconut palms from different areas. There were large variations in leaf composition according to age of leaves and within the sampled leaflets.

Results showed increased uptake of manganese, iron, zinc and boron following solid injections of trace elements into coconut stems. Trace element contents of coconut leaves in all parts of Papua and New Guinea are tabulated and compared with figures obtained elsewhere.

INTRODUCTION

DURING the past few years, research on the trace element requirements of coconut palms has received an increasing amount of attention. A number of references (Fremond (1958, 1961), Pomier (1964), Meadows (1964), Bachy and Hoestra (1958)), quote chemical analyses for trace elements and give details of fertilizer and injection experiments with the trace elements, particularly iron and manganese.

A considerable number of trace element analyses has been made in Papua and New Guinea in conjunction with major nutrient analysis and investigations of nutritional problems in coconut areas. The tentative critical levels proposed by Fremond (1961) have been used as a guide to the trace element status of various areas and plantations.

This paper describes investigations carried out to determine the distribution of these trace elements in the leaves of untreated palms and the effect of solid injections on the trace element contents of the leaves. It also summarises other trace element results so far obtained in Papua and New Guinea.

DESCRIPTION OF SITES

Three areas were selected for this initial investigation. All were believed to have a low, but not necessarily deficient, trace element status as they were situated on soils with a high base status and tending towards alkalinity. The main investigations took place at Finschhafen, New Guinea (Site 1), where soils were derived from coral limestone. At this site deficiency symptoms, particularly those caused by manganese and iron, were prevalent in coffee, cocoa, legumes and ornamentals.

There were symptoms of chlorosis and necrosis in some coconuts and it had been thought that they could have been due to a trace element deficiency, but events subsequently showed that they were more likely to have been caused by leaf hopper insects.

Site 2 was situated at Hisiu, Papua, on an alluvial area known to have a marginal sulphur status. The palms were healthy and showed no abnormalities. Palms at Site 3, Kapogere, Papua, were also in healthy condition, although zinc deficiency had occurred in a nearby rubber nursery.

All the palms selected were immature and under 5 years old. There were no more than 12 leaves on each so that the ten leaf positions selected covered the range from young to old leaves.

SAMPLING METHODS

Leaf samples were collected from consecutive fronds, the first partly opened frond being counted as No. 1. Six leaflets from the medial part of the fronds were selected and the middle thirds, minus midrib, used for the sample. In each case, the leaves from no less than five palms were composited to form the final sample. In the case of Sites 1 and 3, additional samples consisting of the basal and tip parts of the leaflets were also sampled and in the latter case the leaflet midribs were also kept for analysis.

INJECTION METHODS

Injections were carried out at Site 1 where palms were a little older and had developed a short trunk. Six holes were bored at equidistant positions around the bases of five palms, using a brace and ¾in. bit. Holes were about four inches deep. The solid salts were forced into the holes using a plastic syringe and the holes were sealed with cotton wool and a sealing compound. The types of salts and amounts of each were as follows:-

Manganese sulphate	5 cc
Ferrous sulphate	5 cc
Copper sulphate	5 cc
Zinc sulphate	5 cc
Borax	5 cc
Sodium molybdate	5 cc

Samples of leaves were collected ten weeks after the injections had been carried out. At the same time control samples were collected from a group of untreated palms immediately adjacent. The injections produced no visible effects on the palms at the time of sampling or later.

RESULTS AND DISCUSSION

The results of all analyses of the trace elements manganese, iron, copper, zinc and boron are given in *Tables* 1 to 5. Molybdenum was not determined. The analytical methods used were those given by Southern and Hart (1968).

The trends according to leaf age and sampling position are depicted graphically in *Figures* 1 to 5. (Note that the contents in parts per million are now always represented by the same scale).

From examination of the analytical results and graphs the main conclusions of the investigations were as follows:-

Manganese Contents.

Variation within leaflets. There were no consistent differences between analyses for the basal, central or tip positions of the leaflets (*Fig.* 1a). However, the manganese contents of the midribs on the site investigated were much less than the contents of the leaves for every leaf position.

Variation with age of leaves. As is the case with other plants, manganese tended to accumulate in the older leaves. For the three sites the increase in manganese content with age of leaves was well demonstrated (*Fig.* 1b). Although the leaf values for the young leaves were fairly similar, differences in manganese contents for the older leaves were very large. Thus it is apparent that sampling of the older leaves is preferable when comparing manganese uptake (and availability) in different coconut areas.

Effect of injections. Solid manganese salt injections were clearly effective in increasing the content of the leaves. Large increases in manganese content following trunk injections have also been reported by Fremond (1961), Pomier (1964) and Meadows (1964), working on palms in coral soils where soil amendments are ineffective. They also noted some foliage colour improvement due to the injections although iron effects were greater. Two and a half months after injection at Site 1 in these experiments, manganese contents had risen markedly but translocation in the palms was very uneven. In general, the effects were greater for the younger leaves and there was evidence that manganese was still being absorbed at the time of sampling.

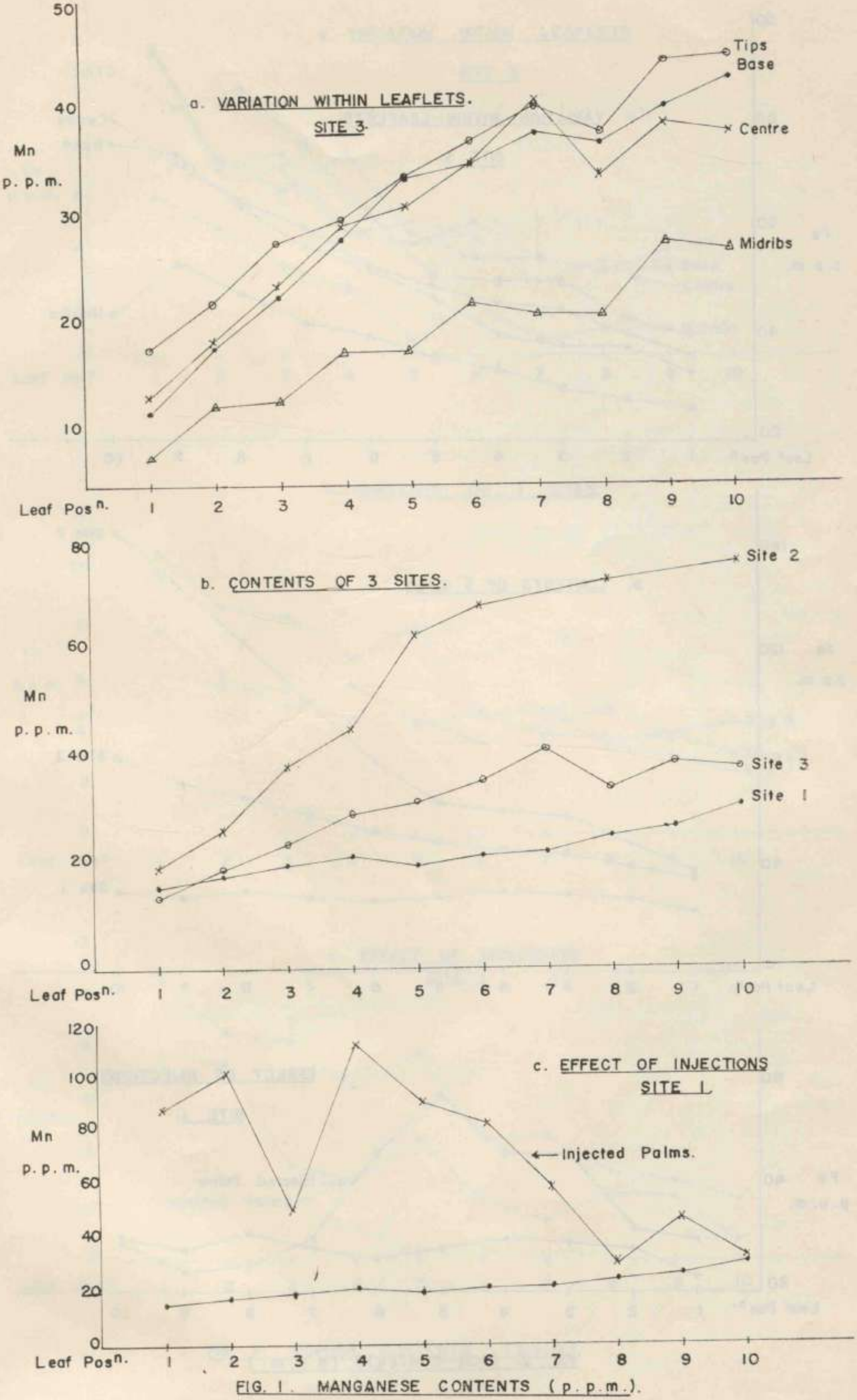


FIG. I. MANGANESE CONTENTS (p.p.m.).

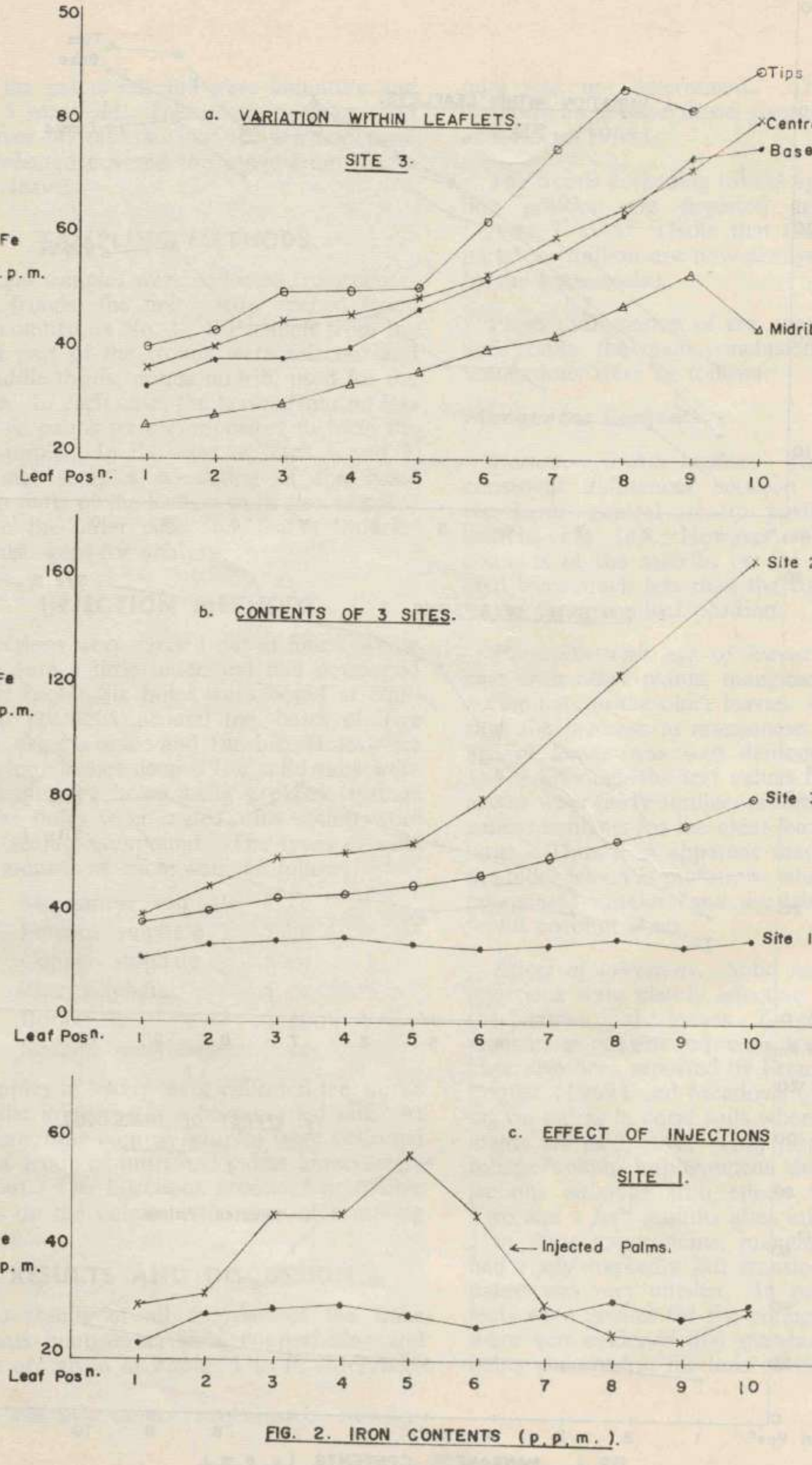


FIG. 2. IRON CONTENTS (p.p.m.).

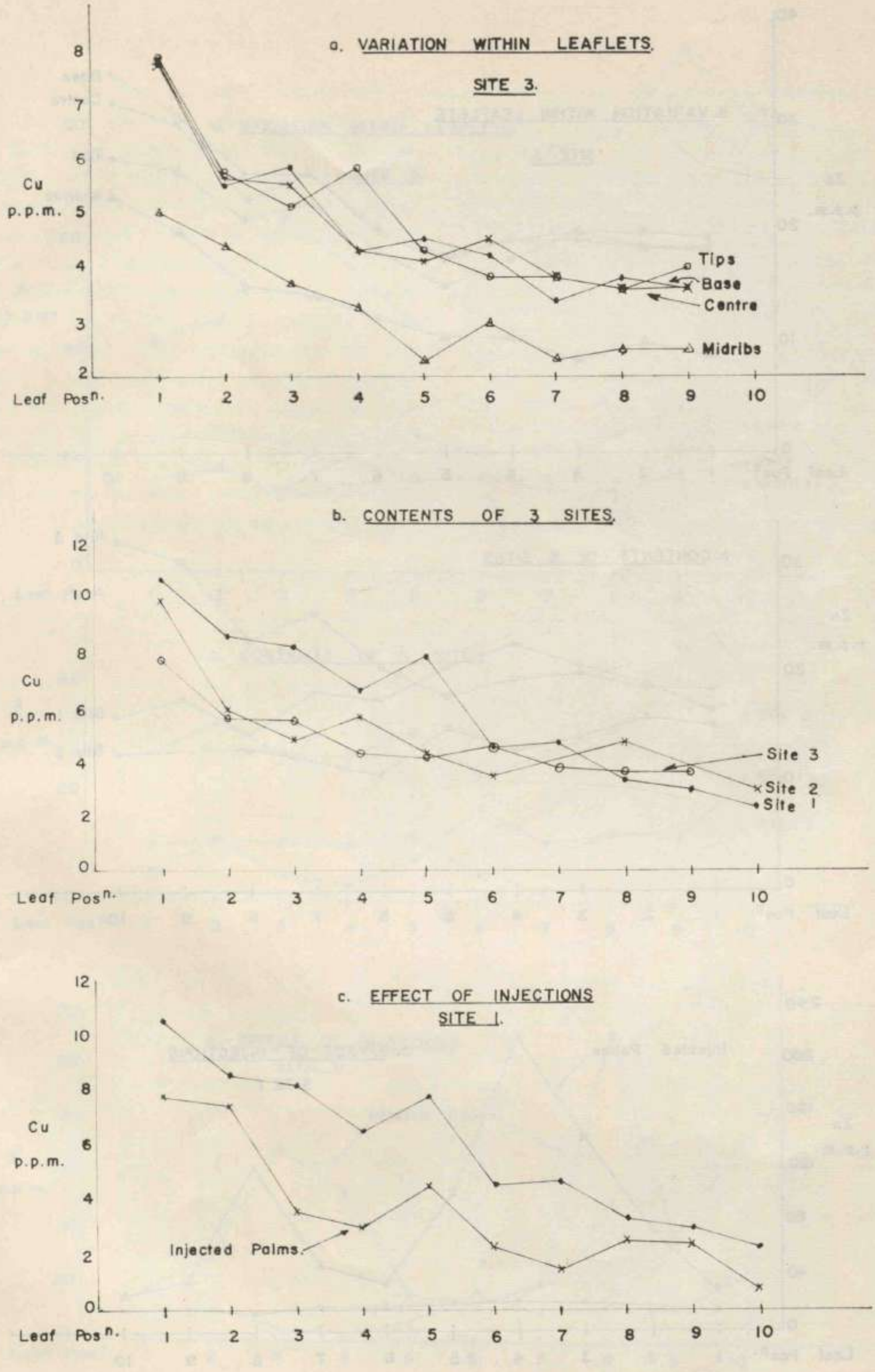


FIG 3 COPPER CONTENTS (p.p.m.).

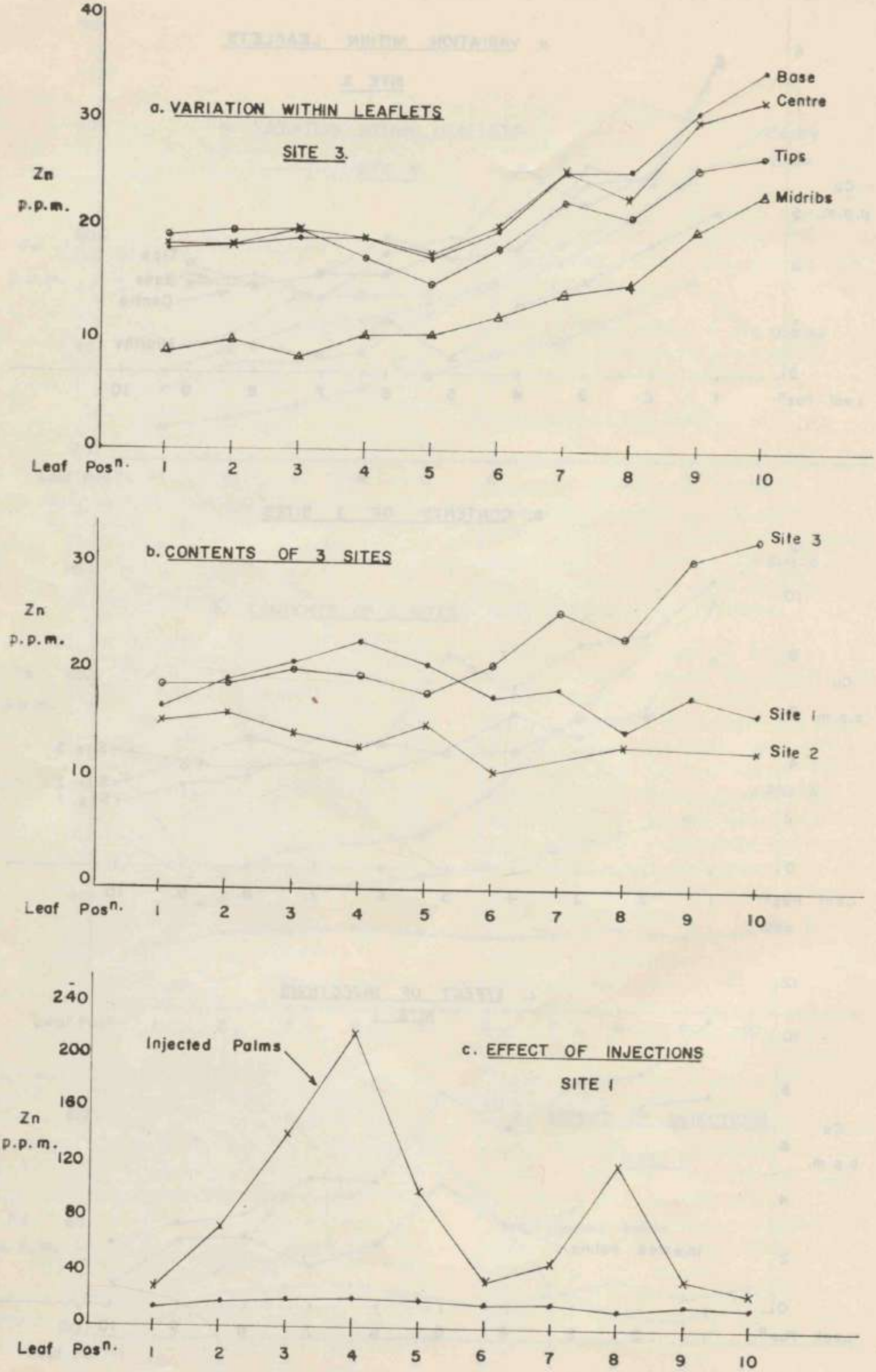


FIG. 4 · ZINC CONTENTS (p·p·m·)

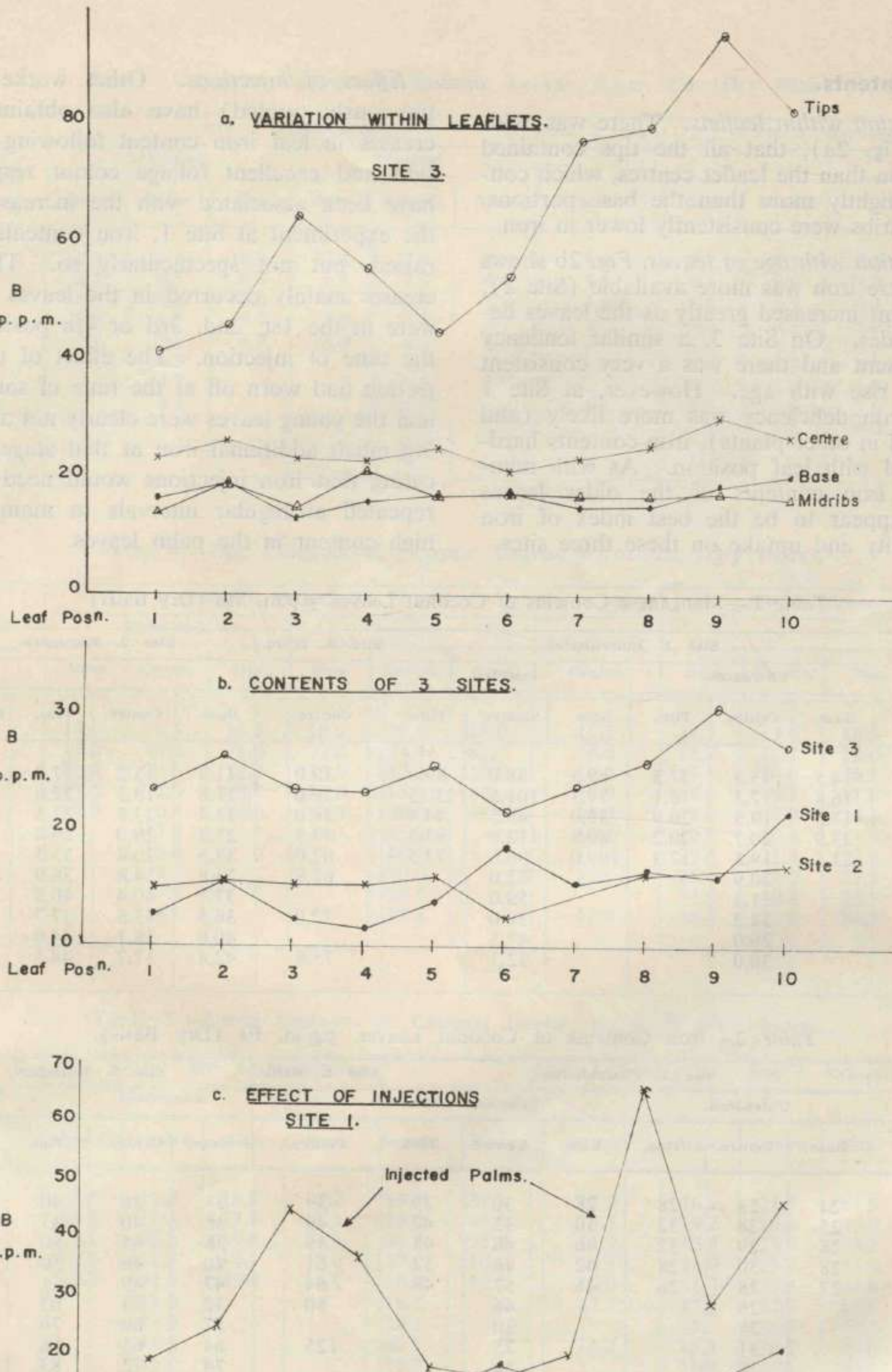


FIG. 5. BORON CONTENTS (p.p.m.).

Iron Contents.

Variation within leaflets. There was evidence (*Fig*. 2a), that all the tips contained more iron than the leaflet centres, which contained slightly more than the base portions. The midribs were consistently lower in iron.

Variation with age of leaves. *Fig*. 2b shows that where iron was more available (Site 2), its content increased greatly as the leaves became older. On Site 3, a similar tendency was present and there was a very consistent gradual rise with age. However, at Site 1 where iron deficiency was more likely (and occurred in other plants), iron contents hardly varied with leaf position. As with manganese, iron contents of the older leaves would appear to be the best index of iron availability and uptake on these three sites.

Effect of injections. Other workers (as previously quoted) have also obtained increases in leaf iron content following injection and excellent foliage colour responses have been associated with the increase. In the experiment at Site 1, iron contents were raised, but not spectacularly so. The increases mainly occurred in the leaves which were in the 1st, 2nd, 3rd or 4th position at the time of injection. The effect of the injection had worn off at the time of sampling and the young leaves were clearly not absorbing much additional iron at that stage, indicating that iron injections would need to be repeated at regular intervals to maintain a high content in the palm leaves.

Table 1.—Manganese Contents of Coconut Leaves, p.p.m. Mn (Dry Basis)

Leaf Position.	Site 1. Finschhafen.						Site 2. Hisiu.	Site 3. Kapogere.			
	Untreated.			Injected.							
	Base.	Centre.	Tips.	Base.	Centre.	Tips.	Centre.	Base.	Centre.	Tips.	Midribs.
1	14.5	15.5	17.5	89.5	88.0	89.0	19.0	11.9	13.2	17.8	7.8
2	16.8	17.5	18.1	79.3	101.5	130.5	26.0	17.8	18.5	22.0	12.4
3	17.5	19.5	20.9	39.0	49.5	44.4	38.0	22.4	23.5	27.5	12.8
4	23.9	20.7	20.2	86.8	112.0	83.3	44.5	27.8	29.0	29.4	17.4
5	23.5	19.5	17.3	109.0	90.0	77.5	62.0	33.5	30.8	33.5	17.4
6		20.9			82.0		67.8	34.8	34.8	36.9	22.0
7		21.4			59.0			37.7	40.4	40.0	20.9
8		24.2			30.0		72.0	36.5	33.5	37.7	20.6
9		26.0			47.5			40.0	38.1	44.0	27.4
10		30.0			32.3		75.8	42.4	37.7	44.5	26.8

Table 2.—Iron Contents of Coconut Leaves, p.p.m. Fe (Dry Basis).

Leaf Position.	Site 1. Finschhafen.						Site 2. Hisiu.	Site 3. Kapogere.			
	Untreated.			Injected.							
	Base.	Centre.	Tips.	Base.	Centre	Tips.	Centre.	Base.	Centre.	Tips.	Midribs.
1	24	23	28	28	30	39	39	33	36	40	26
2	25	28	32	30	32	42	49	38	40	43	28
3	28	29	32	46	46	43	59	38	45	50	30
4	28	30	28	42	46	52	61	40	46	50	34
5	27	28	26	46	57	48	64	47	49	51	36
6		26			46		80	52	53	63	40
7		28			30			57	60	76	42
8		31			25		125	64	65	86	48
9		28			24			74	72	83	54
10		30			30		166	76	81	90	44

Table 3.—Copper Contents of Coconut Leaves. p.p.m. Cu (Dry Basis).

Leaf Position.	Site 1. Finschhafen.						Site 2. Hisiu	Site 3. Kapogere.			
	Untreated.			Injected.							
	Base.	Centre.	Tips.	Base.	Centre.	Tips.	Centre.	Base.	Centre.	Tips.	Midribs.
1	11.0	10.5	10.3	7.0	7.8	7.8	9.8	7.7	7.7	7.8	5.0
2	8.5	8.5	8.4	8.5	7.5	6.0	5.9	5.5	5.6	5.7	4.4
3	8.5	8.2	7.0	5.0	3.6	5.8	4.8	5.8	5.5	5.1	3.7
4	6.9	6.5	5.7	5.3	3.0	4.7	5.6	4.3	4.3	5.8	3.3
5	7.0	7.8	6.2	6.0	4.5	3.6	4.3	4.5	4.1	4.3	2.3
6		4.5			2.3		3.5	4.2	4.5	3.8	3.0
7		4.7			1.5			3.4	3.8	3.8	2.3
8		3.3			2.5		4.7	3.8	3.6	3.6	2.5
9		3.0			2.4			3.6	3.6	4.0	2.5
10		2.3			0.8		2.9				

Table 4.—Zinc Contents of Coconut Leaves, p.p.m. Zn (Dry Basis).

Leaf Position.	Site 1. Finschhafen.						Site 2. Hisiu.	Site 3. Kapogere.			
	Untreated.			Injected.							
	Base.	Centre.	Tips.	Base.	Centre.	Tips.	Centre.	Base.	Centre.	Tips.	Midribs.
1	17.7	16.5	16.5	29.6	29.6	31.0	15.2	18.3	18.6	19.5	9.1
2	17.0	19.0	18.0	72.2	74.3	63.7	16.0	18.7	18.7	20.0	10.0
3	20.4	20.6	18.7	115.0	142.0	100.0	14.2	19.5	20.0	20.1	8.5
4	21.1	22.3	18.4	185.0	216.0	133.0	13.0	19.5	19.5	17.6	10.4
5	21.5	20.4	17.0	98.0	100.0	96.0	15.0	17.6	17.9	15.1	10.6
6		17.5			35.8		10.8	20.0	20.4	18.4	12.3
7		18.2			48.1			25.4	25.4	22.8	14.4
8		14.3			120.0		13.1	25.4	23.0	21.1	15.1
9		17.5			36.5			31.0	30.1	25.8	20.1
10		16.0			27.8		12.8	34.8	32.0	26.9	23.4

Table 5.—Boron Contents of Coconut Leaves, p.p.m. B (Dry Basis).

Leaf Position.	Site 1. Finschhafen.						Site 2. Hisiu.	Site 3. Kapogere.			
	Untreated.			Injected.							
	Base.	Centre.	Tips.	Base.	Centre.	Tips.	Centre.	Base.	Centre.	Tips.	Midribs.
1	12.8	12.8	18.8	18.2	19.4	37.3	15.0	16.1	23.5	41.5	14.0
2	14.2	15.6	17.0	18.3	25.0	47.8	15.7	19.2	26.3	46.0	19.5
3	11.8	12.2	19.8	21.3	44.8	95.5	15.3	13.8	23.6	65.1	15.0
4	10.8	11.5	19.3	32.0	37.0	110.0	15.3	16.0	23.2	55.9	21.4
5	11.0	13.9	19.8	16.0	18.2	29.2	16.0	16.7	25.4	44.9	16.8
6		18.6			16.5		12.5	17.2	21.5	54.5	17.5
7		15.3			20.5			15.3	23.8	78.0	16.8
8		16.5			66.5		16.2	15.5	25.9	80.0	17.1
9		16.0			29.3			18.6	30.5	96.0	17.8
10		21.5			46.5		17.0	20.3	27.2	83.0	16.6

Copper Contents.

Variations within leaflets. There were no consistent or large differences between the various parts of leaf tissue, but midribs contained less copper than the laminae.

Variation with age of leaves. The copper contents of the first leaves were the highest at all three locations and the values decreased with age so that the oldest leaves contained about one third of the young leaf content. Differences in copper contents between the three sites were not consistent and it was not clear which sampling position would best show differences in uptake. It is possible that copper availability at the three sites was similar; certainly leaf analysis could not differentiate between them satisfactorily.

Effect of injections. Copper contents of injected palms were considerably lower than those of untreated palms and thus the injections were not successful. This was a surprising result and is considered in the general discussion.

Zinc Contents.

Variation within leaflets. The differences between the three portions of leaflets were not great but there was a definite tendency for the tips to contain less zinc, particularly in the older leaves. This tendency was also shown at Site 1. The midribs again contained much less of the trace element.

Variation with age of leaves. For Site 3 where zinc uptake was generally higher, there was a tendency for zinc to accumulate in the older leaves. For the other two sites there were no general trends. Older leaves would appear to give a better indication of zinc uptake and status than the young leaves, where zinc contents did not vary greatly between areas.

Effect of injections. The results and *Fig.* 4c show that zinc salt injections were extremely effective in increasing zinc contents, with the fourth leaves increasing in content by nearly 200 p.p.m. Increases were irregularly distributed, with a tendency for higher contents at the fourth and eighth leaf positions.

Boron Contents.

Variation within leaflets. These results were interesting. The tips contained very high concentrations of boron, the centres much less, with the base portions and midribs less again and only one third to one fifth the content of the tips. Similar results were obtained at Site 1, but the tip content of untreated palms was not nearly as high by comparison. However, after injecting with boron the increased concentration at the tips became obvious (*Table* 5). It is clear that sampling must be carried out very carefully if an adequate result for the boron content of leaves is to be obtained.

Variation with leaf position. Results were variable and no consistent trends were noted for the three sites. All leaf positions for Site 3 gave higher boron contents than for the other two sites, thus no particular sampling position could be recommended from the results.

Effect of injections. There were large increases in boron content following injection of borax but there was evidence that boron was only translocated to certain leaf positions (*Fig.* 5c). Peak absorption occurred in leaves 3-4 and 8-10. The reasons are not clear but it has already been noted that such irregular distribution of injected nutrient also occurred with zinc and manganese.

DISCUSSION OF RESULTS

The injection of a variety of inorganic salts into the transpiration stream of plants could well produce a number of possible changes in ionic equilibria affecting absorption and translocation. The ability of particular elements to reach the growing point and be translocated to the leaves would depend on a number of factors, e.g. their compatibility with other ions (i.e. their position in the electrochemical series). Thus, in the injection experiments conducted, irregular distribution or no uptake at all (in the case of copper) could be due to the effect of other ions injected. Possibly copper could be injected by itself with better results. (It should be noted that Bachy and Hoestra (1958) achieved some uptake following injections with copper). This points to a possible side effect of injecting high concentrations of single salts in that they may disturb the normal distribution and functions of other elements, particularly where known ionic relationships exist (e.g. Fe-Mn).

The experiments were conducted on young palms but the results should still be applicable to mature palms as a good range of young to old leaves was taken. Other samples collected from widely separated areas in Papua and New Guinea and using various leaf positions confirmed the main trends, namely that iron and manganese tend to accumulate in older leaves, leaf copper contents are higher in the young leaves, while boron and zinc contents may vary.

It is perhaps possible to determine whether iron or manganese are being supplied in sufficient quantity by examining the trend with leaf position in a certain area. If the elements are being accumulated in the older leaves, there is probably a sufficient supply (e.g. Site 2, *Figs.* 1b and 2b). Where no accumulation is occurring (Site 1), the supply of iron and manganese may be only just meeting the plant's requirements or may even be deficient. It is interesting to note that consistent trends were obtained for these relatively immobile nutrients, even though palms at Sites 2 and 3 were subject to severe long dry periods. The uptake as reflected by nutrient content for the various leaf positions thus does not appear to fluctuate much during a year's growth.

Table 6.—Range of Trace Element Contents for Various Districts of Papua and New Guinea (p.p.m. on dry basis).

	Mn	Fe	Cu	Zn	B
1st LEAVES					
Central	13 - 40	22 - 100	3.3 - 9.8	10-22	11-24
Morobe	11 - 27	22 - 68	2.8 - 10.5	12-22	10-19
New Britain	13 - 54	35 - 57	3.5 - 6.8	10-24	9-25
Papua and New Guinea	11 - 54	22 - 100	2.8 - 10.5	10-24	9-25
4th LEAVES					
Bougainville	30 - 75	40 - 62	4.8 - 9.5	19-39	10-15
Central	24 - 87	38 - 284	2.3 - 5.6	10-22	11-27
Gulf	15 - 126	60 - 228	2.8 - 5.8	11-34	14-20
Milne Bay	30 - 37	64 - 100	4.5 - 5.3	21-22	18-20
Morobe	10 - 52	18 - 133	1.9 - 8.3	12-24	11-29
New Britain	24 - 105	70 - 146	2.4 - 4.4	11-19	12-22
New Ireland	8 - 18	32 - 41	2.9 - 5.0	12-23	14-20
Sepik	35 - 51	46 - 56	4.3 - 6.5	13-16	10-11
Papua and New Guinea	8 - 126	18 - 284	1.9 - 9.5	10-39	10-29
9th LEAVES					
Bougainville	46 - 60	52 - 80	4.5 - 7.0	15-55	10-13
Central	14 - 72	32 - 322	2.5 - 8.9	12-30	12-35
Madang	18 - 59	39 - 75	3.2 - 5.3	13-20	13-20
Milne Bay	4 - 30	48 - 60	1.4 - 4.5	7-36	16-24
Morobe	14 - 57	18 - 190	1.6 - 4.5	13-31	12-24
New Ireland	8 - 140	30 - 138	2.9 - 6.4	12-65	9-34
Sepik	39 - 74	49 - 52	3.3 - 3.5	14-20	10-14
Papua and New Guinea	4 - 140	18 - 190	1.4 - 8.9	7-65	9-35
14th LEAVES					
Bougainville	26 - 178	44 - 196	2.3 - 9.3	11-144	13-22
Central	15 - 84	40 - 315	3.0 - 7.9	13-39	12-23
Madang	20 - 69	44 - 74	2.6 - 3.8	12-20	17-22
Morobe	14 - 60	28 - 238	1.7 - 3.0	20-48	13-39
New Britain	21 - 144	44 - 196	3.2 - 6.6	11-40	13-21
New Ireland	5 - 200	35 - 150	1.4 - 6.4	6-53	9-31
Northern	48	57	3.0	24	20
Papua and New Guinea	5 - 200	28 - 315	1.4 - 9.3	6-144	9-39

Table 7.—Comparison of Papua and New Guinea values with those in other countries

	Mn	Fe	Cu	Zn	B
4th LEAVES					
Average, Papua and New Guinea	8 - 126	18 - 284	1.9 - 9.5	19-39	10-29
British Solomon Islands	51	42	2.9	23	15
Western Samoa	147 - 343	58 - 154	3.9 - 4.9	10-19	13-15
Tonga	18 - 75	48 - 164	3.1 - 8.0	11-21	10-21
French Polynesia (coral)	18 - 28	25 - 35	1.0 - 1.4	13-16	24-30
9th LEAVES					
Average, Papua and New Guinea	4 - 140	18 - 190	1.4 - 8.9	7-65	10-35
Tonga	27 - 96	62 - 254	4.9 - 7.5	11-21	14-21
Cocos Island (coral)	9 - 27	24 - 130	2.5 - 4.5	9-21	11-39
14th LEAVES					
Average, Papua and New Guinea	5 - 200	28 - 315	1.4 - 9.3	6-144	9-39
British Solomon Islands	51 - 61	46 - 49	6.4 - 7.3	17-22	17-21
Cocos Island (coral)	7 - 34	36 - 102	2.0 - 4.8	8-21	12-38
French Atolls (coral)	4 - 25	30 - 56	1.8 - 6.7	—	18-33
Other French Territories	40 - 656	98 - 151	3.6 - 8.4	13-78	6-18
I.R.H.O. Critical Levels	120	100	5	—	10

The results presented should give basic information to agronomists or chemists experimenting with trace element injections and using foliar analyses as a guide to trace element status. Many other analyses have been made in Papua and New Guinea of coconut foliar material from various leaf positions and these are summarized in *Table* 6. They show a very wide range of contents. In addition, samples from other South Pacific countries and from Cocos Island (a typical coral atoll) have been examined and these results are given in *Table* 7, together with the I.R.H.O. critical levels and results from French atolls and other French territories (Fremond, 1961).

Most values for iron and manganese found in the 14th leaves in this country have been much lower than Fremond's provisional critical levels. Only one case of probable iron or manganese deficiency symptoms was reported, on an atoll in the Milne Bay district. There the 9th leaves had low manganese (4-30 p.p.m.), fairly low iron contents (48-60 p.p.m.), low copper contents (1.4-4.5 p.p.m.), some low zinc contents (7-36 p.p.m.) and satisfactory boron contents (16-24 p.p.m.).

It would appear that Fremond's critical levels are too high for iron and manganese. Values of about half his proposed levels for these nutrients are suggested from the results obtained in Papua and New Guinea, where obviously healthy palms have been sampled. Copper levels in this country are usually between 2 and 5 p.p.m., zinc levels between 10 and 50 p.p.m., while boron contents are in the range 10-40 p.p.m. All these levels are associated with coconuts growing in areas where trace element deficiencies are not suspected, but unfortunately there is no agronomic information available and it is not known whether yields have always been optimal.

SUMMARY

Investigations carried out in Papua and New Guinea showed the distribution within leaflets and for various leaf positions of the trace elements iron, manganese, copper, zinc and boron. The main findings were:-

(a) Iron and manganese contents were greater in the older leaves, copper contents were greater in younger leaves, zinc and boron had irregular distribution.

(b) Boron contents increased markedly from the basal to the tip portions of leaflets. The same tendencies were found for iron and zinc, but they were not so strong. The midribs had low contents of all trace elements.

(c) Generally the sampling of older leaves appeared to give the best definition of trace element status.

(d) Injections of six trace element salts into the same palm gave greatly increased contents of manganese, zinc and boron in leaf tissues, smaller increases of iron and no increase of copper.

The range of values obtained in Papua and New Guinea for trace element contents of coconut leaves are summarized. Comparisons are made with results obtained elsewhere and with suggested critical levels.

(Accepted for Publication, October, 1967.)

REFERENCES

BACHY, A. AND HOESTRA, H. (1958). Contribution a L'etude de la "Maladie de Kaincope" du Cocotier au Togo. *Oleagineux*, 13: 721-729.

FREMOND, Y. 1958). Le Cocotier en Polynesie. *Oleagineux*, 13: 501-508.

FREMOND, Y. (1961). Improvement of the Coconut Palm Cultivation on Tropical Pacific Atolls. *Tenth Pacific Science Congress, Honolulu, Hawaii, August to September*, 1961.

MEADOWS, D. J. (1964). Coconut Grove Improvement in the Gilbert and Ellice Islands. *Oleagineux*, 19: 687-90.

POMIER, M. (1964). Restoration and Nutrition of Established Coconut Plantations on Coral Soil. *Oleagineux*, 19: 615-20.

SOUTHERN, P. J. AND HART, GAVIN, (1968). Nutritional Studies of Coffee in the Territory of Papua and New Guinea. *Dept. Agric. Stock and Fish. Research Bull. No.* 1 *(Crop Production Series)*.

AUTHORS' NOTE

This paper was a contribution to the South Pacific Commission Technical Meeting on Coconut Production, Rangiroa, French Polynesia, in August, 1967. It should be noted that the iron contents as reported in the original paper differ from those reported in this paper. The latter are the correct values. In addition, considerable changes have been made in the script.

LETTUCE OBSERVATIONS AT VUDAL AGRICULTURAL COLLEGE, NEW BRITAIN

A. S. PETERSON*

ABSTRACT

Lettuce trials in wet tropical lowland at Vudal Agricultural College in 1966 showed the variety Pennlake to be outstanding in setting firm heads and not bolting to seed. Direct seeding was a failure compared with nursery seeding and transplanting. Shading of transplants with trash covers in a traditional gardening manner was not necessary and seriously retarded the crop.

INTRODUCTION

LETTUCE crops are grown by Papuan and New Guinean farmers throughout the Territory for sale at local markets where European shoppers are present. Lettuces with good firm heads have been the exception rather than the rule despite the shoppers' preference and willingness to pay more for such types.

Gazelle Peninsula farmers purchase seed from Rabaul stores and have been known to buy the cheapest seed available regardless of variety. It was considered desirable to compare under uniform growing conditions the different seed lines offering in Rabaul stores, so that variety recommendations might be made to growers, resulting in a better type of lettuce arriving at the markets.

Trials were conducted at Vudal Agricultural College by the foundation students who were then in their second year. The college is some 30 miles from Rabaul, near Keravat, and is at a latitude of 4 degrees south and an altitude of 200 feet above sea level. The average annual rainfall is 109 inches and the soil is a fertile pumice brown loam typical of the Gazelle Peninsula. Results obtained might well be widely applicable to wet tropical coastal lowlands after making due allowance for differing soil types. As far as is known there have been no previous publications in scientific literature of lettuce research in Papua and New Guinea.

METHOD

A variety trial was sown on the 10th August, 1966, into seed pots in a shaded nursery. Varieties were Pennlake, Imperial 615, Imperial 847, Iceberg, Butterhead and Mignonette. They were transplanted on the 24th August, into freshly cleared virgin soil which had been rotary hoed. Each plot consisted of six plants placed one ft. apart in the row, with four ft. between plot rows. Varieties were replicated in three blocks and randomized. All plants were covered with small shade shelters made in a traditional gardening manner from sorghum grass trash. A separate bed of reserve plants was not covered with shade shelters. Two replicates were hilled before planting, but the third was planted directly onto level soil. No fertilizer was applied. Misses were replanted on 27th September, 1966.

A fertilizer demonstration was sown on the 11th October, 1966, directly into the field. The same varieties were used but were not replicated. Rows 11 yards long were sown with seed ⅛ to ¼ in. deep. Half of each row had fertilizer banded 2-3 in. below the seed at the rate of four cwt. per acre 20-20-14 NPK and ½ cwt. per acre flowers of sulphur. Establishment was very poor and the trial was re-seeded two weeks later, but once more establishment was so bad that the trial could not be continued.

RESULTS

Germination was excellent in nursery seed pots but, following transplanting under grass trash, survival was as follows on 27th September, five weeks after transplanting *(Table 1)*.

Thirty-three plants survived out of a total 108 transplanted, giving a loss of 69 per cent. This loss was apparently caused by overshading and/or insect damage fostered by the grass trash. Adjacent areas of reserve seed-

* Formerly lecturer in Agriculture, Vudal Agricultural College, Keravat, New Britain. Present address C.S.I.R.O., Division of Land Research, Kimberley Research Station, Kununurra, Western Australia.

Table 1.—Lettuce transplanted under trash shade shelters—survival counts per plot of 6 plants.

		Pennlake	Iceberg	Imperial 615	Imperial 847	Butterhead	Mignonette
	A	0	2	0	0	2	3
Replicate	B	3	6	0	0	1	5
	C	0	2	1	2	3	3

lings, transplanted without trash shelter, survived well and suffered little or no loss. Following the replanting of the missing plants on 27th September, the variety Pennlake was outstanding as the only variety to set firm heads, and as the last variety to flower.

DISCUSSION

Despite a high number of re-plants, the variety Pennlake set firm heads and was the last to flower. It cannot be argued that Pennlake did better because of not being replanted as much as other varieties. Iceberg and Mignonette each with ten surviving plants out of 18 were affected least by replanting yet they both flowered earlier than Pennlake. Imperial 615, Imperial 847 and Butterhead required approximately the same amount of re-planting as Pennlake, but Pennlake flowered later than these.

It could not be expected that Butterhead and Mignonette would set firm heads as these are non-hearting varieties known as butterleaf (Poole, 1959) or butter-head (Morgan, 1962) types. But the remaining varieties do set good heads under favourable temperate conditions. Only Pennlake succeeded in doing so under the existing tropical lowland conditions.

Whilst too much emphasis should not be placed on the results of this one trial, and other sowing times in different years may produce varying results, it is of interest to note that the superiority of Pennlake as a hot climate lettuce has been demonstrated in Queensland where in 1955, Morgan (1955) reported it to be the most reliable of the available warm weather varieties. Morgan (1962) again confirmed this and outlined the history of the search for a suitable summer lettuce in Queensland saying that the butterhead type had been the main summer variety for many years. Consumer preference changed with the advent of Imperial lettuce strains, but they were subject to tip burn, a serious physiological disorder of summer lettuce. A reliable hot weather lettuce came in the Great Lakes variety produced by the United States Department of Agriculture in 1941. It showed some resistance to tip burn and headed well under fairly hot conditions. Pennlake is an early, medium sized variety of the Great Lakes type.

Ward (1967) says that recent observations in Queensland lend doubt to the reported tip burn resistance of Pennlake, and Kruger (1966) attributed tip burn in Pennlake to a deficiency of calcium in the young leaves.

The failure of plants to establish in the direct-seeded fertilizer trials may have been due to high soil temperatures. Morgan (1962) states that a temperature of about 75 degrees F is best and that higher soil temperatures delay and reduce germination. Higher temperatures would have been obtained in these trials, and whilst the precise reason for failure cannot be stated, it is evident that direct seeding of lettuce could be risky under Gazelle Peninsula conditions.

CONCLUSIONS

A far wider use of the variety Pennlake would seem warranted in the tropical lowland areas of Papua and New Guinea when market preference is for lettuces with good firm heads.

Comparisons of Pennlake with the latest Great Lakes strains and new tropical varieties like Kauwela and Kulanui developed by Poole (1959) in Hawaii would seem to be the next step for lettuce research in lowland Papua and New Guinea.

(Accepted for Publication, January, 1968.)

REFERENCES

MORGAN, C. N. (1955). Lettuce, Celery and Some Other Greens. *Queensland agric. J.*, April 1955.

MORGAN, C. N. (1962). Summer Lettuce Growing is Highly Specialised. *Queensland agric. J.*, 88 : 554-556.

POOLE, C. F. (1959). New Sweet Potato and Lettuce Varieties Developed by H.A.E.S. *Hawaii. Farm Science*, 8 : 1-2.

KRUGER, N. S. (1966). Tip Burn of Lettuce in Relation to Calcium Nutrition. *Queensland J. agric. anim. Sci.* 23: 379-385.

WARD, K. M. (1967). Pers. comm., Chief Horticulturist, Redlands Horticultural Research Station, Ormiston, Queensland.

POWDERY MILDEW OF RUBBER IN PAPUA

DOROTHY E. SHAW*

ABSTRACT

The first record in Papua of powdery mildew of rubber, caused by Oidium heveae, *was made in September, 1967. How, where or when the fungus entered the country is not known. A survey carried out during the subsequent two months showed that the disease was present in the Central, Gulf, Milne Bay and Northern Districts, with the heaviest infections leading to leaf fall and flower blight in the Central District, nearest to the main port of entry. In an endeavour at least to slow down the spread of the disease to the islands and isolated areas an internal restriction on movement of unprotected rubber material was proclaimed in December, 1967.*

FIRST RECORD

ON 13th September 1967 Mr. R. Shepherd (Harrisons and Crosfield, Malaysia) and Messrs. A. E. Charles and A. van Haaren (Department of Agriculture, Stock and Fisheries) noted powdery mildew on young rubber flushes at Sogeri, a plateau mainly devoted to rubber growing, approximately 25 miles by direct line from Port Moresby.

The identification of *Oidium heveae* Steinmann was confirmed by microscopic examination in the laboratories at Port Moresby. A survey carried out immediately confirmed that much of the new season's growth throughout the Sogeri rubber areas was infected. Many of the trees were wintering but no mildew was detected on the old hardened leaves still remaining on some trees.

TERRITORY SURVEY

In an endeavour to determine how far the disease had already spread, collections were obtained from most of the rubber areas in both Papua and New Guinea. The results are shown in *Tables* 1 and 2.

The specimens were mainly collected at random (marked R in the column labelled "Collector" in *Table* 1) by agricultural officers and plantation managers, and in same cases by pathologists and rubber crop specialists (marked S in *Table* 1). Most collections were forwarded to Port Moresby in plastic bags by air and a few local ones by road or ship. Most arrived in good condition. The first few each averaged about 40 leaflets; larger collections were then requested and the numbers of leaflets recorded.

The material was examined macroscopically and microscopically in Port Moresby and the presence or absence of mildew noted (marked "Infected" or "—" respectively in *Table* 1). An assessment of the severity of the infection in each collection was attempted, the scoring being given in the last column of *Table* 1. The scale used was as follows:

The data in *Table* 1 are summarised in *Table* 2. In *Fig.* 1 the locations of the main rubber plantings in the Territory are given with their relative sizes indicated diagrammatically by the size of the circles; the percentages of collections infected are also shown diagrammatically.

INTERPRETATION OF THE RESULTS OF THE SURVEY

From a study of the Tables and the Figure it will be noted that the area with the most widespread infections and the greatest spore production on the leaflets was the Sogeri Plateau. This area is probably the most heavily affected to date, even considering the facts that most of the collections there were

1 Sparse—only a few leaflets with one infection each; no spores present when examined.
2 Slight—small portion of some leaflets infected; few spores present.
3 Medium—about one half of total number of leaflets and about one half of each leaflet surface infected; spores present.
4 Heavy—practically the whole surface of many young flush leaflets infected; spores abundant.

* Principal Plant Pathologist, Department of Agriculture, Stock and Fisheries, Port Moresby.

Table 1.—Results of the examination of rubber flush collections* during two months after the first record of powdery mildew.

Map Reference.	Locality	Distance from Sogeri (Miles)	Collector	No. of collections examined	No. of leaflets	Powdery mildew	Severity of infection
1.	SOGERI PLATEAU						
	Bisianumu		S	Many	Many	Infected	3
	Mageri		S	Many	Many	Infected	4
	Ilolo		S	1	39	Infected	4
	Koitaki		S	2	65	Infected	4
	Sogeri		S	2	60	Infected	4
	Itiki		S	1	36	Infected	3
	Eilogo		S	1	48	Infected	4
	S.A.		S	1	39	Infected	2
	Subitana		R	4	120	—	—
	Daradai	7	R	2	70	1 —	—
						1 Infected	1
	Jawarere	7	R	2	60	1 Infected	1
						1 Infected	2
2.	BROWN RIVER	20					
	"2 Mile Block"		S	2	48	—	—
	"4 Mile Block"		S	3	72	2 Infected	1
						1 —	—
3.	GALLEY REACH	40					
	Lolorua		R	3	120	2 —	—
						1 Infected	2
	Nusa		R	1	40	Infected	1
	Doa East		R	1	40	Infected	2
	Moale		R	1	40	Infected	1
	Kanosia		R	3	120	2 —	—
						1 Infected	1
	Rubberlands		R	2	80	—	—
	Veimauri		R	4	160	—	—
	Mariboi		R	8	300	5 —	—
						2 Infected	1
						1 Infected	2
4.	KEREMA	145					
	Epo		R	6	72	4 Infected	1
						2 —	—
	Murua (several sites)		R	5	296	—	—
	Cupola		R	1	22	—	—
5.	KIUNGA	460					
	Several sites		R	1	52	—	—
	Mepu		R	1	14	—	—
	Timindemasuk		R	1	24	—	—
	Drimdemasuk		R	1	48	—	—
6.	RIGO SUBDISTRICT	30					
	Kapogere		R	15	580	10 —	—
						5 Infected (62 spots on 42 leaflets)	1

* Collections were not obtained from the following areas:

Kabuna — v in Fig. 1.
Kikori — w in Fig 1.
Daru — x in Fig 1.
Wewak — y in Fig. 1
Buin — z in Fig. 1.

Table I Contd.

Map Reference.	Locality	Distance from Sogeri (Miles)	Collector	No. of collections examined	No. of leaflets	Powdery mildew	Severity of infection
	Poligolo		R	2	255	1 — 1 Infected (6 spots on 6 leaflets)	— 1
7.	CAPE RODNEY	90					
	Several sites		R	5	about 144	—	—
8.	EAST PAPUA						
	Mariawatte	200	R	2	80	1 — 1 Infected	— 1
	Sagarai	220	R	2	77	2 Infected	1
9.	KOKODA	45					
	Kokoda (several sites)		R	2	81	—	—
	Mamba		R	1	21	—	—
10.	POPONDETTA	80					
	P.A.T.I.		R	5	152	—	—
	Plantation 1.		R	2	about 18	—	—
	Plantation 2.		R	2	about 18	—	—
	Awala		R	4	54	2 — 2 Infected	— 1
	Sangara		R	3	48	2 — 1 Infected	— 1
	S.S. blocks		S	2	24	—	—
11.	LAE	190					
	Bubia		R	1	about 36	—	—
12.	LORENGAU MANUS ISLAND	500					
	Tamat		R	1	[redacted] 21	—	—
13.	NEW IRELAND*	520					
	Kavieng		R	7	about 319	—	—
			S	4	272	—	—
			R	7	about 319	—	—
			S	4	272	—	—
	Kavieng, Tokapi		S	1	60	—	—
	Kapsu	22 miles ex Kavieng	S	2	188	—	—
	Fissoa	60 ,, ,,	S	1	96	—	—
	Soubu	63 ,, ,,	S	1	135	—	—
	Bolegila	73 ,, ,,	S	1	84	—	—
	Libba	76 ,, ,,	S	2	239	—	—
	Lossu	80 ,, ,,	S	1	69	—	—
	Pinikindu	92 ,, ,,	S	1	54	—	—
	Suma	115 ,, ,,	S	2	162	—	—
		132 ,, ,,	S	2	128	—	—
	Namatanai	164 ,, ,,	S	2	57	—	—
14.	BOUGAINVILLE	600					
	Aropa 5 sites		R	1	40	—	—

* The New Ireland plantings were checked by a second specialist in the field in November, 1967.

Table 2.—Summary of information on collections in Table 1.

Map Reference	Locality	Total Colls.	No. Infected	Percentage Infected
1.	Sogeri	Many	All except 5	over 90%[1]
2.	Brown River	5	2	40
3.	Galley Reach	23	8	35
4.	Kerema	12	4	33
5.	Kiunga	4	0	0
6.	Rigo Subdistrict	17	6	35
7.	Cape Rodney	5	0	0
8.	East Papua	4	3	75
9.	Kokoda	3	0	0
10.	Popondetta	18	3	17
11.	Lae	1	0	0
12.	Manus Island	1	0	0
13.	New Ireland	38[2]	0	0
14.	Bougainville	1	0	0

[1] Collections mainly made by specialists with experience in disease collection.

[2] Areas in New Ireland re-checked by second specialist in the field one month after check by first specialist and microscopic examination.

made not at random but by specialists with some experience in collection, and also that they usually reached Port Moresby more quickly than those from other areas, which may have accounted to some extent for the large number of spores found on the leaflets.

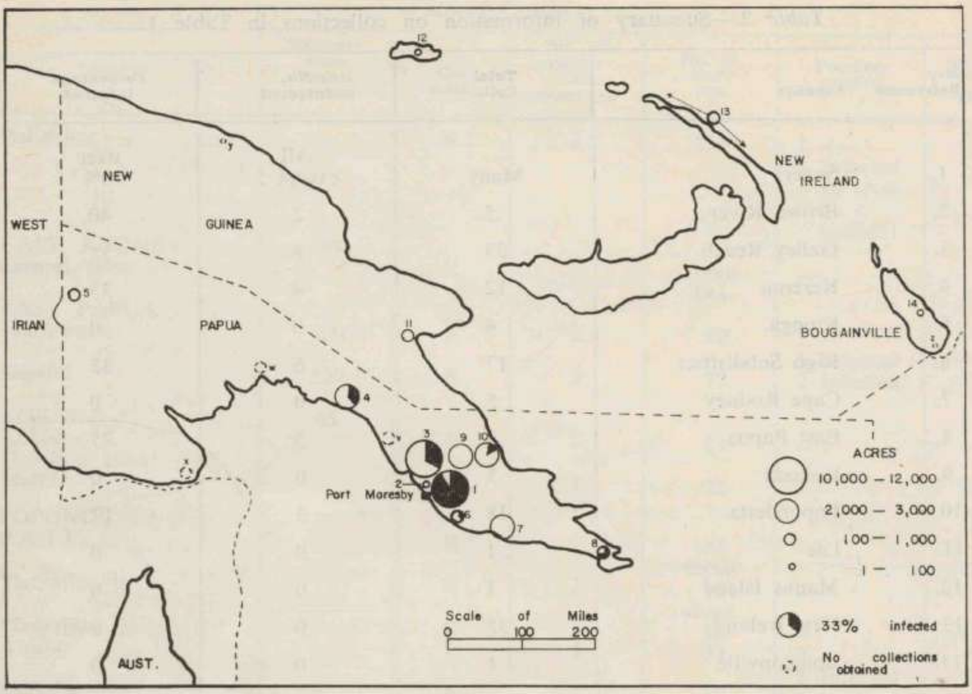
Even one positive recording in an area with many negative recordings indicates that the disease is present in the locality, although incidence may be low. Negative recordings for all the collections examined from an area, however, only means that no infections were found on those collections—it does not necessarily mean that there was no mildew in the area.

Bearing this in mind, it is probable that the disease was already present in Areas 7 (Cape Rodney) and 9 (Kokoda). On the other hand the negative findings from the large number of collections examined for Area 13 (New Ireland) coupled with nil recordings in field examinations of the rubber plantings by two specialists one month apart indicates that this island was probably still free from the disease.

SYMPTOMS

The majority of infections consisted of diffuse, slightly translucent areas on the leaflets when held to the light, affected areas appearing slightly paler green by reflected light; they ranged in size from about half a centimetre in diameter to the whole leaflet surface.

On the undersurface of the leaflets the site of the infection can be distinguished with experience as an interruption to the homogeneous green texture of the healthy area. This effect is difficult to describe and photograph.



In only one case to date were infections seen which could be called even slightly 'powdery' to the naked eye. They were found while carrying out spot checks on a plantation in the Sogeri area and occurred on a few leaflets of very young flushes produced early in the season, but appeared powdery macroscopically only when the leaflets were held at a certain angle to catch the light. No examples at all have been found as yet resembling the 'whitewash' spots illustrated by Wijewantha (1965).

Under the stereomicroscope the surface mycelium of infected areas is easily discernible in fresh specimens as a sparse network of fine glistening threads on the upper surface of the leaflets. Spore production is most clearly visible as a short, stiff pile along the sides of the midrib on the undersurface if the midrib bisects an infected area.

To date infections have been most evident on the young bronze-green leaflets and especially on the light-green immature leaves. Leaf fall was reported from seven plantations in the Sogeri area during the month after the first record. It was especially evident by the carpet of young wilted leaves on some plantation roadways. Samples of fallen leaves examined by the author revealed the presence of mildew, not *Gloeosporium albo-rubrum,* although this latter fungus occurred in some areas during this growing period, and in the past has caused leaf spotting, tip curling and some defoliation.

Flower attack occurred at Sogeri but no information on this aspect is yet available from the other rubber-growing areas of the Territory, since most of the collections received lacked flowers. It may be possible to estimate the amount of flower attack later in the season by comparing yield of seed set during the period when the first infections were noticed with the yields in previous years, unless adverse weather conditions also affect seed yield during the season.

By the end of November it was becoming difficult to find infections even at Sogeri, which, besides being the area apparently most heavily infected, is at an altitude of approximately 1,700 feet; the temperature at that altitude is lower, particularly during the night, than in the lowland rubber areas, the lower range being more favourable to the fungus. By March, 1968, spot checks by two specialists and the author found it difficult to locate the disease even on young leaves at Sogeri.

Therefore, while mildew will probably cause infection of young leaves with some leaf fall as well as flower blight at the refoliation period each year, it is hoped that diminution of severity will occur once the first flush leaves have fallen or hardened. This, in fact, is what occurs in most seasons in Malaya.

ENTRY OF THE FUNGUS

It is not known when, where, or how the fungus entered the Territory. Seed has been imported from Malaysia for many years but has had to be dusted with sulphur before despatch otherwise it was not permitted entry. Budwood had been imported from Malaya up till July, 1964, but such importations were also prohibited without fungicide treatment in Malaya—usually alcoholic mercuric chloride solution, followed after drying by dusting with sulphur.

Within the Territory there has been unrestricted movement of seed mainly from two sources on the Sogeri Plateau and limited movement of budwood and budded stumps from one source on the Sogeri Plateau. There has also been limited movement by personnel between rubber areas. Areas 1, 2 and 6 are joined by road and the sites in Area 13 (New Ireland) are scattered along 165 miles of coastal road. Communication and passage of goods between all other areas is by air with limited sea transport.

Since 1955, when the pathology service was established, specimens of wilted and occasionally abscissed rubber leaves have been examined from time to time. Hitherto they were always found to be infected with *G. albo-rubrum*. It is possible that mildew infections were present but not identified before September, 1967. However, when leaf fall was reported, collections were made early in the morning so that spores if present should have been undesiccated. Also, spores were deliberately sought-for microscopically, with mildew in mind, during the examinations of any leaf fall specimen.

As abundant spores did occur on the collections made at Sogeri in September, 1967, it is difficult to see how infections would have been missed had they occurred previously on specimens from the area.

SIGNIFICANCE OF THE OUTBREAK

During the last five years first records of three important crop diseases have been made in Papua and New Guinea, viz., blister smut of maize (*Ustilago maydis*) in 1963, coffee leaf rust *(Hemileia vastatrix)* in 1965*, and powdery mildew of rubber (*Oidium heveae*) in 1967.

It is interesting to note, and probably significant, that the first record of *U. maydis* was made near the most important port on the north coast of New Guinea and the first records of *H. vastatrix* and *O. heveae* were both made near the most important port of entry for both aircraft and ships in Papua and New Guinea, despite rigorous surveillance by the quarantine staff.

As increases occur in the speed of air and sea transport and in the diversity of ports of embarkation and routes to the Territory, as well as in the number of travellers, the risk of accidental importation of foreign diseases also increases. The fullest co-operation of the public in conforming to the requirements of the Plant Quarantine Ordinance 1953 will be necessary to support the vigilance of the quarantine staff in order to obviate further accidental importations of diseases of plants of economic importance to this Territory.

INTERNAL RESTRICTION ON RUBBER PLANTING MATERIAL

The survey revealed that the plantings in New Ireland and the small plantings in a few other isolated areas were apparently still free from the disease. In an endeavour to slow down its spread, a prohibition was proclaim-

* A previous authenticated record of *H. vastatrix* was made in 1903, but as far as is known there was no connection between the two outbreaks (Shaw, 1968).

ed in December, 1967, on the movement of any rubber plant or part of the plant from the Central, Gulf, Milne Bay and Northern Districts to the other Districts of the Territory without a permit from the Department certifying prior treatment with sulphur or another approved fungicide.

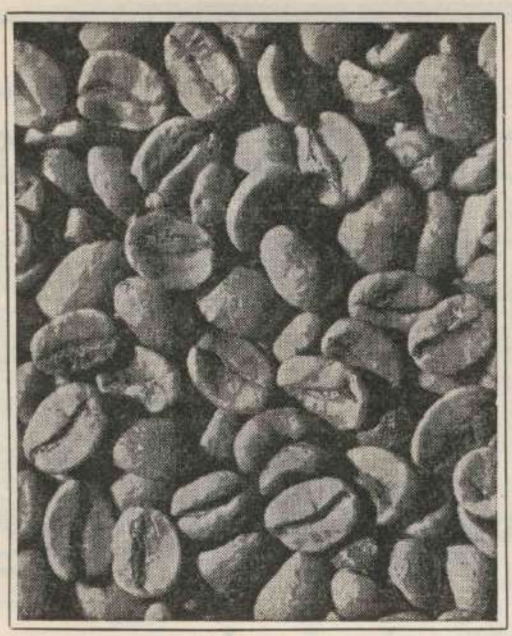
ACKNOWLEDGEMENTS

Grateful acknowledgement is made to the following: Mr. R. Shepherd (Harrisons and Crosfield, Malaysia) who brought in the first specimens of mildew; the managements of many plantations for forwarding specimens promptly on request; officers of the Department of Agriculture, Stock and Fisheries (especially Mr. W. Hastie, Mr. A. van Haaren and Mr. R. M. Burnett) for collection of specimens and for field checks; to Mr. M. Johnson for mapping assistance and to Mr. A. W. Charles for critically reading the paper.

REFERENCE

SHAW, DOROTHY E. 1968. Coffee rust outbreaks in Papua from 1892 to 1965 and the 1965 eradication campaign. *Dept. Agric., Stock. and Fish. Res. Bull. No. 2, Plant Path. Series,* pp. 20-52.

WIJEWANTHA, R. T. 1965. Some breeding problems in *Hevea brasiliensis. Quart. J. Rub. Inst. Ceylon,* 41: 12-22.



ten reasons why you should use 'Gramoxone'® (Paraquat) to kill weeds and grass in your coffee plantation:

1. It kills **all** green growth with which it comes in contact.

2. It is cheaper than traditional manual methods of weed control.

3. It does **not** damage mature coffee trees if applied to weeds around trunk base. (Young and seedling trees must be protected.)

4. It is rapidly absorbed by weed foliage and its effects can be seen within a few hours.

5. It can be applied in almost any weather, being unaffected by drought conditions or rain falling shortly after spraying.

6. It is inactivated on contact with the soil and cannot be taken up by plant roots.

7. It is NON VOLATILE and is free of the risks attached to hormone weed-killers.

8. It has no long term phytotoxic effects as there is no risk of harmful residues building up in the soil.

9. It is easily mixed with water and is active at low concentrates.

10. There is no danger to operators from diluted 'Gramoxone' (Paraquat) and no special protective clothing is required for spraying.

Get 'Gramoxone' (Paraquat) from all branches of:

BURNS PHILP (N.G.) LTD.
STEAMSHIPS TRADING CO. LTD.
COLYER WATSON (N.G.) LTD.
ISLAND PRODUCTS LTD.
NEW GUINEA CO. LTD.

Enquiries to:
Mr. C. Cannon,
Manager,
ICIANZ Ltd.,
P.O. Box 137, Lae.

ICI

®Registered Trade Mark of Plant Protection Limited, England.

SPECIFIED FOR THESE COMMONWEALTH DEPT. OF WORKS PROJECTS:

New Guinea
Housing for Papuan Infantry Regiment.
Taurama Army Barracks.
Commonwealth Banks.
Reserve Banks Honiara, Port Moresby.
Lae Army Barracks.
P.M.G. Station, Rabaul.

Australian Capital Territory
Orroral Valley Tracking Station.
2CA Canberra.
Tidbinbilla Tracking Station.
Bureau of Mineral Resources.
The Secretariat Building.
Royal Military College —Duntroon.
Dept. of Navy— H.M.A.S. Harman Barracks.

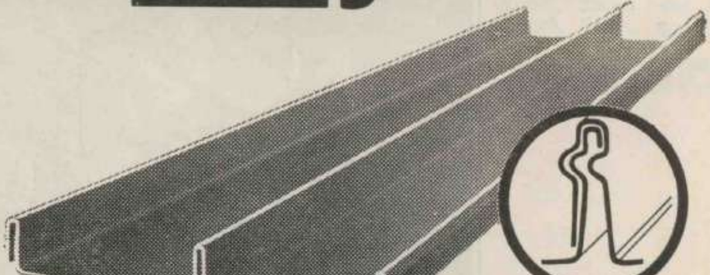
Northern Territory
Darwin Hospital.
Reserve Bank.
Commonwealth Education Dept.
R.A.A.F. Hangars.

New South Wales
Holsworthy Army Camp.
R.A.A.F. Base, Richmond.
Kapooka Army Camp.
D.C.A. Buildings, Mascot.
Atomic Energy Commission.

... and similar projects in other States

Fiji
Derrick Technical Institute, Suva.
Suva Post Office.

Brownbuilt
the strong roof!



Brownbuilt's unique button-punching process.

Here's proof:

Tests supervised by the Department of Civil Engineering, University of Melbourne, proved the ability of the Brownbuilt decking system to withstand upward suction loads equivalent to winds of cyclonic force.

POSITIVE CONCEALED FIXING.

Brownbuilt's great strength lies in its deep rib profile, concealed fixing method and exclusive, proven button-punching process for sheet interconnection. The combination of all three results in a completely secure, weatherproof, maintenance-free roof unaffected by heat expansion.

Note these other features:

1. Greatest span strength permits economical roof frame designs.
2. Most versatile—adaptable to all roof designs . . . flat skillion, steep pitch, up-and-over and radial pitch.
3. Wide selection of materials—galvanised steel, copper, aluminium, stainless steel, pre-coated "COLORARMOR."
4. Unmatched service—qualified technical representation coupled with smooth-running shipping facilities through our Export Division. Prompt and complete documentation—we take care of the details.

Brownbuilt
LIMITED

METAL SECTIONS DIVISION

499 Princes Highway, Kirrawee, Sydney 2232.
Cable: Metform.

Local Distributors

Morobe Constructions Pty. Ltd., Saraga Street, 6 Mile, **Port Moresby.**
D. C. Watkins Ltd., Angau Drive, Boroka, Port Moresby.
John Stubbs & Sons (Papua) Ltd., Lawes Road, **Port Moresby.**
Madang Building Supplies, Madang.
Lae Plumbing Ltd., Lae.
Reddy Constructions, Suva, Fiji.

BB:P16