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(continued overleaf)

THE COMPOSITION OF SOME NEW GUINEA FOODS

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The nitrogen, fat, ash, fibre, water and gross energy contents of 87 raw and cooked Papua New Guinean highland and coastal foods were analysed. Carbohydrate was obtained by difference and the available energy was calculated using appropriate factors. Information on the edible portion, average serving or portion size and the ratio of available to gross energy contents of these and other foods is presented.

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SHORT COMMUNICATION:

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J. Dodd, *Papua New Guin. agric. J.*, 30 (1 — 3): 41-42

Infestation with *Meloidogyne incognita* reduced the mean number of fruit per plant by 5.5($P<0.05$) in tomato variety 'Red Cloud', which represented a crop loss of 23.4 percent. Fruit size and plant dry weight (excluding fruit) were not affected. Fruit of infested plants showed significantly less Growth Cracking but earlier Blossom End Rot.

THE EFFECTS OF SHIFTING CULTIVATION ON SOIL PROPERTIES: AN EXAMPLE FROM THE KARIMUI AND BOMAI PLATEAUX, SIMBU PROVINCE, PAPUA NEW GUINEA

A.W. Wood*

ABSTRACT

The analysis of soil samples removed from both rainforest and subsistence food gardens on the Karimui and Bomai Plateaux revealed that shifting cultivation has a marked effect on soil chemical properties. With cultivation there is a reduction in available P, exchangeable Ca and Mg, cation exchange capacity and %C and %N. The decline in soil fertility with cultivation is thought to be due mainly to a reduction in soil organic matter resulting from the clearance of the rainforest vegetation.

The likely effects of resettlement are discussed, and it is thought that only about 5500 people could be resettled on the plateaux under the existing system of shifting cultivation. A further increase in population would require more intensive cultivation techniques to be developed, and these could result in soil deterioration and environmental disturbance.

INTRODUCTION

This paper is based on the results of a soil and land use survey carried out in September 1977 by a group of staff and students from the Department of Geography, University of Papua New Guinea (Wood and Pain 1978). The survey followed a request from the Simbu Provincial Government for more information on soil fertility and the land use possibilities of the Karimui and Bomai areas.

The Karimui and Bomai Plateaux are situated in southern Simbu Province of Papua New Guinea (latitude 6°30′ S., longitude 144°50′ E.) and occupy an intermediate position between the highlands to the north and the lowlands to the south. The plateau areas lie between 800 and 1200 m and form the greatest area of flat and gently undulating terrain in Simbu Province. The two plateaux are formed on volcanic lavas, agglomerates, mudflows and volcanic ash from the extinct Pleistocene volcanoes of Mt. Karimui and Mt. Au shown in *Figure 1* (Bain and Mackenzie 1975). These volcanic deposits have covered the Tertiary and Cretaceous sediments in the area. The two plateaux are separated by the Tua River, a major tributary of the Purari.

The climate of the area is warmer and wetter than the north of the province. The lower elevation results in mean minimum and maximum temperatures being 2 to 3°C higher in Karimui (Min. 18°C; Max. 28°C) than in Kundiawa (Min. 14.6°C; Max. 26.1°C). Annual rainfall totals are significantly higher: 3386 mm at Karimui, 4855 mm at Unani on the Bomai plateau, and only 2224 mm at Kundiawa (Simpson 1975).

Much of the Karimui and Bomai Plateaux are covered with lower montane rainforest vegetation, and true montane forest occurs on Mt. Karimui and Mt. Au.

The population in the south of the province is concentrated on the plateau areas, although densities are quite low, with about 24 persons per km^2 on the Karimui Plateau and only 4 persons per km^2 on the Bomai Plateau.

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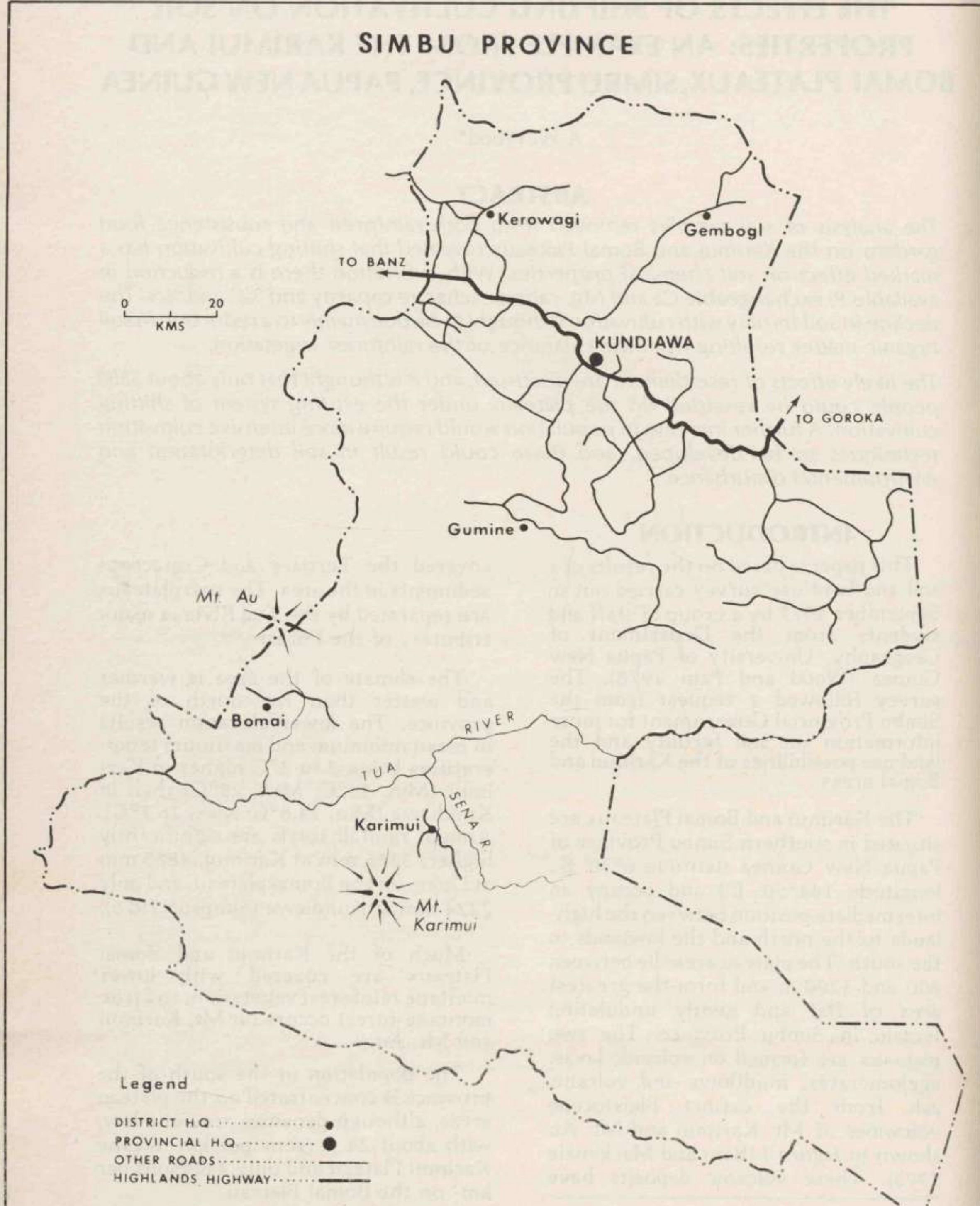

Figure 1. — Map of the Simbu Province

SURVEY METHODS

Fifteen gardens around Karimui and twelve around Bomai were examined in detail. Information was collected on soil and site characteristics, crop types, age and cultivation history, cultivation techniques and land ownership for each garden. This information was collected both by interview and by observation.

The boundaries of each garden were plotted by compass traverse, and distances were measured either with a tape measure or by pacing. A plan of each garden was drawn up on squared paper and the area was calculated.

Soil samples were removed from each garden for chemical analysis. The sampling technique consisted of removing a number of samples (usually about 10) from the cultivated topsoil (0-15 cms) in a garden, and then mixing these into one bulk sample. Samples were also removed in a similar manner from the top 15 cms of soil under rainforest and in old gardens under grass fallow, with a view to finding the changes in soil properties which occur with cultivation.

A selection of soil samples was taken for chemical analysis and standard procedures were used. pH was measured electrometrically on a 1:5 soil:water mixture, and available phosphorous was measured by the method of Olsen *et al.* (1954). The exchangeable cations were determined by atomic absorption spectrophotometry after leaching the soil with neutral ammonium acetate, and the exchange capacity was found by measuring the ammonium ions absorbed by the soil exchange complex, using the method described in Black (1965). Organic carbon was determined by the method of Walkley and Black (Black 1965:1372) and total nitrogen by the Kjeldahl procedure (Black 1965:1162).

CULTIVATION TECHNIQUES

The traditional method of cultivation in the area is a form of shifting cultivation or bush fallowing, which is widely used in the zone of intermediate elevation (500-1500 m) in Papua New Guinea (Powell 1976). Gardens are prepared by clearing the forest: the bush is cleared away, the smaller trees are felled and some of the larger ones are ring barked.

The debris from the clearing is commonly piled up around the base of the larger trees and is fired. Gardens are usually fenced and weeded before planting. The size of gardens studied ranged from 0.06 to 2.01 ha, with an average size of 0.65 ha. A typical garden on the Bomai Plateau is shown in *Plate* I.

The main crop is sweet potato and this is planted by dibbling, with no further working of the soil. A large range of other crops is grown including banana, beans, cabbage, cassava, cucumber, groundnut, maize, paw paw, pineapple, pit pit, pumpkin, sugar cane, taro, tobacco, and various greens.

Gardens are cultivated for 1-2 years and are then left fallow as yields decline. Some crops such as bananas continue to be harvested while gardens are being fallowed.

SOIL TYPES AND PROPERTIES

The main soil type is a Humic Brown Ash soil which has many similarities with soils developed on volcanic material throughout the Papua New Guinea Highlands. It is characterised by a dark brown, friable organic topsoil of clay texture ranging from 15-35 cm in depth, which overlies yellowish brown to brown clay. The organic topsoil is generally thinner and lower in organic matter than those of highlands volcanic ash soils, and this is probably due to

Plate I. — A large garden cut in rainforest on the Bomai Plateau. This garden was cleared about 6 months before the photograph was taken.

the warmer temperatures in southern Simbu which promote a more rapid breakdown of organic matter.

The soils around Karimui and Bomai have formed in volcanic parent materials. Those around Karimui appear to have formed largely in airfall volcanic ash, whereas those near Bomai are formed in reworked ash. The Bomai soils are more massive than those around Karimui and in places contain large rounded boulders of lava. The Bomai soils probably occur on volcanic mudflows which have moved down the slopes of Mt. Au.

The soils of the Bomai Plateau have been surveyed by Hartley and Aland (1962) who termed them "highly leached organic clays of low overall fertility". Only the organic topsoils were considered to contain adequate nutrient supply.

The chemical properties of the soils analysed are shown in *Table 1* which gives mean values and the range of values for the chemical analysis of topsoils (0-15 cm) under different types of vegetation. Only a small number of samples were analysed, and the range for some analyses is wide. However, these are the only results available for this area which illustrate the effects of cultivation on soil chemical properties.

Soils under rainforest show the highest fertility status with a moderate acidity, moderate levels of available P, high exchangeable Ca and Mg, high cation exchange capacity, high base saturation, and moderately high organic matter levels (%C and %N). With forest clearance and cultivation there is a marked reduction in available P, exchangeable Ca and Mg, and cation exchange capacity. Organic matter levels are lower and this probably accounts for the reduction in cation

Table 1. — Chemical analyses for topsoils under different types of vegetation

Vegetation Types	Number of Soil Samples	pH	Available P (Olsen) p.p.m.	Exchangeable Cations me%				Cation Exchange Capacity me %	Base Saturation %	% C	% N
				Ca	Mg	K	Na				
Rainforest	3	5.8 (5.4-6.4)	11.7 (8.8-15.6)	35.2 (29.1-43.3)	7.3 (6.2-9.6)	0.9 (0.5-1.4)	0.5 (0.4-0.6)	41.1 (34.3-53.3)	97 (91-100)	10.8 (9.9-11.7)	1.0 (0.9-1.1)
Cultivated Gardens	6	5.8 (5.2-6.1)	7.2 (4.3-9.8)	20.7 (12.0-28.6)	3.9 (1.6-6.8)	1.2 (0.5-2.4)	0.5 (0.2-0.9)	29.4 (25.4-32.5)	81 (53-90)	8.5 (5.8-10.1)	0.9 (0.6-1.0)
Fallow Gardens	1	5.4	2.8	15.0	2.4	0.8	0.3	19.2	96	6.8	0.7

Mean values are shown and the range is given in brackets.

exchange capacity. The abandoned garden under fallow shows a much lower fertility status with more acid conditions, low available P, lower values for exchangeable cations, and only moderate exchange capacity and organic matter levels.

THE EFFECTS OF SHIFTING CULTIVATION

The impact of shifting cultivation on soil properties and soil fertility has been well documented for tropical areas, in particular by Nye and Greenland (1960). The main effect of forest clearance is to break the natural cycling of nutrients which operates between the rainforest vegetation and the soil. Once the trees have been felled and the vegetation cleared and burned, the major source of organic matter and plant nutrients is removed. Under cultivation the heavy rainfall and high temperatures encourage the rapid breakdown of organic matter and the leaching of plant nutrients. Available plant nutrients are also lost from the soil due to crop uptake.

The decomposition of organic matter is probably the most important result of clearing and cultivation. In the majority of tropical soils it is the organic matter that contains the bulk of the nutrients available to plants, including nearly all the nitrogen, most of the available phosphorous and some of the available potassium. Moreover with a decline in the organic matter content of the topsoil, the structural aggregates of soil are likely to break down. This causes a reduction in pore space and permeability, and increased run off, which could lead to an increase in the removal of topsoil by erosion.

The changes in soil chemical properties given in *Table 1* are similar to findings elsewhere in the tropics. Sanchez (1977) has described changes in fertility for South American soils under shifting cultivation and in some cases the decline in fertility occurs more slowly than in this situation. The chemical data show a gradual reduction in organic matter from rainforest soils to cultivated soils to those soils under fallow where the vegetation is beginning to regenerate. There is also a decline in the cation exchange capacity, which suggests that there is a strong relationship between organic matter levels and cation exchange capacity. The organic matter is the main "store" for plant nutrients in the soil. As organic matter levels decline, so will the soil's capacity for holding exchangeable cations, and these will be released and become more susceptible to removal by leaching.

Although the soil texture is clay in both the topsoil and subsoil, the permeability is high particularly in the topsoil which has a grannular or crumb structure. This allows leaching to proceed rapidly once the soil is exposed to heavy rainfall.

The effects of the reduction in cation exchange capacity and of leaching are illustrated by the figures for exchangeable cations in *Table 1*, all but potassium showing a decline. Base saturation remains high indicating that although the exchange complex remains almost saturated, the reduction in organic matter and cation exchange capacity leads to a reduction in available plant nutrients.

Available P also shows a marked decline with cultivation. Tropical soils, and particularly those developed on volcanic ash, are noted for their ability to "fix" phosphate and render it unavailable to plants (Parfitt and Mavo 1975). The organic matter in these soils contains most of the available phosphate and this will decline with a reduction in organic matter levels.

Thus the removal of the rainforest vegetation and the cultivation of the soil will lead to a decline in soil fertility, although it is not known how rapidly this decline takes place. Few gardens are cultivated for more than two years and this suggests that the change in the amount of available nutrients is fairly rapid. However, this may be a reflection of the low population densities in the area which allow the cultivators to move their gardens more regularly.

The main crop, sweet potato, is not generally planted more than three times before a garden is abandoned. The reason most commonly given by those farmers interviewed for abandoning a garden and moving to another site was that yields of the second or third crop had declined to such a low level that it was no longer worthwhile to continue cultivation of the garden. Charles (1976) has suggested that the multiplication of weeds, pests and diseases is a more important factor than declining soil fertility when explaining the fall off in productivity of subsistence gardens. The Karimui people, however, considered this to be less important than declining fertility when giving reasons for abandoning a food garden.

The soil which has been cultivated, gradually regains its fertility under fallow. Grasses and woody shrub species appear first, then larger trees begin to recolonise the area. With the restoration of the nutrient cycle, organic matter levels are built up. This in turn increases the cation exchange capacity of the soil and fertility levels begin to rise. Fallow periods are commonly between 15 and 20 years before the site is recultivated.

Similar systems of shifting cultivation are practised on many types of soil over much of Papua New Guinea. The soils at Karimui and Bomai are in the author's opinion probably more fertile than most soils because they are derived from volcanic ash parent materials. Although the ash is fairly old, highly weathered and consists mainly of clay sized particles, it contains a small reserve of weatherable, sand sized minerals. Plant nutrients are being constantly released as the weathering of primary minerals proceeds in the soil, although much of this weathering is taking place well below the soil surface and it is doubtful whether many of the nutrients released can be utilised by growing plants. Those nutrients that cannot be held in the soil by the exchange complex are likely to be leached out, and since cation exchange capacity values in the subsoil are low, most of the nutrients released by weathering are probably removed by leaching.

THE EFFECTS OF INTENSIVE CULTIVATION

The Karimui and Bomai Plateaux have been considered as a possible resettlement area for up to 40,000 people from the more densely populated northern part of Simbu Province (Simpson 1975). The present system of shifting cultivation with long fallow periods provides satisfactory subsistence crop yeilds for the relatively small resident population. However, a large increase in the population density could place the agricultural system under stress, and would result in a reduction in the length of fallow periods and an overall decline in soil fertility.

It is possible to make an estimate of the number of people that can be resettled on the plateau areas from the results of the garden survey. Families subsist from an average of 2 gardens, and the average garden size is 0.65 ha. If gardens are cultivated for 2 years and fallowed for 15 years, each settler family would require at least 11 ha of land if present fallow periods are to be maintained. This gives a population carrying capacity of 9 families per km^2 or about 45 persons per km^2, given an average family size of 5 persons.

Although the plateaux contain the largest area of flat land in Simbu Province, the total area of suitable land for cultivation is limited to about 300 km^2. There are already about 8000 people living in the area, and so there is only room for a further 5500 people to settle on the plateaux. If the plans for resettling 40,000 people in the area go ahead, shifting cultivation in its present form could not be practised, and a more sedentary form of agriculture based on the intensive use of a small area of land would need to be developed.

Newton (1960) has considered

various alternative agricultural systems to shifting cultivation which involve rotations combining food crops with leguminous cover crops and green manures. In high rainfall tropical rain-forest areas he concludes that shifting cultivation will maintain soil fertility as effectively as any other system of agriculture, and that rotation trials have failed to maintain yields. Where land shortage exists, the use of commercial inorganic fertilisers and cover crops is recommended.

Charles (1976) also saw shifting cultivation as an efficient method of subsistence agriculture for Papua New Guinea conditions, and considered that problems were only likely to occur when land pressure resulted in shortened fallow periods. He listed various alternatives and modifications to shifting cultivation including the use of fertilisers, but stressed that many of these techniques are alien to subsistence cultivators, who would be slow to adopt them.

Any attempts to intensify the present agricultural system in order to support a large influx of people would face difficulties. The proponents of resettlement argue that in the higher, northern part of Simbu Province there is a more intensive cultivation system with only short fallow periods, supporting population densities of up to 200 persons per km², and that incoming settlers from the north would already have a knowledge of these intensive techniques. However, the environmental conditions in the north are quite different from those at Karimui. The risks of soil deterioration and environmental degradation are much greater in the south of the province, and intensive cultivation associated with widespread forest clearance would result in a more rapid decline in soil organic matter content, due to the warmer temperatures and higher rainfall. This would also result in accelerated leaching and nutrient loss, and a high risk of soil erosion, particularly on steeper slopes.

The development potential and limitations to cultivation in the Karimui and Bomai Plateaux are quite different from those in the northern part of Simbu Province. It is not known fully what the effect of an intensification of cultivation techniques would be on the soils of the area. However, it seems likely in view of the soil and climatic differences between the north and south of the province that intensification of agriculture could not take place to the same extent in the south without severe soil deterioration occurring.

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IODINE STATUS OF EWES IN PAPUA NEW GUINEA

E.A. Walton*

ABSTRACT

Serum thyroxine concentrations were determined in 296 ewes from 10 locations in Papua New Guinea. Normal values were found at all locations except Mt. Hagen and Menifo. At Mt. Hagen, iodine deficiency was present in 49% of the flock and at Menifo serum thyroxine levels were considered marginal. The possibility that iodised salt may be masking an environmental deficiency is considered.

INTRODUCTION

Iodine deficiency is a widespread disease of man and grazing animals and has been documented in all continents (Underwood 1966). A high incidence of still births and weak newborn animals are the most common symptoms of this deficiency. Partial or complete hair loss together with a markedly enlarged thyroid gland are other symptoms, and in animals of breeding age iodine deficiency may severely reduce reproductivity. Adult sheep in iodine deficient areas may show thyroid enlargement but are otherwise clinically normal. Iodine is concentrated in the thyroid gland where it is incorporated into the hormone thyroxine. Serum thyroxine levels are therefore a good indication of the iodine status of the animal.

Human endemic goitre was once common in both the eastern and western part of the New Guinea Island (Choufoer *et al.* 1965; Buttfield and Hetzel 1966) and iodine deficient goitre has been described in lambs at Mt. Hagen (Walton and Humphrey 1979). This survey was undertaken to determine, by measuring serum thyroxine concentrations, the iodine status of sheep flocks at various locations in Papua New Guinea.

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MATERIALS AND METHODS

The survey involved 296 ewes at ten locations *(Figure 1)*, bled during the period 13th September, 1977 to 4th October, 1978. All Highland sheep and those at Erap were progeny of animals imported from New Zealand in 1975 and held in quarantine at Menifo (21 km south east of Goroka). Sheep at Kila Kila, Bisianumu and Vudal were progeny of ewes which have been in the country for many years.

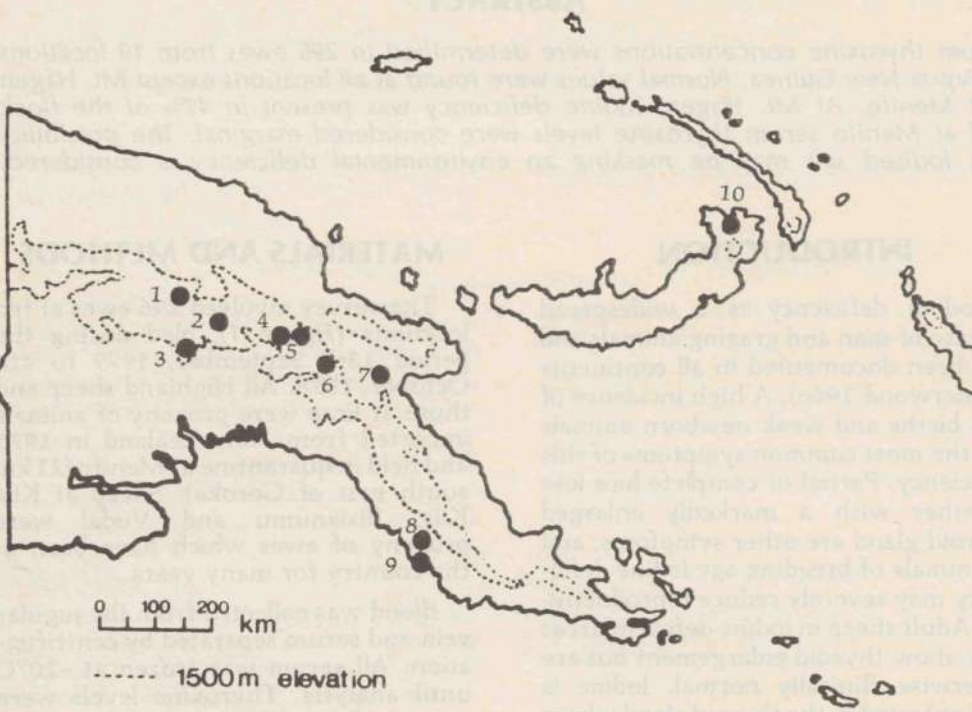
Blood was collected from the jugular vein and serum separated by centrifugation. All serum was frozen at -20°C until analysis. Thyroxine levels were measured by radioimmunoassay using 50 µl of serum and 300 mg of 8-anilino-1-napthalene sulphonic acid per tube to displace thyroxine from thyroxine binding proteins present in serum. Antiserum was prepared in sheep, and polythylene glycol was the separating agent.

RESULTS

Serum thyroxine levels found in flocks of sheep at ten locations throughout the country are given in *Table 1*.

The results of analyses of sheep serum from Mt. Hagen are shown in *Figure 2*. Although the mean thyroxine level of the flock was 65 nmol/L, 49% of the animals had serum thyroxine levels below 50 nmol/L and 45% had levels above 80 nmol/L.

Figure 1. — Locations where ewes were bled for measurement of serum thyroxine concentrations



1. Yogos	3. Muli	5. Bena Bena	7. Erap	9. Kila Kila
2. Mt. Hagen	4. Menifo	6. Aiyura	8. Bisianumu	10. Vudal

In other flocks, with the exception of Menifo, there were occasional individual animals with serum concentrations below 50 nmol/L, but levels in the flock were generally well above this level. At Menifo, however, 42% of the flock had levels below 50 nmol/L and 16% were below 40 nmol/L.

DISCUSSION

In a survey of lactating ewes in Australia, Wallace *et al.* (1978) found a mean plasma thyroxine concentration of 62 nmol/L and regarded properties carrying sheep with mean levels below 50 nmol/L as possibly iodine deficient.

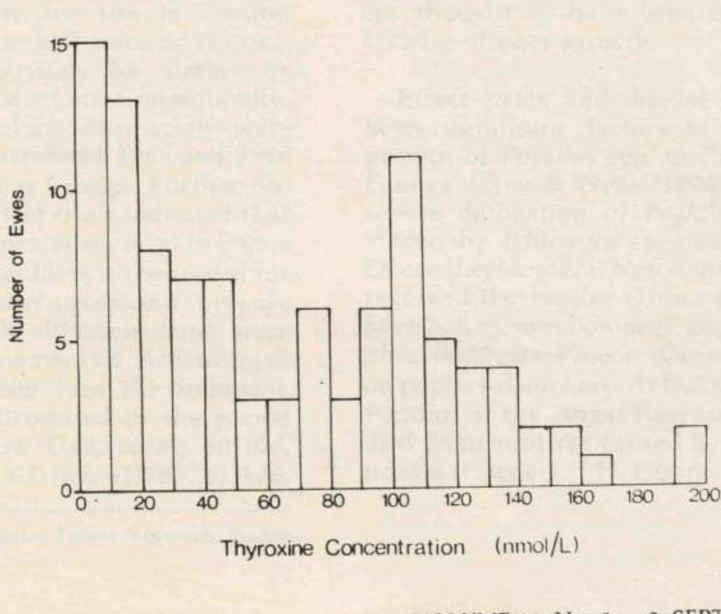
Some ewes in the Mt. Hagen flock had received an iodised oil injection (Lipiodol, May and Baker) prior to the survey. Most serum thyroxine concentrations at Mt. Hagen can be assigned to one of two groups as a result of the iodised oil injection. Although no record was kept of which animals were injected *Figure 2* clearly demonstrates that the iodine status of some animals was very poor whereas other ewes had adequate iodine levels.

Excluding the Mt. Hagen results, the survey indicated that in the areas investigated, iodine intake was sufficient except at Menifo where thyroxine levels were marginal.

Table 1. — **Serum thyroxine concentrations of ewes at ten locations throughout Papua New Guinea**

Location	Province	Age	Preg./Lact. Status	n	Thyroxine (nmol/L) Mean ±S.D.
Menifo	Eastern Highlands	5-6 yrs	Non Preg.	19	55.1 ±16.1
Bena Bena	Eastern Highlands	6 mths	Non Preg.	14	90.7 ± 22.0
Aiyura	Eastern Highlands	12 mths	Non Preg.	17	93.6 ± 19.6
Mt. Hagen	Western Highlands	2-3 yrs	Non Preg. & Preg.	102	64.8 ± 49.9
Muli	Southern Highlands	2 yrs	Lactating	42	86.0 ± 36.3
Yogos	Enga	2 yrs	Lactating	31	107.2 ± 34.6
Erap	Morobe	2-4 yrs	Lactating	20	96.3 ± 24.2
Erap	Morobe	1½-8 yrs	Pregnant	25	86.2 ± 24.2
Vudal	East New Britain	2-6 yrs	Pregnant	11	68.8 ± 27.5
Kila Kila	Central	3yrs	Non Preg.	2	72.5 ± 26.2
Kila Kila	Central	6-9 mths	Non Preg.	4	71.5 ± 10.7
Kila Kila	Central	3 yrs	Lactating	6	72.0 ± 16.1
Bisianumu	Central	1-2 yrs	Lactating	3	113.3 ± 18.2

Figure 2. — **Serum thyroxine concentrations of ewes at Mt. Hagen**



At the time of bleeding, iodised salt licks were available at all locations except Kila Kila. Such licks may maintain satisfactory dietary iodine levels and conceal environmental deficiencies. Highland areas of Papua New Guinea are likely to be deficient in iodine because high annual rainfall causes leaching of iodine from the soil and distance from the sea precludes replenishment with oceanic iodine (Blood and Henderson 1968).

Low thyroxine levels found in individual animals in flocks where the mean thyroxine level is satisfactory may indicate that individual animals vary considerably in the amount of iodised salt they choose to consume.

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POPLAR RUST IN PAPUA NEW GUINEA

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ABSTRACT

The history of poplar (Populus) *introductions into Papua New Guinea, and the diseases and pests of those poplars, is briefly reviewed. The detection and spread of the poplar rust* Melampsora larici-populina *Kleb. is described. The possible origin of the outbreak, methods of control, and significance of the disease are discussed.*

INTRODUCTION

In 1965 scions of a large number of clones of species of *Populus* were introduced into Papua New Guinea from Australia. This material included *P.deltoides* Marsh ssp. *angulata* Ait., *P.deltoides* ssp. *monilifera* Henry, *P.nigra* L., and *P.x euramericana* (Dode) Guinier, all of section *Aigeiros*, the black poplars; and *P.trichocarpa* Torr. & Gray of section *Tocamaha*, the balsam poplars (FAO 1958). The scion material was planted in the humid, warm coastal lowlands at Oomsis near Lae, and in the cooler highlands at Lapegu near Goroka. At Oomsis the few scions which developed roots grew poorly and all scions were eventually destroyed. At Lapegu, however, establishment of scions was good and several clones showed promise for use in erosion control, as shelterbelt trees or as ornamentals and possibly for timber or matchwood production. Consequently, additional introductions of scions were made from Australia in 1967 and 1968 and established at Lapegu. Further observation and field trials indicated that none of the clones introduced to Papua New Guinea was likely to be useful for commercial timber production because of poor growth although some were attractive as ornamentals. According to Office of Forests files the following clones were introduced in the period 1965-1968:— G3, G48, 56/31, 60/106, 60/129, 61/124, 61/165, 61/183, 61/186, 62/2, 62/4, 62/18, 65/27, 65/32, 65/33, 65/34, 65/35, 65/42, Evergreen, Honduras, and Calcurado.

Growth of most clones of *Populus* is strongly influenced by photoperiod, seasonal photoperiod rhythms, and temperature (Pryor & Willing 1965). The more successful clones in Papua New Guinea were semi-evergreen, and usually had as one parent *P.nigra* cv. 'Evergreen' or its hybrids, which have growth rhythms uninfluenced by photoperiod or temperature changes (Pryor & Willing 1965). Many cuttings from the clones established at Lapegu were distributed throughout Papua New Guinea, especially the highlands. The identity of the poplars now growing in Papua New Guinea is not accurately known, although all *P.deltoides* clones are thought to have been eliminated because of poor growth.

Insect pests and disease have not been significant factors in the poor growth of *Populus* spp. in Papua New Guinea. Gray & Wylie (1974) reported severe defoliation of *Populus* at Mt. Hagen by *Ichthyura* sp. near *I.rubida* Druce (Lepidoptera: Notodontidae), and recorded the beetles *Oribus destructor* Marshall (Curculionidae) and *Pterolophia duplicata* Pascoe (Cerambycidae) on poplars elsewhere. At Bulolo a row of *Populus* at the Forest Research Station died from root rot caused by *Phellinus noxius* (Corner) G.H. Cunn..

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Figure 1. — Map of Papua New Guinea showing location of poplar rust outbreaks

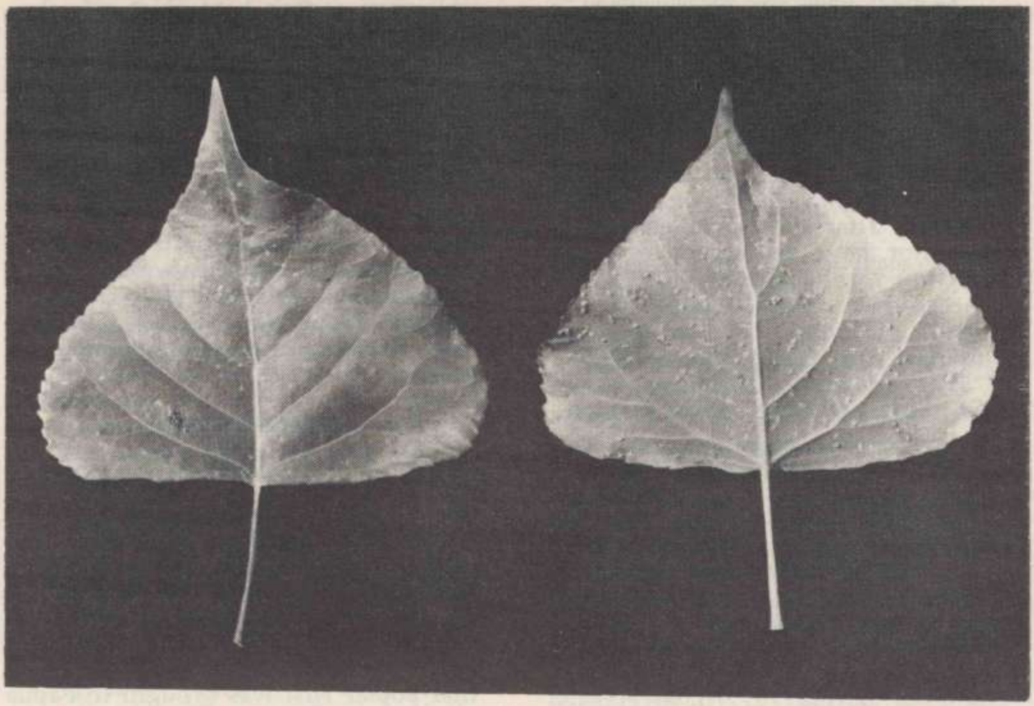

Plate I. — *Melampsora larici-populina* on upper (left) and lower (right) surfaces of poplar leaves

DEVELOPMENT OF POPLAR RUST DISEASE

On 8th January 1975, samples of rust infected poplar leaves were received from Mendi in the Southern Highlands Province. The pathogen was identified as *Melampsora larici-populina* Kleb.. Subsequently an inspection was made between 19th and 26th January 1975, of poplars growing at various localities throughout the highlands. Rust infected poplars were found at Mendi, Ialibu, Mt Hagen and Kundiawa. In each instance the pathogen was identified as *M. larici-populina*. No sign of poplar rust was found at Tari, Goroka, Lapegu, Kainantu, or Bulolo. This distribution pattern (*Figure 1*) indicated that the centre of the outbreak was the Mt. Hagen area. In September 1975, *M. larici-populina* was recorded for the first time at Goroka, Lapegu and Kainantu. It was deliberately introduced to Bulolo in May 1976, and was observed on poplars at Tapini, possibly from scions introduced from Goroka, in September 1977. It has not been observed on poplars growing in the lowlands.

Rust infected poplars were rarely completely defoliated even in periods of prolonged wet weather. However, the sparsely foliated trees looked unsightly and most poplars in the highlands have been destroyed. No field resistant poplar trees were seen.

Infected leaves developed small angular chlorotic lesions in which the erumpent subepidermal bright yellow hypophyllus uredinia, of 0.1-0.5 mm diameter developed (*Plate* I). Infection usually occurred first on older leaves but uredinia may develop on all but the most recently formed leaves. Urediniospores from the first formed uredinia gave rise to new infections and the leaves soon became finely flecked with irregular chlorotic lesions which eventually became necrotic and coalesced into extensive irregular dead areas. Urediniospores were broadly ellipsoid to clavate, mostly 26-42 × 14-18 µm, with yellow guttule, surface echinulate, with cyanophilous spines to 1.5 µm high, except at one end which was smooth. Telia have not been observed on either attached or fallen poplar leaves, nor have aecia been seen on needles on various species of *Pinus* adjacent to rust infected poplars. The 'natural' alternate host for *M.larici-populina* is *Larix* (FAO 1958) but Spiers (1975) has shown that basidiospores can infect needles of *Pinus radiata* D. Don..

So far *M.larici-populina* is the only species of poplar rust that has been found in Papua New Guinea. In Australia *M.larici-populina* was first recorded on *Populus* in February 1973 (Walker *et al.* 1974) one year after *M. medusae* Thum. was first observed there. In March 1973 both *M. medusae* and *M.larici-populina* were detected in New Zealand (McMillan 1973). Heather & Sharma (1977) have reported finding urediniospores of *M. medusae* in poplar rust samples from Papua New Guinea but we have not been able to confirm this despite an intensive study of the retained portions of the collections sent to them for study, and of large amounts of material subsequently collected from numerous localities.

ORIGIN OF *M.LARICI-POPULINA* IN PAPUA NEW GUINEA

The means by which poplar rusts were introduced into Australia is not positively known but it is suspected that they were introduced on illegally imported scion material. Both *M. medusae* and *M. larici-populina* are presumed to have been introduced into New Zealand as urediniospores blown across the Tasman Sea from Australia (Mcmillan 1973). Wide dispersal of poplar rust in south-east Australia and in New Zealand was very rapid after the initial outbreaks were observed (Walker *et al.* 1974: Sheridan *et al.* 1975). The situation in Papua New Guinea was similar.

It is a possibility that poplar rust was carried to Papua New Guinea from Australia by the south-east trade winds which originate from close to latitudes 25°-30° south during the southern winter period (Ford 1974) but it is unlikely as the airborne urediniospore population in Australasia would then be minimal, and it is the 'dry' season in most of Papua New Guinea. Furthermore poplars are nowhere common in tropical Australia or in Papua New Guinea, thus the chances of *M.larici-populina* urediniospores reaching a susceptible host in the Mt. Hagen area are extremely small. This is the opposite of the situation discussed by O'Brien (1977) who considered it possible that peanut rust *(Puccinia arachidis* Speg.*)* was introduced into Queensland as windborne urediniospores carried from Papua New Guinea by the summer north-westerlies. It seems more likely that poplar rust was brought to Papua New Guinea on scion material illegally introduced from Australia or New Zealand.

CONTROL

There is great variation in the susceptibility of various species and sections of *Populus* to different species of *Melampsora* (FAO 1958; Pinon 1973). Within *Populus* species, clones and progenies also differ in susceptibility to any particular species of *Melampsora* (Stout & Schreiner 1933). Heritability estimates indicate that large genetic gains for resistance can be expected by selecting and breeding from resistant clones (Thielges & Adams 1975) but this work is slow and no resistant clones have been observed in Papua New Guinea. It has been estimated that a minimum of 10 years testing may be required before clones can be confidently recommended for commercial planting (Palmberg 1977). Van der Meiden (1959) and Suzuki (1973) have shown that tree nutrition also greatly affects resistance of poplar leaves to *M.larici-populina*.

In New Zealand copper fungicides at 0.1% elemental copper, or Benodanil at 0.05%, applied at two to four week intervals, have provided effective protection (Fullerton & Menzies 1974; Spiers 1974; Sheridan *et al.* 1975) and would probably be effective in Papua New Guinea.

We have frequently observed uredinia colonised by a species of *Cladosporium,* and by unidentified mycophagous mites but neither effectively controlled poplar rust.

DISCUSSION

Other better adapted species of trees are available which fulfill all the intended purposes for which species of *Populus* were introduced. *M.larici-populina* is apparently not pathogenic to *Pinus* in Papua New Guinea. It is probable that both *Populus* and *M.larici-populina* will become extinct in Papua New Guinea in the next one or two decades. The significance of the poplar rust outbreak has been to emphasise the importance of observance of plant quarantine regulations, of the risks associated with introduction of vegetative plant material, and of the potential windborne spread of plant diseases between Australia and Papua New Guinea.

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BIOLOGICAL AND CHEMICAL CONTROL OF *OSTRINIA FURNACALIS* GUENEE (LEPIDOPTERA: PYRALIDAE) ON THE MAINLAND OF PAPUA NEW GUINEA

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ABSTRACT

Ostrinia furnacalis *Guenee (Pyralidae) is commonly found on maize in the Markham Valley, Morobe Province, Papua New Guinea.* Trichogramma *sp. appears to be the only parasite controlling populations of* O. furnacalis. *Insecticide trials at two sites in the Markham Valley using monocrotophos, lindane (granules and emulsifiable concentrate) and D.D.T. significantly reduced the number of holes bored and cob damage, but no significant increases in yield over the control were obtained.*

INTRODUCTION

Ostrinia furnacalis Guenee (Pyralidae) has been recorded on maize from New Britain, New Ireland, and the northern side of the Papua New Guinea mainland from sea level to 1189 metres, but not on the southern Papua New Guinea coast. The main host is maize but it has been also recorded from grain sorghum, rice and sugar cane. The taxonomy and distribution of *O. furnacalis* in Asia and the Pacific has been dealt with by Mutuura and Munroe (1970).

Damage by *O. furnacalis* to maize in commercial and experimental plantings in the Markham/Ramu valleys has been slight, although one observation plot at Bubia Research Centre (mean annual rainfall approx. 2790 mm) suffered 797 holes bored/50 stems (Young, unpublished data).

In Thailand and the Philippines eggs and larvae of *O.furnacalis* are preyed on by the earwig *Poreus simulans* Stal. (Dermaptera Chelisochidae), which is found behind leaf sheaths and ear husks (Meksongsee pers. comm.; Litsinger pers. comm.). This niche in Papua New Guinea may be filled by the Pacific earwig *Chelisoches morio* Fab. (Chelisochidae) which has been observed preying on *O. furnacalis* larvae. *C. morio* has been recorded at densities of 5.9 to 47.0 adults/100 maize plants at Bubia, but its significance is not known (Young, unpublished data).

Trichogramma australicum Girault (Trichogrammatidae) is an important egg parasite in Thailand, parasitising up to 90% of eggs (Meksongsee, pers. comm.). A *Trichogramma* sp. has been recorded from the Markham Valley, parasitising up to 98% of egg masses at a mean density of 13.4 egg masses/100 plants (Young, unpublished data).

Two species of parasites have been raised from pupae collected in the Markham Valley; *Brachymeria lasus* Walker (Chalcididae) at levels of 4-5%, and a Tachinidae of indeterminate genus and species at 1-2% (Young, unpublished data).

Yunus and Thian Hua (1969) have reviewed the biology and chemical control of *O. furnacalis* in West Malaysia. O'Sullivan and Bourke (1975) carried out an insecticide trial at Keravat, East New Britain, in which monocrotophos and lindane granules significantly reduced the incidence of *O. furnacalis* in stems and cobs. There were no significant differences between yields from the various treatments, however the average yield of 2208 kg/ha

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Table 1. — Insecticide treatments

Insecticide	Formulation	Application Rate (kg active ingredient/hectare)
DDT	25% w/v e.c.	1.5
Lindane	16% w/v e.c.	1.0
Lindane	6% w/v granule	1.0
Monocrotophos	40% w/v w.s.c.	1.0

Table 2. — Effect of treatments on yield, insect damage to cobs and stems — Marambung

Treatment	Yield kg/hectare	Number of holes bored/50 stems	Per cent insect damaged cobs
Lindane (e.c.)	937 a	2	49.1
Monocrotophos	1827 a	5	30.6
Lindane (g)	1801 a	3	27.6
DDT	1891 a	8	34.3
Control	1838 a	9	22.0
s.e.	±321.8	n.a.	n.a.
(cv%)	(38.8)	(n.a.)	(n.a.)

Treatments followed by the same letter do not differ significantly at $P< 0.01$.
(Results analysed by Student-Newman-Keul test).

Table 3. — Effect of treatments on yield, insect damage to cobs and stems — Mutsing

Treatment	Yield kg/hectare	Number of holes bored/50 stems*	Per cent insect damaged cobs
Lindane (e.c.)	5662 a	10.2 (104) c	10.7 a b
Monocrotophos	5600 a	8.3 (69) b	12.0 a b
Lindane (g)	5371 a	5.7 (32) a	8.5 a
DDT	5177 a	10.8 (117) c	16.3 b
Control	4826 a	15.7 (246) d	14.2 a b
s.e.	±199.7	±0.58	±1.44
(cv%)	(8.4)	(12.9)	(26.07)

* Analysed as square root transformation; figures in brackets are backtransformed values.

Treatments followed by the same letter do not differ significantly at $P< 0.01$ for yield and number of holes bored/50 stems and at $P< 0.05$ for per cent cobs damaged. (Results analysed by Student-Newman-Keul test).

was low and may have been below the level at which *O. furnacalis* begins to limit yield.

Medrano and Raros (1973) in the Phillipines estimated yield loss, by simple linear regression, at 0.95% per borer tunnel and 0.76% per borer from counts made from the basal half of the plant.

In view of the low average yield in the Keravat insecticide trial it was decided to conduct a similar trial at two sites in the Markham Valley, Marambung and Mutsing (mean annual rainfall approx. 1250 and 1600 mm respectively). The trials were carried out from late January to early May, 1977.

MATERIALS AND METHODS

The treatments *(Table 1)* were compared in a 5 × 5 Latin square design at Mutsing and a randomised block design with 4 replications at Marambung. Lindane granules were applied from a jam tin and the emulsifiable and water soluable concentrates were applied by knapsack sprayer at 4, 6, 8, 10 and 12 weeks after sowing. Plots had 6 rows, 90 cms apart and 7 m long which were sown with the variety Metro and thinned to 50,000 plants/ha after 2 weeks. Fertilizer was applied as sulphate of ammonia at the rate of 100 kg nitrogen/ha.

At harvest, yield (dried grain), number of holes bored/50 stems, and percent cobs damaged, were recorded from the middle two rows of each plot. Cobs were examined for the presence of *O. furnacalis* larvae and pupae.

Analysis of variance was carried out on the yield/plot from both sites. Counts on the holes bored/50 stems from the Mutsing trial were transformed to square roots before analysis. In view of the very low levels of stemborer in stems and cobs at Marambung this data was not analysed.

RESULTS AND DISCUSSION

The low yield of the Marambung trial *(Table 2)* was mainly due to a 6 week period of very low rainfall midseason. There were no significant differences between treatment yields. Stemborer damage was negligible. *Heliothis armigera* Hubn. (Noctuidae) accounted for almost all the pupae and larvae found on the cobs at harvest.

At Mutsing *(Table 3)* stemborer infestation became apparent at 6 weeks after sowing and at harvest all the larvae and pupae recovered from cobs were *O. furnacalis*. All insecticide treatments showed significantly lower numbers of holes bored/50 stems than the control, with lindane granules and monocrotophos providing significantly better protection than the other insecticides. This did not result in any significant difference in yield over the control. Cob damage was low, the best treatment being lindane granules. These results are in agreement with findings at Keravat (O'Sullivan and Bourke 1975).

It appears, from the Mutsing trial, that maize can tolerate up to 5 holes bored/stem without loss of yield, although the stage of growth when the infestation occurs may be a critical factor. Present levels of *O. furnacalis* on maize in the Markham Valley do not warrant control.

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THE COMPOSITION OF SOME NEW GUINEA FOODS

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ABSTRACT

The nitrogen, fat, ash, fibre, water and gross energy contents of 87 raw and cooked Papua New Guinean highland and coastal foods were analysed. Carbohydrate was obtained by difference and the available energy was calculated using appropriate factors. Information on the edible portion, average serving or portion size and the ratio of available to gross energy contents of these and other foods is presented.

The results confirm the low protein and energy contents of sweet potato and taro, the staple food stuffs. Considerable variations were found within and between the different varieties of the staples, owing to variations in water content probably caused by different methods of food preparation.

INTRODUCTION

An important factor in the accuracy of dietary surveys in all parts of the world is the accuracy of available information on composition of local food stuffs. Where a staple crop assumes a considerable role in the diet, as in Papua New Guinea, it becomes of greater importance to obtain precise information on its composition. As part of a lengthy nutritional survey carried out in two localities in Papua New Guinea, 104 samples of 87 raw and cooked foods were collected, dried and analysed for nitrogen, fat, ash, crude fibre and gross energy content. These analyses have been used to calculate the nutrient and energy contents of the diets of subjects we have studied (Norgan *et al.* 1974; Ferro-Luzzi *et al.* 1975) and may be useful in other areas of Melanesia, S.E. Asia and the tropics. Some analyses of uncooked foodstuffs from these areas have been published (Hipsley and Clements 1950; Massal and Barrau 1956; Peters 1958; Platt 1962; and Bailey 1968) but the available information is not extensive, particularly for coastal areas of Papua New Guinea. Further information on the composition of the common foodstuffs, on the many varieties of the staple and on the effect of different methods of preparation is required.

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METHODS

Area of study

The samples were collected in the Lufa area of the Eastern Highlands District and in the Kaul villages of Kar Kar Island, off the northern coast of Papua New Guinea. Details of these places and of the nutrition study carried out have been published (Norgan *et al.* 1974). Sweet potato *(Ipomoea batatas)* was the staple foodstuff in Lufa although yams *(Dioscorea* spp.*)* and bananas (*Musa* spp.) were common in the diet. In Kaul, taros (*Colocasia* and *Xanthosoma* spp.) were the staple although at some times of the year breadfruit (*Artocarpus altilis*) was the most important dietary item. Bananas were also plentiful. Particular attention was paid to the collection and analysis of different varieties of the staple foods and of the other common foodstuffs. This explains why large numbers of sweet potatoes and taros were analysed.

Collection and drying of samples

Representative samples were collected at meal times from foods prepared for family consumption. Whole items, e.g. one tuber, were taken to avoid variations in composition in different parts of a food. The sample sizes were 400-600 g for roots and tubers, 150 g for green leaves and 200-300 g for the remainder. With larger items, such as breadfruit, longitudinal sections were made and sampled. The samples were allowed to cool to eating temperature before weighing. Some samples collected at a distance from the field laboratory were weighed cool but any condensate was retained with the sample. The samples were transferred to weighed porcelain evaporating basins and dried to constant weight in a vacuum oven at 60°C. Some samples were stored at -5°C in sealed plastic containers before drying. The dried samples were transported to the U.K. in sealed jars for analysis.

Analysis of the samples

Analyses of moisture, nitrogen, fat, fibre and ash were performed separately on the dried samples by Thomas McLachlan and Partners, London and the Department of Food Science, University of Strathclyde, Glasgow. Gross energy content was determined at the Institute of Physiology, University of Glasgow.

MOISTURE

The moisture content of the field dried samples was determined by mixing the samples with acid-washed sand and 95% (V/V) ethanol, removing the ethanol by gentle heating on a water bath and drying the mixture to constant weight at 103 ± 2°C. The moisture content of the dried samples was considered to be a measure of the residual water remaining after drying in the field.

FAT

Fat was determined by a 5 hr extraction of samples with light petroleum spirit, boiling point 40-60°C. For samples presumed to have a fat content > 10% the extraction period was lengthened. The petroleum spirit extract remaining after drying at 100°C was regarded as fat.

PROTEIN

The nitrogen content of foods was determined by a standard semi-micro Kjeldahl method. Protein was calculated from N × 6.25 except for nuts and seeds (N × 5.30), rice (N × 5.95) flour and bread (N × 5.8) (Watt and Merrill 1950).

CRUDE FIBRE

Crude fibre was determined as the insoluble material remaining after extraction with petroleum spirit, acid hydrolysis (200 ml of 2.55N H_2SO_4 per 3 g sample boiled for 30 min), alkaline hydrolysis (200 ml of 0.313N NaOH per residue for 30 min) less the ash of the insoluble material. Crude fibre differs from dietary fibre in that it includes cellulose and lignin but not pectins and hemi-celluloses.

ASH

Samples were incinerated at 500-600°C in a muffle furnace with magnesium acetate as an ashing aid. Ash was calculated as the weight of residue, corrected for the weight of magnesium oxide yielded by the added magnesium acetate.

CARBOHYDRATE

This was calculated as the difference between 100% and the sum of moisture, protein, fat, ash and crude fibre percentages. It is not synonymous with "total carbohydrate" or carbohydrate by difference, as understood by Merrill and

Watt (1955), as crude fibre has been subtracted. It includes all of the available carbohydrates (sugars, dextrins, starches) and some of the unavailable carbohydrates (pectins and hemicelluloses) but not celluloses. In some cases, crude fibre and ash were not determined directly, owing to insufficient material for analysis (see missing values in *Table 1*). They were estimated from the ash or crude fibre contents of similar foods, analysed here or given by Peters (1958).

ENERGY

Gross energy contents were determined by combustion of samples in an adiabatic bomb calorimeter (Gallenkamp Ltd., England), according to the method described by Southgate and Durnin (1970). Available energy contents were calculated using the energy conversion factors for protein, fat and carbohydrate given by Merrill and Watt (1955). For starchy roots, fruits and nuts the conversion factors for protein are 11.63 kJ (2.78 kcal)/g, 14.06 kJ (3.36 kcal)/g, and 14.53 kJ (3.47 kcal)/g respectively; for fat 35.02 kJ (8.37 kcal)/g; and for carbohydrate 16.86 kJ (4.03 kcal)/g in starchy roots, 15.06 kJ (3.60 kcal)/g in fruits and 17.03 kJ (4.07 kcal)/g in nuts.

Expression of results

All analyses were performed on the field dried samples. The results are most usefully expressed on a wet weight basis. The method of calculation of the nutrient and energy contents of the food is shown in *Appendix 1*. It will be noted that the moisture content is a component of the dry weight (dry weight = moisture + protein + fat +ash +crude fibre + carbohydrate) and this has been taken into account. The water content was calculated from the water content determined in the field plus the moisture content of the field dried sample.

RESULTS

The energy and nutrient contents of the analysed foods are shown in *Table 1*. The figures refer to edible portions, except where stated. Information onthe edible portion percentage of some of these foods and of many others is given in *Appendix 2*. English and botanical names are given, if known, followed by the Melanesian Pidgin or vernacular name. The method of cooking is included where appropriate. In Kaul, foods were boiled in brackish water, in coconut water, or in coconut milk (prepared by scraping coconut flesh, separating the oil and mixing it with the water). Foodsboiled in different ways have not been listed separately. In Lufa, all boiled foods were boiled in fresh water. 'Roasted' refers to cooking over a fire or in hot ashes, not cooking with fat. 'Mumu'd' foods had been steamed in an earth oven, as described by Norgan *et al.* (1974). Foods cooked in green bamboo are considered to have undergone steaming.

Highland Foods

SWEET POTATOES

The varieties of sweet potatoes showed a wide range of protein (0.6-2.6 g/100 g) and energy contents (320-670 kJ (77-160 kcal)/100 g). The variety 'mangalove' is one of four traditional varieties (those present before European contact) still grown and it has the lowest energy and protein content. It was analysed because of its antiquity; it occurred only once in the dietary survey out of some 3500 man-days. All the other varieties listed have been introduced into the area by Europeans or been taken from neighbouring areas since contact with Europeans. 'Konime' is widespread throughout the highlands and 'seyapan' (meaning Japan?), which has a high protein content, · is probably the Okinawa variety popular in the Mount Hagen area (Bailey 1968).

Table 1. — cont'd

NAME, LOCAL NAME AND METHOD OF COOKING	WATER	PROTEIN	FAT	CARBO-HYDRATE	ENERGY		GROSS ENERGY	FIBRE	ASH
	g (range)	g	g	g	kJ	kcal	kcal	g	g
Sweet potato, *Ipomoea batatas*, Ferama, roasted	57.8	2.0	0.4	37.4	669	160	170	1.0	1.4
Sweet potato, *Ipomoea batatas*, Karigoya, boiled	66.3	2.6	0.4	29.1	535	128	138	0.8	0.8
Sweet potato, *Ipomoea batatas*, Konime, boiled	71.2	0.8	0.2	25.0	439	105	114	0.6	2.1
Sweet potato, *Ipomoea batatas*, Konime, mumu'd (3)	66.5 (63-71)	1.9	0.1	29.6	523	125	135	0.7	1.3
Sweet potato, *Ipomoea batatas*, Konime, roasted	66.5	1.3	0.1	30.3	531	127	130	0.7	1.1
Sweet potato, *Ipomoea batatas*, Kopumeni, boiled	70.8	0.6	0.1	16.6	460	110	117	0.7	1.2
Sweet potato, *Ipomea batatas*, Kopumeni, mumu'd	64.6	1.6	0.1	31.8	556	133	136	1.2	0.8
Sweet potato, *Ipomoea batatas*, Kopumeni, roasted	70.7	1.5	0.3	25.6	460	110	116	0.6	1.3
Sweet potato, *Ipomoea batatas*, Mangalove, roasted	78.2	0.6	0.1	18.5	322	77	82	0.7	1.9
Sweet Potato, *Ipomoea batatas*, Miniminiso, boiled	73.5	0.9	0.1	24.1	418	100	105	0.6	0.9
Sweet potato, *Ipomoea batatas*, Miniminiso, mumu'd	75.7	1.5	0.1	21.3	380	91	97	0.6	0.8
Sweet potato, *Ipomoea batatas*, Miniminiso, roasted	61.8	1.8	0.8	33.8	619	148	154	0.5	1.3
Sweet potato, *Ipomoea batatas*, Seyapen, mumu'd	69.5	2.0	0.1	25.8	460	110	116	1.1	1.5
Sweet potato, *Ipomoea batatas*, Sorara, boiled	70.9	1.0	0.1	25.1	439	105	117	0.5	2.5
Sweet potato, *Ipomea batatas*, Sorara, mumu'd (2)	68.6 (67–70)	1.3	0.2	27.3	481	115	122	1.3	1.4
Sweet potato, *Ipomoea batatas*, Sorara, roasted	68.2	1.2	0.2	28.8	506	121	123	0.5	1.0
Sweet potato, *Ipomoea batatas*, Yambalualope, mumu'd	71.3	[illegible]	0.2	[illegible]	[illegible]	108	114	[illegible]	[illegible]

Table 1. — cont'd

NAME, LOCAL NAME AND METHOD OF COOKING	WATER	PROTEIN	FAT	CARBO-HYDRATE	ENERGY		GROSS ENERGY	FIBRE	ASH
	g (range)	g	g	g	kJ	kcal	kcal	g	g
Taro, *Colocasia esculenta*, Fepi, mumu'd	64.1	1.2	0.1	32.7	568	136	148	0.7	1.1
Taro, Litina, mumu'd	57.7	1.4	0.2	39.4	686	164	169	0.5	0.8
Yam, *Dioscorea alata*, Hokepa, mumu'd	68.7	2.1	0.1	27.6	493	118	126	0.4	1.1
Yam, Wai, mumu'd	59.6	3.0	0.0	36.0	640	153	154	0.3	1.1
Yam, Wai, roasted	49.8	3.7	0.4	44.8	811	194	196	0.2	1.1
GREEN LEAVES (Kumu)									
Cabbage, *Brassica* spp., Apus, mumu'd	91.4	1.4	0.3	5.6	109	26	38	0.5	0.8
-, Fagasa, mumu'd (2)	84.9 (84-86)	5.4	0.6	6.5	172	41	65	1.5	1.2
-, Kio, mumu'd	84.8	4.1	1.4	5.2	167	40	64	1.5	2.9
-, Lengisi, mumu'd	89.1	4.6	0.1	4.6	117	28	51	0.1	1.4
Amaranthus spp., Maita, mumu'd	88.7	2.7	0.3	4.9	113	27	38	1.2	2.3
FRUITS									
Banana, *Musa* spp., Borua, roasted	66.3	1.0	0.1	30.9	481	115	137	0.4	1.3
Banana, *Musa* spp., Hayapa, roasted	49.2	1.7	0.5	46.7	744	178	200	0.7	1.4
Banana, *Musa* spp., Opine, mumu'd (2)	62.4 (61-64)	1.3	0.2	34.8	548	131	153	0.2	1.2
Banana, *Musa* spp., Opine, roasted	53.3	2.4	0.2	42.4	677	162	185	0.4	1.2
NUTS									
Pandanus julianetti?, Karuga, dried	6.0	11.7	43.8	26.5	2144	513	618	7.8	4.2
Pandanus julianetti?, Karuga, roasted	67.6	4.1	16.3	8.3	769	184	221	2.2	1.4

Table 1. — THE COMPOSITION OF PAPUA NEW GUINEAN FOODS
(all values expressed on the basis of wet weight, except where indicated, per 100 g edible portion)

HIGHLAND FOODS

NAME, LOCAL NAME AND METHOD OF COOKING	WATER	PROTEIN	FAT	CARBO-HYDRATE	ENERGY		GROSS ENERGY	FIBRE	ASH
VEGETABLES	g (range)	g	g	g	kJ	kcal	kcal	g	g
Beans, Katanaku, in bamboo	51.6	12.1	0.7	32.1	748	179	217	1.6	2.0
Beans, Katanaku, mumu'd	60.9	8.8	0.8	27.4	623	149	172	1.1	1.1
Winged bean, *Psophocarpus tetragonolobus*, Okani, mumu'd	70.6	8.1	5.4	12.9	527	126	152	1.9	1.1
Winged bean, *Psophocarpus tetragonolobus*, Okani, young pods, mumu'd	87.0	3.2	0.9	6.5	188	45	62	1.6	0.8
Winged bean, Ass bin, root, mumu'd	60.1	6.4	0.1	25.4	485	116	168	6.5	1.5
Corn, *Zea mays*, cob, mumu'd	73.3	3.6	1.0	20.5	422	101	119	0.8	0.8
Corn, *Zea mays*, cob, roasted	65.2	5.2	1.2	26.8	552	132	155	0.6	1.0
Setaria palmiflora, Pitpit, mumu'd	91.4	1.6	0.3	5.1	105	25	33	1.4	0.2
ROOTS AND TUBERS									
Manioc, *Manihot* spp., Kavabaya, mumu'd	58.9	1.4	0.3	37.8	665	159	163	0.8	0.8
Manioc, *Manihot* spp., Kavabaya, roasted (2)	54.1 (50-58)	2.0	0.3	41.5	729	175	-	0.8	1.4
Sweet potato, *Ipomoea batatas*, Ferama, boiled	68.2	1.1	0.3	28.0	493	118	129	0.8	1.5
Sweet potato, *Ipomoea batatas*, Ferama, mumu'd (3)	65.2 (61-68)	1.4	0.5	30.8	553	132	141	0.6	1.5

Table 1. — cont'd

NAME, LOCAL NAME AND METHOD OF COOKING	WATER	PROTEIN	FAT	CARBO-HYDRATE	ENERGY		GROSS ENERGY	FIBRE	ASH
	g (range)	g	g	g	kJ	kcal	kcal	g	g
Pandanus conoideus? Marita, mumu'd with seeds (a)	64.7	2.5	9.1	9.1	527	126	177	12.4	2.2
Pandanus conoideus? Marita, sauce	75.8	1.4	16.7	5.4	732	175	-	-	-
MISCELLANEOUS									
Pig meat, roasted	64.1	30.1	4.1	0.1	694	166	208	0.1	1.4
White rice, boiled	61.8	3.2	0.1	34.5	656	157	155	0.1	0.2
Fried flour	41.4	7.2	12.4	37.7	1195	286	310	0.2	1.1

COASTAL FOODS

NAME, LOCAL NAME AND METHOD OF COOKING	WATER	PROTEIN	FAT	CARBO-HYDRATE	ENERGY		GROSS ENERGY	FIBRE	ASH
VEGETABLES	g (range)	g	g	g	kJ	kcal	kcal	g	g
Taro, *Colocasia esculenta*, black, boiled	*78.7*	*0.8*	*0.4*	*18.8*	*339*	*81*	*88*	*0.4*	*0.7*
Taro, *Colocasia esculenta*, red, boiled	*72.0*	*0.9*	*0.4*	*24.2*	*431*	*103*	*104*	*0.6*	*1.9*
Taro, *Colocasia esculenta*, white, boiled (3)	*74.6 (73-76)*	*0.9*	*0.6*	*22.4*	*410*	*98*	*101*	*0.5(b)*	*1.4(b)*
Taro, *Colocasia esculenta*, white, roasted (2)	59.9 (53-67)	1.4	0.2	35.7	623	149	148	1.5	1.4
Taro, *Colocasia esculenta*, yellow, boiled	67.2	0.7	0.4	29.8	523	125	128	0.6	1.3
Chinese taro, *Xanthosoma* spp., boiled (4)	75.5 (73-78)	1.1	0.4	21.3	385	92	91	0.6(b)	1.4(b)
Chinese taro, *Xanthosoma* spp., roasted (2)	65.0 (60-70)	1.5	0.1	30.8	539	129	131	1.5	1.4
Taro, cooking water	93.1	0.6	2.2	2.8	134	32	33	0.1	1.0

Table 1. — cont'd

NAME, LOCAL NAME ANI METHOD OF COOKING	WATER	PROTEIN	FAT	CARBO-HYDRATE	ENERGY		GROSS ENERGY	FIBRE	ASH
GREEN LEAVES (c)	g (range)	g	g	g	kj	kcal	kcal	g	g
Hibiscus manihot, Aibika, boiled	77.0	3.4	2.0	7.4	213	51	139	-	-
Gnetum gnemon, Tulip, boiled	85.6	1.6	2.0	5.1	163	39	-	-	-
-, Tuwer, boiled	85.8	1.2	2.0	5.4	163	39	-	-	-
FRUITS									
Banana, *Musa* spp., Amii boiled	75.4	1.1	1.1	21.2	372	89	102	0.4	0.9
Banana, *Musa* spp., Ami roasted	71.2	1.4	0.1	25.1	401	96	111	1.1	1.1
Banana, *Musa* spp., Ararang, boiled	77.1	0.9	0.4	20.4	334	80	88	-	-
Banana, *Musa* spp., Sas boiled	74.5	1.4	0.1	22.9	368	88	100	0.3	0.9
Banana, *Musa* spp., Signikin, boiled	77.1	1.2	0.5	19.9	334	80	90	0.5	1.0
Banana-galip purom ( ), Galuk (2)	64.1 (62-67)	1.1	8.8	24.6	690	165	200	-	-
Bread fruit, *Artocarpus altilis*, Kapiak, boiled	81.0	1.3	0.9	14.4	268	64	79	1.5	0.9
Bread fruit, *Artocarpus altilis*, Kapiak, roasted (2)	73.8 (72-75)	1.3	0.6	22.1	372	89	106	1.5	0.9
Bread fruit, *Artocarpus altilis*, Seeds, boiled	59.3	5.3	2.3	30.3	673	161	178	1.8	1.1
Bread fruit, *Artocarpus altilis*, Seeds, roasted	49.7	6.2	2.7	37.8	828	198	216	2.2	1.3
-, Mon, ripe	69.3	2.4	0.3	25.2	422	101	117	-	-

Table 1. — cont'd

NAME, LOCAL NAME AND METHOD OF COOKING	WATER	PROTEIN	FAT	CARBO-HYDRATE	ENERGY		GROSS ENERGY	FIBRE	ASH
NUTS	g (range)	g	g	g	kJ	kcal	kcal	g	g
Terminalia spp., Talis, ripe	42.9	10.7	31.7	6.3	1367	327	409	6.1	2.4
Inocarpus edulis, Aila, boiled	56.7	4.1	1.7	34.5	706	169	175	-	-
Inocarpus edulis, Aila, roasted	42.0	5.9	4.2	43.7	978	234	247	-	-
Canarium spp., Galip, ripe	23.2	10.2	59.3	3.3	2278	545	647	-	-
Canarium spp., Galip, dried	12.1	12.1	51.8	24.0	2395	573	730	-	-
ANIMAL FOODS									
Phalanger, Cuscus, boiled	64.1	21.7	11.3	1.8	844	202	239	0.1	1.0
Flying fox, Black bokis, boiled	61.5	20.5	9.3	7.6	840	201	236	-	-
Pig, fat, boiled	26.5	4.0	68.3	0.0	2700	646	635	0.1	1.2
Pig, meat, boiled	68.5	19.5	6.5	4.8	673	161	195	-	-
Pig, meat and skin, (1:1), boiled	64.5	27.0	5.4	2.1	719	172	201	-	-
STORE FOODS									
Bread, local produce	39.5	8.9	0.5	49.9	941	225	255	0.5	0.6
Mackerel in natural oil, tinned	62.1	18.6	12.0	6.0	882	211	236	0.1	1.4
Flour, fried	12.4	12.1	5.2	68.9	1509	361	390	0.7	0.6
Rice, white, boiled	73.9	1.8	0.9	22.6	451	108	113	0.4	0.3
Rice, brown, boiled with fish	66.[illegible]	2.7	5.2	24.2	640	153	168	0.5	0.5

Footnotes:

Numbers in parantheses are the numbers of samples analysed.

— Not determined

(a) Analysed as served, waste usually 60%

(b) Mean of two samples

(c) Amount of fat determined was arbitrarily reduced to 2 g/100 g as it was considered that part of the material estimated as fat was waxes and other indigestible fatty residues.

(d) Boiled banana mixed with oil extracted from galip nuts.

Table 2. — The composition of sweet potatoes cooked in different ways (mean and standard deviations)

	Boiled	Mumu'd	Roasted[1]
Number of samples	6	12	5
Water %	70.0 ±2.3	67.9 ±3.8	65.1 ±4.8
Protein g/100 g	1.2 ±0.6	1.5 ±0.4	1.6 ±0.3
Energy kJ/100 g	464 ±39	502 ±68	556 ±75
kcal/100 g	111 ±9	120 ±16	133 ±18

[1] omitting 'mangalove'

It is not possible to make a strict comparison of the nutrient content of the different varieties or the effects of method of preparation on nutrient content because the origin of the samples, i.e. the type of soil, age and altitude of the garden from which they came, was not controlled. However, some useful information can be given.

The variety 'konime' was found to have a composition, when boiled, of 0.8 g protein, 440 kJ (105 kcal)/100 g; when roasted 1.3 g protein, 530 kJ (127 kcal)/100 g; and when mumu'd 1.9 g protein, 523 kJ (125 kcal)/100 g. The effect of method of preparation on consumption is illustrated more fully by the results in *Table 2.* The differences in composition between cooking methods reflect, to some extent, the differences in water content occurring with the method of preparation. The protein and energy contents listed are within the ranges for uncooked sweet potatoes given by Peters (1958) and those of Bailey (1968) calculated on a wet weight basis.

Of the other roots and tubers, taros have nutrient and energy contents similar to sweet potatoes, while those of yams are higher. Green leaves have higher protein contents than roots and tubers even though their water contents are appreciably higher. Cooked bananas and dried 'karuga' nuts were found to have a composition similar to those reported previously but the protein content of beans was considerably less than that reported by Bailey (1968).

Coastal Foods

TAROS

The energy contents of all cooked taros were considerably lower than those described for raw taros (Peters 1958). Taros do not appear to be superior in energy and protein content to sweet potatoes, neither does the high yielding Chinese taro (*Xanthosoma*) appear to be nutritionally inferior to 'true' taro *(Colocasia).* Roasted taros have higher nutrient contents than boiled taros, approximately 1.5 g protein and 585 kJ (140 kcal)/100 g compared to 1.0 g protein and 418 kJ (100 kcal)/100 g respectively, for white taro, reflecting their different water contents, 63% and 74%.

A small number of analyses of different samples of a food prepared in the same way was performed on coastal foods. The data suggest a fairly constant composition in the staple foodstuffs. White taro boiled in coconut milk (3 analyses) shows the following ranges: water, 73.4-74.9 %; protein, 0.8-1.0 g/100 g; fat, 0.3-0.8 g/100 g; and energy, 397-426 kJ (95-102 kcal)/100 g. For boiled Chinese taro the results of 4 analyses were: water, 73.4-78.4 %; protein, all = 1.1 g/100 g; fat, 0.3-0.5 g/100 g; carbohydrate, 18.4-23.6 g/100 g; and energy, 334-426 kJ (80-102 kcal)/100 g.

Taro cooking water was consumed frequently and in amounts of several hundred grams. The sample analysed [1] was thicker than usual and came from a pot where taro, beans and pig meat had been boiled in sea water and coconut milk. The protein and fat contents are not insubstantial when compared to other foods, such as taros.

Bananas and breadfruit were important in the diet of the coastal population studied, providing variety and acting as alternative staple foodstuffs. 'Galip' nuts and breadfruit seeds were good sources of vegetable protein.

Foods which may show the greatest variation in composition are those made from two or more ingredients. Such a food is 'galuk', a banana and 'galip'-oil dough. However, the two analyses agreed reasonably well; fat 7.1 and 10.4 g/100 g; energy, 620 and 760 kJ (148 and 182 kcal)/100 g.

DISCUSSION

The results indicate a low nutrient density in most of these Papua New Guinea foods. Beans, nuts and green leaves are the only protein rich vegetable foods and the distribution of fat is similarly limited, mainly to nuts and coconuts. Few of these foods are important in the diets of Papua New Guinean adults or children (Norgan *et al.* 1974; Ferro-Luzzi *et al.* 1975). The most common varieties of the staples, e.g. 'sorara' and 'konime' sweet potatoes in Lufa and white, 'true' taro in Kaul, which were popular because of their taste, texture, yield, etc. were not appreciably different in composition.

The diets of the Papua New Guineans of Lufa and Kaul are characterised by low protein (< 50 g/day), fat (< 40 g/day) and, in some cases, low energy intake (Norgan *et al.* 1974; Ferro-Luzzi *et al.* 1975). In Lufa, 76% of the total energy intake and 53% of the total protein intake was derived from vegetables, the contribution from sweet potatoes alone being 64% and 37% respectively. In Kaul, vegetables were similarly the most important food group and taros alone provided 42% of the total energy intake and 24% of the total protein intake. The dietary pattern in Kaul was more varied in that fruits, nuts and storefoods, e.g. rice, made significant contributions to the diet but in neither area was the contribution from animal foods noteworthy. Thus, the diets, like the foodstuffs, are of vegetable origin and of low nutrient density. A Lufan must consume 2 kg of sweet potato to derive 2400 kcal and 24 g protein while a Kaul villager would need to consume a larger quantity of taro to gain the same nutrient intake.

The calculation of nutrient and energy intakes requires accurate information on the true availability of the nutrients and energy in foods. The figures in *Table 1* are intended to represent available nutrient and energy contents. However, Oomen *et al.* (1961) found the real protein of New Guinea highland sweet potatoes to be, on average, 85% of 'crude' protein (N × 6.25). Since a substantial proportion of Papua New Guinean protein intakes is from vegetable sources, the real protein intakes may be lower than those calculated from N × 6.25. However, the

[1] Other samples taken were lost because they could not be separated from the evaporating basins after drying.

non-protein nitrogen in roots and tubers may include important amounts of amino-acids. Peters (1958) found that the amino-acid nitrogen as a percentage of total nitrogen was 90% for lowland sweet potatoes, 92% for taro, 79% for yams and 78% for coconuts. Also, Chick (1951) has shown that the addition of the non-protein nitrogen component of potatoes to diets containing potato protein 'tuberin' stimulated growth of rats to a greater extent than could be explained by the addition of free utilisable amino-acids.

A further factor reducing true protein intakes is the digestibility of crude protein, which for potatoes and starchy roots consumed by Europeans, is reported to be low, 74% on average (Merrill and Watt 1955). For taro protein, the value is even lower, 50%, range 20-75%. Until further information is available it is difficult to assign corrections applicable to Papua New Guinean diets. These corrections may be relatively minor as many studies have shown that N equilibrium can be achieved on low intakes of nitrogen from potatoes alone (Chick 1946), e.g. Kon and Klein (1928) maintained N equilibrium over 167 days on intakes of 5.7 gN/day in a male and 3.8 gN/day in a female. Thus, low intakes of protein from vegetable sources, as in New Guinea, could be adequate.

The energy conversion factors of Merrill and Watt (1955) have been used in the calculation of the available energy contents of the foods (see *Appendix 1*). They are based on the heat of combustion (gross energy) of protein, fat and carbohydrate adjusted for losses in digestibility and, in the case of protein, in metabolism. Individual factors have been derived for different groups of foods from studies in the literature. These have been derived, in the main, from limited measurements on Europeans consuming European foods and it is not known if they are applicable in other circumstances. The energy conversion factors for protein in the types of foods that form the bulk of Papua New Guinea foods are low (11.6-14.5 kJ/g) compared to the values for protein in cereal and meats (14.6-16.7 kJ/g) because of the nature of the foods. Thus, the energy conversion factors for protein include an adjustment for non-protein nitrogen and digestibility which for starchy roots is taken to be 40% and 75% respectively. In a similar way the energy conversion factor for fats 35.0 kJ/g, is lower than those for fats in vegetable oils or animal foods 36.8-37.7 kJ/g. Thus, the energy derived from protein and fat in Papua New Guinean foods is lower than that from identical intakes in European foods because of the chemical and physical properties of the foods. However, in these Papua New Guinean diets with relatively small amounts of protein and fat, the effect on the total energy intake is small. In contrast, carbohydrate represents approximately 80% of the total energy intake. The carbohydrate energy conversion factors of Merrill and Watt (1955) will underestimate the energy available from carbohydrate because they are for total carbohydrate (by difference) rather than the total carbohydrate minus crude fibre given in this paper. The underestimation will be, on average, 3% of the total energy intake, assuming the digestibility of carbohydrate to be 96% because of the crude fibre content, and the carbohydrate energy from starchy roots to be 75% of the total energy intake. The question of the applicability of heats of combustion measured on European foods and digestibility measured on Europeans to Papua New Guinean foods and subjects remains unanswered.

The gross energy contents of foods are not immediately useful in dietary surveys but they have been included in *Table 1* because if new information, e.g. on the digestibility of Papua New Guinean foods by Papua New Guineans, is published, the available energy contents of these foods could be modified.

Most of the published information on the composition of tropical foods refers to uncooked foods. These analyses of edible portions of cooked foods should reduce one source of error in dietary surveys, that is the effect of changes in the composition of foods with cooking. The information should be of use to nutritionists in many parts of the world and in Melanesia in particular, where so much interesting work has yet to be performed. As Platt (1962) has stated, perhaps the most important factor affecting the composition of tropical foods is the variability in water content of foods. When results are compared on a dry weight basis, many differences in composition disappear and perhaps the most useful measure that can be made under field conditions is the water content of the staple foods. Much more information is still required, particularly on the digestibility and availability of nutrients in Papua New Guinean foods. These await more sophisticated studies under difficult field conditions, although notable efforts have been made (Oomen *et al.* 1961; Luyken *et al.* 1964; Oomen and Corden 1970; Oomen 1972).

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Appendix 1

Example of calculation of nutrient and energy content
Sample: Sweet potato, 'Konime', boiled
Field dry weight = 30.4%
Laboratory analysis of field dried sample.

moisture	= 5.29%
nitrogen	= 0.44%, protein (N × 6.25) = 2.75%
fat	= 0.57%
ash	= 7.07%
fibre	= 2.03%
carbohydrate (by difference)	= 82.3%
gross energy content	= 113 kcal/100 g (5.56MJ kg^{-1})
water content	= (100 − 30.4) + (5.29 × 30.4/100) = 71.2%

Nutrient content on wet weight basis:

Protein	Fat	Carbohydrate
30.4 × 2.75	30.4 × 0.57	30.4 × 82.3
= 0.8 g/100 g	0.2 g/100 g	25.0 g/100 g

Available energy = 0.8 × 2.78* 0.2 × 8.37* 25.0 × 4.03*
= 2.2 + 1.7 + 100.8
= 105 kcal/100 g wet weight

* Energy conversion factors (Merrill and Watt 1955)

Appendix 2

Information is given below on the edible portion, as a percentage, of cooked and raw foods that have an inedible part. Some figures are also given of the average size of discrete edible portions where these are fairly standard e.g. weights of nuts. Roots and tubers are very variable in size, particularly sweet potatoes, even if they are cut up into manageable pieces for boiling. Thus, these have not been included.

This information may be useful to nutritionists, anthropologists and ecologists wishing to estimate dietary intakes or horticultural energy balances from gross weight or other data.

	Edible portion		Type of portion	Weight of edible portions	
COASTAL FOODS	n	mean %		n	mean g
Aila nuts, boiled	-	-	1 peeled	46	40
Bananas,					
boiled in skin	-	62		-	-
sasi, roasted	-	-	1 peeled	18	40
sibiri, roasted	-	-	1 peeled	10	45
tamkilel, roasted	-	-	1 peeled	53	35
sigenikin, roasted	-	-	1 peeled	38	45
maike, roasted	-	-	1 peeled	16	65
Breadfruit, roasted	26	70		-	-
Breadfruit, seeds	-	-	boiled	96	5
Corn, boiled	4	70		-	-
Corn, roasted	6	67	1 cob	6	135
Crab, roasted	14	67	1 serving	14	75
Flying fox, boiled	15	75	1 serving	15	45
Galip nuts, ripe	-	-	1 kernal	320	2
Mons, raw	20	80	1 fruit	150	17
Papaya, raw	108	63	1 serving	-	180
Phalanger, cuscus, boiled	7	62	1 serving	-	25
Sok insects, roasted	-	-	1 roasted	6	30
HIGHLAND FOODS					
Winged bean (as bin) root, mumu'd	-	92		-	-
Bananas,					
opine, mumu'd	-	-	1 fruit	8	80
hayapa, roasted	-	-	1 fruit	14	40
Winged bean, mumu'd	10	60		-	-
Corn, roasted	20	60	1 cob	-	70
Pandanus nuts (% of comb and shell)	25	65		-	-
Pandanus, sauce	16	38		-	-
Setaria, pit-pit, mumu'd	7	65	1 stem	8	35
Sugar cane, raw	22	50		-	-
Sweet potatoes, roasted					
konime	30	87		-	-
sorara	54	83		-	-
kopumena	10	85		-	-
Passion fruit, raw	27	55		-	-

EFFECTS OF INFESTATION BY ROOT KNOT NEMATODE *MELOIDOGYNE INCOGNITA* CHITWOOD ON YIELD AND QUALITY OF TOMATOES IN THE PORT MORESBY AREA OF PAPUA NEW GUINEA

J. Dodd*

ABSTRACT

Infestation with Meloidogyne incognita *reduced the mean number of fruit per plant by 5.5 (P< 0.05) in tomato variety 'Red Cloud', which represented a crop loss of 23.4 percent. Fruit size and plant dry weight (excluding fruit) were not affected. Fruit of infested plants showed significantly less Growth Cracking but earlier Blossom End Rot.*

INTRODUCTION

The root knot nematode *Meloidogyne incognita* Chitwood is widely recognised throughout the tropics as a major pest of tomato. In Papua New Guinea it was recorded as a pest by Thrower (1958, 1960) and Shaw (1963), and it is frequently encountered in the Port Moresby area.

This communication reports correlations between *M. incognita* infestation and fruit yield and quality.

MATERIALS AND METHODS

The analysis is based on data recorded on twenty plots of a spraying trial reported by Dodd (1977, in press). Four plants chosen at random from each plot were evaluated for *M. incognita* infestation. Measurements were made of the total number of fruit per plant, and of mean fruit size (mean weight in grams of individual undamaged fruit) over four consecutive harvests for two of the four plants, after which they were dug up. The degree of nematode damage to roots was assessed using a four point scale modified from Martin (1959) as follows: 1 = roots normal with no sign of galls, 2 = slight damage with small galls sparsely distributed on some roots, 3 = moderate damage with galls on most roots, 4 = severe damage, with large coalescing galls along nearly all roots. After assessment, shoots were cut off at the former soil level, oven dried at 90°C for 24 hours, and dry weights were recorded. Correlations between root damage score, shoot dry weight, fruit number per plant and mean fruit size were calculated using results from 36 of the original 40 plants, four of which were excluded as they died during the harvest period.

The general level of infestation within each plot was calculated by totalling root damage scores. Correlations were calculated between this value and plot results for total yield and the incidence of the physiological fruit disorders Growth Cracking and Blossom End Rot.

RESULTS AND DISCUSSION

Of the 36 plants assessed for fruit number, fruit size, shoot dry weight and root damage, 13 were healthy; amongst the 23 infested plants, 34.8 percent were severely galled. Nematode infestation significantly reduced yield from a mean of 23.5 fruit per plant to 18.0 for infested plants, representing a crop loss of 23.4 percent (P<0.05) and there was a significant negative correlation between fruit number per plant and

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root damage score (r = −0.39; P<0.05). Plot values of the total weight and total number of fruit per plant showed highly significant negative correlations with values for plot infestation levels (r = −0.70 and −0.72 respectively; P<0.001 for both). Fruit size and shoot dry weight were unaffected and the latter showed no correlation with fruit number, fruit size or plot infestation level, thus lower yields did not result from a reduction in fruit or plant size. The exact cause of yield reduction is not clear but an increased rate of abortion of flowers and immature fruit is a possible factor.

The significant negative correlation between plot infestation values and the proportion of fruit with the physiological disorder Growth Cracking (r = −0.46; P< 0.05) probably resulted from the disruption of vascular tissues and water uptake following nematode infestation (Krusberg 1963), since Growth Cracks are mainly caused by rapid movement of water into developing fruits (Wilson 1957). The different fungicide and insecticide treatments which the plots received were shown to have had no effect on the level of nematode infestation (Dodd, in press).

The 23.4 percent reduction in fruit yield amongst infested plants shows that *M. incognita* is an important factor in lowering the productivity of tomato crops. Control of this pest and other species of root knot nematode requires expensive and laborious treatments such as soil fumigation and drenching, which are quite inappropriate for the home food garden and are not yet used by commercial vegetable growers in Papua New Guinea. Similarly, the grafting of tomato plants onto resistant root stocks of tomato or other Solanaceous species has neither been practised nor advocated in P.N.G. The avoidance of soils known to be infested would seem to be the best way of dealing with this pest.

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CORRINGENDUM

The pages of *Table 1* which starts on page 28 have been printed out of order and numbered incorrectly. The correct page order is 30, 28, 29, 31.