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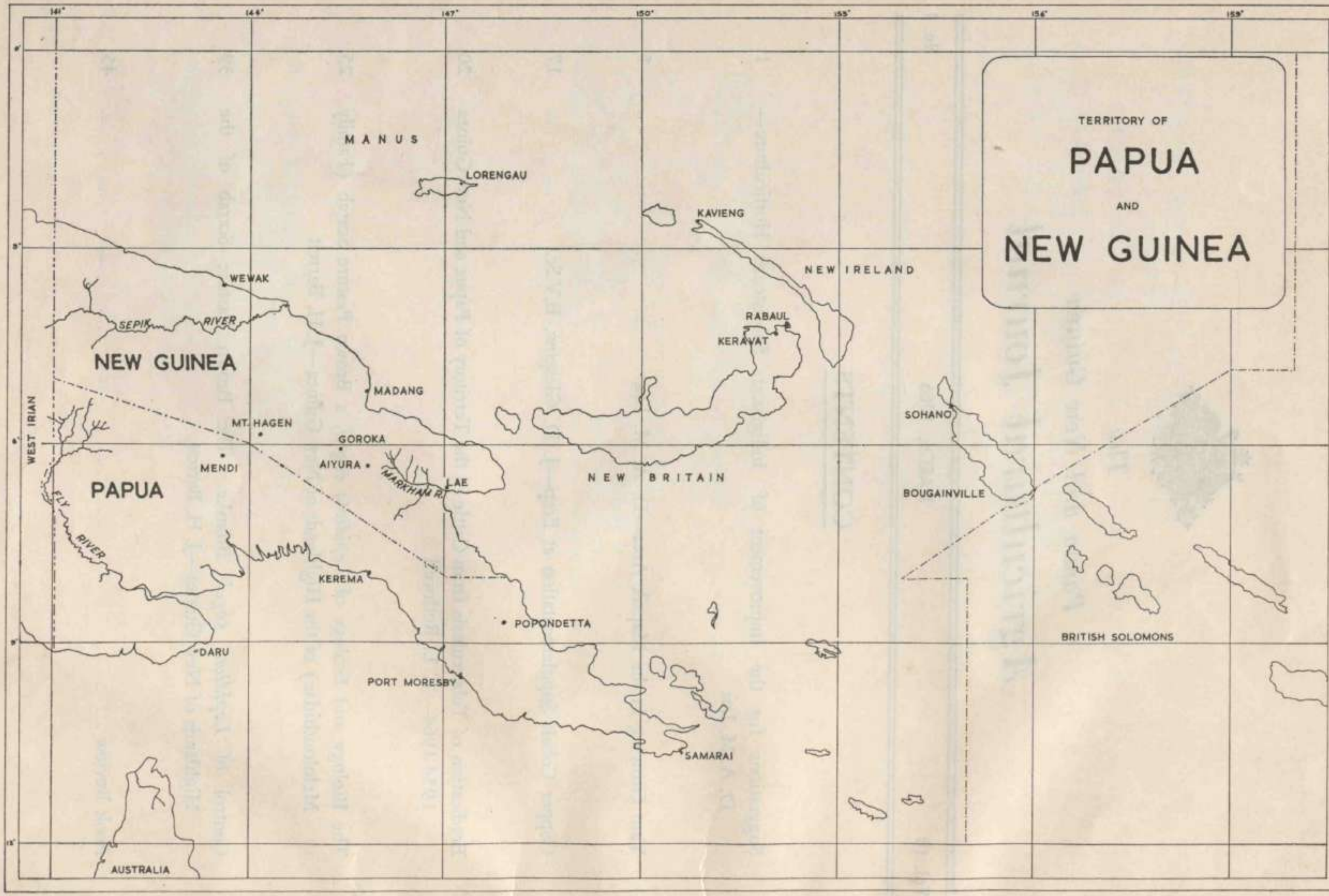

TERRITORY OF
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Suggestions for the Improvement of Indigenous Subsistence Horticulture.

D. A. M. LEA.*

ABSTRACT.

This paper notes some thoughts on possible improvements of subsistence horticulture in the Territory of Papua and New Guinea as seen by a Geographer. It also suggests lines for future research.[1]

INTRODUCTION.

AS Gourou noted, "To change the agrarian system affects the family and the whole of the rest of the economic edifice. That does not shut out necessary reform, but yet reform should be carried out in the full knowledge of its economic and social consequences and also of its repercussion on the physical environment." (Gourou 1959 : 98) This is the first requirement of reform, that the reformer should know what he is doing and should not force changes that will result in social distress between man and his environment. The second requirement is that the indigenes should be educated so that they desire improvement and realize that it is necessary : They would also be more willing to experiment themselves and to be discriminating in their selection and rejection of reforms.

> "There are two principal aims in native education : One is to foster all that is worthwhile in native culture as it exists ; the other is to fuse into it, or graft upon it, various acceptable improvements from our own." (Williams 1933 : 6)

On the whole, indigenous systems of land use are better suited to local physical conditions than anything that has yet been devised to replace them, and wisely, few changes have been deliberately made. However, in a changing demographic situation in particular, and changing social, economic and political circumstances in general, progress from a purely subsistence economy is essential. Cash cropping is the obvious answer but in some areas under stresses of overpopulation or land shortage, modern technology could offer some minor palliatives within indigenous land use systems as well as serving as an introducion to commercial and scientific agriculture.

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SUGGESTED METHODS.

1. *The Upgrading of Staple Foods.*

It is well known that most species of important food crops throughout the Pacific Islands have many different varieties in small localities.[2] There is no doubt that some varieties have a consistently higher yield or higher protein content than other varieties. Recently it has been found that in the Highlands of New Guinea the Okinawa variety of sweet potato has a higher protein content than any other variety. (Bailey 1963) My own work in the Maprik Subdistrict also suggest that there are varieties of yam with higher protein content than others. (Lea 1964 : 178) There is also no doubt that the yields of some varieties of staple foods are consistently higher than other varieties. Trials could certainly be carried out in many areas to determine which are the best varieties : Such trials should be followed by extension work to encourage wider planting of the best varieties. Taste preferences and prejudices are very real in all societies and, in all probability, they would not be overcome with adults. Extension work should therefore concentrate on encouraging children to eat new foods : This could well be linked with education. As Williams noted, "We should aim at improving the culture of native products before we begin the scattering of unknown seeds.". (Williams 1933 : 7)

[1] This brief article is based on Appendix F of Dr. Lea's thesis (Lea 1964). Although these suggestions are made with particular emphasis on the Abelam people of the Maprik area, many of them may well apply to New Guinea in general.

[2] There are over 100 different varieties of yam in two villages of the Abelam. (Lea 1966) Sasuke (1953 : 159) reports over 200 varieties of yam on Ponape.

2. *The Introduction of New Food Plants.*

This topic has been discussed extensively elsewhere (e.g., Williams 1933, Barrau 1958 : 100-102, Barrau 1960) but among the Abelam those food crops which are rich in protein and capable of being stored such as nuts, cereals and pulses are the most essential. To encourage the adoption of these crops the methods of cultivation must be easier and the returns higher than crops which are grown now or there will be no incentive to plant them. It should also be noted that " the acceptability of a new plant food is in proportion to the similarity it has to traditional subsistence crops so that it involved no change in land use technology or land holding ". (Barrau 1958 : 86) Thus maize, the only cereal successfully introduced at the village level, was accepted because it resembled 'pit pit' (*Saccharum edule*) which has an edible inflorescence. (Barrau 1958 : 49)

3. *Improved Hand Implements and Mechanization.*

Even although labour is very cheap in the area some form of mechanization is necessary to show that the Administration is concerned with improving the indigenous way of life and also to give some incentive to the introduction of new crops. Some possibilities that immediately spring to mind are scythes instead of grass-slashing 'sarap'; the sago rasper of Malaysia instead of the labourious methods now practiced (*cf.* Morris 1953, Burkill 1935 : 1463) ; hoes for weeding and grinders for peanuts (which keep almost indefinitely when ground to a paste). If rice could be easily grown and milled in the villages, it is reasonable to suppose that unpolished rice might be eaten and that rice itself would be more widely grown. Much interesting work has been done by Pirie, Davys, Byers, Morrison and others at the Rothamsted Experimental Station in England on extracting leaf protein. Mr. Pirie believes that village units could well be set up extracting protein from 300 to 500 lb. lots of leaf.

4. *Mulch and Green Manures.*

The planting of legumes as green manures is probably not feasible because the necessary cultivation technique results in the soil lying exposed whilst the legumes become established. Nye and Greenland (1960 : 136) state that " the nitrogen status maintained beneath a forest fallow is good, and there is no reason to think that short-term leguminous fallows would offer any advantage ". Probably the best use that could be made of legumes would be to encourage more inter-cropping during the productive life of the garden in order to offset leaching by symbiotic fixation of nitrogen.

Mulching, especially when localized to yam mounds, would probably be far more successful.[3] If dead organic matter and ashes from the burn were concentrated in yam mounds there is no doubt that yields would increase. By providing organic matter, plant nutrients would be supplied and the structure and moisture holding capacity of the soil improved. Yams could probably then be planted in the same holes for a number of successive years. With some mulch around the top of the yam mounds the soil would be protected from the pounding of the rain and the breaking down of the crumb structure of the soil.

5. *Soil Conservation.*

Soil conservation is closely connected with mulching. If ground is to be used for several years before it reverts to fallow, the practice of exposing the soil for long periods and sweeping it clean before planting would have to cease.[4] Cover crops would have to be planted as soon as possible and vegetable waste from the fallow and the garden could be used as a protective cloak over the soil. It would certainly be better to plant yams much closer together in order to get higher yields per given area as well as providing cover for the soil, even though this may result in individual plants having smaller tubers. This would be difficult to encourage because large yams are so ritually important and are a status symbol. As far as yams are concerned many yam growers are megalomaniacs and one's gardening ability is judged by the size of each tuber rather than by the total yields from each garden or even from each hole.

[3] Mulching is not unknown in the Pacific area : For examples see Defugin (1959 : 53), Meggitt (1958 : 305), Barrau (1961 : 68) and Brookfield (1962 : 244-5).

[4] Often ash from the burn is swept behind logs or stumps for aesthetic reasons and I have even seen some Abelam gardeners removing ash mixed with top soil and garden rubbish from the garden.

Some form of terracing is also possible, even if it is only the very simple form at present practised by the West Woseras where logs are placed horizontally to the slope for the expressed purpose of 'holding the soil'. Also where rainfall is excessive some form of drainage is often essential. Most people who have been into gardens are familiar with the sight of ash and top soil piled up against fences at the bottom of gardens.

6. *Improved Storage Methods.*

It is difficult to imagine a more effective method of storing whole yam tubers than that used by the Abelam for the large ceremonial yams. (*Dioscorea alata*) Each tuber is suspended from a pole by cane ropes, tied so that it is supported every 9 in. of its length. The pole is lashed to the rafters of a house where the tuber is off the ground, safe from vermin, well shaded and surrounded by circulating air. Tubers stored in this way keep well for periods of up to nine months. The smaller yam tubers (mainly *D. esculenta*), although they keep well in the yam houses, do lie at least in part on the ground. Probably storage would be better if the tubers were lifted off the ground or stored on a raised cane floor permitting a better circulation of air around them.

As it seems that a surplus is regularly produced in most villages (Lea 1965 : 203), it is important that all means of preserving this surplus should be investigated. Possibilities include pit storage methods (*cf.* Morgan 1959 : 61), flour or meal making (Burkill 1935 : 816), dehydration and other drying techniques, the use of chemicals which would aid preservation or stop sprouting (*cf.* McKee 1957 : 20) and finally by preserving food in ensilage or in the ground. (*cf.* Williamson 1912 : 198)

7. *More Intensive Tree Cultivation.*

Many trees and palms and their products are securely integrated into the Abelam economy. However, there is still plenty of scope for more intensive planting of nut, leaf and fruit bearing trees, and timber trees could be more intensively planted around hamlets and along ridgetops to provide shelter and to control runoff. Research should also be done to see whether it is worth leaving corridors of trees between gardens to aid reseeding and to act as firebreaks and into the merits of planted fallows[5] and of the possibility of the 'taungya' system. (Allsop 1953)

8. *More Intensive Use of Livestock.*

Pigs and fowls are the only productive animals used by most of the indigenous people in New Guinea. Better use could be made of the products from both these animals[6] and the quality could be vastly improved by better breeding and selection. On the Sepik grasslands and along paths and roads there are considerable areas of grass. If stock, particularly cattle (Zebu crosses) and goats, could be put onto these areas they could provide work, manure and protein-rich foods and they would only occupy what are at present waste areas. Goats are a problem with their destructive eating habits but with peg and chain they could be controlled.

Many other improvements are possible such as fertilizers, irrigation,[7] more intensive use of the floodplains by growing wet rice, use of pig manure, better cooking methods, but as Barrau notes, "the only real progress possible is through developing cash crops". (Barrau 1958 : 91) In conclusion we could again quote Barrau—

> "It is absolutely essential that technical officers and agricultural assistants be thoroughly convinced that their purpose is to adapt new crops and methods without upsetting and destroying traditional agriculture. They must always take into account the merits of former horticultural techniques which have the advantage of being based on a profound knowledge of the natural environment and its requirements". (Barrau 1961 : 77)

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[5] Some examples of planted fallows are *Casuarina* in the Central Highlands of New Guinea (Brookfield and Brown 1963 : 50-1) and *Acioa barteri* in West Africa (Nye and Greenland 1961 : 136-7).

[6] *cf.* Conroy 1953.

[7] Irrigation is not unknown in New Guinea (*cf.* Williams 1933 : 33) and the old irrigated taro terraces of the New Hebrides and New Caledonia bear witness to its widespread use in these territories.

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Yam Growing in the Maprik Area.

D. A. M. LEA.*

ABSTRACT.

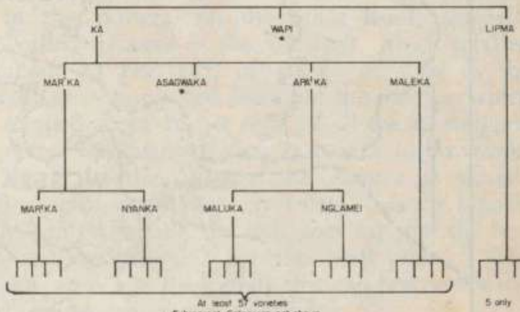
This article is an attempt to look into one aspect of gardening as the people construe it according to the categories of their ethnoscience, and to describe the rather unique yam growing technique of the Abelam.

INTRODUCTION.

THE Abelam are a tribe of some 30,000 people living round the patrol post of Maprik in the Sepik District of New Guinea. (*Figure* 1) Most of the group live between 400 and 1,000 ft. on the southern foothills of the Prince Alexander Ranges on Pliocene mudstones and siltstones. They are basically swidden horticulturalists but they obtain significant amounts of food from trees, palms, and the trade stores.[1] The most important of the tree crops is sago which is the staple food during a dietary lean period from about February to May when the gardens are producing very little food. The Abelam have two types of gardens, the main food gardens (*ka yawi*), and the ceremonial yam gardens (*wapi yawi*). (*Figure* 2)

THE KA GARDENS.

The *ka yawi* are planted with numerous varieties of *ka* (*Dioscorea esculenta*), *lipma* (*D. bulbifera*), *yabweo* (*D. pentaphylla*), and *wapi* (*D. alata* and *D. nummularia*). In two villages alone there were 112 different varieties of yam (59 varieties of *ka*, 43 of *wapi*, and seven of *lipma*).[2] The *ka* varieties in the northern villages fall into four main groups which could conveniently be called sub-types. These sub-types are *mar'ka*, *asagwaka*, *apa'ka* and *maleka*, each of which has easily recognizable characteristics.[3] In some regions certain sub-types are divided into two further groups so that in the Wosera area, for example, the *apa'ka* sub-types consists of two groups, the *maluka* which is generally a high yielder and the *nglamei* which is a low yielder.[4]



There are regional preferences for each sub-type. The people of the West Wosera like the strong tasting and low yielding *maleka*, the people of the Central and East Wosera prefer the high yielding but rather coarse *asagwa* and the North Abelam plant mainly the low yielding and 'sweet' *mar'ka*. (*Plate* I)

All the sub-types names mentioned above are also used for particular varieties within the appropriate sub-types. The criteria which determine different varietal names are the size, shape and colour of the leaf and tuber, the hairiness of the tuber, the colour of the shoot, the size

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[1] Diet is discussed in some detail in Lea, 1965. (Appendix A)

[2] These native yam varieties are almost certainly clones.

[3] The main characteristics of these four sub-types are—

Mar'ka—has a small leaf and a small inflorescence, and is generally a low yielder.

Asagwa—has a hairy tuber, which is rather coarse and fibrous when cooked. It also has a long flower and is usually planted without a trellis.

Apa'ka—has a large leaf and its tubers are fat rather than long.

Maleka—has a small leaf and its tubers are small, round, and have a distinctive taste. The tubers grow up from the bottom of the hole.

[4] Unfortunately variety names vary a little throughout Abelam territory, *nglamei* in the Wosera is known as *wolimile* in the North Abelam area.

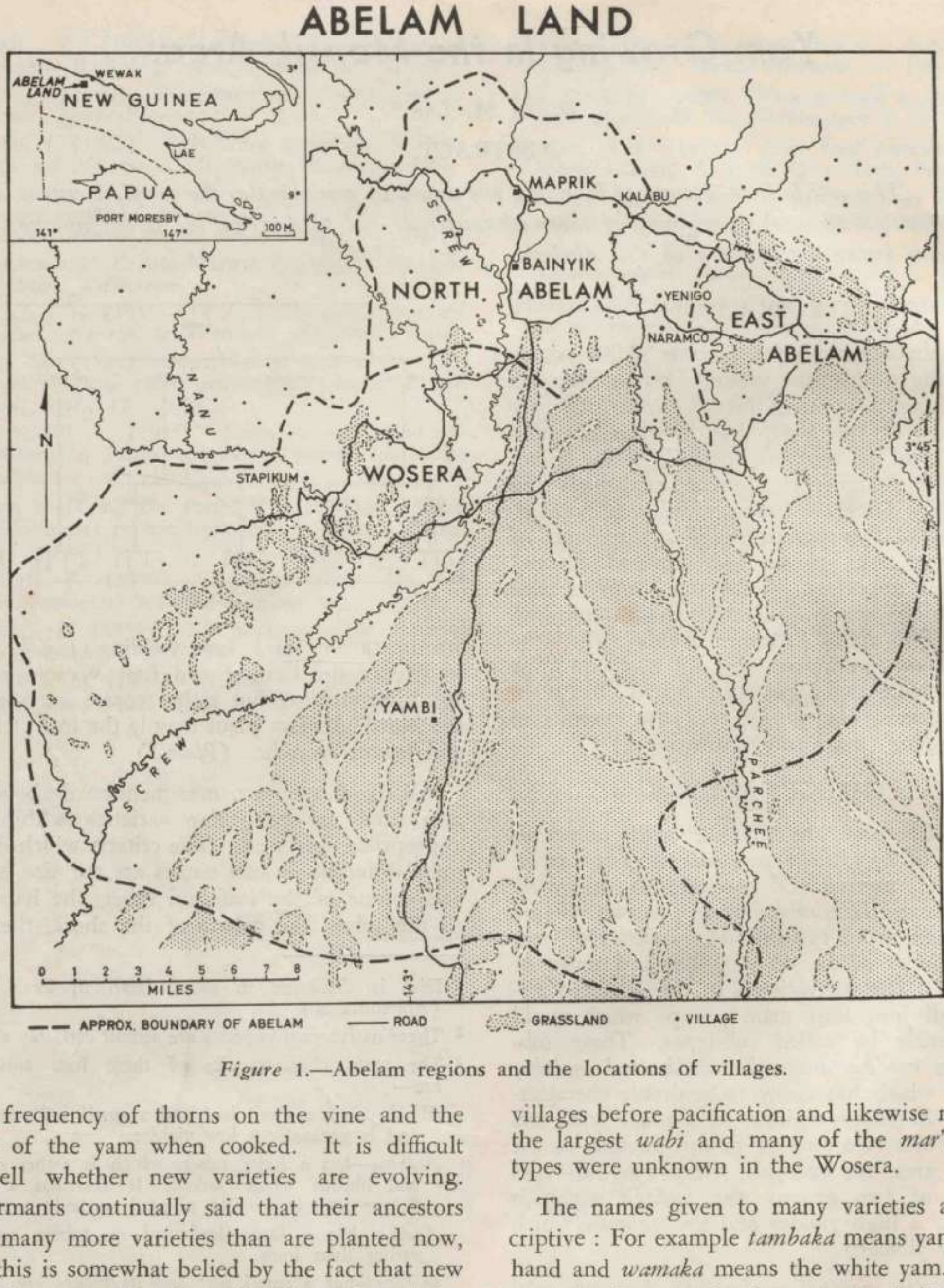

Figure 1.—Abelam regions and the locations of villages.

and frequency of thorns on the vine and the taste of the yam when cooked. It is difficult to tell whether new varieties are evolving. Informants continually said that their ancestors had many more varieties than are planted now, but this is somewhat belied by the fact that new varieties are coming into all villages from other areas in Abelam territory and from other areas in New Guinea. The *maleka* and *asagwa* subtypes were either rare or unknown in the north villages before pacification and likewise many of the largest *wabi* and many of the *mar'ka* subtypes were unknown in the Wosera.

The names given to many varieties are descriptive : For example *tambaka* means yam like a hand and *wamaka* means the white yam. They may also be named after an animal, bird, man or kinship term ; some examples are *nyamioka* meaning the dove yam, *apa'ka* the father yam and *asagwaka*, the mother yam. Many varieties

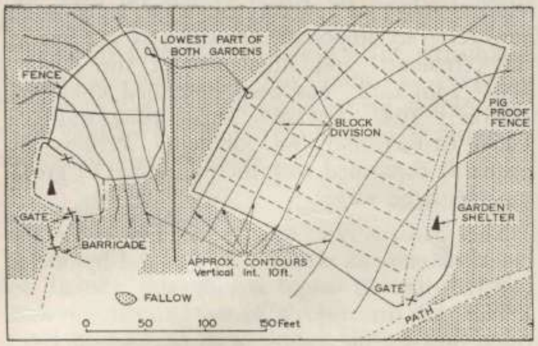

Figure 2.—Examples of typical Abelam gardens. On the left are two ceremonial yam gardens both 0.10 acres in size and containing 26 large yams (*wapi*). The plan on the right is an ordinary *ka* garden, 0.18 acres in size and containing 696 small yams, 1,979 *Colocasia esculenta* and many other plants. Usually about half the blocks within the garden are given to kin and affines.

have complex names such as the *walangguk'ka* and *gilewanbaka* which mean a spirit's egg yam and the black ear yam respectively. However the etymology of many yam names was obscure to the Abelam themselves.

In Yenigo, a North Abelam village, no variety of *ka* was considered early or late nor was any variety considered more suitable than any other for any particular environment. In Stapikum in the Wosera, on the other hand, *wolimile* (called *nglamei* in the Wosera), which totalled about 27 per cent, of all *ka* weighed in the village, was planted first, and the *asagwa*, which totalled about 56 per cent. of all the *ka* weighed there, was planted about a month to six weeks later. In the Wosera the *asagwa* is usually grown on the alluvial river flats. It is the highest yielding yam and the indigenes say that the best soils are reserved for the best yams. The *asagwa* is also the variety that can best withstand flooding and damp conditions.

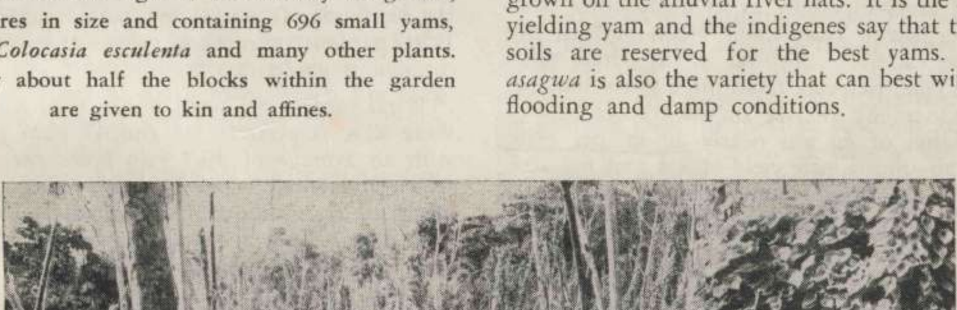

Plate I.—Several contiguous *ka* gardens in the West Wosera. These *ka* plants are mainly *maleka* and the vines climb up 'ropes' to the top of trees which serve as trellises. The horizontal logs on the slope are said to hold the soil.

Taro, mainly *Colocasia esculenta* with a few *Xanthosoma*, bananas,[5] beans,[6] green vegetables,[7] sweet corn, tobacco, sugar cane, cassava, tomatoes, 'pit pit' (*Saccharum edule*), paw-paw and many other crops are interplanted among the yams. (Appendix A) The *ka* gardens are usually planted with yams at the beginning of the wet season (October) and the main harvesting takes place six or seven months later at the beginning of the following dry season (May or June). Other crops are planted and harvested in a more haphazard fashion. *Ka* gardens, usually just over half an acre in size, and having a fallow period of 10 to 20 years, have been described elsewhere [8] and are not very different from other Melanesian lowland food gardens. The main point of interest is that yields of yams from the gardens are high when compared with other tropical areas especially as so many other crops are interplanted (taro alone yields at least two tons per acre). Typical yields from other tropical countries vary from three to six tons per acre [9] but among the Abelam the average yield of all varieties of *ka* was nearly 20 lb. per plant giving an approximate yield of 8.4 tons per acre. It must be borne in mind, however, the variety planted, the techniques used and the environment in which the yam is planted all lead to great deviation from this figure. Yields between 40 and 70 lb. are quite common for *ka* grown by special techniques for ceremonial purposes. These techniques are very similar to those used to grow the ceremonial *wapi*.

Table 1.—**Statistical Summary of Gardens in Yenigo Village 1961-1962.**

Population 1962	234
Village Area	1,158 acres
Average number of *ka* gardens	51
Average number of *wapi* gardens	38
Average area under *ka* garden	32.59 acres
Average area under *wapi* garden	3.75 acres
Average size *ka* garden	0.69 acres
Average size *wapi* garden	0.10 acres
Total area cultivated per person per annum	0.15 acres
Number of *ka* per acre (approximately)	950 - 2090/ha
Number of taro per acre (aproximately)	2,000

THE WAPI GARDENS.

The *wapi* gardens produce less than 10 per cent. of the yams in most villages and in terms of time and effort expanded this is a very low return. The *wapi* from the *wapi* gardens is, however, very important for the part it plays in the ceremonial and ritual life of the people. The 'Yam Cult' has been described elsewhere (Kaberry 1941, 1941-42, Forge 1962 and Lea 1964 : 61-63) and the following sections are primarily concerned with the techniques of growing the large *wapi*.

The gardens are usually hidden from the casual observer by dense regrowth and by one or two barriers of sago fronds and canes. In Yenigo all the *wapi* gardens were on or near ridge tops on the friable soils originating from yellow siltstone, avoiding the heavier mudstone and colluvial soils on the lower slopes. Inside the outer barriers are a garden house and a high, strong pig-proof fence around the actual growing area. If two or more gardens are together, high but flimsy sago frond fences separate each garden. *Wapi* gardens are often in groups of two to nine contiguous gardens.

Wapi gardens are small and in 1961 and 1962 there were respectively 33 and 47 *wapi* gardens with an average of 30.7 yam holes per garden which gives a density of 340 *wapi* holes per acre. Many of the yams were in small holes 3 to 5 ft. deep. Only about six *wapi* in each garden were planted in holes up to 10 ft. deep which produce the huge tubers, which often weigh over 100 lb. and measure more than 6 ft. in length. The smaller holes usually produce tubers weighing between 25 and 60 lb.

Most villages have their favourite *wapi* garden sites ; each site may be used for four years in succession and only left fallow for three to five years. Sixteen of the 1961 gardens in Yenigo were on the same site as 1960 gardens and ten gardens were being used for the fourth year in succession.

Only the *wapi* which produce long or heavy tubers are grown in the *wapi* gardens. Of the 41 varieties known to the author in Yenigo, only

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5 Over 30 varieties of both taro and bananas.

6 *Psophocarpus tetragolobus* and *Vigna sinensis*.

7 The main green vegetables are *Brassica chinensis*, *Brassica* spp., *Abelmoschus manihot*, *Amaranthus tricolour*, *Amaranthus hybridus* and *Deeringia amaranthoides*.

8 Lea 1964 : 78-110 ; Lea 1965.

9 International Bank 1965 : 71 ; Barrau 1958 : 45 ; Morgan 1959 : 146 ; Johnston 1958 : 115.

four were planted in nearly all *wapi* gardens, seven were commonly planted and nine were only occasionally planted. (*Table* 2) The remaining 21 varieties were seen only in the *ka* gardens. Occasionally a few taro are grown within the *wapi* gardens but their consumption is reserved for ceremonial occasions.

The Seed Wapi.

The *wapi* are stored in rows on the floors of yam houses, though any tubers over 5 ft. long are hung from poles (*Plate* II) and suspended from the roof of the yam house or some other house within the village which is not used for any domestic purpose. The largest of the yams are often allowed to rot after they have been exchanged and some of the other tubers used in exchanges are allowed to rot if an exchange is rejected.[10] The yam sprouts at the head of the tuber about four or five months after the harvest and when the sprout is about a yard long it is taken to the garden, which has been completely cleared and prepared for planting.

Table 2.—Some Yield Data of the *Wapi* Gardens, Yenigo, 1961.

Variety of Wapi.	Total holes.*	Number Weighed.	Average weight lb.	Maximum weight lb.	Maximum length. ft. in.	†
Yepmane	176	33	30.75	117	7 2	A
Mambatap	173	57	47.63	100	7 8¼	A
Kwandjel	154	52	51.29	140	8 11½	A
Nggwokurpi	148	30	29.10	52	?	A
Mbalepane	54	20	29.80	49	?	B
Yame	42	8	49.63	76	7 0	B
Landji	42	7	27.14	40	6 5½	B
Tswagap	35	....	....	....	....	B
Wundunggul	28	9	26.89	42	?	B
Ambekurpi	23	8	24.00	43	5 8½	B
Yaimbu	20	4	35.50	41	3 2	B
Tseam	5	....	....	....	....	C
Kwandji	4	....	....	....	....	C
Mane	4	....	....	....	....	C
Yilan	4	....	....	....	....	C
Kwarind'ngil	4	....	....	....	....	C
Mbut'nggup	3	....	....	....	....	C
Ambnunmuna	2	....	....	....	....	C
Masu	1	1	50.00	50	?	C
Vi'a	1	....	....	....	....	C
Muna'	1	....	....	....	....	C

* Total holes planted (30 gardens only).
† Frequency of occurrence in the 30 gardens counted.
A Abundant.—In more than 20 gardens.
B Common.—In more than eight but less than 15 gardens.
C Rare.—In less than three gardens.

Immediately before planting takes place, the top 12 in. of the tuber, with the sprout attached, is cut from the rest of the tuber. This section is then hollowed out to prevent the seed tuber from rotting and planted in the mounds of the deepest holes where the largest of the yams will be grown. The rest of the tuber is cut into sections about a foot long. Some of these are hollowed out and planted immediately in the sides of the large yam mounds even though they have no shoots. Other hollowed out sections are put in the garden house and covered with mounds of moist earth taken from the *wapi* garden ; this procedure is said to encourage the rapid development of the sprout. After two or three weeks the sections of the tubers have shoots and are planted in the gardens.

The Preparation of the Garden for Planting.

Clearing of the garden sites in Yenigo begins when the *wapi* first sprout which is between late September and early October. The clearing is not difficult and a garden which has been used for growing yams the previous year only needs to be weeded. A new garden site usually has a five-year fallow growth of low bush dominated by *Saccharum robustum*, and the only difficult work is removing the roots of the stumps of cane. The men do all the work in the *wapi* gardens with the exceptions of the final clearing and sweeping of the garden which is done by young girls and old women (i.e., those women who do not menstruate).

Food and sex taboos are observed by all the ceremonial *wapi* growers for about seven months of each year which is the time from planting until the final harvest. Most of the married males over 30 years of age are ceremonial *wapi* growers. The younger men, who help with the planting and who entrust one or two yams to the care of an older man, observe temporary taboos but relax them after the planting has finished. After planting, only those men observing all the taboos are allowed in the gardens until the harvesting takes place. Women are inimical to the growing of the yams and the strongest of

10 In a hostile exchange between a man in Yenigo and a man of Naramco, the Yenigo man let some Naramco yams hang in the rafters of a 'talking' house until they were rotten. This made the Naramco man very angry and resulted in a new series of exchanges in which the Naramco man refused to accept a yam. This also was left in a prominent place and left to rot.

Plate II.—Preparing to weigh a *wapi.* The yam was attached to a pole with rattan supports.

all the taboos is on sexual intercourse.[11] Other taboos prohibit the eating of meat and fish, and they are not allowed to accept any food from anyone but their wives, who are assumed to be observing similar taboos.

The Planting of the Wapi Garden.

By late October both the gardens and the seed tubers are ready for the planting.[12] Holes from 8 to 12 ft. apart are dug to depths varying from 3 to 10 ft. One boy or young man digs each hole and two to five men break up the clods of earth as they are thrown up. The top soil is kept to one side, separate from the sub-soil. Usually two to four holes are dug at the same time so the work force within the garden will consist of about 15 men, some working, some resting and some just looking, supervising or talking.

On the day after the digging, the boys are dismissed and the men proceed with the planting. A long piece of cane is first placed in the middle of the hole and then the soil, carefully broken by hand, is put back into the hole ; top soil goes into the centre of the hole and the sub-soil around the outer edges of the hole. Additional top soil is collected from the surrounding area, 6 to 12 ft. from the centre of the hole and is added to create a cone-shaped mound 3 to 4 ft. above the surface of the ground which has been slightly lowered by the removal of the top soil. (*Figure* 3) The cane down the centre of the hole is then removed leaving a small hole and the hollowed out seed tuber is placed on top of the mound [13] with the roots over the small

[11] " The cultivation and distribution of long yams may be termed a phallic cult ". (Kaberry 1957 : 7), Mahony (1959 : 9) and Defugin (1959 : 61) note similar taboos in Ponape and Yap. In one yam garden in Yenigo, nearly all the yams died and the planter admitted that he had had sexual intercourse.

[12] Like the *ka*, planting of the *wapi* among the Woseras and the Abelam west of Maprik is earlier than in Yenigo. Planting in the Wingei area is even later than in Yenigo.

[13] Before the seed yam is planted it is first rubbed with strong smelling magical leaves and grasses. Each *wapi* variety has an acknowledged expert who is sometimes called in to do these tasks and to generally supervise planting. More often the yam planter performs his own magic.

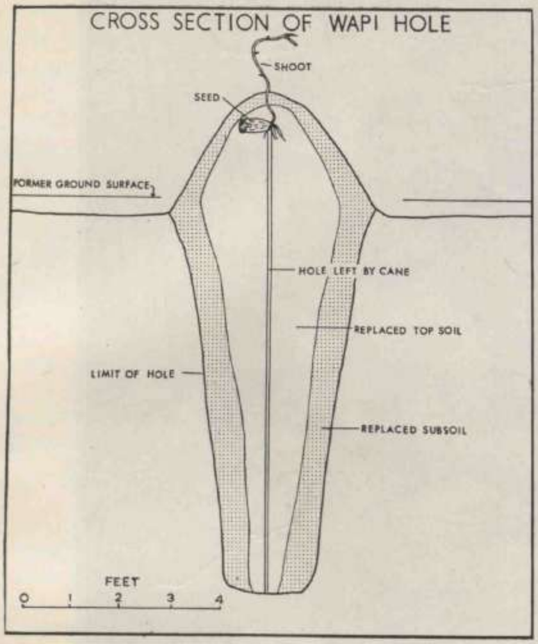

Figure 3.—A cross section of a *wapi* hole.

hole. The tuber is then carefully covered with soil so that the shoot comes out of the top of the mound. The mound is patted firm with sub-soil, which is more resistant to erosion than the top soil, in a layer over all the outside of the mound. (*Plate* III) The mounds are decorated with hibiscus flowers and a sprouted coconut is placed alongside the yam and will remain there until the harvesting.

Most *wapi* gardens contain about 6 to 10 large *wapi* and each one takes between 25 to 35 man hours to plant. The smaller *wapi*, usually at the bottom of the garden,[14] are each planted in about four man hours for the holes are only about 3 ft. deep and they are not planted with as much care as the large *wapi*.

The Care of the Wapi.

The growing point of the shoot is nipped off with thumb and forefinger when the shoot is 3 or 4 ft. long ; below this cut two to eight new shoots develop. Pieces of cane radiating out from the top of the mound guide each shoot on to the main trellis which is 20 to 30 ft. high. (*Figure* 4) If the land is level, rows of *wapi* may be planted on both sides of the trellis. Smaller yams at the botom of the garden usually have a lower and more simple trellis.

After the trellis is made the garden is kept clean weeded by the yam grower, errant shoots are trained onto the trellis, much magic is performed [15] and the tubers are periodically inspected. The first inspection hole is made into the top of the yam mound about two months after planting and, if more than one tuber is developing, all but the largest are removed. After about four months inspection holes are dug to see how

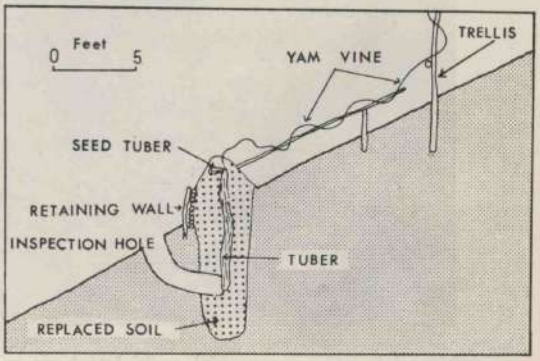

Figure 4.—A cross section of a ceremonial *wapi* hole on a hill slope. The trellis is often from 25 to 30 ft. high.

[14] *cf.* The Fijian practice where "....planting of best seed yams is at the bottom of the slope where the soil is deepest" (Watters 1960 : 44). In Stapikum the biggest of the *wapi* were also planted at the bottom of the garden because on the top slopes soils were generally shallow and hard sandstones often outcropped or lay close to the surface. In Yenigo the higher, friable and better drained soils originating from siltstone were considered infinitely better than the lower, heavier and often colluvial soils.

[15] After planting there are three main periods of magical activity and the magic varies a little with each variety of *wapi*. The first stage is when the garden is cleansed of all female influence ; the second is when the vine is encouraged to climb to the top of the trellis and the final stage is when the development of a large tuber is urged. Cooked mixtures of strong smelling leaves are the main ingredients though leaves of large creepers are important ingredients in the second stage and pounded roots of the same creepers are important in the final stage. The mixtures are poured into small holes made in the yam mounds. In all stages appeals are made to the *nggwalndu* (ancestral spirits) to look after the yams. Carvings representing the *nggwalndu* are placed in the *wapi* garden houses to watch over all stages of the *wapi* growing.

Plate III.—The ceremonial *wapi* has been planted and two men are firmly patting down the outside of the mound and making it smooth.

the tuber is developing.[16] (*Figure* 4) Soil is carefully loosened around the growing point, magic paint is put on the side of the tuber [17] and the soil is replaced. There may be two to four of these inspections before the harvest. At the last inspection the approximate length of the tuber is measured and pieces of cane of equal lengths to the tubers, are put in a line in the hamlet of the grower. These tallies advertise the proficiency of the grower and herald the coming exchange and associated 'sing-sings'. The yam is considered mature when the creeper dies and short rootlets appear at the growing point of the tuber.[18]

The Harvesting of the Wapi.

The wapi are individually harvested as they mature, about seven months after planting. The varieties of the sub-type *kurpi* (*nggwokurpi*, *mbalepane* and *ambekurpi*) usually take about eight months to mature and they are harvested and exchanged later than the other varieties.

When each yam is dug out, a narrow trench about 2 ft. wide and 6 ft. long is made so that the tuber, which grows vertically downward, is at the head of the trench. (*Plate* V) Most of the soil is removed by digging sticks and hands though spades are sometimes used for removing soil from that part of the trench furthest away from the tuber. Near the plant dibble sticks and fingers carefully pry away the soil from around the tuber. Because *wapi* are often over 6 ft. in length they need very careful handling and as many as six men may be needed to lift them out and carry them to the garden house. Here they remove all soil from

16 Mahony (1959 : 9) notes similar techniques in Ponape.

17 Forge (1962 : 10) writes, "The supposed action of the paint was described to me as follows :—the paint is so 'hot' that it irritates the sides of the yam . . . ., and the yam squirming and stretching to relieve the irritation drives itself further into the ground thus getting longer and longer".

18 As soon as a yam grows to more than about 5 ft. 6 in. it is given a name. These names are the same as may be given to a man, for example they may be named after an ancestor, or they may even be given satirical names. In an exchange in 1961 a man was called 'driman', which is Pidgin for a dreamer, by his exchange partner. This man grew a large yam in 1962 and he called it 'driman'.

Plate IV.—A *ka* garden shortly after it has been planted. The mound at the bottom right contains two *wapi*. A small retaining wall supports the mound and crossed supports take the vine to the trellis at top left. The *ka* garden also is planted with taro, sweet corn and tobacco.

the tuber with their fingers and small sticks until it is quite clean. The yam is then suspended from a pole by cane rope, tied so that it is supported every 9 in. The pole is then lashed to the rafters of the garden house until the yam needs to be decorated and prepared for exchange.

Yields from the Wapi Gardens.

Although of some value, the yield data shown on *Table* 2 should not be regarded as giving accurate data nor will it stand any sort of analysis. It was impossible to collect valid yield data from the *wapi* gardens for the following reasons :—

1. There were numerous taboos and a desire for secrecy in the *wapi* gardens. When my wife was in the field I was asked not to go into the *wapi* gardens between planting and harvesting and I had to make observations from over the fences.

2. No one would let me weigh the tubers until after they had been presented to the *tshambera* (exchange partners). This was mainly through fear that the tuber might get damaged but also partly because they thought that the yam, almost humanized, would be offended.[19] It was impossible to check on all yams for the small ones often were not exchanged and the long *wapi* frequently changed hands again after they had been given to *tshambera*.

3. All large *wapi* were weighed while attached to a pole. It was impossible to watch all lashings and the scale at the same time so some of the readings are probably inaccurate.

4. The number of big *wapi* planted in each *wapi* garden depended on the ambitions of the yam grower and the amount of labour

[19] Often the yams are spoken of as being 'like men' for they have spirits and can hear but cannot speak (Kaberry 1941 : 356).

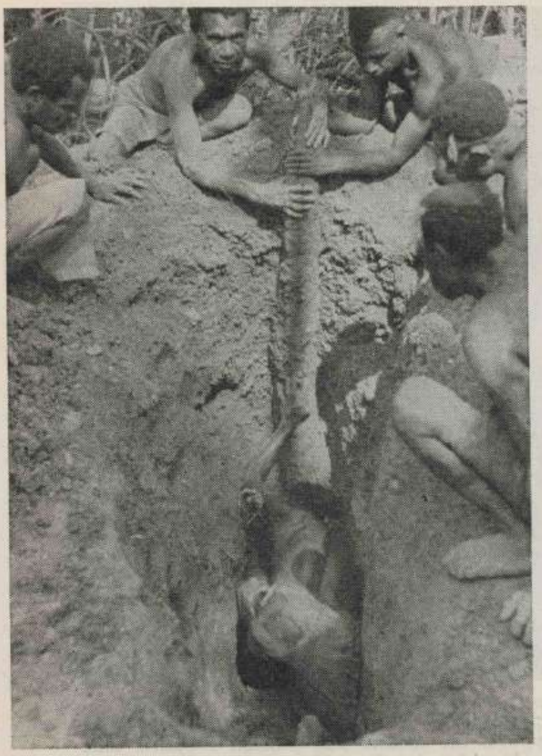

Plate V.—Harvesting a *wapi*. This particular tuber weighed 98 lb. and was 7 ft. 8½ in. long.

on which he could call. Thus the density of planting varied greatly from garden to garden.

5. Sometimes two *wapi* were planted in the same hole. In the 30 gardens counted (2.66 acres) there were 921 *wapi* holes which gives an average density of 346 holes per acre; however I estimate that there were about 1,150 tubers harvested.
6. Many of the gardeners were ashamed of small specimens which were either discreetly hidden in the yam houses or eaten immediately by the yam grower and his family.

The average yield of all *wapi* from the *wapi* gardens was 39.65 lb., but, as many of the smaller ones were not weighed (*see* 6 above) the actual average yield per tuber is certainly somewhat lower, probably around 33 lb. However, as there are sometimes more than one tuber per hole, the yield would be approximately 41 lb. per hole, giving a total yield per acre of about 6.3 tons. By referring to *Table* 1 the total product of *wapi* in Yenigo is only about 24 tons a year which is very little compared with the 285 tons of *ka*.

Maximum weight and length of various varieties are also shown in *Table* 2. The *kwandjelwabi* weighing 140 lb. and measuring 8 ft. 11½ in. in length was the longest tuber seen in 1961 or 1962 though cane markers showed that in previous years yams up to 11 ft. 8 in. in length had been grown.[20] Such huge tubers make the Abelam rather unique among yam growers although yams up to 8.5 ft. long have been found in New Caledonia (Barrau 1956a : 399, 1958 : 45) and yams weighing 250 lb. have been reported on Rotuma (Hartley 1963 : 60) and Burkill (1935 : 815) mentions yams up to 130 lb. in the Malay Peninsula.

CONCLUSION.

With a gradual decline in the indigenous culture the ceremonial incentive is becoming less important and men are finding new outlets for their time in cash cropping, agreement work, inter-village visiting and travel. (Many of the younger men no longer grow ceremonial *wapi*, and many of those that do plant the *wapi* in *ka* gardens, don't bother to observe the taboos or to grow huge tubers.) Also as more non-seasonal crops such as sweet potato, and crops easier to cultivate such as cassava, become more common and trade store foods become more predominant in the diet, taste prejudices and the keeping quality of the yam are not as significant. Thus it seems inevitable that the yam among the Abelam will follow the fate of the yam in New Caledonia (*cf* Glaumont 1897 and Barrau 1956b), Fiji and many other Pacific Islands—it will become less important in the diet and the techniques of growing ceremonial yams will gradually become moribund.

(Received September, 1965)

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[20] This yam was grown in Naramco just before the war. It was called *tsimban* and was a *mambatap wapi*. Cane markers are always accurate for *tshambera* see to it that there is no exaggeration. Kaberry (1957 : 41) measured one yam 11 ft. 2 in. long in Kalabu.

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APPENDIX A. SOME PLANTS IDENTIFIED IN THE MAPRIK AREA.[1]

In the right hand column the Abelam name, as spoken in Yenigo village, is shown italicized, the English name follows in ordinary print and the Pidgin English name follows in inverted commas.

Garden Plants.

Botanical name	
Abelmoschus manihot (L.) Med.	*tsagne* (many variety names), 'apika'.
Allium sp.	onion, 'anien'.
Amaranthus hybridus L.	*kumbur'ie* aliagwus (Wosera) 'aupa'.
Amaranthus tricolor L.	*bare*, 'aupa'.
Amaranthus sp.	*wuraman*, leaves eaten. A coarse wild variety fed to pigs.
Ananas comosus (L.) Merr.	*tuan na djwia*, pineapple, 'ananas'.
Arachis hypogaea L.	peanut, 'kasang'.
Brassica chinensis L.	Chinese cabbage, 'kabis'.
Brassica c.f. *juncea*	*mil*, 'kabis'.
Capsicum sp.	chilli.
Capsicum frutescens	capsicum, 'lambau'.
Carica papaya L.	*mbale-minya*, paw-paw, 'popo'.
Celosia cristata L.	*kumburie* (leaf eaten).
Citrullus vulgaris Schrad.	water melon, 'melen'.
Coffea canephora Pre.	Robusta coffee.
Colocasia esculenta (L.) Schott	*Mai* and *waula* (many varieties), taro, 'taro'. Leaves eaten of four varieties.
Cucumis sativus L.	*amangg*, cucumber, 'kukamba'.
Cucurbita maximima Duchesne	squash.
Cucurbita pepo DC	pumpkin. (shoots eaten) 'pamken'.
Deeringia amaranthoides (Lmk.) Merr.	*winba*, 'kumul'.
Dioscorea bulbifera L.	*lipma*, aerial yam, 'patata'.
Dioscorea alata L.	*wapi*, yam, 'yam'.
Dioscorea nummularia	*wapi*, yam, 'yam'.
Dioscorea esculenta Bkl.	*ka*, yam, 'mami'.
Dioscorea pentaphylla	*yabweo*, yam.
Ficus wassa Roxb.	*kwandjel*, 'kumul'.
Ipomoea batatas (L.) Lam.	*kiwika*, sweet potato, 'kau kau'.
Lycopersicum esculentum Mill.	tomato, 'tomato'.
Manihot esculenta Crantz.	*tsagopi*, cassava, 'tapiok'.
Musa spp.	*lapu*, (many varieties), bananas, 'banana'.
Nicotiana tabacum L.	*nyinggwus*, tobacco, 'brus'.
Oryza sativa L.	rice, 'rais'.
Psophocarpus tetragolobus (L.) DC	*mbermargu* and *kwasiminim'gwu*, green and red winged bean.
Saccharum edule Hassk	*kundia*, edible 'pit-pit'.
Saccharum officinarum L.	*nggwi*, sugar-cane.
Vigna sinensis (L.) Savi.	*bin ma'gwu*, long bean, 'bin'.
Xanthosoma sp.	*ya'mei*, 'taro kong kong'.
Zea Mays L.	*tsua ma'gwu*, sweet corn, 'kawn'.

Some Food Producing Trees and Plants.

Botanical name	
Annona muricata L.	*mi-wal*, soursop, 'kapiok'.
Areca catechu L.	*masa*, betel nut palm, 'bwoi'.
Artocarpus atilis Fosberg	*talumba* and *kam*, (nuts only eaten), breadfruit, 'kapiok'.
Artocarpus atilis Fosberg	*wal* (flesh and nuts eaten), breadfruit, 'kapiok'.
Bambusa sp.	*danggwu*, bamboo with edible shoots.
Canarium sp.	*mainggio*, 'galip'.
Carica papaya L.	*mbale-minya*, paw-paw.
Citrus sp.	lemons, limes, etc.
Cocos nucifera L.	*tipma*, coconut, 'kokonas'.
Dioscorea cf. *alata* L.	*duawapi*, yam, 'wild yam'.
Diospyros sp.	*kelau* (inside kernels of fruit eaten).
Ficus aff. *F. cynaroides* Corner	*mar'ru* (shoot and fruit eaten).
Ficus copiosa Steud.	*kwarmbi* (nut *kombasik*), 'kumul'
Ficus wassa Roxb.	*kwandjel*, 'kumul'.
Graptophyllum sp.	*mbar'gl* (leaf eaten often planted in hamlets).
Gnetum gnemon	*yuit*, 'tulip', leaf and fruit eaten.
Kleinhovia hospita L.	*weireman*, leaves eaten—also tree of the fallow.
Mangifera indica L.	*tsake*, introduced mango.
Mangifera minor	*tsake*, native mango.
Medusanthera papuana Becc.	*mi-tip*, leaves eaten. Also fallow tree.
Merremia vitifolia (Burm. f.) Hellier	*nyambil*, 'wild bin'.
Metroxylon sagu Rottb.	*nang*, sago, 'sak sak'.
Morinda citrifolia L.	*tsimbia* (the red-hot fruit).
Pandanus conoideus ?	*dkwia*, 'arang' or 'garoka'.
Phaseolus lunatus L.	*dungumene*, a pea-like plant of the early fallow—immature white seed eaten.
Piper betle L.	*kwarsi*, 'daka'.
Pometia pinnata For	*wa* (many varieties), 'taun'.
Syzygium malaccanse L. Merr. and Perr.	*nggwanggwale*, Malay apple, 'lor lor'.
Leguminosae	*kwarandungu* (leaf eaten. Often planted to mark boundaries).

NOTES.—

1. The following garden plants are also grown outside the gardens: *Abelmoschus manihot, Amaranthus* spp., *Ananas comosus, Arachis hypogaea, Brassica* spp., *Capsicum* spp., *Cucumis sativus, Cucurbita* spp., *Manihot* spp., *Musa* spp., *Nicotiana tabacum, Lycopersicum esculentum* and *Celosia cristata.*

2. Fronds from the following ferns are also eaten:—*mbandjip, mbumi, wangguk, tserai. See also* some edible shoots under palms. Also many wild Cucurbitaceae eaten: *tsargelen, kwarmbut* (*Trichosanthes* sp. ??) *marte-kinjo,* (*Luffa* sp.) *arsel, yamekinjo* (leaf also eaten), *katabi.*

[1] ... for identifying many of the plants listed here and

Copper Cobalt Supplementation at Erap.

J. D. Glasgow, B.V.Sc.*

ABSTRACT.

A trial to assess the value of copper and cobalt supplementation was conducted at the New Guinea Lowlands Livestock Station, Erap, in which four matched groups of eight steers were used. One group received copper supplementation, another cobalt, the third both, and the fourth was control. Weight gains were recorded for a little over 12 *months. At the final weighing the copper-cobalt group was heaviest, but a statistical analysis of the results indicated that the benefits were not quite significant enough to be credited to the supplementation. Thus copper or cobalt supplementation of cattle cannot be regarded as a worthwhile measure in the Erap area of the Markham Valley.*

INTRODUCTION.

At the New Guinea Lowlands Livestock Station, Erap, 30 miles from Lae in the Markham Valley, slow growth rates, rough coats and low calving percentages have been observed in cattle. Although these problems could be attributed to the unsuitability of the Station Shorthorn cattle for the tropical lowlands environment, they resemble some signs of copper and cobalt deficiency. Hence, it was decided to investigate the possible role of these minerals.

The essential physiological role of copper was first demonstrated in 1928, when it was shown to be necessary for the formation of haemoglobin. In the ensuing decade, workers in many parts of the world showed wasting diseases of domesticated ruminants to be caused by a copper and/or cobalt deficiency. Copper deficiency in the animal may result from soil or pasture deficiency and be complicated by interference of their uptake or utilization by molybdenum and organic sulphate levels.

The precise functions of copper in the animal body are not yet defined but it is believed to be involved in the synthesis of haemoglobin and in several enzyme systems. Deficiency symptoms vary according to the severity of deficiency and whether complicated by cobalt and other deficiencies. Principal signs include progressive loss of condition in adult cattle, unthriftiness and retardation of growth rate in young stock and rough, dull coat. Some workers associate infertility, especially in heifers, with copper deficiency but further evidence is necessary to verify this.

Cobalt is utilized by rumen microflora in the elaboration of Vitamin B12 which contains 4 per cent. cobalt in its molecule. Thus cobalt must be given orally to be of any use to the animal. It has no other bodily functions. Deficiency symptoms range from lowered growth rate of young stock to wasting and death of even adult animals.

Copper and cobalt deficiencies were treated initially by supplementation in licks and drinking waters, individual drenching and later by addition of small quantities of copper and cobalt salts to fertilizers. These methods were all successful but more modern techniques are the intramuscular injection of copper glycinate which

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is slowly absorbed, satisfying the animal's copper requirements for several months and the lodging of a bullet of a relatively insoluble cobalt salt in the reticulum. The bullets sometimes become coated with insoluble substances so that a short brass grub screw is administered concurrently to prevent such a coating building up. Cobalt requirements for up to six months are satisfied in this manner.

MATERIALS AND METHODS.

Four groups, each of eight Shorthorn and Africander-Shorthorn cross steers were chosen. The groups were as similar as possible with regard to age, breed, coat type, weight and conformation.

They were aged, at the commencement of the trial in November, 1962, from 8 to 17 months and weighed from 280 to 454 lb. One group was given 450 mg. copper glycinate intramuscularly, the second group was given a cobalt bullet, the third group was given both treatments whilst the fourth constituted the untreated control.

The treatments were repeated after eight months. The four groups were run together and received a supplement of coarse salt. They were weighed on days 8, 36, 65, 93, 121, 149, 177, 212, 239, 267, 295, 322 and 375 after commencing the trial.

RESULTS.

The average weights of each group at each weighing are given in *Table* 1 and graphed in *Figure* 1.

A linear regression on time was fitted to the weight data to determine the mean rate of increase in weight per day for each animal. Analysis of the data took into account differences in gain due to differences in initial weight. The regression of rate on initial weight was .0001257, which was not quite significant at the 5 per cent. level.

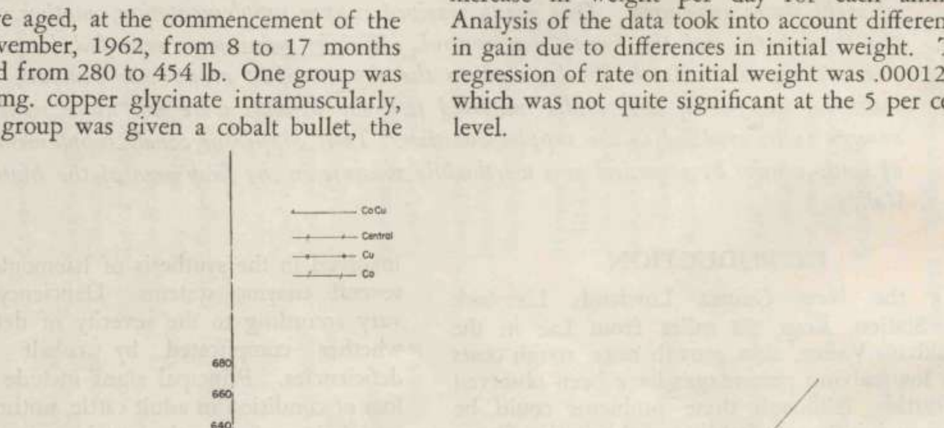

Figure 1.

Table 1.—Average Body Weights of Trial Groups.

	Cobalt Group. Lb.	Copper Group. Lb.	Copper-Cobalt Group. Lb.	Control Group. Lb.
8.11.1962	370	386	393	387
6.12.1962	383	404	415	409
4.1.1963	405	413	439	427
1.2.1963	417	422	457	446
1.3.1963	409	423	459	436
28.3.1963	408	426	465	439
26.4.1963	433	459	499	469
31.5.1963	456	484	526	489
27.6.1963	479	511	551	520
25.7.1963	500	532	578	543
22.8.1963	510	542	588	552
19.9.1963	529	569	614	575
9.11.1963	572	615	668	624

CONCLUSION.

The results indicated that no significant gains resulted from giving copper or cobalt or both as supplements to cattle grazed in the Erap region of the Markham Valley.

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Eradication of Tuberculosis from Cattle in the Territory of Papua and New Guinea 1954-1964.

T. L. ROTHWELL.*

ABSTRACT.

Progress in the eradication of tuberculosis from cattle in the Territory of Papua and New Guinea is described. Incidence was reduced from 2.3 *per cent. in* 1954-1955, *the first year of testing, to nil in* 1963-1964. *Cattle under test increased in that period from* 1,515 *head in* 25 *herds to* 14,597 *in* 190 *herds.*

INTRODUCTION.

IT has been the policy of the Territory of Papua and New Guinea Administration to establish a cattle industry free, as far as possible, from serious infectious and parasitic diseases. (Anderson 1962) Tuberculosis (caused by infection with *Mycobacterium tuberculosis*) is one of the most important diseases of cattle, because of the economic loss it causes, and because the bovine strain of *M. tuberculosis* can affect man.

The symptoms exhibited by tuberculous cattle depend on the extent and location of the lesions. If the disease is progressive, general symptoms are weakness, anorexia, emaciation and low-grade fever. An intermittent cough may be present when the lungs are involved. In non-progressive cases affected animals may appear normal but nevertheless shed the causative organism and spread the disease.

A clinical diagnosis of tuberculosis is only possible in advanced cases, by which time the affected animal is generally shedding tubercule bacilli. The detection of non-clinical cases depends on the tuberculin test. Tuberculin is a derivative of some of the specific proteins of tubercule bacilli. When it is injected intradermally into affected animals it causes a local reaction characterized by inflammation and swelling. If injected subcutaneously in an appropriate dosage, it causes a systemic reaction characterized by a transient fever.

Control of tuberculosis is generally based on testing of all cattle with a tuberculin test and slaughter of positive reactors. Other methods include segregation of positive reactors, immunization of all exposed cattle, and chemo-therapy of reactors to a tuberculin test.

When it became apparent in 1952 that bovine tuberculosis was present in the Territory of Papua and New Guinea, it was decided to control and ultimately attempt eradication of the disease while cattle numbers were still low. Because of the management conditions existing at the time, a test and slaughter scheme was decided on. The scheme was initiated in areas where veterinary officers of the Animal Industry Division were available to carry out the tuberculin tests. As staff increased and communications improved the scheme was extended to the majority of cattle in the Territory. This paper records progress in the eradication of tuberculosis from 1954 to 1964.

TESTING METHODS AND FIELD ORGANIZATION.

The Tuberculin Test.

All cattle over six months of age were tested.

Tuberculin SM[1] was injected intradermally into the caudal fold of cattle under test, generally using a pre-set automatic hypodermic syringe[2] graduated to deliver 0.1 ml. of tuberculin. Preparation of the site of injection was not routinely practised.

As the majority of cattle under test were beef cattle, most testing was carried out in crushes, animals being packed in tightly for restraint. Dairy cattle were generally tested in milking bails.

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1. Tuberculin SM prepared by Commonwealth Serum Laboratories, Parkville, N2. Victoria.

2. McLintock pre-set tuberculin testing syringe.

Interpretation of the Test.

The test was read 72 to 96 hours after injection, depending on the circumstances, but the longer interval was preferred. Palpation of the fold after raising the tail was routine, with visual examination of suspected reactions.

In the initial period of the campaign, only positive and negative reactions were recognized. As herd histories became better known, it became practice to class doubtful reactions in known infected herds as positive. In herds where the disease had not occurred or was considered eradicated, doubtful reactors were retested one to two months later.

Frequency of Testing.

Until 1962-1963 the aim was to test all herds at six-monthly intervals. If a reactor was found, three-monthly testing was introduced until three consecutive negative tests were obtained. The disease was then considered eradicated from the herd and six-monthly testing begun.

In 1962-1963 12-monthly testing was introduced with a two-monthly interval in infected herds. Eradication was considered accomplished after three consective two-monthly negative tests and another six months later.

Fate of Reactors.

Reactors to the tests were identified by description and ear tag numbers, immediately removed from the herd and slaughtered on the property as soon as possible. Post mortem examination was carried out whenever possible and material for histopathological and bacteriological examinations forwarded to the Veterinary Laboratory, Kila Kila. Unexamined reactors and condemned parts from those examined post mortem were burnt.

Compensation.

Compensation for cattle slaughtered during the tuberculosis eradication campaign was either replacement with a similar animal from an Administration owned herd or at the Administrator's discretion, in cash.

Testing Prior to Movement.

All cattle over six months of age were required to be subjected to a tuberculosis test prior to movement unless tested within the previous two months. Cattle from infected herds were tested within two months of arrival at their final destination.

Legislative Powers.

The legislative powers for the tuberculosis eradication campaign were embodied in the Animal Disease and Control Ordinance of 1952-1957.

Quarantine Regulations.

Cattle, pigs and goats imported into the Territory of Papua and New Guinea required a certificate from a Government Veterinary Officer that they had given a negative reaction to the intradermal test for tuberculosis within 30 days of embarkation.

RESULTS.

A summary of the annual results of tuberculosis testing from 1954 to 1964 is given in *Tables* 1 and 2 and *Figure* 1. In the first year of the scheme 35 positive reactors were identified from 1,515 cattle tested, an overall infection rate of 2.3 per cent. This was reduced to nil by the tenth year. In the first year, reactors were identified in 6 or 24 per cent. of herds tested and this was reduced to nil by the tenth year.

Table 1.—Summary of Tuberculosis Testing 1954-1964.

Year.	Total Cattle Tested.	Cattle Under Test.	Herds Under Test.	Infected Herds. No.	Infected Herds. Per cent.	Positive Reactors. No.	Positive Reactors. Per cent.
1954-1955	1,700	1,515	25	6	24.0	35	2.3
1955-1956	1,790	1,537	16	5	31.3	29	1.9
1956-1957	1,963	1,604	15	3	20.0	8	0.5
1957-1958	7,352	5,133	43	7	16.3	75	1.5
1958-1959	4,816	4,161	37	3	8.1	3	0.07
1959-1960	9,378	8,198	74	13	17.5	42	0.5
1960-1961	12,807	9,953	65	10	15.4	43	0.4
1961-1962	11,129	8,710	58	4	6.9	7	0.08
1962-1963	20,784	16,161	159	7	4.4	8	0.05
1963-1964	14,692	14,597	190	....	....	....	....

Table 2.—District Summaries for Tuberculosis Testing 1954-1964.

District.	Total Cattle Tested.	Cattle Under Test.	Herds Tested.	Number of Infected Herds.	Positive Reactors.
1954-1955—					
Central	613	494	8	2	19
Eastern Highlands	113	113	2	1	5
Madang	289	289	7	1	2
Morobe	669	603	7	2	9
New Britain	16	16	1	....	....
Total	1,700	1,515	25	6	35
1955-1956—					
Central	593	397	8	3	15
Highlands	175	175	2	1	3
Morobe	1,022	965	6	1	11
Total	1,790	1,537	16	5	29
1956-1957—					
Central	421	327	3	1	5
Morobe	751	486	5	2	3
New Britain	791	791	7	....	....
Total	1,963	1,604	15	3	8
1957-1958—					
Central	3,197	1,750	10	1	1
Eastern Highlands	1,556	784	14	4	40
Madang	325	325	6	1	8
Morobe	820	820	3	....	....
New Britain	365	365	5	....	....
Northern	295	295	1	....	....
Western Highlands	794	794	4	1	16
Total	7,532	5,133	43	7	75
1958-1959—					
Central	575	575	7	....	....
Gulf	37	37	1	....	....
Highlands	1,966	1,866	16	2	2
Morobe	183	183	1	1	1
New Britain	2,055	1,500	12	....	....
Total	4,816	4,161	37	3	3
1959-1960—					
Central	929	929	10	....	....
Highlands	3,400	2,400	24	5	10
Madang	920	740	8	2	5
Morobe	2,593	2,593	20	6	27
New Britain	1,536	1,536	12	....	....
Total	9,378	8,198	74	13	42
1960-1961—					
Bougainville	8	8	2	....	....
Central	4,398	3,855	13	4	25
Highlands	903	903	6	....	....
Madang	977	977	9	2	6
Morobe	5,525	3,214	23	4	12
New Britain	274	274	11	....	....
Northern	722	722	1	....	....
Total	12,807	9,953	65	10	43
1961-1962—					
Central	3,023	2,378	14	3	4
Highlands	605	605	6	....	....
Madang	378	378	3	....	....
Morobe	5,345	3,838	27	1	3

Table 2.—District Summaries for Tuberculosis Testing 1954-1964—*continued.*

District.	Total Cattle Tested.	Cattle Under Test.	Herds Tested.	Number of Infected Herds.	Positive Reactors.
1961-1962—*continued.*					
New Britain	984	/17	7	....	....
Northern	794	794	1	....	....
Total	11,129	8,710	58	4	7
1962-1963—					
Central	4,112	3,421	18	....	....
Eastern Highlands	1,634	1,586	41	3	4
Madang	3,377	606	12	1	1
Manus	28	28	3	....	....
Morobe	7,111	5,185	22	1	1
New Britain	925	738	17	2	2
New Ireland	202	202	1	....	....
Northern	972	972	2	....	....
Sepik	396	396	7	....	....
Western Highlands	2,027	2,027	36	....	....
Total	20,784	16,161	159	7	8
1963-1964—					
Bougainville	109	109	13	....	....
Central	564	564	12	....	....
Eastern Highlands	1,893	1,798	34	....	....
Madang	1,494	1,494	7	....	....
Manus	45	45	4	....	....
Milne Bay	282	282	11	....	....
Morobe	7,098	7,098	26	....	....
New Britain	607	607	19	....	....
New Ireland	462	462	7	....	....
Southern Highlands	60	60	11	....	....
Western Highlands	2,078	2,078	46	....	....
Total	14,692	14,597	190	....	....

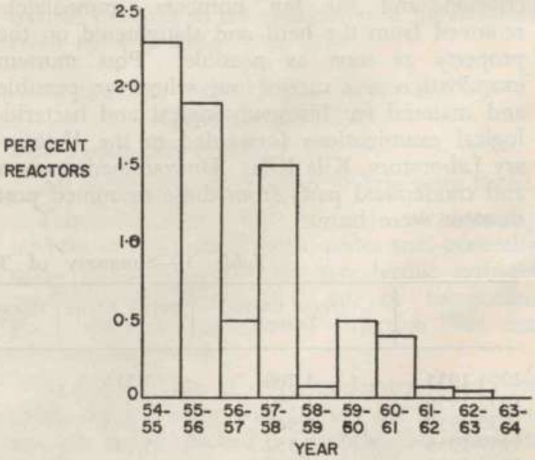

Figure 1.—Per cent. Reactors to Tuberculosis Test 1954-1955 to 1963-1964.

Within herds the highest percentage of infected animals at one test was 12.5 per cent., all being confirmed post mortem. Towards the latter part of the programme no visable lesion (NVL) reactions caused some herds to be classed as infected although only one reactor was identified in them. Thus in 1962-1963 only one of the seven infected herds had a confirmed reactor in it.

The fluctuations in per cent. reactors reflected new staff postings with resultant instigation of testing in previously untested herds. Thus the increases in 1957-1958 and 1959-1960 followed posting of veterinary officers to the Highlands and Morobe Districts respectively.

A summary of the incidence of NVL reactions among those examined each year is given in *Table* 3. No NVL reactions were found in the first year of testing but all execpt one or 83.3 per cent. were NVL's in the ninth year. Two of the reactors examined had histopathological tuberculous lesions only.

Table 3.—Incidence of No Visible Lesion Reactors.

Year.	Total Reactors.	No. of Reactors Examined.	No. of Reactors showing visible Lesions.	NVL but +ve by laboratory methods.	NVL and —ve in laboratory.	% Reactors NVL and —ve in laboratory.
1954-1955	35	10	10	....	....	....
1955-1956	29	15	12	....	3	20.0
1956-1957	8	....	NA	NA	NA	NA
1957-1958	75	5	3	....	2	40.0
1958-1959	3	....	NA	NA	NA	NA
1959-1960	42	12	5	1	6	50.0
1960-1961	43	6	2	....	4	66.7
1961-1962	7	6	1	1	4	66.7
1962-1963	8	6	1	....	5	83.3
1963-1964	....	....	....	....	....	....

DISCUSSION.

The control or eradication of tuberculosis in cattle should be practised firstly on economic grounds, in the interest of the livestock industry and secondly for the maintenance of public health. (Committee on Tuberculosis 1949)

Cattle herds in the Territory of Papua and New Guinea were almost wiped out during the second World War and the desirability of re-establishing herds free from tuberculosis was realized by the Administration. Consequently, quarantine restrictions were applied to provide for the importation of tuberculosis-free stock and an eradication scheme for existing herds instigated. This was based on techniques developed in the United Kingdom, Europe and United States of America and adapted to Australian conditions—that is a test and slaughter scheme based on the single intradermal injection of Tuberculin SM into the caudal fold. The Australian work has been described by Legg and Maunder. (1940 a and b, 1941 a and b), Bazeley and Barraclough (1940) and Gregory (1949).

Three problems associated with tuberculin testing encountered during this programme are discussed below. They were—

(*a*) No visible lesion reactors (NVL's).

(*b*) False negative reactors.

(*c*) Suspicious or doubtful reactors.

(*a*) *No visible lesion reactors* have proved a problem in tuberculosis eradication programmes elsewhere, their importance increasing when the level of tuberculosis in the herds had been greatly reduced and presumably tuberculosis-free herds were being continuously retested. (Gregory 1949) For example, Karlson (1962) cites information that from the year 1893 to 1908, 98.39 per cent. of Tuberculin reactors slaughtered in the United States had tuberculous lesions, while in 1959, 57.6 per cent. reactors had no visible lesions. NVL reactions can be due to too potent tuberculin, non-specific sensitising agents, or incorrect interpretation of doubtful reactions (Maunder 1949), trauma of the caudal fold when carrying out injections (Legg and Maunder 1941a) or specific reactions prior to the development of lesions. (Watts 1949)

The increase in NVL reactors in this Territory's eradication programme from nil in 1954-1955 to 83.3 per cent. in 1962-1963 can be seen in *Table* 3.

The majority of NVL reactors in 1961-1962 and 1962-1963 were considered to be due to incorrect interpretation of doubtful reactions in herds whose history indicated an absence of infection. However, the necessity of exercising skill in interpreting reactions in such herds was demonstrated by the detection of single small reactions after a number of clean tests in two herds. In one case, macroscopic and in the other microscopic tuberculous lesions were revealed post mortem.

(*b*) The difficulty in detecting advanced cases of tuberculosis with the tuberculin test has been described by Legg and Maunder (1941b). *A false negative reactor* of this type prolonged eradication in one herd of over 500 head, being detected when culled. As its presence was suspected on herd history, the short thermal test was attempted on doubtful reactors and other suspect animals. However, the unexpected finding that all cattle had a pre-injection temperature of over 102.8 degrees Fahrenheit prevented its use. The cattle in this case were Shorthorns in a hot lowland environment and these temperatures were recorded even after overnight yarding.

(*c*) Interpretation of *doubtful reactions* to the intradermal tuberculin test has been referred to by Bazeley and Barraclough (1940), Legg and Maunder (1941 a and b), Maunder (1949) and Watts (1949). The procedure adopted with doubtful reactors is outlined above. If this procedure had been routine after the first few years it is considered the percentage of NVL reactors would have been reduced considerably without classing tuberculous cattle as negative.

Legg and Maunder (1941a) refer to the production of doubtful reactions by trauma of the caudal fold with the needle in poorly restrained cattle. Most of the cattle in this eradication programme were beef animals, many being Brahman crossbreds of vigorous disposition. Crushes were often rudimentary and not designed with ease of intradermal injection into the caudal fold in mind. Under these conditions needle trauma was common and considered to be a cause of doubtful reactions.

To date, the test and slaughter method for the eradication of tuberculosis based on the intradermal tuberculin test is considered to have been successfully applied in Papua and New Guinea and is seen as some contribution towards the establishment of a successful dairying and grazing industry. Continued annual testing of all Territory cattle is planned for some time into the future. Extension of testing to small herds in inaccessible locations will be difficult. Utilization of helicopters represents an expensive but practical method of carrying out initial tests in such herds, although their status can generally be predicted by tracing their origin to larger herds in the various centres of the Territory.

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The Biology and Ecology of Lepidiota vogeli, *a Brown Pasture Scarab (Family Melolonthidae) of the Highlands of New Guinea.*

J. H. BARRETT.*

ABSTRACT.

The biology and ecology of Lepidiota vogeli *are discussed. Spring rains initiate beetle mating flights. Larvae feed on grass roots. The life cycle lasts one year. Population controlling factors are discussed as such, and in relation to the perennial cycle and to distribution.*

INTRODUCTION.

SPECTACULAR flights of a brown Scarab beetle, *Lepidiota vogeli* Brenske (Family : Melolonthidae), are common at dusk in the Eastern Highlands of New Guinea, following rains in the months of September and October. The larvae of this beetle feed on the roots of various grasses and the damage is so severe in some years that areas of grass are killed. Damage has been serious on airstrips, and has caused concern on golf courses and lawns. Cultivated crops have also been attacked. With the development of cattle-raising this beetle could become a more serious pest and of major economic importance in pastures. With this in view, a study was made of the biology, ecology and control of this insect.

Control will be dealt with in a second paper. Other species were encountered and are included in the discussion.

The work included both field and detailed laboratory studies and the results are to be of general interest as well as being of particular value to entomologists.

HISTORY.

Szent-Ivany (1958) discussed *L. vogeli* at Goroka in 1953, when the runway of the Goroka airfield was severely damaged by the larvae of this beetle. Simon-Thomas (1962) recorded a *Lepidiota* 'near *vogeli*' attacking the roots of *Hevea* rubber and *Cacao* trees in Dutch New Guinea (now West Irian), and also the attack by *L. stigma* F. on roots of Cacao, Coffee, Coconuts, Peanuts, Maize and Bananas.

About 25 species of the genus *Lepidiota* have been described from the Papuan region but little if any further information has been recorded.

DISTRIBUTION OF SPECIES.

The distribution of *Lepidiota vogeli* and some related species is discussed with remarks on the distribution of a few other Scarabs of the family *Dynastidae*, whose larvae are also found in the ground.

(*a*) *Lepidiota vogeli* has been collected at Goroka (elevation 5,100 ft.) in the Asaro Valley, at Henganofi and Moke to the south, and at Aiyura (5,400 ft.) and Kainantu to the south-east of Goroka. Mass spring flights occur in these areas and in the Arona Valley (4,500 ft.) which is further to the east. Both the larvae and the beetles are traditional items in the diet of the native peoples, and are considered a delicacy.

In the west *L. vogeli* has been collected in the Wahgi Valley at Kerowagi and Minj, but mass flights do not occur to a marked extent. Records in the British Museum (personal communication) are from Port Moresby, Ogwarra, Ishurava and the Upper Waria River. These localities are at elevations varying down to sea level. Insects

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regarded as *L. vogeli* were collected at Dagua (near Wewak) in December, 1953, and at Port Moresby in January, 1956, and February, 1964. Specimens in the collection of the Department of Agriculture, Stock and Fisheries at Port Moresby have been collected in that area in the summer season. The sparse summer flights of the beetle at these centres are in marked contrast to the mass spring flights of the Eastern Highlands.

(*b*) A smaller species of *Lepidiota* flies in the Baiyer Valley (4,500 ft.) to the north of Mount Hagen. The spring flight is similar in form to that of *L. vogeli*.

(*c*) A third species of *Lepidiota* is common at Akuna village (4,800 ft.) and flies about a month later than *L. vogeli*. It has not been collected at Aiyura which is only a few miles away to the west and separated by a ridge of 6,000 ft. and upwards in height. One specimen was collected at Bulolo at 2,000 ft. The distribution of this species is presumed to extend to the south and east of Akuna in areas of regrowth forest at elevations below 5,000 ft.

(*d*) Smaller undetermined species of *Papuana* (family Dynastidae), are common throughout the Highlands.

(*e*) A large *Papuana* species similar to *P. woodlarkiana* is common in the Highlands at Minj and areas further west. It is also present on the Papuan fall to the south-west at Chuave (3,800 ft.) where limited collecting has not yielded any *Lepidiota* species.

(*f*) Some adults of a genus close to *Lepidiota* have been taken at Akuna and one at Aiyura; and at Erave (3,800 ft.), Mendi (5,500 ft.), and in the Bomai area. These latter areas are all on the southern fall of the Highlands.

STAGES IN LIFE HISTORY.[1]

1. *The Adult.*

(*a*) *Lepidiota vogeli*, a typical melolonthid beetle, is an inch in length; the colour is brown with a grey tinge which results from white conical scales in shallow pits on the pronotum and elytra. Long, fine, light-grey hairs cover the under parts of the thorax. Beetles from the Wahgi and from areas at lower elevations are generally less than an inch in length—slightly smaller than the average in the Eastern Highlands.

(*b*) The Baiyer species is much smaller than *L. vogeli*—three-fourths of an inch long—and paler brown in colour. The pits on the elytra are very fine and the grey tinge is not marked.

(*c*) The Akuna species of *Lepidiota* is very slightly larger than *L. vogeli*. It is darker in colour, and the greyish tinge is less pronounced. Also, the under side of the abdomen may be darker. These two species are difficult to recognize from individual specimens but differences are apparent when specimens are placed side by side.

(*d*) The *Papuana* species include black beetles common at light at most times of the year but more commonly following a fall of rain. *P. angusta* Arrow is the largest. The smaller species are unnamed but sizes of mated pairs suggest that there are three. All the above species of *Papuana* have a relatively smooth and rounded pronotum.

(*e*) The common species of *Papuana* in the Western and Southern Highlands has processes and marked sculpturing on the pronotum and appears close to *P. woodlarkiana*.

(*f*) The last group comprises clear-brown beetles considered to be close to *Lepidiota*. The sides of the elytra are almost parallel, giving the beetles a more oblong appearance.

2. *The Egg.*

Eggs of *L. vogeli* are white, smooth without being shiny, and slightly elongated in shape. Eggs are initially 2.0 x 2.4 mm. but increase in size as they age, probably due to absorption of moisture. (*Plate* I)

3. *The Larval Stages* (*Instars*).

The larvae of *L. vogeli* are typical 'White grubs' or 'Pasture grubs'. The general colour is creamy-white, with areas of the abdomen darker due to gut contents visible through the cuticle. The hard sclerotised areas of the head capsule are brown. The legs, along with two small shields behind the head and the line of spiracles (breathing holes) along each side of the body, are yellowish-brown.

The three pairs of legs near to the head are typical of larvae of the family.

There are three stages of larval development. The soft body expands at a relatively uniform rate in this type of larva but the hard (sclero-

[1] Where a species is not indicated the information refers to *L. vogeli*.

tised) parts grow in three 'steps'. The head, legs, dorsal shields and spiracles remain the same size until the larva sheds its old cuticle (skin). The new cuticle undergoes an increase in size before it hardens. The newly moulted larva has a relatively large head and long legs, and hairs are obvious. When ready to moult again, the body has become large in relation to these sclerotised parts.

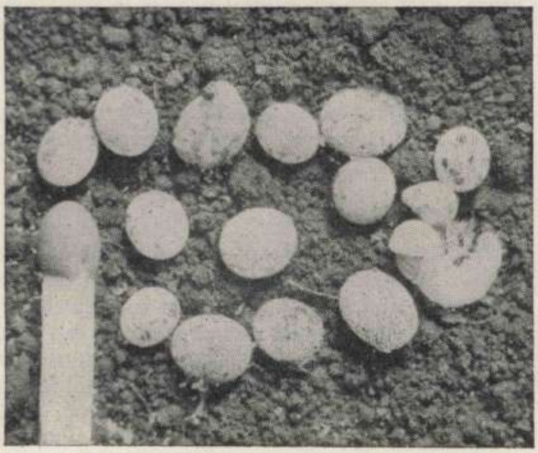

Plate I.—Eggs of *Lepidiota vogeli.* The dark marks on the eggs are adhering fragments of soil. Size comparison—head of match. Size differences are correlated with age and probably are due to the absorption of moisture. Two eggs have hatched. (Photo. author)

The average head capsule widths of *L. vogeli* larvae are—

First stage (from egg)	2.1 mm.
Second stage	3.7 mm.
Third stage	7.0 mm.
(range 6.8-7.4 mm.)	

The fully grown larva reaches almost two inches in length. (*Plate* II)

Distinguishing Characters of Larvae of Various Beetles :—

Lepidiota larvae have a band of dark, inturned bristles on the bulbous area in front of the anus (venter). (*Figure* 1) The species from Baiyer has a shorter band which is broader in the central part than that of *L. vogeli* and so is rather elliptical in form. The head width measurements of the Baiyer species are also smaller.

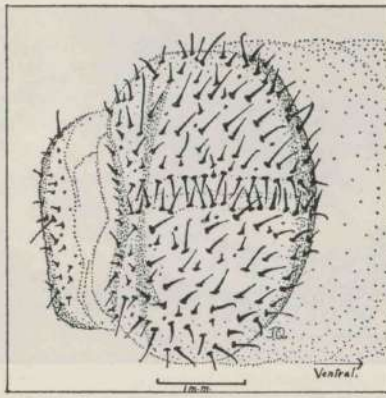

Figure 1.—Lower posterior view of last abdominal segment of a larva of *Lepidiota vogeli* showing bristle arrangement. The two central rows of inturned bristles are of diagnostic value in the identification of *Lepidiota* larvae. (Drawing : Jennifer Quinlan)

Larvae presumed to be of *Papuana* species are sometimes common in the soil. They are more active than *L. vogeli.* The venter is covered with bristles arranged in a random manner. *Xylotrupes* (Elephant beetle) larvae are common in compost and sawdust heaps. They are usually so large as to be distinct but if small, may be grouped with *Papuana* larvae by the scattered bristles. (Rhinoceros beetles *Oryctes* spp. are *not* present in the Highlands.)

Another whitish larva resembling *Lepidiota* is commonly found in rotten sap wood. This is the larva of the large bronze-green Stag beetle *Lamprima adolphinae* Gestro. It is different from *Lepidiota* in a number of characters but the one most easily recognized is that of the outer margins of the mandibles being straight, and not curved as in *Lepidiota.*

4. *The Prepupa.*

Although not a separate instar this stage of *L. vogeli* is easily recognized. The larval skin becomes shrivelled and yellowish-brown, and the typical curled attitude becomes much less apparent. (*Plate* II) This general change in form is due to loss of moisture, excretion of the solid contents of the gut, and the development of the Fat-bodies.

5. *The Pupa.*

The pupa is pale-brown in colour, and about one and a quarter inches in length. It lies free in an earthen cell, there being no cocoon. Its

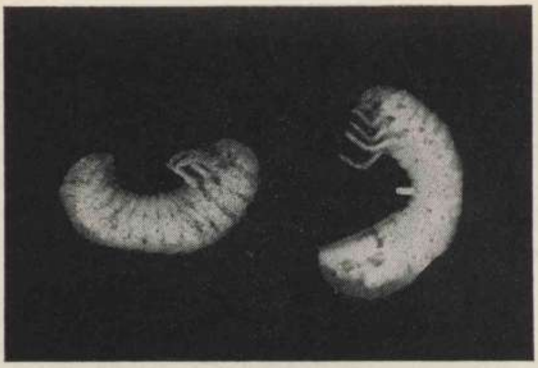

Plate II.—Fully grown larva of *L. vogeli* (right) carrying an attached egg of *Campsomeris formosa.* On the left is a prepupa. (Photo. author)

cuticle is shaped in the general form of the adult ; the developing head, legs and wings being easily discernible. (*Plate* III) With age, some parts begin to darken. The eyes are first followed by the legs and wings as development approaches the time when the pupal skin will be shed by the soft but fully developed adult.

HABITS AND ECOLOGY.

1. *The Adult.*

(*a*) *Habitat.*

Mass mating 'flights' of *L. vogeli* are mostly restricted to areas where gardening, cultivation, or the establishment of new plants has interfered with the natural plant species. These areas include centres of settlement, old garden areas in various stages of early regrowth development, and banks of streams. Flights are also to be seen in the open grassland. Few beetles fly in the forest, except perhaps very close to the margin.

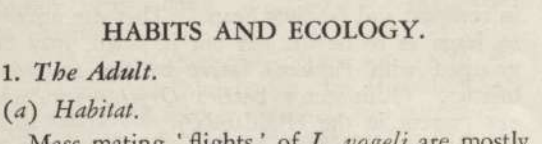

Plate III.—Pupae of *L. vogeli.* (The scale is 1 in. in length.) (Photo. author)

It is very probable that the mass flights of the insect, now regarded as a normal habit of this beetle, are a phenomenon associated with man's interference with its natural habitat in the Highlands. Some hundreds of years ago, before the present inhabitants became numerous and before gardened lands were of significant area, *L. vogeli* was most likely of little significance, being one of the many insect species dispersed through the grasslands.

(*b*) *Season of Flight.*

At Aiyura, the first and largest flight follows within 28 hours of the first fall of rain of over 50 points and after the middle of September. Evidence from Goroka indicates that it can be a week or so earlier in that area ; temperatures are slightly higher. Rainfall records from Aiyura for the relevant periods of the years 1960, 1962 and 1963 are given in *Table* 1. These illustrate the relationship between rainfall and flights of beetles. (*Figure* 3)

In the year 1960, the first flight at Aiyura did not occur until the first day of October, although a storm at Kainantu some two weeks earlier resulted in a mass flight in that area, only six miles from Aiyura. Falls of rain of 100 points and 50 points in early September of 1962 and 1963, respectively, did not result in general flights.

The first general flight of the year has been found to be followed by flights on following evenings. Numbers fall off abruptly if no further rain falls, but remain fairly high for three or four evenings if wet conditions continue. Marked flights can be expected until late October, particularly if falls of rain remain low for intervals of ten days or so. In 1962 there were flights at this time and one sparse final flight on 21st November, but this was unusually late.

Falls of rain earlier in the season occasionally bring a response from a few beetles, e.g., a small flight on the 22nd August, 1962, following 70 points of rain.

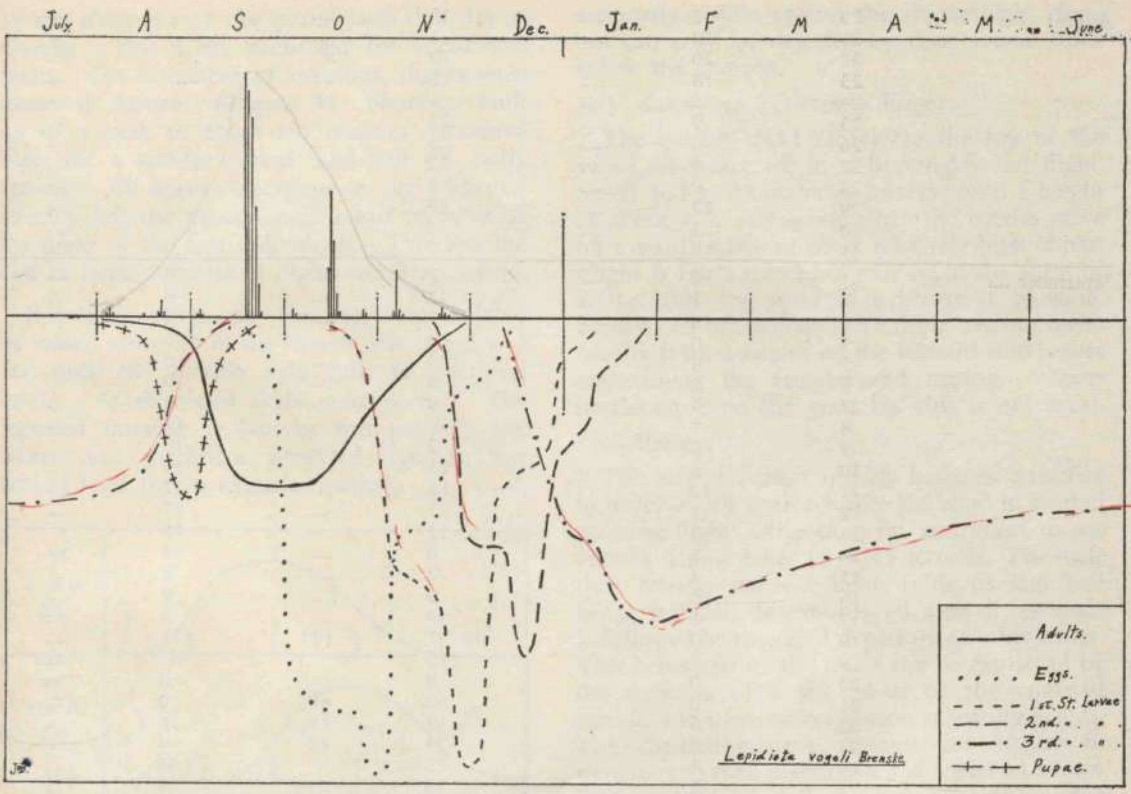

Figure 3.—Relative distribution of the various stages of ***Lepidiota vogeli*** over a year. The vertical lines represent flights of beetles, and the curves relate to the below-ground stages. Of note are—(*a*) Reduction in numbers from the first to the second stage larvae. (*b*) The long life of the third stage larvae. (*c*) The second rise in egg numbers due to a flight of beetles a month after the first flight.

Under laboratory conditions where 7 lb. tins of soil were used, each with a clump of grass growing in it, emergence took place as early as June. Routine watering tended to be irregular, and the soil in the pots was inspected at intervals to check on development. Of the factors which were abnormal, perhaps the most important was the laboratory temperature. This was up to 15 degrees Fahrenheit above the day screen temperature, and about five degrees higher at night. Soil temperatures in the field are relatively uniform. Thus, larvae in pots were subjected to a greater fluctuation in temperatures at levels well above those of the soil.

In the field the general mating flights show relations, firstly to the time of the year, and secondly to rainfall. From observation it seems highly likely that development is controlled by a cumulative factor of soil temperature, and further, that once the beetle has shed the pupal skin and hardened it becomes responsive to a factor related to rainfall. The response, to dig upwards to the base of the sward or close to the surface of the soil, could be to flooding of the pupal chamber. The soils are generally well drained and this could explain the response to individual falls of rain of over 50 points.

(*c*) *Time of Diurnal Emergence.*

Emergence from the ground is fairly closely related to waning light intensity. On dull evenings emergence is earlier than when conditions are brighter, as when there is a bright glow from light cloud in the west. Szent-Ivany (personal communication) reported an isolated case where the adults were to be seen as early as four o'clock

Table 1.—Rainfall registration in points and flight-level of *L. voglei* at Aiyura in three seasons. Flight ratings indicate *generally* the numbers of beetles as 10's (x), 100's (xx), or 1,000's (xxx).

Year.		1960.		1962.		1963.	
Month.	Date.	Rainfall.	Flight.	Rainfall.	Flight.	Rainfall.	Flight.
August	20	2	....	18	....	....	....
	21	10	....	1	....	....	....
	22	20	....	70	x	....	....
	23	18	....	16	....	....	....
	24	5	....	1	....	....	....
	25	9	....	22	....	....	....
	26	6	....	25	....	....	....
	27	6	....	22	....	....	....
	28	0	....	3	....	....	....
	29	22	....	30	....	....	....
	30	3	....	4	....	....	....
	31	0	....	7	....	....	....
September	1	0	....	23	....	0	....
	2	1	....	42	....	0	....
	3	0	....	3	....	4	....
	4	0	....	90	....	26	....
	5	8	....	100	....	0	....
	6	0	....	0	....	0	....
	7	23	....	8	....	50	....
	8	7	....	9	....	11	....
	9	8	....	2	....	10	....
	10	8	....	11	....	19	....
	11	10	(1)	11	....	21	....
	12	11	....	1	....	47	....
	13	35	....	13	....	16	x
	14	1	....	0	....	54	xx
	15	4	....	2	....	8	....
	16	10	....	6	....	9	....
	17	1	....	0	....	9	....
	18	0	....	1	(2)	11	....
	19	0	....	2	....	67	xxx
	20	0	....	0	....	8	xx
	21	0	....	60	xxx	0	x
	22	6	....	49	xx	16	....
	23	3	....	24	xx	4	....
	24	1	....	9	x	44	....
	25	2	....	13	....	64	....
	26	0	....	1	....	46	....
	27	1	....	32	....	0	....
	28	2	....	95	x	4	....
	29	1	....	23	....	33	....
	30	0	....	69	xx	25	....
October	1	56	xxx	113	xx	....	....
	2	120	xx	2	x	....	....
	3	14	xx	9	....	....	....
	4	0	x	23	....	....	....
	5	17	....	0	....	....	....
	6	3	....	6	....	....	....
	7	140	....	0	....	....	....
	8	37	....	5	....	....	....
	9	2	....	12	....	....	....
	10	0	....	2	....	....	....
	11	2	....	0	....	....	....
	12	23	....	15	....	....	....
	13	39	....	43	x	....	....
	14	56	....	13	x	....	....
	15	55	....	14	x	....	....
	16	23	....	28	x	....	....
	17	25	....	39	x	....	....
	18	10	....	37	....	....	....
	19	7	....	1	....	....	....
	20	4	....	3	....	....	....
	21	46	....	21	....	....	....
	22	0	....	5	....	....	....
	23	106	....	2	....	....	....
	24	42	....	1	....	....	....
	25	35	....	50	(3)	....	....

(1) A heavy storm at about this time in the Kainantu area resulted in a flight in that area, but rain at Aiyura was insufficient to initiate a marked flight.

(2) Beetles were dug up from the ground in a sample area.

(3) Small flights continued in early November and the last one was an isolated instance on the 21st of that month.

Note: Flights resulting from rain after 9 a.m. (time of measurement of rainfall) are recorded for the in the afternoon of one particularly dull day at Goroka. This flight continued for about two hours. On a number of evenings, flights were timed at Aiyura. (*Figure* 2) Numbers built up to a peak in about ten minutes, remained high for a similar period, and fell off fairly rapidly. All beetles emerging on any particular evening left the ground within half an hour of the flight of the first individuals. This was the case in large numbers of flights noted at Aiyura.

It would appear that the beetles, stimulated by water, move up to the base of the sward and rest until the outside light falls to a critical level. At this level flight commences. The reported instance at Goroka was possibly one where dull conditions provided light at this critical level for an extended period.

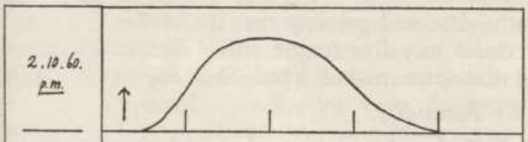

Figure 2.—Graphs of relative numbers of ***Lepidiota vogeli*** in relation to time, flying at Aiyura. The direction of flight, whether from or to the ground, is indicated by the arrows, and the time of day is indicated along with the date.

Figure 2 is drawn from progressive observations during a number of flight periods. During the later stages of the evening flights the beetles are easily visible against the sky or light cloud but can only be detected by their sound when below the horizon.

(*d*) *Ascending* (*Evening*) *Flight.*

The beetles crawl rapidly to the top of the sward, and take off in a laboured spiral flight. Speed and spiral diameter increase until a height of about 4 ft. is reached when the beetles move off towards a tree or other relatively high object. Flight is fairly direct but may be in the form of an arc into the wind if a breeze is blowing. Females settle fairly quickly on the tree but males usually form a swarm on the leeward side before approaching the females and mating. Some beetles mate on the grass but this is not usual.

(*e*) *Mating.*

The settled female quickly becomes attractive to males which approach into the wind in a rapid weaving flight, settle close by, and crawl to the female. Union takes 10 to 15 seconds. The male then releases its foot hold, folds its legs and hangs vertically downwards. Union of one male is followed by the rapid departure of other males. This behaviour of the males can be explained by the emission of a sex odour by the unmated female, and its cessation as soon as mating begins. The copulating male remains for 30 to 40 minutes and then disengages and settles on a nearby twig, remaining there until morning. At the time the males are settling back onto the twigs a few beetles may be taken at light and it is assumed that some beetles fall off the trees and fly.

(*f*) *Descending* (*Morning*) *Flight.*

All beetles move back to the ground in the early morning. This is particularly dramatic, again probably stimulated by a level of light intensity. The whole movement takes less than 20 minutes and the majority move in a five to ten minute period. Two observations are recorded in *Figure* 2.

Many beetles descend directly and enter the ground close to the tree on which they have rested overnight. There is also a general dispersal movement, probably mainly females. They fly to within a few feet of the ground and then move off for varying distances up to several hundred yards. The final stage of flight is close to the sward ; the beetles then land and burrow immediately.

(*g*) *Number of Flights of Individual Adults.*

Evidence available indicates that most individuals fly only once but this is difficult to prove. Samples of females collected from flights a few days apart commenced egg laying uniformly after the elapse of a fixed period from the date of collection. If some females had flown previously this uniformity would not be expected, some females commencing to lay earlier than the rest.

The habit of the adult is fairly consistent. Flight ceases with the onset of darkness. However, beetles can be taken at light an hour or so later, or coincident with a heavy fall of rain. At the former time the males are settling on the trees after mating, as mentioned above. Such numbers have been relatively small when large numbers of beetles have been present on trees in close proximity to a light.

On one occasion 300 beetles from a morning flight were marked and released. They were not present in following flights and there was one doubtful record of a single individual seen dead on the ground some three weeks later, and at a distance of about 10 chains from the point of liberation.

(*h*) *Feeding.*

Some hundreds of adults have been dissected to check on sex and egg numbers. In all cases the gut was empty. Damage to trees has not been observed. Emerging beetles have large 'fat-bodies' and it is concluded that they do not need to feed, all feeding taking place in the larval stage and sufficient reserves being stored to mature the eggs.

(*i*) *Sex Ratio.*

Small samples have not varied significantly from a 1 : 1 sex ratio. (*Table* 2)

(*j*) *Longevity.*

From data available it can be stated that males and females have a similar longevity of about 30 days.

Five females collected on the 22nd September, 1962, died after 38.5 days (s.e. 5.5) and 16 females collected on the 27th September, 1962, died in 26.1 days (s.e. 2.7). This suggests that females emerging on different days during a period following heavy rain die off at about the same date and possibly that the earlier emerging females may live longer still. Ten males taken in the same period lived 33.3 days (s.e. 3.2).

(*k*) *Fecundity.*

Each female produces about 16 eggs of which 13 are deposited. The largest egg load carried in a single female was 38. There is an indication of a fall-off of egg numbers late in the season.

Some 130 females were collected and examined, and 23 were studied in individual

Table 2.—**Counts of males and females of *Lepidiota vogeli* in samples taken at Aiyura in 1962. Females were dissected and eggs counted. About 20 per cent. of eggs are not deposited by females.**

Date.	Sample.		Eggs per Female.		Collection Data.
	Males.	Females.	Mean.	St. Error.	
21.8.1962	5	5	12.5	4.25	8 p.m. Light.
18.9.1962	3	17	....	....	x Soil. Eggs small; Fat bodies large.
22.9.1962	32	29	15.8	1.2	Evening Flight.
22.9.1962	....	5	19.8	4.5	Evening Flight (Held in pots).
24.9.1962	29	30	15.0	1.3	Evening Flight.
27.9.1962	....	16	10.4	1.6	Evening Flight.
1.10.1962	14	4	9.5	4.5	Morning Flight.
18.10.1962	1	6	17.8	7.0	8 p.m. Light.
22.10.1962	10	17	....	....	U.V. Light (Eggs not examined).
3.11.1962	2	6	8.1	2.7	Evening Flight.
4.11.1962	15	15	7.0	1.8	Morning Flight.
21.11.1962	4	6	....	....	Evening Flight.

pots of soil. Results are given in *Table* 2. Five females taken on the 22nd September, 1962, carried 19.8 eggs (s.e. 4.5) per female, of which 90 per cent. were deposited. Sixteen females of 27th September, 1962, carried a mean of 10.4 eggs (s.e. 1.6) of which 80 per cent. were deposited.

(*l*) *Time of Egg Deposition.*

Females in pots in the laboratory deposited 60 per cent. of all eggs on the 8th to the 10th day after mating, and a further 35 per cent. in the next eight days. Of the 23 females observed only one deposited eggs after the 32nd day.

(*m*) *Egg laying.*

Eggs are deposited singly about three-quarters of an inch apart in cells about one-third of an inch in diameter in a wandering column of compressed soil. Eggs are found at depths of 4 to 7 in. In the laboratory the depth of laying was controlled by compacting the lower layers of soil in the pot before the beetle was put in. In a pot compacted from the top only, the eggs were at the bottom of the tin. If bottom layers were compacted before the remainder of the soil was put in, the eggs were placed at the top of this layer. It can be assumed that in the field the depth of egg laying is controlled by the depth of any impacted layer less than about 8 in. deep in the soil.

2. *The Egg Stage.*

(*a*) *Duration.*

Eighty eggs from about ten females were kept on moist soil in plastic containers. Larvae emerged on the 28th to the 31st day after oviposition.

(*b*) *Distribution.*

Egg numbers are generally higher in areas covered by low grass or herbage and areas of cut or grazed grass have higher populations of larvae initially than areas where the grass is long. The grass species is of less importance. Areas of grass seem to be preferred to weeds or other plants. Development of larval populations in cultivated areas (Peanuts and Strawberries) has been noted but may have resulted from eggs deposited before the crops were planted. High populations also develop in certain areas of *Themeda* and other grassland species where the cover is tall.

3. *The Larval Stage.*

(*a*) *Seasonal Occurrence.*

Larvae can be found six weeks after the first flights of females. The greatest density is reached in November, when most of the eggs have hatched and larval mortality is still low. These are predominantly first stage larvae, the second stage making their appearance in December. The first and second stages are relatively short and by January, the majority of larvae are large and in the third stage. These remain for about six months before becoming comatose as prepupae. (*Figure* 3 and *Plate* II)

(*b*) *Distribution.*

This is determined by the effect of the dominant plant of the area being super-imposed on the distribution pattern of the eggs. Few larvae from eggs deposited in areas of Kikuyu grass survive beyond the first stage and practically none beyond the second.

In areas of suitable food species the distribution is patchy in any one year. At Goroka in 1960, an area in front of the Department of Agriculture, Stock and Fisheries Office was very severely attacked. In the following year, the population was very low in this area while a lawn some 200 yd. distant carried a heavy population of larvae. Reasons for this type of distribution are not known but a heavy attack in one year results in death of grass, weed development, or young grass with relatively sparse roots. These types of cover are incapable of carrying a heavy population of larvae, but other factors are thought to be involved.

(*c*) *Feeding.*

The larva is mainly a grass root feeder although roots of other types of plants can be attacked. Young larvae are found at depths of 4 to 7 in. and apparently feed at random in this stratum. High populations of second or early third stage larvae are usually found closer to the surface. It is thought that depletion of the supply of roots at lower levels is followed by a progressive upward movement. Large third stage larvae may be found in the top 2 in. of soil by the end of January, if populations are high. Since the supply of roots is related to the age of the sward and the plant species, these two factors determine the amount of food available, and so the depth of feeding in the later stage.

(*d*) *Host Plants.*

Attack has been noted on a number of species of grasses at Aiyura and Goroka. 'Thurston Grass', Blue Couch *Digitaria didactyla*, and Carpet Grass *Axonopus compressus*, are all severely attacked. Blue Couch can withstand heavier populations than the other two. Heavy populations have not been found in Common Couch *Cynodon dactylon*. Kikuyu Grass *Pennisetum clandestinum* is notably unsatisfactory as a host plant. The Strawberry is readily attacked, as is the Peanut, but this may result in part from residual populations in the soil prior to planting.

Kangaroo Grass *Themeda australis*, is a satisfactory host and is probably the natural food plant.

(*e*) *Effect on the Host Plant.*

Since the population varies through the season the January population has been taken as a useful measure. The effect on the grass depends very much on the age and vigour of the stand of grass. A vigorous, well developed sward of Blue Couch requires at least four larvae to the square foot to cause death. Three larvae per square foot will kill out Thurston Grass and Carpet Grass The effect on Kangaroo Grass, being tussocky in growth, is difficult to estimate. In one case a stool about a foot across had ten larvae under it. Nearly all the roots had been cut off but there was a vigorous development of new roots from the crown and this particular stool survived.

Larvae may be present in such numbers that the grass runners are destroyed, but if feeding does not reach within about half an inch of the surface of the soil, new roots are produced and the grass will survive. It is quite common for the roots to be cut to such an extent that the grass forms a loose carpet over the churned up soil beneath. Such areas will survive (if not disturbed) except in the occasional years when rains fail in late summer, or conditions in May and June are particularly dry and sunny. Under such circumstances runners dry out in patches. When rain falls in the following spring weeds commonly take over.

(*f*) *Movement.*

Larval population counts were made at Goroka in January, 1961, in an area where patches of grass had been killed. In the bare areas up to ten larvae per square foot were present. On the margins of the green areas up to 16 were present. Averages of 6 and 7.5 respectively for these areas were not significantly different due to gross variation, but it can be safely assumed that an area with 16 larvae to the square foot could not have been supporting this population for a long period of time. It seems that they had moved into the area. It is concluded that there is some outward movement from heavily infested areas. This would result from random burrowing of hungry larvae, some individuals reaching the green margin in the process. Samples in green areas a few yards from their margins averaged only one per square foot, which was significantly lower than the above populations.

4. *The Prepupa and Pupa.*

Fully fed larvae move downwards in May and June, and excavate cells at depths of 5 to 9 in. The depth is less where the subsoil is hard or stony. The prepupal period lasts a few weeks, when the last larval skin is shed to reveal the pupa. The pupal stage is relatively short, also lasting less than four weeks.

The adult is ready to leave the cell in about two weeks after shedding the pupal skin but the time of movement from the ground depends on outside conditions. All data on these final stages are based on field observations.

NATURAL CONTROL (MORTALITY) FACTORS.

1. *Survival of Adults.*

Adults have been found dead in the pupal cell. Some have been affected with the Green Muscardine Fungus, *Metarrhizium anisopliae* while others have died for unknown reasons.

Adults are eaten by man, being collected in large numbers at the time of the main flights. This has been described by Brass (1964).

A large species of spider takes a toll, the beetles being entangled in the webs on the taller trees.

2. *Survival of Eggs.*

Fungal attack was noted in the laboratory when eggs were crowded in covered containers of damp soil. All clean eggs hatched and it is considered that field emergence of larvae would be close to 100 per cent. No predators are known.

3. *Survival of Larvae.*

(*a*) *Host Plants.*

The importance of food plants has been discussed previously. The species of plant available has a marked effect on the survival of young larvae. The stage of development of the sward may regulate the nutritional level of larvae.

(*b*) *Parasites.*

Two larval parasites are known ; one is a *Scoliid* Wasp and the other an unidentified mite.

I. *Campsomeris formosa* Guer. Family : *Scoliidae* : Szent-Ivany (1958) recorded two species of *Campsomeris* wasps believed to be parasitic on *Lepidiota vogeli*. An early Departmental report describes *C. formosa* but not *C. tasmaniensis* Sauss. attacking larvae caged with these two species of wasps.

(The *Campsomeris* genus of wasps belongs to the Family *Scoliidae*, the Hairy Flower Wasps. They are bright yellow and black in colour and the above species are larger than a honey bee. They commonly feed on nectar in *Eucalyptus* and *Poincettia* flowers on warm sunny days. The males are less robust and have long antennae. They may be seen on flowers or numbers may be seen flying back and forth a few inches above lawns. The two species are very similar. The related *Scolia* species are black, but of very similar form and habits and are parasitic in larvae of at least one *Dynastid* Beetle of the genus *Papuana*.)

On one occasion, at Aiyura in August, parasitised larvae and one parasitised pupa of *L. vogeli* were dug up along with a female wasp. This female *C. formosa* parasitised further larvae in the laboratory. The wasp eggs hatched but the larvae did not survive. The egg was placed ventrally on the larvae, and was dorsal on the pupa observed. (*Plate* II) The wasp stung the host and paralysed it prior to laying the egg.

Collections of *C. formosa* have been made at Baiyer River, Minj, Kerowagi, Goroka, Kainantu, Aiyura and Akuna, in the months of August to October, and January to April. Collections were limited but suggest two generations per year. The first, in March, coincides with the occurrence of well developed third stage beetle larvae. The September (second) generation emerges when only small numbers of late host larvae and pupae are present. This would limit the numbers of wasps, and hence the overall effectiveness of the parasite. In general *C. formosa* cannot be regarded as a very satisfactory parasite in the Highlands areas.

One female of *C. tasmaniensis* was taken at Aiyura in September, and Szent-Ivany and R. S. Carne have collected this species at Goroka in October.

II. *Mites* :Examination of larvae encountered in plots at Goroka in early January, 1961, revealed heavy populations of a mite of pale-amber colour, and large enough to be seen with the naked eye.

Counts ranged from 4 to 260 per larva on 43 larvae. The distribution of the mites is in a marked pattern. When few are present they are concentrated on the basal segments of the second and third legs. With larger numbers they may be seen on the first leg, lower down the second and third legs, and in the body folds. With very high populations they are also present in numbers in body folds, on the mouth parts, and around the spiracles.

Mites were more numerous where larvae were plentiful. Twelve large larvae from an area with about four per square foot had 152 mites (s.e. 18) per larva. Fourteen larvae from where the density was about two per square foot had 77 (s.e. 12.5) per larva. Five larvae from an area of grass not showing damage with 1.1/square foot had 38 mites (s.e. 32) per larva. Another area averaged 105 mites per larva. There was a trend in 'mites per larva' related to the density of larvae. On the larvae examined there was an increase of about 40 mites per larva for each additional larva per square foot.

This trend in mite population may be related with mites breeding on varying larval populations in the previous year ; or with movement of mites from larvae dying-off in a high population of larvae, and concentrating on the remaining larvae.

Mites from larvae which died in pots in the laboratory moved actively through the soil and evidently attached themselves to live larvae. Free mites are few in the soil, particularly in the vicinity of live larvae.

Twenty-five larvae were graded according to mite load and placed in pots with established grass and examined two months (March), and six months later. At the first examination most larvae were active but were yellowish in colour, suggestive of approaching the prepupal stage. This development was abnormally early and may have been due to laboratory temperatures. Some beetles emerged before the second examination. In July, some dead beetles were present along with decomposed pupae and empty skins of dead larvae. Larvae infested with over 200 mites did not develop. There was an indication that large larvae with less than 80 mites had a greater chance of full development than those with more than about 80.

Effects on small larvae have not been investigated but in areas of heavy infestation the loss of hosts by death or emergence results in a high population of free mites. When larvae hatched from eggs deposited by the emerged beetles they would become infested. Such infestation has been observed in the field. Populations would also increase on late-emerging insects, tending to reduce their numbers.

(*c*) *Predators.*

Larvae are destroyed by man, pigs, bandicoots, birds of prey and fowls.

I. At Aiyura areas of grassland are dug up in April and May, by the women who collect the larvae for food.

II. 'Rooting' by pigs is common in re-growth and grassland areas in the general vicinity of villages and hamlets. In some years the animals concentrate on particular tracts of grassland. At Henganofi, in 1961, an area of several acres on the side of the top of a ridge about 600 ft. high was denuded in this way. Only the few scattered hard shrubs remained. A much smaller area on a ridge near the Tairora Creek on the Aiyura-Kainantu road was similarly damaged by pigs in the following year. Pigs find larvae in their usual rooting in grassland and it is thought that some areas were particularly attractive because of the presence of high populations of larvae. The activity of pigs results in uneven ground which holds surface water and contributes to the landslide development common in the Kainantu area ; the characteristic conchoidal form of these slips influencing the topography of the grassland areas.

III. Bandicoot foraging holes are occasionally seen in grub-infested areas where they apparently feed on some larvae.

IV. A Fork Tailed Kite *Milvus migrans*, shot down at Aiyura, contained 11 large *L. vogeli* larvae. This large brown hawk, common in the Highlands at certain times of the year, follows fires and frequents areas of cultivated land. On the occasion at Aiyura there had been no ploughing within eight miles of the collection site and the source of the larvae is not known.

V. Fowls readily scratch out larvae in severely damaged lawns, removing any grass remnants in the process.

(*d*) *Diseases.*

1. The Green Muscardine Fungus, *Metarrhizum anisopliae*, has been identified from the *Lepidiota* at Baiyer River and has been seen on large larvae at Aiyura. Incidence appears to be low. The fungus appears as a white felted mass over the insect and when spores are produced they are white, turning to a dark olive green in a few days. The spores are clumped and come away in loose irregular masses.

2. When dug from the soil, larvae may appear normal but turn bluish-black in a few hours. This has been regarded as due to physical injury or the effects of the sun. Up to 20 per cent. of larvae have been affected. However, work on the Rhinoceros beetle *Oryctes Rhinoceros L.* sp. suggests that this could be due to a virus disease.

(*e*) *Cannibalism.*

This occurs if larvae are confined in containers or small pots. Only two larvae consistently survived if more were placed in a breeding pot. This corresponded to eight larvae per square foot, and suggests that populations will reduce automatically to a maximum of about eight larvae per square foot in the field. Averages over an area would be below this level and field populations with a mean of more than six large larvae per square foot are not usual or to be expected.

(*f*) *Starvation.*

High populations have been observed early in the year in areas where the food supply has been eaten out. The larvae are probably reduced by cannibalism and movement. Remaining larvae may pupate and produce underfed beetles which deposit reduced numbers of eggs.

4. *Climate.*

The climate of the New Guinea Highlands is mild. In summer, cloud and rain are normal and hot dry weather is not unusual. In winter, day temperatures are relatively high. Night temperatures do not reach freezing point in areas where *L. vogeli* is common.

The only marked effect of weather is on the timing of the first spring flights.

General effects of climatic conditions on populations have not been observed.

POPULATION CHANGES.

1. *Annual Cycle.*

(*a*) *Changes.*

The relative abundance of the various stages is illustrated in *Figure* 3 and has been discussed previously in the sections dealing with each stage. The change in numbers may be made clearer by considering the development of a population from eight females. One hundred and four eggs will be produced. One hundred larvae are to be expected and 25 of these will survive to become prepupae. A further five insects die in the prepupal and pupal stages, leaving 20 to develop into beetles capable of mating. Of these, four are lost and in the final 16 half are males and half are females. The original number—eight females—remains and the population is stable.

(*b*) *Determining Factors.*

In the field this balance occurs but rarely. Abundance changes as a result of the varying effects of the mortality agents previously listed. Observations indicate that the most important of these operate against the larval stages.

The total area of suitable food plants determines initially the number of first-stage larvae surviving. In areas where larval density is high the quality (age and vigour) of the food plant sward becomes important, and both cannibalism and starvation may become operative.

Predators are more active when numbers of the insect are high, both against larvae and adults, and disease incidence may rise. Mites are the most obvious of the parasites and, although their effect on large larvae is limited, they may be responsible for the death of small larvae. The soil of areas carrying an abundance of grass-grubs would be provided with such a mite population in the following season.

2. *Perennial Cycle.*

(*a*) *Changes.*

Reliable information is not available on flights before 1949. Beetles were reported in that year and were probably from the last of a series of flights over a few years. There was a peak in 1952, 1953 and 1954, when the Goroka Airfield was seriously damaged. In 1960, 1961 and 1962, beetles were again very abundant. These records suggest a cycle of about seven years. If this is a fact a build up can again be anticipated about 1966, with a peak in the years following. → 1973 → 1980.

Peaks are spread over three or four years. This results from a patchy distribution of larvae. Areas of a few square chains may carry peak populations in one year, while adjacent areas may be affected one, or two years later. In many parts of an area larvae may be present for the whole period without the development of acute affects on the grass.

(*b*) *Determining Factors.*

Where the sward is severely damaged weeds tend to take over and larvae in the following year are few due to reduced egg deposition or larval mortality. In areas of chronic infestation development of mite populations may be the operative factor.

In each case the factors leading to the increase of mortality are governed by the levels of the populations in previous years. There can be no new development of high insect numbers until these factors are eliminated—grass replaces weeds, and mites (or other agents) are rendered inactive by the absence of the host.

3. *Populations in Lowland Areas.*

(*a*) *Incidence.*

Mass flights have been neither observed nor reported. Beetles have been collected from late December, to early February.

The populations of the lowlands may be 'normal', and the mass flights of the Highlands an 'abnormal' development, the food supply of the area being the basic cause.

(*b*) *Possible Factors.*

Of the agents active in the Highlands the *Campsomeris* wasps offer the best possibility of explaining the occurrence in the lowlands. Adaptation to conditions at lower altitudes could result in the apparent ineffectiveness of these parasites in the Highlands.

Alternatively, two ecological forms or even sub-species of *L. vogeli* may be present.

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ACKNOWLEDGEMENTS.

Assistance was received from members of the staff at the Highlands Agricultural Experiment Station, Aiyura, and officers of the D.A.S.F. staff at Goroka and Baiyer River. Dr. A. R. Brimblecombe, Miss K. Barnard, Mr. N. Heather and Mr. W. Yarrow of the Entomology Branch, Department of Primary Industries, Brisbane, and Dr. T. E. Woodward of the University of Queensland, have made most valuable comments on the earlier draft of this paper. The author is most grateful for this help, and also to Mrs. Jennifer Quinlan, of Aiyura, for the drawing of *Figure* 1.

IDENTIFICATION.

Campsomeris tasmaniensis, C. formosa, and *Scolia* spp. were identified by scientists of the Commonwealth Institute of Entomology and the British Museum (London).

Lepidiota vogeli, *Lepidiota* sp. (Baiyer River), *Papuana angusta*, *Papuana* spp., *Lamprima adolphinae*, and *Xylotrupes* sp. were identified by Dr. E. B. Britton of the British Museum (Natural History) now of Division of Entomology, C.S.I.R.O., Canberra, and Mr. R. W. Pope of the Commonwealth Institute of Entomology, now of the Department of Entomology, British Museum (Natural History), London. The author gratefully acknowledges the efforts and interest of these specialists.

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Control of Lepidiota vogeli *Brenske. The Brown Pasture Scarab of the Highlands of New Guinea.*

J. H. Barrett *

ABSTRACT.

Insecticidal trials were carried out in the field at Goroka and Aiyura using dieldrin, B.H.C., and aldrin. The results indicate effective control with all materials.

Control methods and rates of application are discussed.

INTRODUCTION.

THE biology and ecology of this insect was treated in another paper by Barrett (1966). Control was first attempted by J. J. H. Szent-Ivany[1] and R. S. Carne[1] who established two insecticide trials in Goroka prior to 1955. Szent-Ivany (1958 and personal communication) reported that populations of larvae decreased naturally and before satisfactory experimental results could be obtained. Barrett (1966) indicates that this fall-off in numbers of young larvae is normal at the time of the year when the trials were carried out and also when Kikuyu Grass *Pennisetum clandestinum* is the host plant.

For a number of years after 1955, *Lepidiota* grubs were scarce and further trials were delayed until 1961.

INSECTICIDAL TRIAL—GOROKA.

Site.

An area of Blue Couch, *Digitaria didactyla* was selected on the lawn in front of the old residence of the Animal Industry Station. The area had been cut regularly; grub damage was severe in some parts. The grass on some sections was becoming yellowish in colour and in small patches it was loose and dried out as a result of larval activity. A larval count, made as a preliminary to the application of insecticides, revealed a grub population of between five and six per square foot.

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Trial Design.

A 7 x 4 randomized block was used, each plot being 3 metres by 4 metres in size; area—0.003 acres.

Treatments.

A. Dieldrin (15 per cent. emulsion) at 4.25 lb. act. const./per ac.

B. Dieldrin (15 per cent. emulsion) at 10.6 lb. act. const./per ac.

C. No treatment.

D. BHC (10 per cent. dust) at 10.0 lb. act. const./per ac.

E. Aldrin (40 per cent. emulsion) at 1.9 lb. act. const./per ac.

F. Aldrin (40 per cent. emulsion) at 4.75 lb. act. const./per ac.

G. Water only.

Method of Application.

Treatments A, B, E and F were applied in water at the rate of 2 gal. per plot (= 660 gallons per acre) through a garden watering can, and G similarly. Treatment D was applied with a hand duster. For each treatment the plot was marked off into lanes with twine, and approximately half the material applied. Lanes were then laid out at right angles to the first series and the remainder applied. Progressive treatment of narrow strips ensured a relatively even distribution of insecticide on each plot.

1 Then Entomologist and Agricultural Officer respectively of the Department of Agriculture, Stock and Fisheries.

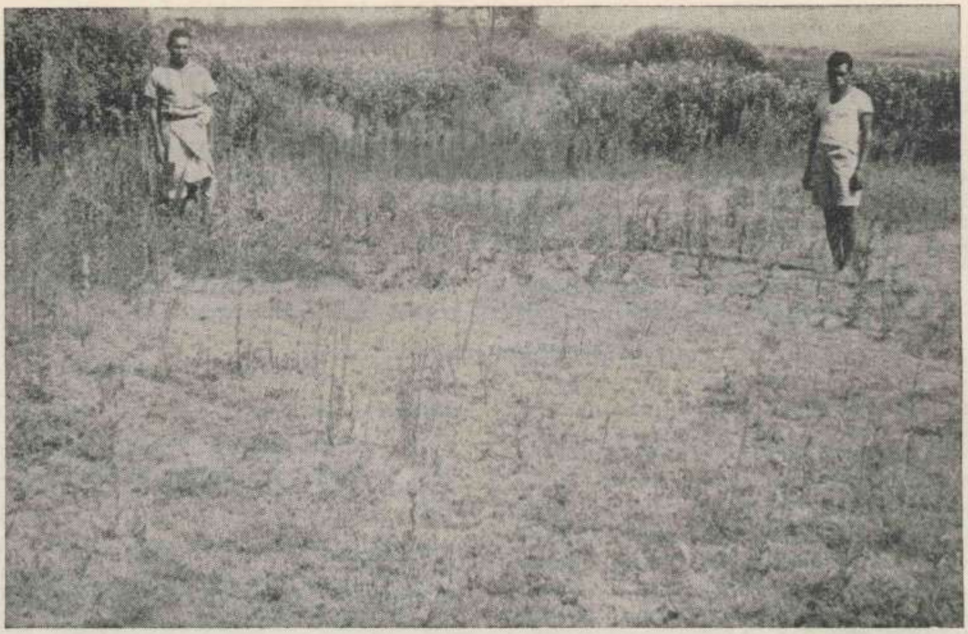

Plate I.—*Lepidiota vogeli* control trial area at Goroka, one and one-half years after the application of insecticides. Central and mid-distant plots have no larvae. Weeds are absent and the grass cover is complete. Strongly developed weeds are seen on the left where one man is standing, and less dense weeds on the right round the second man. Both of these plots have high populations of larvae.

Date of Application.

Treatments were applied on the 3rd February, 1961.

Counting Method.

Areas of 1 sq. ft. were examined at random in each plot; a strip 18 in. wide along the margin being avoided. Examination to a depth of 9 in. was found to be adequate, the soil being dug out with a spade and the numbers of larvae recorded.

Results of Counts.

Treatment.	Larval Count 2.3.1961 (Total in 16 sq. ft.).	Total Count 10.1.1962 (Total in 8 sq. ft.).
B. Dieldrin 10.6 lb./acre	0	0
A. Dieldrin 4.25 lb./acre	2	0
F. Aldrin 4.75 lb./acre	1	0
E. Aldrin 1.9 lb./acre	5	0
D. BHC 10.0 lb./acre	41	3
G. Water (660 gal./ac.) only	63	26
C. No treatment	64	17

The first count was made four weeks after the application of the insecticides. At the date of the second count 11 months had elapsed and larvae were from the generation of beetles laying eggs about eight months after the insecticides were applied.

The figures were not analyzed.

Treatment D (BHC dust) was not effective one month after application, probably due to lack of penetration. The result in the following year was satisfactory. All levels of dieldrin and aldrin gave a good kill within a month of application and grubs were absent in the following year.

Persistence of Effects.

The trial area was observed in October, 1963, two years and nine months after the treatments were applied. Two generations of larvae had developed since the initial infestation. All treated plots were covered with dense grass, mowing of the area having been discontinued. The untreated areas carried a growth of tall weeds.

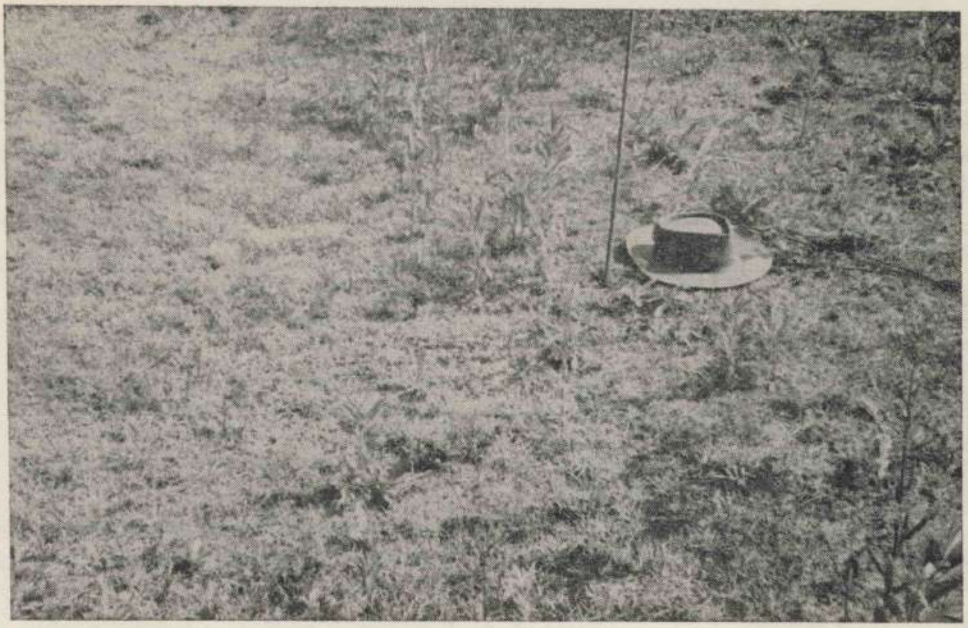

Plate II.—*Lepidiota vogeli* control area at Goroka, one and one-half years after treatment. Grubs have been controlled in the triangular area extending to the left. Weeds (*Erigeron* sp.) and a thin grass cover with some bare soil are visible on the right on both sides of the hat.

Damage to grass by the grubs reduces its vigour and weeds can enter and compete in the sward. This was very clearly seen in the second season of the Goroka trial. Weed growth was so consistently present in untreated plots that the plot plan was marked out in the field. (*Plates* I and II) There was a general correlation between weeds and grub counts. (This point was omitted from the previous paper—Barrett 1966.)

INSECTICIDAL TRIAL—AIYURA.

Trial Design.

The layout was a 5 x 5 Latin square, each plot being 32 sq. yd. in area.

Site.

Restricted areas of infestation made it impossible to use an area of uniform soil and grass cover. The area used was on the lawn of Residence No. 5 at the Highlands Agricultural Experiment Station, Aiyura.

Replication numbers 1 and 2 were on sloping ground with a brown clay soil overlying a lateritic subsoil at 8 to 10 in. The cover was carpet grass, *Axonopus compressus*. Replications 3, 4 and 5 were on a darker clay soil with a clay subsoil. The grass cover was blue couch, *Digitaria didactyla.*

Treatments.

A. Aldrin (40 per cent. emulsion) at 1.2 lb. of active ingredient/ac.

B. Dieldrin (15 per cent. emulsion) at 0.9 lb. of active ingredient/ac.

D. Dieldrin (15 per cent. emulsion) at 2.6 lb. of active ingredient/ac.

E. Aldrin (40 per cent. emulsion) at 2.8 lb. of active ingredient/ac.

C. No insecticide applied.

Method of Application.

All materials were applied in water at the rate of 48 oz. per plot (= 40 gal. per acre) using a 'Fontan' motorized variable volume sprayer. The 7 mm. jet was selected for use on this occasion. To prevent spread of material to adjacent plots, a length of hessian was laid along the outside of the borders of each plot prior to the application of the treatment.

Date of Application.

All treatments were applied on the 14th February, 1962.

Results.

Counts were made in the same manner as in the Goroka trial and details are as follows :—

Date of Count	14.5.1962	17.9.1962	4.3.1963
Total area sampled	100 sq. ft.	50 sq. ft.	75 sq. ft.
Total live insects	144	77	81
Live insects per plot—(mean of log (n + 1) transformation.)			
D. Dieldrin 2.6 lb./ac.	.631	.251	.060
E. Aldrin 2.8 lb./ac.	.620	.260	.396
B. Dieldrin 0.9 lb./ac.	.922	.564	.420
A. Aldrin 1.2 lb./ac.	.827	.715	.797
C. No treatment.	.891	.582	.752
General mean per plot	.778	.474	.485
Variance ratio	3.27 (x)	2.11 (n.s.)	9.19 (xx)
Least sig. diff. 5 per centum	.244	.440	.305
Least sig. diff. 1 per centum	.342	.617	.428
Treatment Differences	B C A D E X X B X X C X X A	A C B E D	A C B E D X X XX A X X XX C X B X E

NOTE.—Counts on the 14.5.1962 and 4.3.1963 were of larvae. Pupae and adults were present on the 17.9.1962.

The above counts were made at periods 3, 7 and 13 months after the application of insecticides. After three months the higher levels of dieldrin and aldrin had significantly reduced the population. At seven months the trend had continued but the sampled area was too small to give significance in the results. In the following year the figures show that dieldrin, at 2.6 lb./ac., under the conditions of this trial, effectively removed the grub population. Aldrin at 2.8 lb. was equal to 1.24 lb. of dieldrin and removed over 50 per cent. of the larvae.

DISCUSSION.

Factors producing some inconsistency in the results of the two trials may be (1) soil, (2) grass cover, (3) volume of solution applied.

The soil variation at Aiyura resulted in differences between replications but the trend of results was towards a reduced effect on the darker clay soil. This soil is most nearly akin to the soil at Goroka.

The grass in both cases was cut a few days before the insecticides were applied, and the amount of material remaining would have been similar in each case.

The volume of water per acre was markedly different in the two trials and this factor is considered responsible for the reduced effects of insecticides in the Aiyura trial. At Aiyura 2.8 lb. of aldrin in 40 gal. of water per acre gave a similar control to 1.9 lb. of aldrin in 660 gal. of water per acre in the trial at Goroka. It is considered that relatively high volumes of water are necessary to ensure that the insecticides are carried through the grass and close to, or on to the surface of the soil. The delayed effect of BHC when applied as a dust may also be due to poor initial penetration of the insecticide.

The relative effectiveness of aldrin and dieldrin is indicated in the second trial where 0.9 lb. of dieldrin gave a control approaching that of 2.8 lb. of aldrin per acre.

CONTROL.

Necessity to Apply Control Measures.

In the previous paper, Barrett (1966) discussed the effect of larvae on various host plants. Populations of over three to four larvae per square foot, depending on the species, age and vigour of the plant, are capable of causing marked damage to grass. (*Plate* III)

Since the population of larvae falls as the season progresses, a set time of counting is necessary and the above figures apply in early January.

Relatively large spring flights of beetles will indicate the possibility of sufficient numbers of larvae to cause damage and areas of grass, if of a susceptible species, should be examined in early January.

Sampling to Determine Larval Population.

Presence of larvae in areas which it is desired to protect may be determined by counting the numbers in sampling holes. Each hole must be 1 ft. square, and dug to a depth of 6 to 8 in. Larval populations are variable, hence a minimum of 10 holes *or* 40 larvae is required to give a dependable estimate of the population in an area. Where an area extends over a number of acres, more than one series of sample holes is necessary.

Control Materials.

Complete removal of larvae can be expected following the application of—

(*a*) *Aldrin* as a 0.05 per cent. solution in water at the rate of 1 gal. to 12 sq. yd. (2 lb. of active constituent per acre) ; or

(*b*) *Dieldrin* as a 0.025 per cent. solution in water at the rate of 1 gal. to 12 sq. yd. (1 lb. of active constituent per acre) ; or

(*c*) *BHC* as a 10 per cent. dust at the rate of 4 oz. per 12 sq. yd. (10 lb. of active constituent per acre).

Plate III.—*Lepidiota vogeli* damage, Goroka, in the area adjacent to the trial. The grass roots have been eaten off an inch below the ground and the mat of grass is shown after being broken and rolled back to leave loose grub-turned soil. (Note matchbox)

Application.

Grass on the area to be treated should be cut as short as possible and the cuttings removed prior to the application of the insecticides.

It should be noted that the above rates are the maximum necessary to give good control within four weeks of application. Control will persist for at least two seasons and some effect can be expected up to the fourth year. This will cover one cycle of abundance of the beetle, as indicated in the previous paper by Barrett (1966).

Since low populations of larvae may beneficially affect 'sod-bound' stands of grass by removing old roots, it may not be desirable to establish complete control. In this case a reduction in the above rate of application should be considered. The above trial results suggest that a reduction of up to 50 per cent. could give a sufficient control. In the case of BHC dust an even greater reduction in the rate of application may be satisfactory.

The choice of materials should be based on the relative cost per unit area of the treatment. In the above trials the readily available emulsion formulations of aldrin and dieldrin were used. For the treatment of large areas water application may be inconvenient. Aldrin and dieldrin are both available as dusts but these formulations were not used in the trials. Similar results could be anticipated at equivalent rates of application per acre, but the rate of initial kill may be a little slower.

Prevention of Damage.

Areas planted to grass in years of beetle prevalence may be conveniently treated at planting. This will allow more effective penetration of the insecticide into the soil and prevent damage to the sward before it becomes established.

Availability of Materials.

Diminishing acceptability of the chlorinated hydrocarbons is evident for the treatment of pastures, and chemical companies are reducing the production of this type of chemical. At present no alternative materials of acceptable toxicity and persistence are available. While there is no great hazard in the use of aldrin and dieldrin in non-grazed areas these materials may become less readily available and further work may be necessary to establish new methods of control.

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ACKNOWLEDGEMENT.

Mr. J. Lewis of the Animal Industry Branch kindly allowed the use of his lawn for the work.

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Book Review.

FARM MACHINERY.

H. G. HARRIS, T. B. MUCKLE, J. A. SHAW. OXFORD UNIVERSITY PRESS, 1965. 240 pages. Price in Australia $4.12.

The book compresses into its relatively small compass a wealth of information that would be of value to the student of agricultural engineering.

Whilst it has been written to assist students engaged in agricultural courses held in Great Britain, the subject matter will appeal to students engaged in similar pursuits in other parts of the world.

Dealing, as it does, with the fundamentals of physics and the basic rules of engineering, the book goes on to apply these rules to the mechanization of agricultural production.

The book is recommended not only to the student but also to the Principals of Colleges for inclusion in the libraries of such institutions where agriculture forms part of the curriculum.

A. W. JEFFORD.

Port Moresby: V. P. Bloink, Government Printer.—18885/11.66.