INSECTS ASSOCIATED WITH THE COCO-NUT PALM.

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INTRODUCTION.

In this and subsequent articles it is intended to deal with all insects which have been found in direct association with the coco-nut palm in this Territory. Much of the information has been given in previous articles, but now all available data, including sections that have not been previously published, are gathered together in this series.

Some of the insects listed are of considerable economic importance, while others are only of such status for a relatively short period during the growth of the palm, or, in some cases, the insects apparently do little or no damage, although found commonly on the palm.

A full account of the research work carried out on the problem of the "Coco-nut Tree-hoppers", *Sexava* spp., over the period 1930-38 is now presented, and as this insect is the most serious pest of coco-nuts in this Territory, it will be considered first.

In the following list of insects found in association with the coco-nut palm, the species are grouped in accordance with that portion of the palm with which they are associated:—

INSECTS ASSOCIATED WITH THE COCO-NUT PALM IN THE TERRITORY OF NEW GUINEA.

Foliage and Mid-rib of Fronds—

ORTHOPTERA ..	*Tettigoniidae* ..	*Sexava novae-guineae*, Branc. *Sexava nubila*, St.
	Gryllidae ..	*Cardiodactylus novae-guineae*, Haan.
COLEOPTERA ..	*Hispidae* ..	*Promecotheca papuana*, Csiki. *Brontispa froggatti*, Sharp. *Brontispa simmondsi*, Mlk. *Brontispa longissima*, Gestro. *Oxycephala papuana*, Gerst.
	Curculionidae ..	*Rhabdocnemis obscura*, Boisd. *Diocalandra frumenti*, F.
RHYNCOTA ..	*Coccidae* ..	*Aspidiotus destructor*, Sign. *Mytilaspis* sp. *Chionaspis* sp.
	Aleyrodidae ..	*Aleurodicus destructor*, Mackie. *Aleurocanthus cocois*, Cork.
LEPIDOPTERA ..	*Hesperidae* ..	*Telicota bambusae*, Moore.
	Lyonetiidae ..	*Decadarchis ophiocypha*, Meyr. *Opogona Taochroa*, Meyr. *Erecthias flavistriata*, Wals

Spathe—

Rhyncota ..	*Pentatomidae* ..	*Axiagastus campbelli*, Dist.
Lepidoptera ..	*Pyralidae* ..	*Tirathaba rufivena*, Walk.
Coleoptera ..	*Dynastidae* ..	*Xylotrupes gideon*, L. *Scapanes grossepunctatus*, Sternb.
	Curculionidae ..	*Meredolus cocotis*, Mshll. *Barystethus cleutsi*, Heller.
	Cetonidae ..	*Lomaptera batchiana*, Thoms. *Panglaphyra nigerrima*, Voll. *Panglaphyra douboulavi*, Thoms. *Poecilopharis emilia*, White. *Ischiopsopha wallacei*, Thoms.
	Lucanidae ..	*Eurytrachelus egregius*, Moll. *Metopodontus bison*, Ol. *Cyclommatus speciosus*, Boid. *Dorcus intermedius*, Gestro.
Hymenoptera ..	*Apidae* ..	*Halticus* sp. on blossom.
	Formicidae ..	*Oecophylla smaragdina virescens*, F. in head of palm.

Trunk, Head of Palm and Bole—

Coleoptera ..	*Dynastidae* ..	*Xylotrupes gideon*, L. *Scapanes grossepunctatus*, Sternb. *Trichogomphus semmilinki*, Rits. *Papuana laevipennis*, Arr. *Oryctoderus nanus*, Arr.
	Curculionidae	*Rhyncophorus papuanus*, Kirsch. *Rhyncophorus schach*, F. *Sparganobasis subcruciata*, Mshll.

The major pests in the insects listed above are—

Foliage—

Sexava novae-guineae, Brancs.
Sexava nubila, St.
Promecotheca papuana, Csiki.
Brontispa spp.

Trunk, &c.—

Rhyncophorus spp.
Papuana laevipennis, Arr.
Sparganobasis subcruciata, Mshll.
Xylotrupes gideon, L.
Scapenes grossepunctatus, Sternb.
Trichogomphus semmilinki, Rits.

SEXAVA SPP. (COCO-NUT TREE-HOPPERS).

Outside the Territory of New Guinea, the only record of *Sexava* as an economic pest is in that portion of the Netherlands East Indies, bounded by the coast of Dutch New Guinea, the Aroe Islands, Amboina, Boeroe, Soela Islands, Halmahera and Talaud Islands; the species recorded are *S. nubila* and *S. coriacea*. There are portions of this area in which the pest seldom, if ever, assumes serious proportions, and there are others in which it is of definite economic importance. Even in the worst infested areas there is a period of severe attack followed by a period of very slight activity.

In the Territory of New Guinea, *Sexava* spp. are fairly generally distributed, with the exception of the Kieta District (the northern end of the Solomon Island group), where they are as yet unknown. In some districts, or even portions of districts, they are always present to a slight extent, but seldom, if ever, cause any material damage to the palms, while there are others in which they periodically cause severe defoliation, resulting in loss of production for one and a half to two years. It must, however, be stated that in the latter cases, when the palms do recover and come into bearing again, the crops carried are very heavy ones; unfortunately, there are no figures available to compare the actual loss of production during the infested period with the increased crop after recovery.

As a general rule, the records show that *Sexava* infestation is always worst, and of most frequent occurrence, in areas in which no regular dry period occurs during the year, this factor causing desiccation of eggs and also very adversely affecting the first instar nymphs in particular.

In the Territory of New Guinea two species are recorded, *Sexava nubila*, St. and *Sexava novae-guineae*, Brancs., the former occurring on New Ireland, New Britain and in the Madang District and New Hanover areas, and the latter in the Manus District and on New Hanover.

The adults and nymphs are essentially arboreal in habit, living in the head of palms, where they shelter on the undersurface of the pinnae of the fronds during the day; they are able to cling very firmly to the foliage, but are often dislodged by high winds. Feeding usually occurs at night, but on dull days it may be observed during the afternoon.

In 1931 detailed field research was instituted into the problem of *Sexava* on coco-nuts with the appointment of an Assistant Entomologist, who was first stationed in the Manus District, the worst infested "hopper" district in the Territory; the field laboratory was later moved to New Hanover, then to the Arawe District of New Britain, and finally back to Manus.

In 1933 the senior author was sent to Amboina, in the Netherlands East Indies, where three egg parasites of *Sexava* spp. had been recorded by Dr. Leefmans. These parasites were *Leefmansia bicolor*, Waterst., *Doirania leefmansi*, Waterst., and *Ooletrastichus dubius*, Waterst. The first of these had been reported by Leefmans as being the most promising, and a satisfactorily large colony of it and a smaller one of *D. leefmansi* were bred in Amboina, and successfully brought by direct transport to Manus, where breeding and study of life-history, &c., was immediately begun. At this time, the only egg parasite of *Sexava* known in this Territory was *Doirania leefmansi*, Waterst., which had been bred from eggs collected on New Hanover by the senior author in 1930.

The rate of increase of population of *Sexava* in any area, is relatively slow, as shown by the very long life cycle and manner of breeding. This insect never occurs as a huge swarm in a similar manner to the locust plagues in many parts of the world. On one plantation kept under regular observation for more than twelve months, there was a heavy infestation in April at one end of the plantation, and by November of the same year, the pest had spread over a considerable portion of the whole area, but had nowhere become serious, while the portion at first severely attacked was then showing definite signs of decrease in activity of the pest, new foliage on the palms showing little or no signs of feeding.

Life-history and Habits.

The Egg.

The eggs are always deposited singly, although several may be found close together, as though laid in succession by the one female; they lie, micropilar (head) end upwards, just under the soil surface or to a depth of half an inch. When freshly deposited, they are a deep biscuit colour with flattened sides; the colour deepens to dark brown and the sides swell out as development proceeds. The eggs at first measure about 9 mm. in length, increasing to 11 mm. before maturity. In some parts, there are considerable numbers of eggs deposited in the fibre in the crown of the palms, and in the epiphytic growths on the trunks of the palms; this is most prevalent on New Hanover, and to a slightly less extent in the Manus District. When the infestation is severe, eggs may also be found in the rotting bases of fronds, in coco-nut skins, rotten logs and amongst palm roots lying above ground at the base of the palms.

In the plantations, oviposition apparently always takes place at night, but where the insects are caged up in the laboratory, this act may occur during the day. In the field, the sites most favoured for deposition of eggs are bare surfaces of moist, loosely compacted sandy soil, dry ground being avoided. The orientation of the egg in relation to the surface of the ground does not necessarily affect the emergence of the baby "hoppers".

The period for the eggs to reach maturity shows considerable variation, ranging from 45 to more than 100 days, although the majority of nymphs emerge in 45 to 60 days from deposition. From a large series of observation, the average number of eggs laid by a single female in her lifetime has been 30, while as many as 49 have been recorded.

With eggs laid in cages, the percentage of fertility (determined by dissection) has been about 91, with a percentage of hatching of 69 to 86; eggs collected in the field over the same period gave percentage of fertility about 76, and the hatching percentage about 74.

The eggs can withstand a very wide range of abnormal conditions without entirely losing their fertility. Eggs were kept in very dry soil for 110 days, and then the soil was moistened; within ten days after watering, approximately 40 per cent. of the eggs yielded normal nymphs. In plantations, however, where not only dryness but heating of the soil occurs a much heavier mortality by desiccation is found to take place. Eggs kept in moisture saturated, but drained, soil, gave a normal percentage of hatching.

Eggs laid by the one female on the same night usually mature at about the same time, but those laid on different, even successive nights, show wide variations in reaching maturity.

In order to determine the danger of dispersion of the pest by birds, feeding on female "hoppers" with mature eggs in the ovaries and passing these in the faeces, a number of dissections were made, and eggs apparently ready for deposition were incubated in the ordinary way, using others separated from soil in breeding cages as controls; in no case was a single nymph bred from the former.

The Nymphs.

When the egg reaches maturity, the shell splits along the dorsal ridge for about one third of its length, and then at right angles to this line for about two-thirds of the circumference, thus freeing the vermiform larva, which pushes its way to the surface and sheds its skin; these may be seen on the surface of the soil in emergence jars in the laboratory, although not so readily noticed in the field. The nymphal moult then takes place immediately. The head and thorax are freed first, and by twitching of the legs and body the nymphal skin is gradually cast off backwards; the antennae may still be contained in their sheath at this stage, but these are freed by the insect passing them slowly through the mouth parts by bending the head downwards and then backwards; this portion of the operation occupies about three minutes. The antennae are at first flaccid, but within one minute of being freed, they harden and are capable of normal movement. The full emergence occupies about five minutes. Emergence normally takes place in the early evening, the nymphs commencing the ascent of the palms the same night.

Development of the nymphal stages takes place by a series of moults of which there are six or, in some cases, seven, in the males, and seven in the females; the act of moulting always occurs at night. Two types of male nymphs were observed during the research work carried out at Manus, one having six instars, and the other seven; the former have been called "micropterous" and the latter "macropterous". The macropterous males, in the fifth instar, develop wings and elytra which reach back over the third abdominal tergite, the elytra being superimposed on the wings. The micropterous males, in the fifth instar, only have small wing-buds which do not reach back over the abdominal tergites, and which are situated one in front of the other. In the sixth instar, the micropterous type attains a development similar to that reached by the macropterous type in the fifth instar while the latter type develops much larger wings and elytra, and corresponds to the sixth instar of the nymphs noted on New Hanover.

The average duration of the instars observed at Manus are given in the following table:—

——	First.	Second.	Third.	Fourth.	Fifth.	Sixth.	Seventh.	Total Length Range.	Average.
Macropterous male ..	13.8	13.3	11.5	13.0	14.2	17.7	..	78– 91	83.5
Micropterous male ..	13.8	13.3	11.5	13.0	13.1	14.1	18.1	91–117	96.0
Female	13.8	13.3	11.5	13.0	14.5	15.4	19.4	90–124	100.9

It has been noticed that the numbers of nymphs caught by adhesive bands is much greater for the first two or three nights after rain, and it appears probable that climatic conditions play a considerable part in regulating the rate of emergence of the nymphs from the eggs.

The following description of the various instars, prepared by Mr. N. E. H. Caldwell, B.Sc., formerly Assistant Entomologist in this Department, has proved a satisfactory key for the differentiation of the instars, with the addition of the modification for the macropterous male nymphs given above:—

Males—

1st. Wing rudiments. A very slight differentiation of the sides of the meso- and meta- thorax is discernible.
Genitalia. The hypandrium may be seen as two small buds on the ninth abdominal segment.

2nd. Wing rudiments. Quite easily distinguishable, the elytra being pointed and narrow, and the wings being much broader and still rounded at the tip. Both at right angles to the longitudinal axis of the body.
Genitalia. The hypandrium now takes the form of two prongs directed straight back, with little or no basal portion.

3rd. Wing rudiments. The wings are now pointed, the elytra slightly curved and both slanting slightly backwards, thus making the anterior margins longer than the posterior. There may be a trace of venation on the anal area of the wing.
Genitalia. The hypandrium now definitely consists of a basal portion and a bifurcated portion, of about equal length, the whole reaching about half way along the paraprocts, and with the points of the bifurcated portion incurved.

4th. Wing rudiments. Both wings and elytra now slanting backward markedly. The elytra are decidedly curved, and there may be one or two raised lines thereon. The wings now somewhat longer than the elytra, and the venation is quite distinct in the anal area.
Genitalia. The points of the hypandrium are strongly incurved, and the whole reaches to the divergence of the paraprocts or beyond.

5th. Wing rudiments. The rudiments are now lying along the back, the wings overlying the elytra and both reaching to about a third of the way along the second abdominal segment. Longitudinal veins well developed on the wings, but no cross veins, only two or three longitudinal on the elytra and cross veins can be seen on holding up to the light.
Genitalia. Hypandrium reaches back beyond the paraprocts, and as far back as the cerci.

6th. Wing rudiments. The wings occupy the same relative positions, are considerably increased in size and extend back to at least the end of the third abdominal segment. Both longitudinal and cross venation well developed.
Genitalia. The hypandrium now extends beyond the end of the body and two short styles have appeared, one on the end of each prong of the bifurcated portion.

Females—

1st. Wing rudiments. The same as in the male of the same stage.
Genitalia. Two pairs of buds can be distinguished, one on the eighth and one on the ninth abdominal segments. Under high magnification, the posterior pair resolve into pairs.

2nd. Wing rudiments. The same as in the second male stage, except that the wings are still rounded.
Genitalia. The valves of the ovipositor have increased considerably in size. The lateral and posterior valves can now be distinguished closely appressed in pairs. All valves are the same length, but the anterior pair reach only to the base of the others.

3rd. Wing rudiments. Both pointed, but the elytra not curved, both slanting slightly backward. No venation.
Genitalia. Another marked increase in size, the lateral and posterior valves being more clearly distinguishable, but still closely appressed, while the anterior pair are relatively slightly longer.

4th. Wing rudiments. Both rudiments slanting backward, the elytra somewhat curved, and there is a suggestion of venation on the anal area of the wings.
Genitalia. All the valves are about the same length and closely appressed to each other thus forming a compact organ, which is about one tenth of an inch long, and reaching to the end of the paraprocts.

5th. Wing rudiments. The elytra markedly curved, slightly shorter than the wings, clearly-visible venation on the anal portion of the wings.
Genitalia. The ovipositor had doubled its length and now reaches to about the end of the body.

6th. Wing rudiments. The rudiments are now lying along the back and corresponding to the fifth male stage.
Genitalia. The ovipositor is now about half an inch long, and extends for a considerable distance beyond the body.

7th. Wing rudiments. These are in the same position as in the sixth male stage.
Genitalia. The ovipositor is now an inch or slightly more in length.

One of us (B.A.O'C.) has worked out a further means of separation of the various instars by measuring the hind tibiae, as per the appended table.

IDENTIFICATION OF INSTARS BY MEASUREMENT OF HIND TIBIAE.

(Measurements in 1/40th".)

Instar.	Males.		Females.	
	Range.	Average.	Range.	Average.
First	13–14	13.3	13–14	13.3
Second	17–18	17.5	16–18	17
Third	21–25	21.7	20–22	21.4
Fourth	26–31	27.3	24–27	26.1
Fifth	34–37	35.3	31–35	33.1
Sixth	42–48	44.7	38–44	41.3
Seventh	..	..	48–55	41.3
Adult	55–67	60.5	66–75	70.8

The nymphs, when newly hatched, are always a deep green, but the colour lightens in the second instar; there is usually little or no subsequent change in colour of the other nymphal stages, although it becomes somewhat lighter in tint before moulting. There is a brown variant not uncommonly found but it is not usually abundant; this usually has a plum coloured tinge, the full brown colour not being assumed until the adult stage is reached. Brown and green nymphs may emerge from the one batch of eggs.

Immediately after moulting, the nymph is definitely macrocephalic (head larger than the remainder of the body), and the body tapers down to the pointed telson; as the instar develops, the abdomen increases until just before the moult, when the head is microcephalic. The abdomen is swollen as far as the penultimate segment, which is to be expected, for the last segment bears all the external genetalis in the male, and most of them in the female, and these change in size only at moulting.

The size of the various instars, taken from a large series of measurements, is given in the following table, the measurements being in millimetres :—

Instar.	Males.	Females.
1st	10–17	10–17
2nd	16–20	17–21
3rd	21–26	22–26
4th	25–31	24–30
5th	31–39	35–38
6th	38–46	36–45
		45–53

In insectaries in Rabaul, it was observed over a period of three years that within two weeks of the dry season setting in, all first to fourth instar nymphs on the palms were killed, even although the foliage was sprayed with water.

Experiments were carried out in breeding cages to ascertain the rate of feeding of the nymphs; difficulty was experienced in keeping alive the first four instars in these trials, but figures were obtained for some of the others. Sixth instar males and seventh females, in lots of mixed sexes, ate approximately 3.3 square inches of leaf surface per individual in 24 hours; batches in which female nymphs predominated averaged 3.9 square inches, while with males predominating the amounts consumed were about the same as the first figure given.

Just before moulting, the food consumption is very much reduced, and may even cease for three days, and always for 36 hours before the moult takes place.

In tests on longevity of nymphs without food, it was found that first instar nymphs will live under such conditions for seven days, although some will be dead at the end of four days. Nymphs of the last two stages will live under such conditions for seven days, although some will be dead at the end of four days. Nymphs of the last two stages will live as long as seven days, unless they are almost ready to moult. Under such conditions they will survive longer; one specimen lived for twelve days, when it transformed into the next instar.

There is a heavy mortality in the early instars, especially in the first, which may be aggravated in the later stages of an infestation when all the older foliage has been eaten and only fronds are available. If first and second instar "hoppers" are fed on young leaves, the fuzz along the edges of the leaf apparently clogs the mandibles, and the insects will be observed attempting to clean the mouth parts with the tarsal claws. It is regularly found that if old and young foliage are put in the same cage together with *Sexava* at any stage of development of *Sexava*, that the old foliage will be consumed first, and the young left entirely, or almost entirely, untouched.

From the information already given, it is evident that the life-cycle is a long one, and may be summarized as follows:—

	Days
Egg period	49–107
Nymphal period, male	78–117
Nymphal period, female	90–124

This gives a full cycle for males of 127–224 days, and for females 168–241 days, or 18–32 weeks in the former and 24–34 weeks in the latter.

Adults.

The adult insect is, in most cases, rich green in colour with the distal margins of the wings and elytra brownish; when the wings are folded this marking forms a medium brown line along the back. Otherwise there are no prominent markings. A brown variation in colouration is not uncommonly met with, but is not usually abundant; in these cases the colour is a light chocolate brown, with no markings. These remarks hold good for the species occurring in all districts except New Hanover; most of the "hoppers" in this locality are brown in colour with the elytra marked with darker markings in an irregular pattern, while the inside of the femur of the hind legs is almost black.

The following measurements are an average of a large series:—

	mm.
Body length, male	48–57
Body length, female	57–63
Head to tip of distal extremity of folded wings, male	74–83
Head to tip of distal extremity of folded wings, female	86–92
Antennae, longest	209
Antennae, average	204
Ovipositor	31–33

Emergence of the adult usually occurs at night, the cast skin being consumed by the insect shortly after emergence is completed.

Copulation has been observed in the field shortly before sundown, but is probably most common at night. In breeding cages, females have been observed with the spermatophore attached to the genitalia as early as 5 p.m.; this has also been noticed in the case of females collected in the field between 8 and 9 a.m., but in such cases copulation could have taken place the previous night.

When about to copulate, the male ranges alongside the female, facing in the same direction, depresses the abdomen and passes it underneath that of the female. When the genitalia of both sexes are in juxtaposition, the male extrudes a gelatinous blob containing the semen (the spermatophore), and fastens it to the genitalia of the female, where it remains for a considerable time, probably 12 to 24 hours. The whole act of copulation occupies only a few seconds.

From observations made in the adults bred in captivity and kept in field breeding cages, the period from emergence of adult to copulation has been 10–12 days, while the period from copulation to first oviposition has been 21–31 days. Adults kept in these cages have given a length of life of 35–110 days (average 72.3) for males, and 28–91 days (average 67.1) for females.

The number of eggs laid by a single female in captivity has averaged 40, although as many as 52 have been counted.

Although oviposition continues throughout practically the whole lifetime of the female, the rate is greater in the earlier than in the later portion. Mating has been observed to take place a number of times during the life of the female, so that it would appear that more than one mating is required for the fertilization of successive batches of eggs.

The period covered by a complete generation, i.e., from deposition of egg to deposition of egg by the female of that generation, averages 212 days, made up as follows :—

	Days.
Egg period	78
Hatching to adult	101
Adult to oviposition	33

In night collection of "hoppers" in the plantation, it has been found from counts made of adults coming down the trunks of the palms that the percentage of females is very much greater than that of the males. This movement is, however, very largely influenced by the local climatic conditions. The number collected is always greatest on dark cloudy nights after rain, especially when the rain has fallen late in the afternoon, and is least on bright clear nights after a dry day, or on bright moonlight nights. A long series of counts has given the following percentages for males and females collected at night: males 14 (range 4–31), females 86 (range 69–96).

The proportion of the sexes has been difficult to obtain. From collections made by natives from palms in the plantation over a period of six months, the figures were males 55 per cent. and females 45 per cent. On the other hand, in conjunction with insecticidal dusting trials (*see* "Control Measures"), the *Sexava* population of a large number of palms was counted by cutting off the fronds of selected palms, lowering the fronds carefully to the ground, and there counting the number of adult and nymphal forms present in the foliage. A watch was kept for any "hoppers" that might have left the frond when being cut or lowered, any such being collected and added to the count. The proportion of the sexes of adult *Sexava* determined in this way was an average of 70 per cent. male and 30 per cent. females. On the other hand, in the counts of the nymphal forms in the above cases, the proportion of sexes was 49.5 per cent. males and 50.5 per cent. females.

In field cages with ample food, the longevity of male adults was 35 to 110 days (average 82.8), and of female adults 28 to 91 days (average 67.1). Without food the adults lived 3½ days.

The adults and nymphs require water in addition to the moisture contained in the foliage, as shown by the fact that when kept in captivity and the foliage sprayed with water, all stages were noted sucking up the droplets of water.

The powers of flight of the adults are very poor, wings used more to volplane from the head of the palms to the ground. When disturbed, they may fly from one palm to the next, but this is practically the limit of flight, and even then loss of elevation is noted. In trying to take off from the ground, it is always noted that they can only rise 2 to 3 feet and, after covering a distance of about 30 feet, they fall back again, alighting on the grass, &c.

Stridulation is not apparently entirely a sex call and although particularly strong at night, it may be heard during the day, especially when the pest population is large. Migration from one centre to another is only likely to take place when coco-nut foliage on which *Sexava* nymphs or adults are present is carried about. Fronds carried around on native canoes have been observed to carry *Sexava* in this manner, and the pest may be thus dispersed over appreciable distances.

Within the confines of a plantation movement of adults and nymphs may take place from palm to palm where fronds of adjacent palms are overlapping, or by adults descending at night from one palm and re-ascending another further away. But as it has been noted that dispersion is so slow, any such movement is probably governed more by food supply than any other factor.

Feeding mostly takes place after dark, but on dull, cloudy or rainy days, feeding may occur also during the day.

Tests have been carried out in field breeding cages to try and ascertain the quantity of leaf eaten per diem per insect; in all these tests mature coco-nut foliage was used for feeding the insects, and fresh leaves were added once or twice every 24 hours. Under these conditions, the average consumption of the adult "hoppers" per 24 hours per insect was 3 to 4 square inches of leaf tissue, i.e., about the same as for the final nymphal instars.

Although coco-nut foliage is the preferred food of *Sexava*, other plants on which the insects have been observed to feed in the field are Sago palm (*Metroxlyn sagu*), Banana (*Musa* spp.), *Pandanus* spp., Betel nut (*Areca catechu*), *Heliconia* spp., *Ravenala* spp., Nipa palm (*Nipa fruticans*). In cages the foliage of *Pennisetum macrostacium* ("karapai" in pidgin) has been fed on freely by *Sexava*.

CONTROL MEASURES.

Mechanical measures, when efficiently carried out in the initial stages of an infestation, will give a satisfactory control of the pest, but where the value per acre of the agricultural product is relatively low, costs must necessarily be closely studied, and if there is an alternative scheme of attack requiring less expenditure, such as biological measures (i.e. the utilization of parasites), it is worthy of the fullest study. Particular attention was paid to this line of research from the very beginning of the work on the *Sexava* problem.

The search for indigenous parasites resulted in finding the egg parasites, *Doirania leefmansi*, Waterst. on New Hanover in 1930. In 1932, a species of *Encyrtidae* and a species of *Trichogrammatidae*, later identified as *Leefmansia bicolor*, Waterst. var. and *Doirania leefmansi*, Waterst. were bred from *Sexava* eggs in Manus; these were apparently rare as they were only bred on a single occasion with each species. Further breeding in the Manus District showed two species of *Scelionidae*, *Prosapegus atrellus*, Dodd. and *Scelio* sp., and *Ootetrastichus dubius*, Waterst. (fam. *Eulophidae*) to be present, but only in very small numbers.

On New Hanover, the following species were later bred from *Sexava* eggs, *Doirania leefmansi*, Waterst., *Leefmansia bicolor*, Waterst. var. and a species of *Mymaridae* (genus near *Anaphes*), all occurring in appreciable numbers, and also *Prosapegus atrellus*, Dodd. and *Ootetrastichus dubius*, Waterst. occurring to a much lesser extent.

In the Arawe District of New Britain, *Prosapegus atrellus*, Dodd. and *Ootetrastichus dubius*, Waterst. were bred from *Sexava* eggs collected locally; the latter species was noted to be more plentiful in this area than elsewhere in the Territory.

On New Ireland, *P. atrellus*, Dodd. and a small species of *Mymaridae*, distinct from that bred in Manus and New Hanover, have been bred from this host, while on Lihir Island, off the east coast of New Ireland, *P. atrellus* and a species of *Eulophidae* were fairly numerous in two lots of *Sexava* eggs sent in.

From both the Rabaul and Talasea sections of New Britain, a species of *Eulophidae*, apparently identical with that from Lihir Island, has been bred on several occasions.

Of the species of parasites indigenous to the Territory of New Guinea, *D. leefmansi, Leefmansia bicolor*, the *Mymarid* from New Hanover and possibly the species of *Eulophidae* from Lihir Island have been found in sufficient numbers and of such frequency as to warrant closer study to determine their possible economic importance, and in the course of the research work, especially on New Hanover, the first three species received particular attention.

All the parasites mentioned belong to the *Hymenoptera*, a group of insects which are popularly known as "wasps", but as the general idea of what constitutes a "wasp" is that of a relatively large insect, a brief note on each of these useful insects may perhaps give the layman a more accurate appreciation of the size of such parasitic wasps.

Doirania leefmansi, Waterst. is approximately half a millimetre* in length, which to the naked eye appears as a minute dark speck: when examined with a magnifying glass it is seen to have a light-coloured thorax and a dark abdomen.

Leefmansia bicolor, Waterst. measures approximately one and a half millimetres in length, and has a reddish thorax and dark abdomen.

Mymaridae sp. (genus near *Anaphes*) measures approximately one-third of a millimetre in length, and is generally dark in colour. An interesting feature with this species is that the males are quite distinct in appearance to the females, being much more robust and wingless and with antennae of thirteen segments. The males emerge on to the surface of the host eggs, and copulate with the females as they emerge: they do not move away from the egg, and die in not more than half an hour.

Ooietrastichus dubius, Waterst. is a black insect with light-coloured legs; it measures approximately one and a half millimetres in length.

Prosapegus atrellus, Dodd. is a dark-coloured insect with reddish-brown legs; it measures approximately seven and a half millimetres in length.

All the other species referred to are less than one millimetre in length.

In the course of the research work carried out on New Hanover during July and August, 1934, a large series of dissections were made of Sexava eggs collected in: (i) the soil; (ii) the fibre in the head of the palms; and (iii) the epiphytic growths on the trunks of the palms to ascertain the relative percentage of parasitism of the indigenous parasites; the results are given in the following table:—

Sexava eggs coll. in—	Percentage of Parasitism by—					Total.
	D. leefmansi.	*L. bicolor* var.	*Mymarid* sp.	*P. atrellus.*	*O. dubius.*	
Soil	6.7	2.3	4.7	Nil	Trace	13.7
Fibre, head of palm ..	11.7	4.4	5.2	Nil	Nil	21.3
Epiphytes	16.3	6.0	3.7	.1	Nil	26.1

On only one occasion were two species found together in the one *Sexava* egg, *D. leefmansi* and *L. bicolor* larvae occurring together; it is indicated, therefore, that parasite interference did not occur between the various species.

* Note.—25 millimetres = 1 inch.

The life-cycle was worked out for four species, as below:—

D. leefmansi	39–41 days (av. 39.8)
L. bicolor var.	31–35 days (av. 33.0)
O. dubius	30–36 days (av. 33.1)
Mymarid sp.	23–25 days (av. 27.8)

With the exception of *L. bicolor,* great difficulty was experienced in breeding these parasites in the field laboratory, regulation of moisture in the breeding tubes being the main cause.

Parasites Recorded in the Netherlands East Indies.

In 1927, Dr. Leefmans recorded *Doirania leefmansi,* Waterst., *Leefmansia bicolor,* Waterst. and *Ootetrastichus dubius,* Waterst. as parasites of eggs of *Sexava nubila,* St. in Amboina.

In 1930, Dr. Reyne recorded *Prosapegus atrellus,* Dodd. and *Ootetrastichus dubius,* Waterst. as parasites of *Sexava* eggs along the coast of Dutch New Guinea; *Ootetrastichus dubius,* Waterst. from Halmahera; and *Doirania leefmansi,* Waterst. from the Banngai Islands.

D. leefmansi and *L. bicolor* were reported by Dr. Leefmans as being of economic importance as parasites of *Sexava* and, as previously stated, a small colony of the former species and a strong colony of the latter species were bred in Amboina by the Senior Author, and successfully brought to this Territory in April, 1933. Particular attention was paid to *L. bicolor* owing to the ease with which it could be bred in the laboratory, and this was commenced immediately to build up stocks for liberation in the plantations, and for distribution to other parts of the Territory. A study was also made of the binomics of the parasite under local conditions, these in most centres being markedly different from those in Amboina.

Leefmansia Bicolor.

The average life-cycle of this parasite in the field laboratory in Manus was 26 days, with a range of 24-29 days. On New Hanover, however, where the night temperatures especially were lower than in Manus, the cycle averaged 28.8 days with a range of 26-31 days.

From *Sexava* eggs parasitized in Amboina, parasites emerged in 28-29 days; this may have been influenced by the varying temperatures and the vibrations on the schooner experienced in the fourteen days' trip from Amboina to Manus.

The age of the host egg has a marked effect on the life-cycle of the parasites, as shown by the following figures of observations made in the field laboratory in Manus:—

Age of host egg in days.	Duration of life-cycle.	
	Minimum.	Maximum.
2– 3	37	49
4– 6	30	35
7–10	35	38
11–14	29	36
16–21	20	27
22–27	18	26
28–37	20	27
38–44	20	26

It is, therefore, evident that the life-cycle of the parasites is considerably prolonged when host eggs of under sixteen days old are placed in the submission jars with the parasites. Apart from the lengthening of the life-cycle, this factor does not appear to have any influence on the number of parasites emerging, their size, virility, &c.

The average longevity with feeding of the adult parasites is seven days, although some have lived for as long as fourteen days; males apparently live longer than females.

Copulation takes place within a few minutes of emergence, and continues throughout life, and oviposition commences soon after copulation. The duration of active parasitism covers several days.

Both sexes are markedly phytotropic (i.e., attracted to light), although this appears to vary according to the container in which they are confined; from a narrow tube they will move towards the light much faster than from a wide tube or a bottle. This habit can be utilized in transferring the parasites from one jar to another or into tubes for liberation of adults.

In laboratory breeding of these parasites, glass preserving jars of two-quart capacity were used for submission of the host eggs to wasps, the eggs forming a thin layer over one side of the jar lying side down; slightly diluted honey was used for food for the live insects.

The total percentage of *Sexava* eggs parasitized in the laboratory averaged 82.4 with a range of 73.7 to 91.6, of which an average of 64.5 per cent. yielded live parasites.

The average number of parasites per host egg was twenty.

In order to test the practicability of emergence of the parasites through the soil, parasitized *Sexava* eggs were buried in loose soil at various depths, and examined periodically; tanglefoot paper was placed on the surface around the sites of burial. It was found that the adults of *L. bicolor* could reach the surface through 1½ inches of loose soil.

Liberation of parasites in the field in bulk lots of host eggs was carried out by placing the eggs in small wire-gauze cages which were suspended by wire from a stake, or the fronds of young palms, in the plantation. Observations made over a long period have shown that the emergence of wasps from these field cages was much heavier than from control lots held in jars in the laboratory.

With continued liberation from laboratory stocks, *L. bicolor* became established in the field fairly readily and rapidly; in most cases, however, it failed to maintain itself after liberation from stocks had ceased. In one case of native groves in the Arawe area, this species was recovered in fair numbers, and in small numbers from a plantation in the same area three years after liberations stopped; on New Hanover this parasite has maintained itself satisfactorily for several years. It may be stated that the latter centre more closely approximates to the field conditions existing in Amboina than most other parts of the Territory where this parasite has been liberated.

With the idea of increasing the number of species of parasites liberated, and on account of the difficulty experienced in the laboratory breeding of *D. leefmansi* and the *Mymarid* sp. on New Hanover, bulk lots of *Sexava* eggs have been collected from time to time from that area, and mixed lots of them have been distributed to other centres of *Sexava* occurrence. The reason for mixing host eggs in this way was that when the junior author was stationed on New Hanover he found that the distribution of the various parasites mentioned was not regular, but that one species would be more prevalent in one or more centres than any of the others; mixing thus gives a better chance for all species to be represented in any lot of host eggs sent out.

Mechanical Measures.

In conjunction with the parasite breeding work, attention was given to other lines of attack on the problem, in order that if one line failed another could be taken up, or a combined scheme of two or more lines might be undertaken to obtain the required result.

Large numbers of adults and nymphs can be collected and destroyed by stacking the old coco-nut fronds along the rows of palms through an infested area, and lighting them from the outside rows inwards to the centre; the heat will cause most of the "hoppers" to lose their hold in the palms, and fall to the ground, as the adults have very poor powers of flight.

Collection of eggs systematically through an infested area will lead to the destruction of many potential "hoppers". Turning over the soil with hoes, or by ploughing where this is possible, so as to bury the eggs below the surface, will prevent large numbers of nymphs reaching the surface; ants, lizards, &c., will attack eggs exposed on the top of the soil during such operations.

The habit, of female adults in particular, of coming down to the ground at night to lay can be made great use of in night collections from about 7 to 9 p.m. It is possible that the use of flame-throwers or even flares made from dry fronds would obviate the hand collection of the "hoppers" without causing material damage to the trunks of the palms.

In cases of a very localized infestation, such as occurs in the initial stages of *Sexava* plague occurrence, "tanglefoot" bands may have an economic value in preventing considerable numbers of first instar nymphs from reaching the crown of the palms. Several series of tests have been carried out with two types of "tree tanglefoot", one with a resin base and the other with a wax base; the latter was quite unsuitable for the purposes required. Although the tackiness is greater when the bands are fresh, this can be "rubbed up" at intervals to break any film on the surface. Such bands made with the resin base material have remained actively tacky for two and a half months, but the initial precaution must be taken of removing any moss or other plant growth from the palm trunk before applying the "tanglefoot". The most satisfactory type of band found in the field trials was 3½ to 4 inches wide and was put on with the hand; where a piece of wood was used, the band was often too thin to last.

Tests were made with these bands to which different poisons had been added, and it was found that nymphs crossing a band of "tanglefoot" to which 10 per cent. of sodium arsenate was added showed 100 per cent. mortality in from 7 to 39 hours. With 10 per cent. mercuric chloride, all the nymphs were paralysed within five hours, and of twelve nymphs used, five were dead in 24 hours, one more in 48 hours; three lived for 72 hours and one for 96 hours, which is approximately the longest period nymphs can live without food. With sodium fluoride, there was 25 per cent. mortality in 24 hours, and 65 per cent. in 48 hours, while all were dead in 72 hours. Paris green gave a mortality of 35 per cent. in 24 hours and 50 per cent. in 48 hours.

An attempt was made to kill the "hoppers" by means of the standard locust bait, composed of Paris green, bran, sodium arsenate, molasses and lemons; this was scattered both in the head of the palms and around the base on the ground, but there was no evidence to show that the insects fed on it at all.

Insecticides Applied to the Palms.

In order to test out the use of insecticides applied to the coco-nut palm foliage, small coco-nut palms were sprayed with arsenate of lead at the usual strength, and the leaves placed in observation cages with adult and nymphal *Sexava*. It was found that feeding ceased after the first night and 100 per cent. were dead within three days. This proved to be toxic eight days after spraying, even although 147 points of rain had fallen in the interim.

Spraying of coco-nut palms on a plantation presents the great difficulty of obtaining an adequate supply of soft water; even in cases where water is available, the cartage would generally be an appreciable cost. Owing to the height of the palm, a high-powered spray plant would be required with some means of traction, which would be expensive.

The application of the insecticide as a dry dust obviates the need of water, and the plant required is much lower in cost than a spraying outfit for the same purpose.

A dusting machine powered with a 6 h.p. petrol engine was purchased by the administration, and tests were first made in the laboratory in wire-gauze cages to determine the most suitable insecticide for field trials.

The dusts experimented with comprised various proprietary preparations and also straight dusts with arsenate of lead, calcium arsenate, Paris green and derris as the toxic constituents.

The cages used were made of copra-bed wire and were 3 feet high and 2 feet in diameter: coco-nut leaves were suspended in the cages with the "hoppers" and dusted. Fresh foliage was added after one night's feeding, and the relative toxicity of the dust was reckoned in the number of "hoppers" killed in three days.

Derris dusts were very irregular in results—a dust which would give a high degree of mortality on one occasion would give a very poor result on another. The arsenicals, on the other hand, gave a consistently high mortality. Paris green was found, in later trials, to scald the foliage, and was, therefore, eliminated from the trials. Both arsenate of lead and calcium arsenate gave highly satisfactory results in field trials, but the latter appeared to possess one advantage, that it had a delayed action in killing the "hoppers" that was not found with the former. One brand showed itself superior in power of adhesion to the leaf.

From the results obtained, it is evident that dusting would require to be done twice, with an interval of about three months between treatments, in order to obtain effective control.

Owing to the very smooth surface of the leaf of the coco-nut palm, adhesion of most dusts is poor, although there is a definite layer left on the upper surface of the leaves. In an endeavour to improve the adhesion of the dust, various fillers were tested, mostly of a "kaolin clay" nature; one proprietary preparation of this type showed particular promise, especially when dusted over foliage on which the night dew was still present.

In later field trials, it was found to be possible to dust two rows of palms together with satisfactory results; this naturally presents a considerable saving in time and material.

From the field trials, it is definitely proved that calcium arsenate dust will kill practically 100 per cent. of the *Sexava* in the palms provided that there is 24 or preferably 48 hours without rain after application of the insecticide.

Other Natural Enemies.

Crows (*Corvus orru*), white-headed hawk (*Accipiter* sp.), "Willie Wagtail" (*Rhipidura tricolor*), Kingfisher (*Halcyon sanctus*) and various lizards have been observed feeding on *Sexava* on the palms. During a normal condition of low pest population these natural enemies probably assist in destroying a number of "hopper" nymphs and adults, but they are nowhere in sufficient numbers to be of any material benefit during heavy infestation.

"Guinea fowls" (*Numidia meleagris*) were introduced into one plantation as, owing to their insectivorous habits, it was thought they would assist in the control of *Sexava* by killing numbers of the "hoppers". The birds were under continuous observation for several months. They proved a complete failure as pest destroyers on account of their habits of rarely straying far from the bungalow, going to roost well before sundown, and not leaving their roost until well after sunrise. For these reasons they were not even as useful as domestic fowls.

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HOW TO MAKE SOAP.

Ingredients.—6 lb. clean dripping, 2 gallons water, 1 lb. caustic soda, ½ lb. resin and 3 tablespoons kerosene.

Method.—Put dripping, resin and water into a kerosene tin and boil for 15 to 30 minutes until all the fat is melted. Add kerosene and remove from the fire. Next gradually add caustic soda direct from the tin, allowing bubbles to subside between each addition. Boil gently for one or two hours and then pour into a box lined with a damp cloth. When solid, cut into bars and store in a dry place till hardened,