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CONTENTS

A CULTIVAR TRIAL WITH YAMS *DIOSCOREA ALATA* L. IN THE BRITISH SOLOMON ISLANDS

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ABSTRACT

In a trial with yam cultivars, the yield of tubers ranged from 15.89 *to* 36.85 *t/ha, after a growing period of* 199 *days. The cultivars with pigmented tubers out-yielded the non-pigmented ones. The mean weight of planting material used was* 2.37 *t/ha and the mean sett weight* 88 *g.*

Storage trials showed that non-pigmented tubers stored better than pigmented ones, and that weight losses were mainly due to respiration. After 172 *days storage, non-pigmented tubers showed a weight loss of* 11.6 *per cent, whilst pigmented ones lost* 24.5 *per cent.* D. alata *tubers lost* 6.3 *per cent of weight due to moisture losses and* 36.2 *per cent due to respiration after a storage period of* 213 *days.* D. esculenta *tubers lost* 22.7 *per cent of weight after* 123 *days storage,* 4.1 *per cent being due to moisture loss and* 18.6 *to respiration. The pigmented tubers of* D. alata *sprouted earlier and more profusely than the non-pigmented tubers.*

INTRODUCTION

YAMS *Dioscorea* spp. together with sweet potatoes *Ipomoea batatas* (L.) Lam. and taro *Colocasia esculenta* (L.) Schott are major food crops in the Solomon Islands. In general, where yam culture is important the taro crop is of less significance; Barrau (1965) has discussed this and emphasized the differing ecological requirements of the two crops.

Sweet potatoes however tend to be grown by both the taro and yam planting communities. Whilst taro production tends to be on the decline partly due to diseases, yam production is sustained in those areas which have a tradition of yam growing.

The two most important yam species in the Solomons are *D. alata* L. and *D. esculenta* (Lour.) Burk. Three others, *D. bulbifera* L., *D. nummularia* Lam. and *D. pentaphylla* L., are sometimes planted, but are also found in the natural state and are often foraged (Barrau 1958).

The climate of the Solomons is wet tropical with a mean annual rainfall which is fairly evenly distributed exceeding 3,000 mm for most coastal areas, with a possible 8,000 mm or more for the mountain ranges located towards the centres of the main islands. Mean monthly rainfall exceeds 125 mm in most areas. Mean maximum temperatures seldom exceed 31° C and mean minimum temperatures seldom fall below 21° C. Average relative humidity approximates to 80 per cent throughout the year.

Many of the coastal soils are formed over raised coral reefs, and have been found to be low in available potassium content (Ballantyne 1961).

Work commenced at Dala Experimental Station on Malaita during 1967 on local food crops, and this paper describes cultivar and storage trials with yams.

MATERIALS AND METHODS

Cultivar Trial

A trial consisting of eight cultivars of *D. alata* from Malaita was planted on 11th September, 1970. The plot size excluding guard rows was 0.0018 ha., i.e., 49 plants spaced at 0.6 x 0.6 m; the experimental design was a randomized block with three replicates.

Land was cleared by cutting and burning of bush which was about 4.5 m high. The tubers were cut into setts nine days before planting, each sett being marked, as is local practice, to indicate the end taken from nearest the tuber head. The mean weight of each sett was 88 g, and the planting rates are shown in *Table* 1.

At planting, the ground was dug and loosened to a depth of about 35 cm, the diameter of the cultivated area per stand being approximately 35 cm at the soil surface. One sett was planted per stand, at a depth of 3 to

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Table 1.—Yield and planting data of yams in cultivar trial

Cultivars of *D. alata*	Yield of tubers (t/ha)	Mean weight of tubers (Kg)	Mean number of tubers per plant	Planting Material	
				(g/sett)	(t/ha)
Lawanihara	36.85a	0.95a	1.7	104.3	2.81
Hutohuto	25.15	0.82b	1.2	78.5	2.11
Inemauri	21.49	0.59bc	1.4	78.5	2.11
Toma	20.96	0.45cd	1.8	112.8	3.04
Talabuli	20.61	0.59bc	1.4	83.1	2.23
Asikare	19.50	0.50cd	1.4	95.3	2.56
Rokea	17.19	0.50cd	1.3	71.7	1.93
Kai	15.89	0.27d	2.3	80.2	2.16
Mean	22.21	0.58	1.6	88.1	2.37
Standard error	±3.31	±0.08	±0.26	±5.11	±0.14
Coefficient of variation	25.9%	24.3%	27.9%	16.6%	16.6%

Mean separation by Duncan's Multiple Range Test.

Means followed by letter 'a' are significantly different from those means not having 'a', etc. (P = 0.05).

4 cm below the surface. Setts were planted at an angle with the head end facing upwards. No hilling was done, the cultivated area being only slightly higher than the undisturbed ground. This is the standard planting procedure for the "Kwara'ae" district of Malaita. The spacing of 0.6 x 0.6 m gave 26,888 setts per hectare.

Stakes of about 2.4 m height were provided at 18 days after planting, one stake for each plant. No fertilizer was applied to the crop. Harvesting took place on 29th March, 1971 at 199 days after planting and the tubers were dug out with digging sticks.

Storage Trial 1

The tubers from the above trial were used in a storage trial, together with tubers from two other *D. alata* cultivars. The tubers were weighed four days after harvest, and then placed on wooden shelves in a well-ventilated rat-proof store room. Only sound undamaged tubers were selected. The design was four randomized blocks, and each unit consisted of 5.0 kg of tubers.

At monthly intervals the tubers were weighed, and the percentage weight losses calculated. A sprouting index was also assessed at monthly intervals, by scoring for the amount and length of sprouts on the following scale: 0 = no sprouting; 1 = slight sprouting; 2 = moderate; 3 = excessive.

The trial started on 2nd April, 1972, and was terminated on 22nd September, 1972, after 172 days' storage.

Storage Trials 2 *and* 3

These trials consisted of one non-pigmented cultivar of *D. alata* "Inemauri", and one of *D. esculenta* "Fananiu". The aim of the trials was to determine the percentage weight losses during storage, and to ascertain if these were due to moisture changes, or to other losses, e.g., respiration.

Storage commenced at seven and two days respectively after harvest for the *D. alata* and *D. esculenta* cultivars. The tubers were stored in the case of *D. alata* for 213 days, and for a period of 123 days for *D. esculenta.*

Moisture determinations were made at monthly intervals by selecting tubers at random, slicing them and oven drying for 24 hours at 100° C. The sprouting indices were assessed as in the first trial. The designs were randomized blocks with five replicates for *D. alata* and four for *D. esculenta.*

RESULTS

Cultivar Trial

Tuber Yields

The yields of tubers in t/ha are given in *Table* 1, from which it can be seen that cv. "Lawanihara" had a significantly higher yield

than the seven other cultivars, all of which produced yields which were not significantly different. There were significant differences between the tuber mean weights of cultivars. The yield of tubers was not correlated with the mean weight of planting material used per hectare, and the mean recovery ratio of weight planted to tuber weight harvested for all cultivars was 1:9.4. The two highest yielding cultivars had pigmented tubers, while the tubers of the other cultivars were non-pigmented.

Pests and Diseases

The mean weight of tubers damaged by the beetle *Papuana* spp. (Stapley, personal communication 1971) in the trial was 0.24 t/ha or 1.0 per cent by weight. The damage to tubers resembled that described by Coursey (1967) in West Africa, as caused by *Heteroligus* spp. The percentage by weight of tubers damaged was very low, and the damage to individual tubers slight.

Only the cv. "Asikare" was infected with an unidentified tuber rot. The weight of tubers of this cultivar infected was 0.55 t/ha or 2.8 per cent by weight.

At about 100 days after planting, symptoms resembling virus infection were observed on all cultivars except for the two with pigmented tubers (cvs. "Lawanihara" and "Hutohuto"). The symptoms were that the young leaves towards the tips of shoots became curled, cupped and leathery, with brown margins and tips.

Leaf spots were observed on the foliage of all cultivars at about four months after planting, but damage appeared to be very slight in most cases. From infected leaf tissue forwarded from Dala, the Commonwealth Mycological Institute isolated the following organisms: *Botryodiplodia theobromae* Pat.; *Collecotrichum capsici* (Syd.) Butler and Bisby; *Colletotrichum* state of *Glomerella cingulata* (Stonem.) Spauld and Schrenk; and *Phomopsis dioscoreae* Sacc. Johnston (1960) found *Glomerella cingulata* and *Biharia* sp. associated with leaf spots of *D. alata* on Malaita.

Climatic Data

During the growing period of the crop, the mean daily rainfall was 14.4 mm, 2,860 mm being recorded for the whole period. The mean daily sunshine was 5.4 hrs, the mean maximum and minimum temperatures 30.3° C and 22.7° C, and the mean relative humidity 79.7 per cent, recorded at 0900 hrs.

Storage Trial 1

The mean percentage weight losses of the tubers together with their sprouting indices are given in *Table* 2. The values refer to the means of the non-pigmented cultivars (8), and of the pigmented cultivars (2). The red-fleshed tubers had a much poorer storage quality than the white-fleshed tubers, and they also sprouted more.

After 172 days storage the non-pigmented tubers had a mean percentage loss in weight of 11.6, whilst that for the pigmented tubers was 24.5. The mean values for the sprouting indices were 42.7 and 100.0 for the non-pigmented and pigmented tubers respectively after 154 days storage. The sprouts were removed after weighing at 154 days storage, but any sprouts which grew after this were included in the final tuber weights recorded.

Storage Trials 2 *and* 3

The moisture contents and percentage losses due to moisture changes and respiration processes are shown in *Tables* 3 and 4 for the *D. alata* and *D. esculenta* tubers respectively.

After 213 days storage the moisture content of the *D. alata* tubers had fallen by 6.3 per cent to 69.1 per cent. The total percentage loss in weight for the period was 42.5 per cent, and respiration processes can thus be assumed to account for 36.2 per cent loss. The sprouts were removed after weighing at 182 and 213 days of storage, and before oven-drying for moisture determinations. The sprouting index at 182 days was assessed as 66.7 per cent.

The *D. esculenta* tubers lost 4.1 per cent of weight due to moisture losses after a storage period of 123 days, the other weight losses assumed to be due to respiration were 18.6 per cent, making a total weight loss of 22.7 per cent. Sprouting commenced after 32 days storage, and the sprouting index was 100 per cent by 100 days.

Mealy bugs *Planococcus dioscoreae* Williams were found on both the *D.* alata and *D. esculenta* tubers in all three storage trials, and tended to be concentrated towards the head end of the tubers from which most sprouts emerged. They became apparent on the *D. alata* tubers after about 150 days of storage,

Table 2.—Mean percentage weight losses and sprouting indices of yam tubers in storage trial

	Storage Period (days)					
	31	62	94	123	154	172
Percentage weight losses						
Non-pigmented tubers (eight cvs)	3.1	4.9	6.0	8.7	10.7	11.6
Pigmented tubers (two cvs)	6.2	7.8	9.6	14.6	21.0	24.5
Sprouting indices						
Non-pigmented tubers	0	0	0	14.6	42.7	
Pigmented tubers	0	8.3	83.3	100.0	100.0	

$$\text{Sprouting index} = \frac{\text{Score} \times 100}{\text{Total possible score}}$$

Table 3.—Percentage weight losses of *D. alata* tubers after storage, showing moisture contents and changes due to moisture and respiration

Days of storage	0	28	59	91	120	151	182	213	Total
Moisture contents (per cent)	75.42	73.92	73.96	75.14	74.22	71.66	71.28	69.14	
Standard error±	0.63	0.24	0.84	2.10	1.38	0.80	0.92	0.84	
Moisture weight changes (per cent)	—	—1.50	+0.04	+1.18	—0.92	—2.56	—0.38	—2.14	—6.28
Other weight losses (per cent)	—	1.04	0.78	4.04	0.66	7.08	17.18	5.44	36.22
Total weight losses (per cent)	—	2.54	3.28	6.14	7.72	17.36	34.92	42.50	
Sprouting indices (per cent)	0	0	0	0	0	16.6	66.7		

Table 4.—Percentage weight losses of *D. esculenta* tubers after storage, showing moisture contents and changes due to moisture and respiration

Days of storage	0	32	61	92	123	Total
Moisture contents (per cent)	72.58	70.73	74.08	71.03	68.53	
Standard error±	1.02	1.39	1.27	1.56	1.73	
Moisture weight changes (per cent)	—	—1.85	+3.35	—3.05	—2.50	—4.05
Other weight losses (per cent)	—	5.25	7.00	3.93	2.40	18.58
Total weight losses (per cent)	—	7.10	10.75	17.73	22.63	
Sprouting indices (per cent)	0	8.3	50.0	100.0	100.0	

and in the case of *D. esculenta* after 100 days. This species of *Planococcus* described by Williams (1960), was found to cause severe damage to tubers of yams in storage in Papua New Guinea.

No rots developed on any of the tubers in the three trials over the entire storage period.

The mean temperatures and relative humidity recorded at the meteorological station at Dala during all three storage periods were similar. The mean maximum temperature was 30.4° C, mean minimum 22.2° C, and mean relative humidity recorded at 0900 hrs was 81.7 per cent. No readings were taken in the storage room.

DISCUSSION

In the "Kwara'ae" district of Malaita, the method of planting *D. alata* is different from that used for *D. esculenta*. In the latter case small seed tubers of approximately 0.26 kg weight are placed at the bottom of the planting hole, with the head end facing downwards. Lea (1966) describes how, in Papua New Guinea, *D. alata* seed tubers are planted near the top of the planting mound. In Trinidad the normal planting procedure is for setts of approximately 113 g to be planted on ridges at a spacing of 1.2 x 0.3 m (Campbell and Gooding 1962). Spacing of setts is normally wider than that used at Dala (Waitt 1963).

Staking is important in its effect on yield (Waitt 1963), and has been shown by Chapman (1965) to increase tuber yields because of the production of a higher leaf area duration, and a more efficient foliage display.

The yields of tubers ranging from 15.89 to 36.85 with a mean of 22.21 t/ha for the eight cultivars are comparable with those quoted for the West Indies, whilst the mean weight of tubers 0.58 kg is smaller than normal (Coursey 1967). This was possibly because of the close spacing used. The growing period in the trial of approximately 200 days is about a month less than that for Trinidad (Chapman 1965, Haynes 1967). The mean number of tubers per plant was similar to the norm for *D. alata* cultivars, and there was no correlation between the yield of tubers, and the mean number of tubers per plant.

Pests and diseases appeared to be of little importance in the trial. The leaf spots probably had little effect if any on yields, as they were not significant until towards the end of the crop cycle.

Gooding (1960) found that *D. alata* cultivars had a percentage weight loss after a storage period of 116 days of 14.1 per cent; 8.7 per cent for the white fleshed cultivars and 23.1 per cent for the pigmented ones. The one *D. esculenta* cultivar in the trial had a weight loss of 24.6 per cent. At Dala the weight losses for the non-pigmented tubers and for *D. esculenta* after 123 days storage were similar to the values given by Gooding (1960).

Campbell *et al.* (1962) reported weight losses of 10-14 per cent in *D. alata* tubers after four months storage, and 20-24 per cent at six months. By seven months, weight losses had risen to approximately 47 per cent. Final weight losses were similar at Dala (*Table* 3) to those determined by Campbell *et al.* (1962) for their untreated tubers. Sprouting was not apparent until 150 days (*Table* 3), whereas in trials by Campbell *et al.*, sprouting commenced after about 100 days' storage. The removal of sprouts at 182 days probably slowed down the losses due to respiration from 17.18 to 5.44 per cent (*Table* 3).

The slight increases of moisture content in *Tables* 3 and 4, at 59 and 91 days for *D. alata*, and at 61 days for *D. esculenta* tubers suggest uptake of water from the atmosphere. Coursey (1961) working with *D. rotundata* considered that respiration accounts for considerable losses in weight of stored yams as only slight changes in the moisture content usually take place during storage. Weight losses other than those due to moisture losses were therefore assumed to be due to respiration in this study, as no rots developed in the stored tubers.

The pigmented cultivars in the trial were the highest yielders, but also the poorest keepers, and they sprouted earlier than the non-pigmented cultivars.

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THE RESEARCH METHODS EMPLOYED IN THE STUDY OF THE PAPUA NEW GUINEA SKIPJACK FISHERY

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ABSTRACT

The major research techniques employed in the study of the rapidly expanding Papua New Guinea skipjack Katsuwonus pelamis *fishery are detailed. The objectives of the total research effort and aims of the individual strategies are briefly discussed. A brief summary of the results of each aspect is presented.*

IN March, 1971, one year after the commencement of commercial skipjack fishing in Papua New Guinea, a research programme was initiated to investigate the stocks of skipjack and tuna and to study the factors affecting the catch of each species. American (Anon. 1971) researchers had suggested that the skipjack resource in the south-western Pacific Ocean was of the order of several hundred thousand tonnes but little information was available to support such claims. The expanding influence of foreign skipjack and tuna fishing vessels in the waters surrounding Papua New Guinea stressed the urgency for the accumulation of sufficient knowledge to facilitate the formulation of management policies for the utilization of resources available to Papua New Guinea. The research programme was therefore geared towards a three year intensive field work and data collection phase from which preliminary resource estimates could be made along with recommended development policies. Following this phase it was intended that catch-effort data and selected biological information would continue to be collected to be used for reviewing resource descriptions at a later date.

To achieve these aims four major research strategies were employed—

(1) Investigation of the migration and biology of skipjack and other commercially important tuna species. Tagging was used as the fundamental research technique.

(2) Analysis of the bait-fish resources and evaluation of the dependency of skipjack and tuna catches on them.

(3) Aerial surveys of all surface schooling tunas.

(4) Collection and analysis of catch and effort data.

(1) *Tagging and Biological Studies*

The original aims and methods of the skipjack tagging programme have been detailed by Kearney *et al.* (1972), and any modifications in technique subsequently developed, will be covered in the report of the 1972 voyages of the F.R.V. *Tagula* (Lewis *et al.*, in prep.).

Skipjack tagging carried out to date has been almost exclusively from the F.R.V. *Tagula*, and small numbers of yellowfin tuna (*Thunnus albacares*) and bluefin tuna (*Thunnus tonggol*) have been marked and released from the F.R.V. *Rossel*. All tags used were of the standard dart type (see Akyuz 1970, page 1) manufactured by Arthur E. King and Co., Sydney, and consisted of a moulded nylon single barb head, fitted and glued into an 11 cm length of vinyl tubing, bearing the inscription "D.A.S.F. PORT MORESBY", bracketed by duplicate numbers printed at each end of the shaft. Although yellow tags were mostly used, smaller numbers of fish were released which carried either red or blue tags.

A cradle was used for all skipjack tagging (see Kearney *et al.* 1972) but many of the yellowfin and bluefin were merely poled and/or hand-lined onto a foam rubber mattress, tagged and released.

In 1971 no tagged fish were measured; rather, an estimate of length was obtained by sampling fish caught from the same school, but not released. This method proved unsatisfactory for fish taken from schools consisting

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of individuals of greatly varying length. In late 1972 the tagging cradle was graduated to allow an estimate of the length of every tagged fish to be made to the nearest centimetre.

Preliminary experiments to evaluate the comparative advantages in using different coloured tags were carried out, but these experiments were largely unsuccessful, due to technical problems with the manufacture of the red tags.

Table 1 gives the number of releases and re-captures by species in each year since tagging commenced. Most of the releases were from the F.R.V. *Tagula*, but 77 skipjack, 168 yellowfin tuna and all bluefin tuna were released from the research vessel F.R.V. *Rossel*.

The information gained from the 496 skipjack returns has greatly increased the understanding of the movements of this species in the general vicinity of Papua New Guinea, and has allowed the first estimates of skipjack growth rates in the region to be made. Because of the complexity of movements of skipjack and the varying fishing pressure in different areas, accurate estimates of tagging, fishing and natural mortalities have yet to be derived, however the returns received are indicators of fishing pressure and represent a foundation upon which future mortality experiments can be based.

Numbers of the other tuna species tagged have been insufficient to enable any meaningful conclusions to be drawn.

Numerous techniques were employed for the accumulation of other biological data on skipjack and tuna and research efforts were concentrated on the following factors:

(1) Reproductive bioligy, oriented towards determining seasons and areas of possible spawning, and size at first maturity.

(2) Length frequency distribution of the catch and length/weight relationships.

(3) Stomach contents and feeding behaviour.

Specimens were analysed from the catches of both research and commercial vessels and the techniques used were as described by Kearney *et al.* (1972).

(2) *The Bait Fishery*

Late in 1972 several of the fishing masters of the joint-venture fleets fishing in Papua New Guinea claimed that the availability of suitable bait-fish had had more influence on skipjack catches than the abundance of skipjack itself. And indeed, there appears little doubt that as long as the skipjack industry continues to be based on live bait and pole vessels, gross fluctuations in the abundance of suitable bait-fish will be reflected to some extent in the catches of skipjack and other tuna. As a result a considerable portion of the research effort given to pelagic fisheries has been devoted to bait research, with particular emphasis on identification, distribution and measurement of abundance of all bait-fishes and on the biology of the most important species.

Most of the species distribution data has been collected on voyages of the research vessel F.R.V. *Tagula*, and a detailed presentation of the methods and preliminary findings has been previously given (Kearney *et al.* 1972). To date, 206 bait collection stations have been investigated from the F.R.V. *Tagula*. In addition, from February, 1972, until September, 1973, each of the four fishing companies was requested to forward bait samples to the fisheries research laboratory fortnightly.

The following information was obtained from each sample:

(1) Species present in the sample.

(2) Numerical abundance and size range of all species present.

Table 1—Releases and re-captures of tuna species in Papua New Guinea

Year	Number Tagged			Number of Recorded Re-captures		
	Skipjack	Yellowfin Tuna	Bluefin Tuna	Skipjack	Yellowfin Tuna	Bluefin Tuna
1971	74	—	—	1	—	—
1972	3459	113	37	249	1	—
1973	4388	389	114	246	—	—
TOTAL	7921	502	151	496	1	—

(3) Length frequency histograms of the numerically dominant species.

(4) Sex composition and reproductive state of the populations of the dominant species.

Examination of all samples has lead to the identification of more than 300 different species, approximately 10 of which appear suitable and are sufficiently abundant to be used as live bait for skipjack and other tuna. Research into the biology of the more important bait-fish has given some indications of the reproductive behaviour of these species and has permitted preliminary estimates of growth rates to be made for a few of them.

A third major phase of bait research was undertaken on samples regularly taken from selected sites near Port Moresby. These stations were maintained primarily to facilitate a more detailed study of the *Stolephorus* spp., which have proved to be the most important bait species in Papua New Guinea. It was hoped that growth rates and reproductive development could be better observed in serial samples taken from the one discrete area. In all, 61 samples from the area have been analysed.

Experimentation with bait handling resulted in improved techniques: it was found that bait mortality was greatly reduced if bait-fish captured at night were held in the net until daylight and then transferred into the bait tanks.

In general, research findings from bait research to the end of 1973 have been most encouraging. While there does not appear to be any single bait species possessing all the attributes of an ideal bait-fish, the species and resources present appear adequate to allow considerable expansion in the skipjack fishery. The major problems appear to be in the management of existing known resources and improvement of handling techniques currently in use.

(3) *Aerial Surveys*

In June, 1972, an aerial survey of skipjack, tuna and other pelagic fish resources in the waters adjacent to Papua New Guinea was proposed, and budget approval for the expenditure of $60,000 was given in September of the same year. The aims and methods of the survey as given by Kearney *et al.* (1973) were:

(1) to investigate the distribution and abundance of surface schools of skipjack tuna species in the waters adjacent to Papua New Guinea;

(2) to derive an estimate of the percentage of the resource occurring within 12 miles of a recognized land mass;

(3) to follow, if possible, any large scale seasonal movements of fish concentrations to complement other facets of the general research programme;

(4) using an infra-red radiation thermometer, to investigate possible relationships between thermal discontinuities at the sea surface and pelagic fish concentrations.

Tenders were called for the charter and the contract was awarded to Territory Airlines Pty Ltd for the supply of a Cessna 336. Although this aircraft had many deficiencies, it was the best available in Papua New Guinea at the time. A professional spotter with considerable experience in Australian pelagic fisheries was employed for the entire survey.

Normally, spotting was carried out at altitudes between 800 feet and 1,400 feet, depending on weather and sea conditions, but after a school had been sighted, the aircraft was often flown much lower to facilitate species identification. The spotter maintained accurate daily flight logs, giving relevant details of time, weather and sea conditions and position and description of every fish school observed.

An infra-red radiation thermometer was hired for use in the survey but, unfortunately, its poor mechanical condition prevented it from being of any value.

The preliminary findings of the survey have been presented (Kearney *et al.* 1973) and a final report is in preparation. In all, a total of 491 hours was flown, and an estimated 36,489 tonnes of pelagic fish (excluding bait-fish) were observed. The survey was most useful in detecting possible new fishing areas by locating good concentrations of fish other than those at present being fished. Under-exploited species, other than skipjack, were also shown to be in good concentration in some areas.

At the completion of the survey it was concluded that the joint-venture fishing companies operating in Papua New Guinea would profit by using light aircraft for fish detection, at least on a part-time basis.

(4) *Catch and Effort Data*

Appreciating the need for accurate description of the catch, a daily catch record form suitable for distribution to the live bait and pole boats was devised. Several modifications to the form were required until the format depicted in *Figure* 1 was accepted and exclusively used in the skipjack and tuna fishery. Some difficulty was encountered in obtaining correctly completed catch returns from all four fishing companies, but with the signing of a fisheries agreement with each company, the Administration* was empowered to suspend any boat or company not complying with reasonable requests for scientific information. Three of the four companies now supply all data required, and most catch returns are submitted within thirty days of the end of each calendar month.

The primary data on the catch returns is coded into a format acceptable to an I.C.L. 1903A computer, and after punching and verifying is sorted and stored on master files by an edit and up-date system coded LE-3 at the Computer Centre, Waigani, Port Moresby.

The programme LE-4 is employed to produce the required reports from the updated master file. Such reports are available in several forms, but for routine analysis a report is given for each moon phase period, each month and each year for every boat, each company and every one degree grid square (*Figure* 2) in which some fishing has taken place in the prescribed period. These reports present the results of only basic data collation and processing (e.g., means for all effects), and no sophisticated statistical procedures are used in the programmes LE-3 and LE-4.

Although values for water temperature and wind and sea condition for each entry are punched and stored on master file, they are not incorporated into the routine reports; it is necessary to store these records for the operation of other statistical programmes, e.g., the stepwise multiple linear regression (see later) which extract appropriate data direct from the records held.

Use of LE-4 allows the monitoring of monthly, seasonal and yearly fluctuations in catch per unit effort, total catch and catch composition. From this information studies of monthly, seasonal and yearly changes in each of the areas fished, and of migration of fish of different sizes throughout the fishing grounds, have been made. In addition, the data is converted to a convenient form for hypothesis testing of the fishery.

At the same time as the completed data sheets are returned, each company is required to submit a summary of the fishing master's monthly report to the company. These reports facilitate evaluation of variations in catch, and are particularly valuable where, despite the abundance of skipjack, catches are poor. Such discrepancies are usually the result of poor response of skipjack to chum, and unless such phenomena are reported separately they may not be detected by examination of the daily catch returns.

Any observed activities by fishing vessels, other than those registered in Papua New Guinea, in the area are also reported in the monthly bulletins.

In addition to the computed monthly summaries of the catch per effort data described above, several other programmes have been used to assist in the investigation of numerous topics of specific importance. These programmes had to be adapted for use on the available computers, the I.C.L. 1903A—the only computer available in Papua New Guinea, and later the C.D.C. 7600 in Canberra. They can briefly be described as follows:

(1) Generation of curvilinear length-weight regression equations—

This programme was adapted from WTLN (Abramson 1971), written by Norman J. Abramson and modified by Patrick K. Tomlinson and Catherine L. Berude. About it Abramson writes: "Fits a curve giving weight as a function of length, produces a table of fitted weights and lengths and provides various related statistics".

(2) The fitting of the von Bertalanfly growth equation to tag return date—

This programme was an adaptation of Patrick K. Tomlinson's original programme, BLG4 (Abramson 1971), which was defined as follows—"Estimates the parameters K and L_α of the von Bertalanfly growth-in-length curve, when only the lengths of individual

* Papua New Guinea achieved self-government on 1st December, 1973.

FIG. 1. CATCH STATISTICS FORM USED FOR ALL SKIPJACK AND TUNA LANDINGS.

DAILY TUNA CATCH RECORD

Boat Type	Form Type	Month	Year	Comp	Boat	Crew	No. of Days	Av.
1	2	3 4	5 6	7	8 9	10 11	12 13	14

COMPANY _____ TYPE OF GEAR (e.g. Pole, long-line or purse seine) _____ MONTH _____

NAME OF BOAT _____

LICENCE NO. _____ NUMBER OF CREW _____

day	grid ref.	water temp.	wind vel.	sea cond	bait (buckets or hooks x 100)	CATCH BY SPECIES WEIGHT IN KG. SKIPJACK Number	SKIPJACK Weight	YELLOW FIN Number	YELLOW FIN Weight	BIGEYE Number	BIGEYE Weight	BILLFISH Number	BILLFISH Weight	MACK TUNA Number	MACK TUNA Weight	SHARKS Number	OTHER SPECIES Species	OTHER SPECIES Number	OTHER SPECIES Weight	TOTAL Weight
1 2	3 4 5	6 7 8	9	10	11 12 13	14 18	19 24	25 29	30 35	36 40	41 46	47 50	51 55	56 59	60 64	65 68	69	70 73	74 78	
01																				
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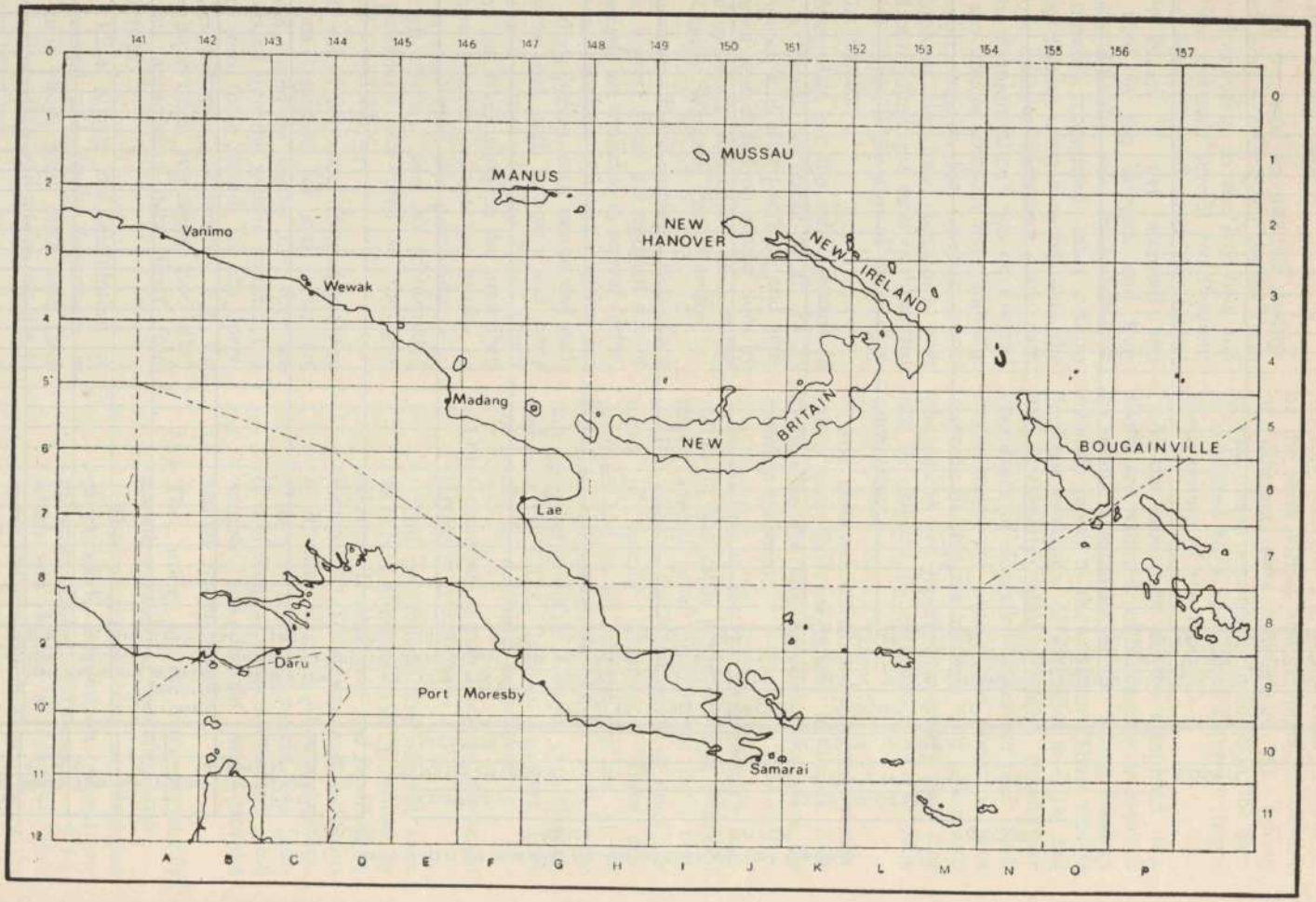
FIGURE 2 PAPUA NEW GUINEA DIVIDED BY ONE DEGREE SQUARES



fish at two points in time are known. This allows the curve to be fitted to tag release and recovery data".

(3) Normal distribution separator—

A programme was adapted from NORMSEP (Abramson 1971), which was a modified (Patrick K. Tomlinson) version of the original, by Victor Hasselblad. This programme "separates length frequency sampling distributions into component normal distributions. Used to estimate age group relative abundance in length samples of unageable species". In this work it was used for skipjack data, and also for the analysis of data on the most important bait species.

(4) Double or triple classification analysis of variance—

This was an adaptation of the Veldman (1967) programme AVAR 23, which was selected because of its ability to handle unequal sample sizes, and to treat zeros as either missing values or valid numbers, as indicated. The programme was used for routine statistical analysis, involving comparisons of results achieved during fishing periods described by variant parameters, particularly for comparing catch per unit effort variations with season, moon phase and the availability of bait.

(5) Stepwise multiple linear regression—

A programme based on REGRAN (Veldman 1967), selected because of its ability to handle up to 50 variables, and to supply tests of significance of the models selected. The programme was used exclusively on data taken directly from the LE master file, with all variables (e.g., weather, water temperature and bait) being included. Models for the description of skipjack catch were obtained for each year of the fishery, and for each individual company. Correlation co-efficients for every pair combination of variables were determined. The dependence of the skipjack fishery on the availability of bait was highlighted.

(6) Fishing Power—

The programme FPOW (Abramson 1971), written by Catherine L. Berude, was used and run on the C.D.C. 7600 computer in Canberra, Australia. Abramson (1971) states the purposes of the programme as "estimating the fishing powers of individual vessels relative to a standard vessel, and estimating the densities of fish in time-area strata, relative to a standard time-area stratum". Use of this programme enabled catch per effort data to be more accurately presented, and also gave more valuable estimates of the relative densities (actually presented as "catch-abilities") of skipjack in each of the one degree squares fished.

The six programmes listed have already been used for numerous data sets and, in addition, two more programmes are being developed, one for the estimation of tagging, fishing and natural mortalities based on tag release and recapture data, and the other for the study of community structure in the species composition of bait stations.

ACKNOWLEDGEMENTS

I am indebted to Mr A. D. Lewis and Mr B. R. Smith for their substantial contributions to all aspects of the research outlined in this report.

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EFFECT OF NUTRITION ON THE INCIDENCE OF *DRECHSLERA INCURVATA* LEAF SPOT OF COCONUTS

H. GALLASCH*

ABSTRACT

Recordings were made on three experiments to determine the effect of various fertilizer nutrients on the severity of Drechslera incurvata (*syn.* Helminthosporium incurvatum) *leaf spot disease on coconut seedlings. The results showed that the severity of* D. incurvata *leaf spot was related to the rate of applied nitrogen. Nitrogen fertilizers increased the susceptibility of the plant to the leaf spot disease while both potassium and phosphorus fertilizers decreased the susceptibility of the coconut seedlings. The application of sulphur fertilizer did not affect the disease severity.*

Growth of the seedlings, measured by total fresh weight at harvest, was markedly reduced when the leaf spot disease was severe for several months prior to harvest.

INTRODUCTION

A NUMBER of fungi are associated with leaf spotting of coconut seedlings on the Gazelle Peninsula of New Britain but microscopic identification revealed the major pathogenic one to be *Drechslera incurvata* (syn. *Helminthosporium incurvatum*). Often *Pestalotiopsis* spp. are also found on the diseased fronds, commonly on tissue apparently killed by *D. incurvata*, or on areas damaged by sprays. Occasionally *Epicoccum cocos* and *Curvularia* sp. are associated with these other fungi on the leaf spots.

A recent report (pers. comm.) has indicated that a loss of 73 per cent of seedling palms over three years occurred on one plantation on the Gazelle Peninsula as a result of this disease. These losses occurred despite good management and regular fertilizing with nitrogenous and sulphur fertilizers.

Drechslera incurvata leaf spot disease has been noted affecting palms in many other coconut growing regions. Zaiger (1967) recorded that most coconut nurseries on Ponape in the Caroline Islands had to be abandoned because of seedling defoliation by this leaf spot. In the British Solomon Islands this disease was more devastating on some varieties of coconuts, especially on the heavy soil types (Foale 1964). *D. incurvata* has been noted, along with several other leaf spotting fungi, on coconuts in other areas of Papua New Guinea (Shaw 1963, 1965). Kirthisinghe (1963) recorded seedling losses of up to 20 per cent in Sri Lanka caused by *D. incurvata* and it is a common but not serious disease of coconuts in Thailand (Meksongsee 1963).

The major plant nutrients N, P and K have often been reported as affecting plant resistance to disease. For example, an inbalance of nitrogen and potassium, resulting in a physiological deficiency of potash, considerably increased the incidence of *Helminthosporium* sp. leaf disease of rice (Akai and Mori 1954). In Africa the manuring of oil palm seedlings in the nursery with phosphate and especially with potassium reduced the incidence of leaf spot disease (*Cercospora* sp.) while nitrogen dressings increased the incidence (Ehsanullah 1970). Menon *et al.* (1950) in India established that low potash increased the incidence of leaf spot and other leaf diseases of coconuts and regarded as particularly important the ratio of potassium to nitrogen. Experiments at Kasarogod showed that a balanced NPK fertilizer treatment would aid in recovery of the palm from leaf spot disease. On a fertilizer experiment in Jamaica, Smith (1966) reported that young palms receiving nitrogen were highly susceptible to attack by the leaf spot fungus *Pestalotia palmarum*,* but that the increased

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* The fungus may in fact have been *D. incurvata* (pers. comm.).

susceptibility could be offset when potassium was also applied. A trial in Sri Lanka (Kirthisinghe 1963) examined the effect of rates of nitrogen, phosphorus and potassium on *Drechslera incurvata* of coconuts and found a decline in disease of 45 per cent with the most effective treatment, an application of potash plus phosphate fertilizer. Nethsinghe (1963) quotes Sri Lanka work as showing the incidence of the disease was generally associated with young palms with phosphorus deficiency receiving high levels of nitrogen.

Because of the potential seriousness of *D. incurvata* leaf spot on the early growth and survival of coconut seedlings investigations were commenced into the influence of some of the major plant nutrients on the disease.

METHODS

Recordings were made on coconut seedlings in two different maintenance-nutritional experiments at Keravat and a third experiment was planted specifically to examine leaf spot severity under the interaction of several nutrients.

Experiment 1

This experiment which was designed to examine maintenance of coconut seedlings was described by Sumbak (1971). It involved clean weeding over a wide area compared with limited ring weeding around the base of the seedlings and grass slashing, all treatments with and without the addition of ammonium sulphate. This fertilizer was applied at 30 g N per application to alternate seedlings. At an age of 16 months, after four bi-monthly applications of fertilizer, the incidence of *D. incurvata* was very high and recordings were made by the author on the degree of disease severity and frond damage.

Recording involved visual assessment of the extent of the frond area damaged by disease on the five youngest fronds of each seedling. Each frond was given a rating from 0-5 where—

0 = Zero to less than 1 per cent of area affected.

1 = 1 to 25 per cent of area affected.

2 = 26 to 50 per cent of area affected.

3 = 51 to 75 per cent of area affected.

4 = 76 to 99 per cent of area affected.

5 = Frond completely killed.

An average plant rating and hence percentage of leaf area affected was calculated for each plant.

Experiment 2

Factorial combinations of five rates of nitrogen and four rates of sulphur were applied as treatments to recently transplanted 14 weeks' old coconut seedlings. Nitrogen was applied initially at rates 0, 0.5, 2.2, 8.6, and 34 g urea per plant and sulphur as elemental sulphur at rates 0, 0.3, 2.5 and 20 g per plant. Rates of fertilizer increased with age in proportion to the estimated dry weight. Frequency of application was once per fortnight for urea and once per three months for sulphur. Treatments were applied to five seedlings per replicate and there were six replicates.

All seedlings were established in a pumiceous sandy subsoil, low in nitrogen and sulphur. Initially the spacing of seedlings was 1.8 x 1.8 m but harvest thinning during the trial increased this to 3.6 x 3.6 m. At an age of seven months there was an increase in the incidence of leaf spot and control was attempted using a regular weekly spraying of the fronds with a fungicide. For seven months a variety of fungicides was used, including copper oxychloride, Difilatan, Zineb and Captan. From October until the trial was completed Duter fungicide (.036 per cent w/v) was applied as a weekly spray. Recordings were made on the degree of leaf spot damage.

Experiment 3

Fertilizer treatments comprising zero and a high rate each of nitrogen, phosphorus and potassium, in factorial combination, were applied to coconut seedlings in polybags at five months after germination.

Rates of nutrients used were 5 g nitrogen as urea, 10 g phosphorus as monosodium phosphate and 15 g potassium as potassium chloride. Fertilizers were applied to the subsoil pumiceous sands in the polybags. Each of the eight treatments was allocated to eight seedlings in four replicates. Treatment applications were applied every six weeks for three applications and on two further occasions over the following six months.

Recordings of the leaf spot severity on the five youngest fronds of each plant were made at seedling ages of 8, 11, 15 and 20 months.

RESULTS

Drechslera incurvata leaf disease caused spotting of the fronds of coconut seedlings and the affected tissue became necrotic (*Plate* I). Under conditions conducive to the disease the spots enlarged and coalesced resulting in the eventual death of the frond (*Plate* II). The reduction in effective leaf area resulted in a substantial effect on the growth of the seedling (*Figure* 1). If a sufficient number of fronds were killed the seedlings died. Observations indicated however, that once seedlings grew taller than about 1.5 m, few deaths resulted from this disease.

In Experiment 1, where an analysis of soil samples indicated a concentration of 0.3-0.5 per cent nitrogen in the topsoil prior to planting, clean or ring-weeded seedlings which were fertilized with ammonium sulphate were severely damaged by *Drechslera incurvata* leaf spot while the unfertilized seedlings were much less affected (*Table* 1). However, seedlings growing under competitive conditions with grass (slashing treatment) showed a reversal of this effect.

The initial recordings in Experiment 2 indicated a fairly even distribution of disease through the planting and a uniform low rate of infection on all fertilizer treatments (*Figure* 2). However, as the severity of the leaf spotting increased, subsequent recordings indicated a marked correlation of damage with rate of applied nitrogen (*Figure* 2). There was a linear correlation between frond area killed and the log of the amount of applied nitrogen. Because the overall level of leaf spot severity varied during the period of the experiment (*Figure* 3) the slope of the linear regression line in *Figure* 2 varied with time.

The relationship between the cube root of the total fresh weight of the coconut seedling (harvested at 86 weeks) has been plotted in *Figure* 1 against the square root of the percentage leaf area damage (recorded seven months prior to harvest). The regression coefficient (r) = —0.74 is highly significant.

In spite of the weekly application of fungicide the disease severely affected seedlings treated with high levels of nitrogen (*Figure* 3). At the zero and lowest level of nitrogen fertilizer there appeared to be a decline in leaf spot damage after July, whereas at the higher rates of applied nitrogen a decline in the extent of leaf damage only commenced in the following January.

Rainfall may have influenced the severity of the disease and was plotted in histogram form in *Figure* 3. Over the period September to January rainfall was uniformly high as was the severity of disease. A marked decline in disease severity corresponds with a period of low rainfall in January and February.

Seedlings within the same treatment were not uniformly affected by leaf-spot disease (*Figure* 4). Without added nitrogen only four per cent of seedlings were affected to the extent of greater than 20 per cent frond necrosis but at the highest rate of applied nitrogen seedlings were affected at all degrees of severity. Although 29 per cent were affected to an extent of greater than 80 per cent of their leaf area there was still some 23 per cent of the seedlings affected to less than 20 per cent of their leaf area.

The rate of sulphur application had little effect on the degree of leaf spot on coconut seedlings (*Figure* 4). Irrespective of the amount of sulphur applied as fertilizer, 67 per cent of all seedlings were affected to less than 40 per cent of their leaf area, the large majority of these to less than 20 per cent of their leaf area.

In Experiment 3 the effect of *D. incurvata* leaf spot disease was reduced by the application of potassium chloride and to a lesser extent by monosodium phosphate (*Figure* 5). Urea fertilizer markedly increased the amount of leaf damage. During the period of highest disease incidence, covered by the September and December recordings, there was around 100 per cent increase in disease damage on seedlings fertilized with nitrogen. Over the same period damage was reduced by 30 per cent on seedlings receiving phosphorus and by 32 per cent on those receiving potassium fertilizer.

DISCUSSION

Effect of D. incurvata *on Coconut Seedlings*

Colonization of the leaf by *D. incurvata* results in spotting, the tissue in these spots becoming necrotic. If the environment favours the disease a large proportion of the leaf area may be killed or rendered ineffective. This reduction in effective leaf area of the seedling affects the growth potential and the weight increase of the plant (*Figure* 1). The linear

Plate I—Drechslera incurvata leaf spot disease on frond of coconut seedling

Plate II—Severe *D. incurvata* leaf spot may result in the death of coconut seedling fronds

Table 1—The effect of nitrogenous fertilizer on the degree of frond necrosis by *D. incurvata* under different maintenance systems

	Per cent of frond area killed		
	Slashing	Ringweeding of seedling	Complete-clean weeding
No fertilizer	50	28	17
Ammonium sulphate (applied every 3 months	23	55	57

relationship of the cube root of total fresh weight to the square root of the leaf area damaged indicates an effect of the leaf spot disease on growth. An increase in the disease severity results in a corresponding decrease in the subsequent growth of the plant.

The plant nutrients nitrogen, potassium and phosphorus affect the susceptibility of coconut seedlings to *D. incurvata* leaf spot disease whereas sulphur does not.

Nitrogen

The nitrogen nutrition of the seedling is a factor affecting the severity of leaf spotting, leaf damage being proportional to the logarithmc function of the rate of fertilizer nitrogen (*Figure* 2). The actual source of the nitrogen is not important. In Experiment 1 the use of ammonium sulphate fertilizer, under conditions of adequate soil nitrogen resulted in increased leaf spotting (*Table* 1). Urea applications in Experiments 2 and 3 similarly increased the seedling susceptibility to leaf spot. Comparable results have been found in Sri Lanka (Nethsinghe 1963 and Kirthisinghe 1963) and India (Menon *et al.* 1950).

Potassium and Phosphorus

Potassium and phosphorus interact with nitrogen in its effect on seedling susceptibility to attack by *D. incurvata.* Applications of potassium and phosphorus in Experiment 3 have been effective in reducing the degree of leaf spot on coconut seedlings. This is shown graphically in *Figure* 5. By comparing the *Nil* point with the *PK* point on each graph, it can be seen that in each case there is a drop in the percentage leaf spot necrosis. Where nitrogen is included in the fertilizer treatment, the drop is even greater, as can be seen by comparing the *N* point with the *NPK* point on each graph.

A similar result was obtained by Kirthisinghe in Sri Lanka (1963), who obtained a decline of 45 per cent in lesion counts three months after a fertilizer application of phosphorus and potassium. Smith (1965) reported comparable results obtained with phosphorus and particularly potassium on the incidence of leaf spot caused by *Pestalotia palmarum.* It appears important that a balance of the major nutrients must be maintained. If it becomes necessary to fertilize with nitrogen then consideration should be given to complementary applications of potassium and perhaps phosphorus to prevent coconut seedlings becoming unduly susceptible to leaf spot disease.

Sulphur

The application of sulphur fertilizer did not influence the susceptibility of coconut seedlings to *D. incurvata* leaf spot (*Table* 2).

Effect of Fungicides on D. incurvata

At the zero and lowest rate of nitrogen fertilizer the reduction in disease incidence noted in August (*Figure* 3) is considered due to the production of new fronds partially protected by the fungicides. The degree of protection was insufficient to reduce the disease incidence on seedlings rendered more susceptible by the higher rates of nitrogen fertilizer. Only after regular spraying with Duter, a fungicide found to be effective against *D. incurvata* (report to be published), was there a dramatic decrease in disease damage. As the youngest five fronds were assessed at each recording period it would be approximately five months after treatments commenced (the time required for formation of five new fronds) before recordings were unbiased by pre-treatment condition of the fronds.

Other factors affecting the incidence of D. incurvata

Many factors undoubtedly affect the level of disease damage on seedlings. These include the genetic type, the rate of frond production, the overall vigour of the seedling and its immediate environment. It is considered that

Table 2—Per cent of frond area affected by leaf spot disease at various rates of applied sulphur

Recording Date (Weeks from Germination)	Rate of Sulphur			
	S_0	S_1	S_2	S_3
6.5.70 (34 weeks)	13	12	11	13
18.8.70 (49 weeks)	33	24	25	31
21.10.70 (58 weeks)	27	20	29	30
8.3.71 (78 weeks)	4	4	4	5

a combination of these factors resulted in the anomalous situation for the slashing treatment in Experiment 1 (*Table* 1). The lack of vigour, a somewhat lower rate of frond production and the different microclimate surrounding the unfertilized seedlings in the tall grass could have combined to result in a high level of disease damage. Ammonium sulphate, used to rectify the nutrient deficiency induced by severe grass competition increased the plant vigour but not the susceptibility to *D. incurvata*.

The commencement of a dry period in January coincided with a marked decline in assessed disease damage in Experiment 2 (*Figure* 3). It is considered that the dry weather conditions most likely contributed towards the recorded decrease in disease on the seedlings.

As the seedling age increases the rate of leaf area production increases rapidly (Foale 1968). Because of this rapid increase in total area of the seedling the significance of *D. incurvata* leaf spot on leaf area decreases with increasing age of the seedling. The final recording on disease damage in Experiment 2 (*Figure* 3) was made at an average seedling age of 18 months, at which stage the disease was less effective in substantially reducing the leaf area of the plant. In Experiment 3 the level of disease damage at age 21 months was less than half that at age nine months but the extent to which this is due to age or to environmental conditions is not known. For the three experiments a seedling height of about 1.5 m corresponded to the stage of growth at which new leaf production was sufficient to minimize the effects of leaf spot necrosis.

CONCLUSIONS

Drechslera incurvata can be a serious disease of coconut seedlings and can result in substantial growth reductions or even death of the seedlings if conditions are conducive for the growth and spread of the disease. This disease is usually only of consequence while the seedlings remain comparatively small. Overseas work, confirmed here, shows that nitrogen fertilization may accentuate the disease while potassium and phosphorus tend to retard it. Consequently care must be exercised in the use of nitrogenous fertilizers on coconut seedlings. In many cases an adequate nitrogen nutrition of seedlings can be maintained by cleanweeding around the seedlings (Sumbak 1971) and the application of fertilizer cannot fully compensate for the lack of clean weeding. If additional nitrogen is required on some soil types it should be used sparingly and the recommended application rates not exceeded. Should the *D. incurvata* leaf spot still become a problem it can be alleviated by the application of 150 g of potassium chloride per year. This is applied every four months during the critical period when the seedlings are less than 1.5 m tall. This added cost is relatively small when compared with the alternative cost of replanting seedlings killed by a bad outbreak of the leaf spot disease.

This method involving the adjustment of plant nutrition by fertilizer applications to reduce susceptibility to disease can be readily applied in the field as well as in the nursery. Alternative methods of control using fungicidal spraying may be quite effective in the nursery but there are practical difficulties involved in using them in control of leaf spot on a large scale in the field.

ACKNOWLEDGEMENTS

The help of the Plant Pathology Section, Department of Agriculture, Stock and Fisheries, in identifying the leaf spot pathogens was appreciated.

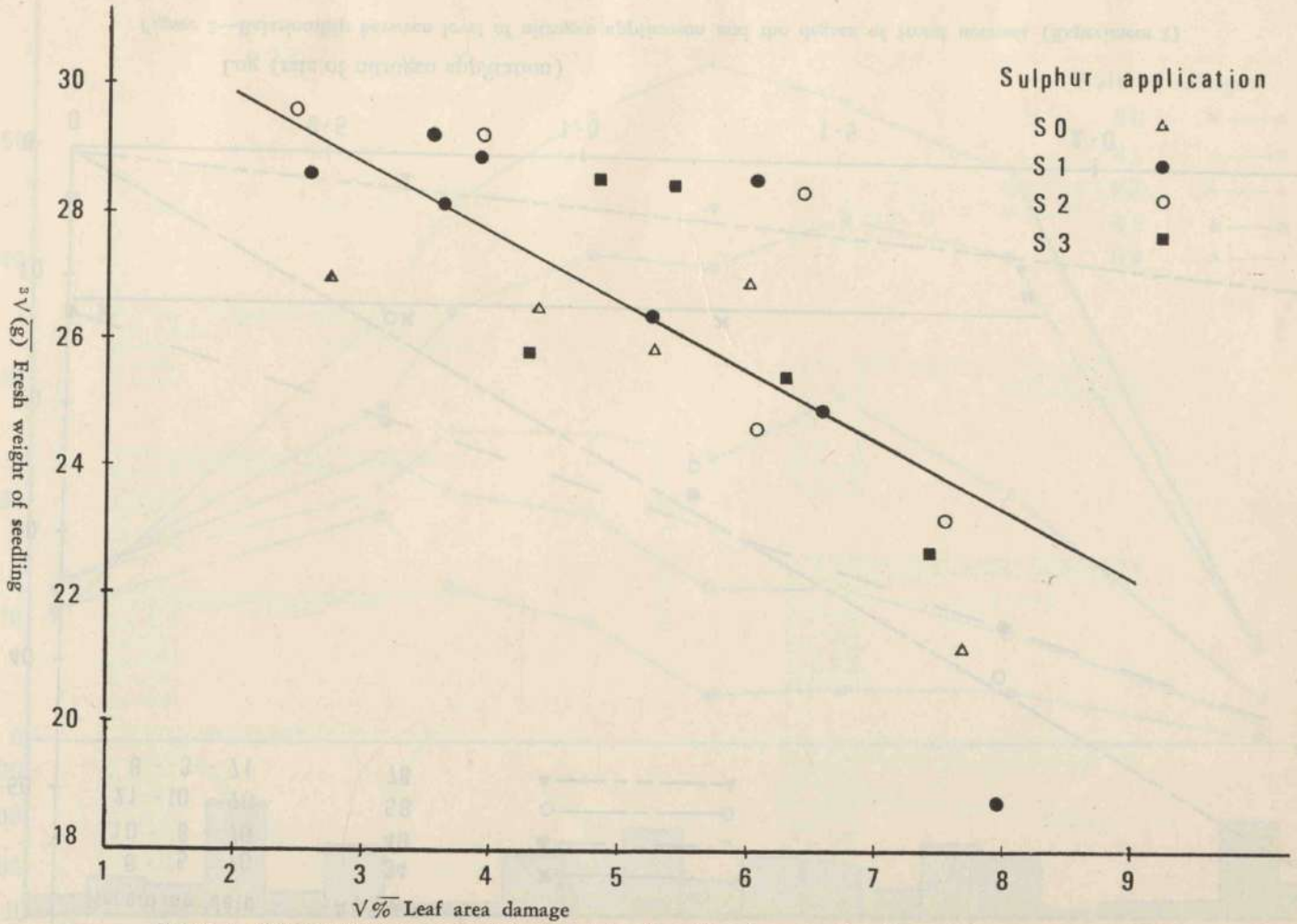

Figure 1—Relationship between total fresh weight of seedling (at age 86 weeks) and previous leaf spot damage: the regression of $\sqrt[3]{\text{(fresh weight)}}$ on $\sqrt{\text{(\% leaf area damage)}}$ (Experiment 2)

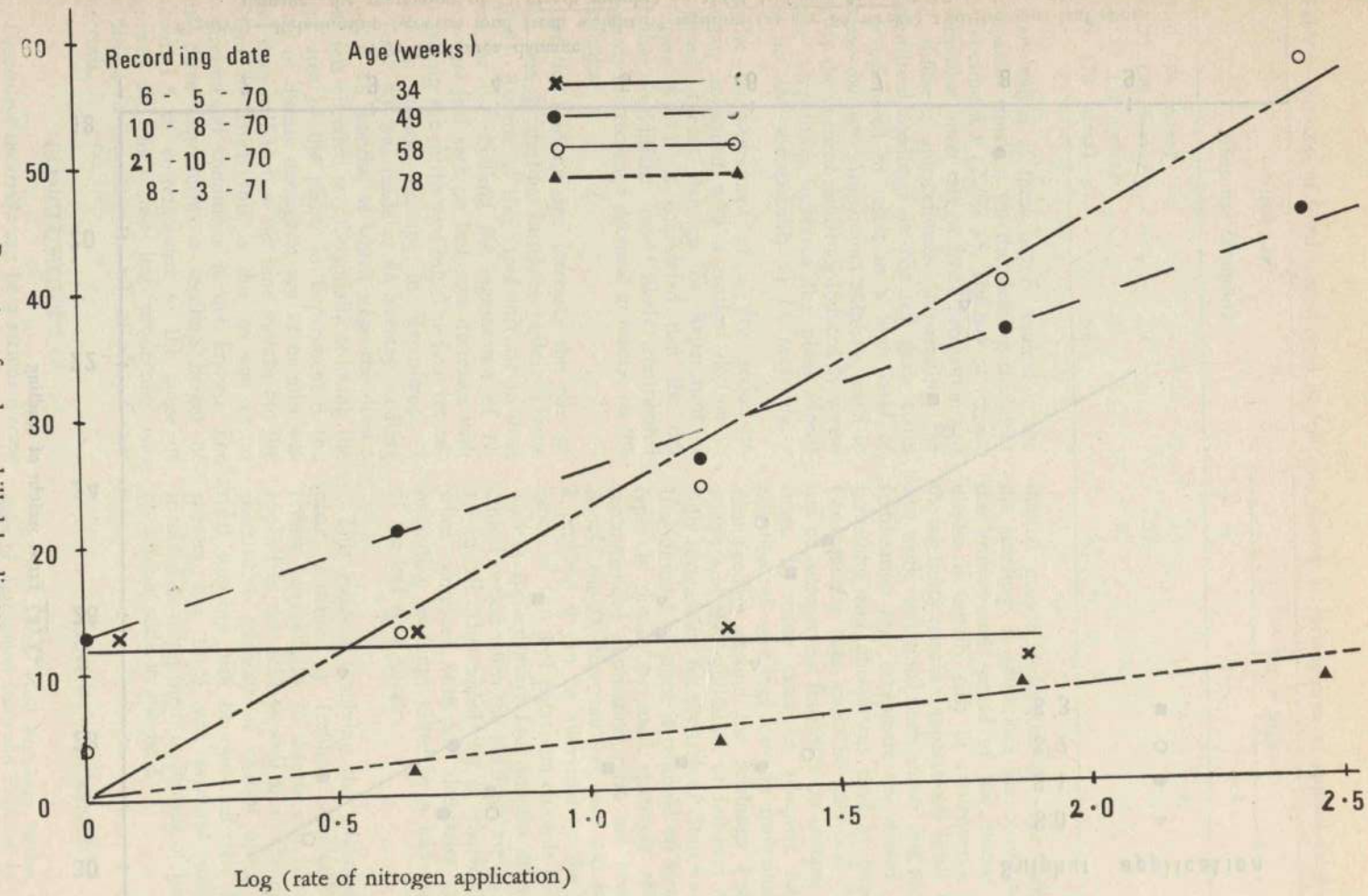

Figure 2—Relationship between level of nitrogen application and the degree of frond necrosis (Experiment 2)

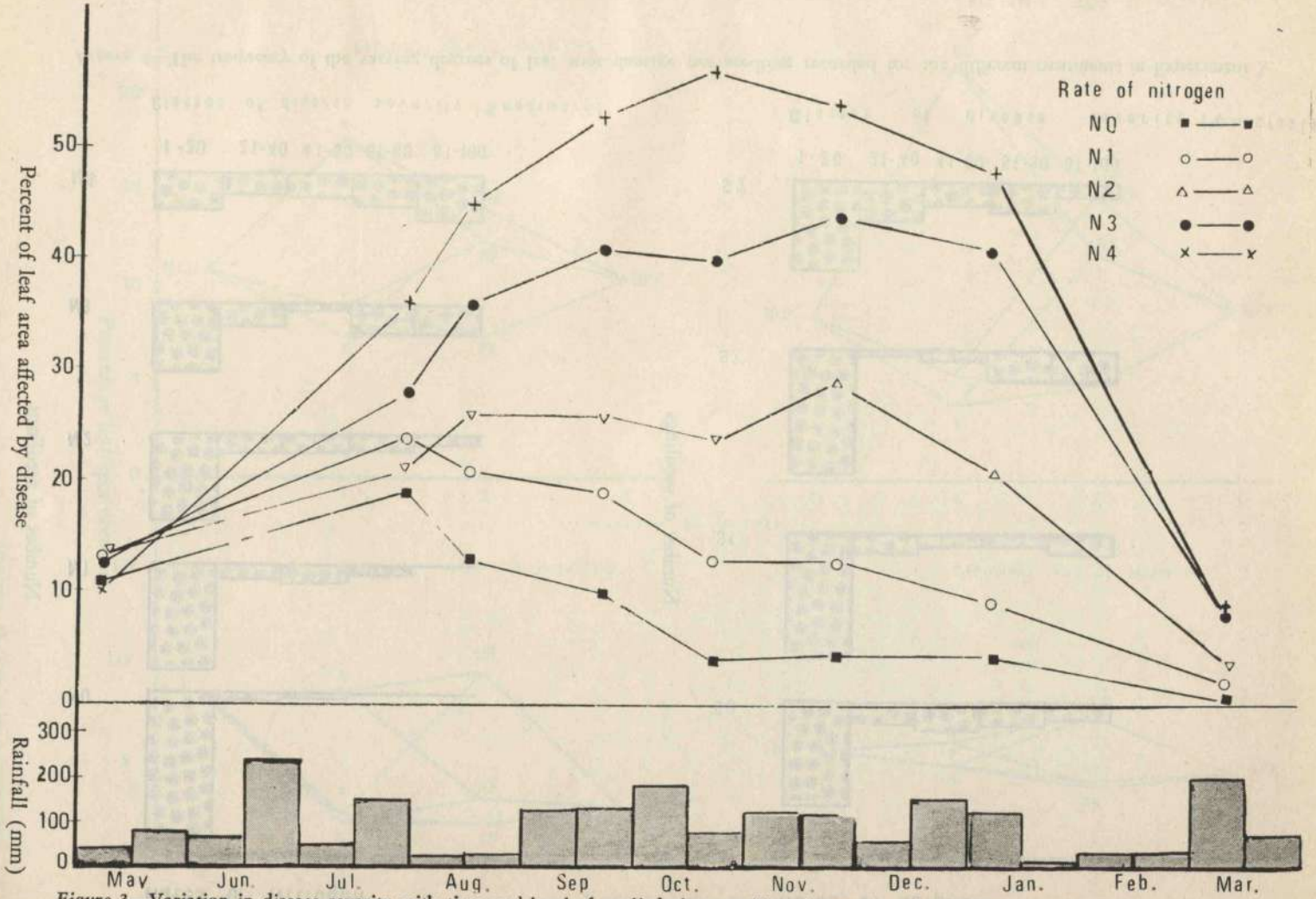

Figure 3—Variation in disease severity with time and level of applied nitrogen (Experiment 2), and rainfall during the period of recording

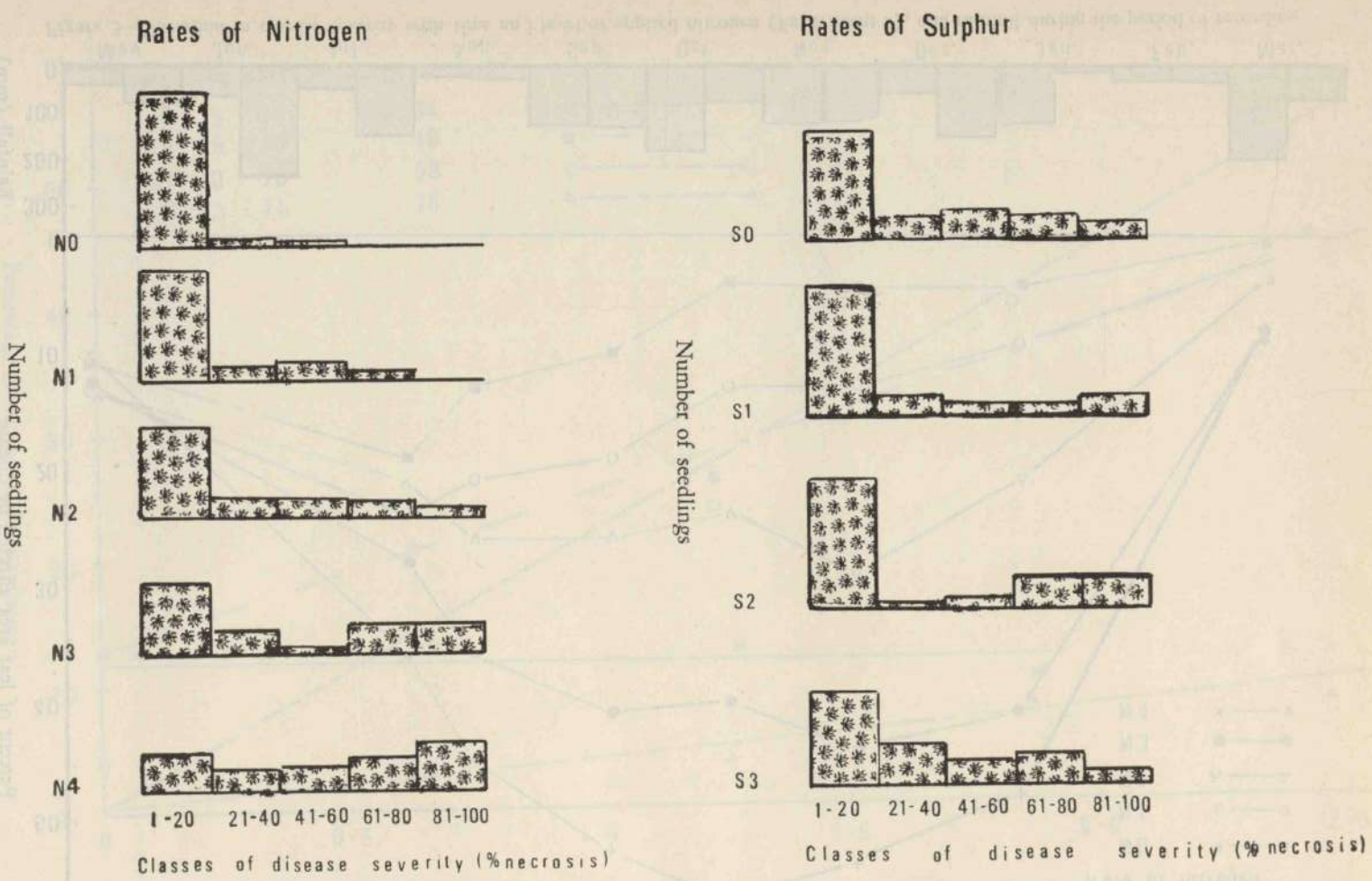

Figure 4—The frequency of the varying degrees of leaf spot damage per seedling recorded for the different treatments in Experiment 3

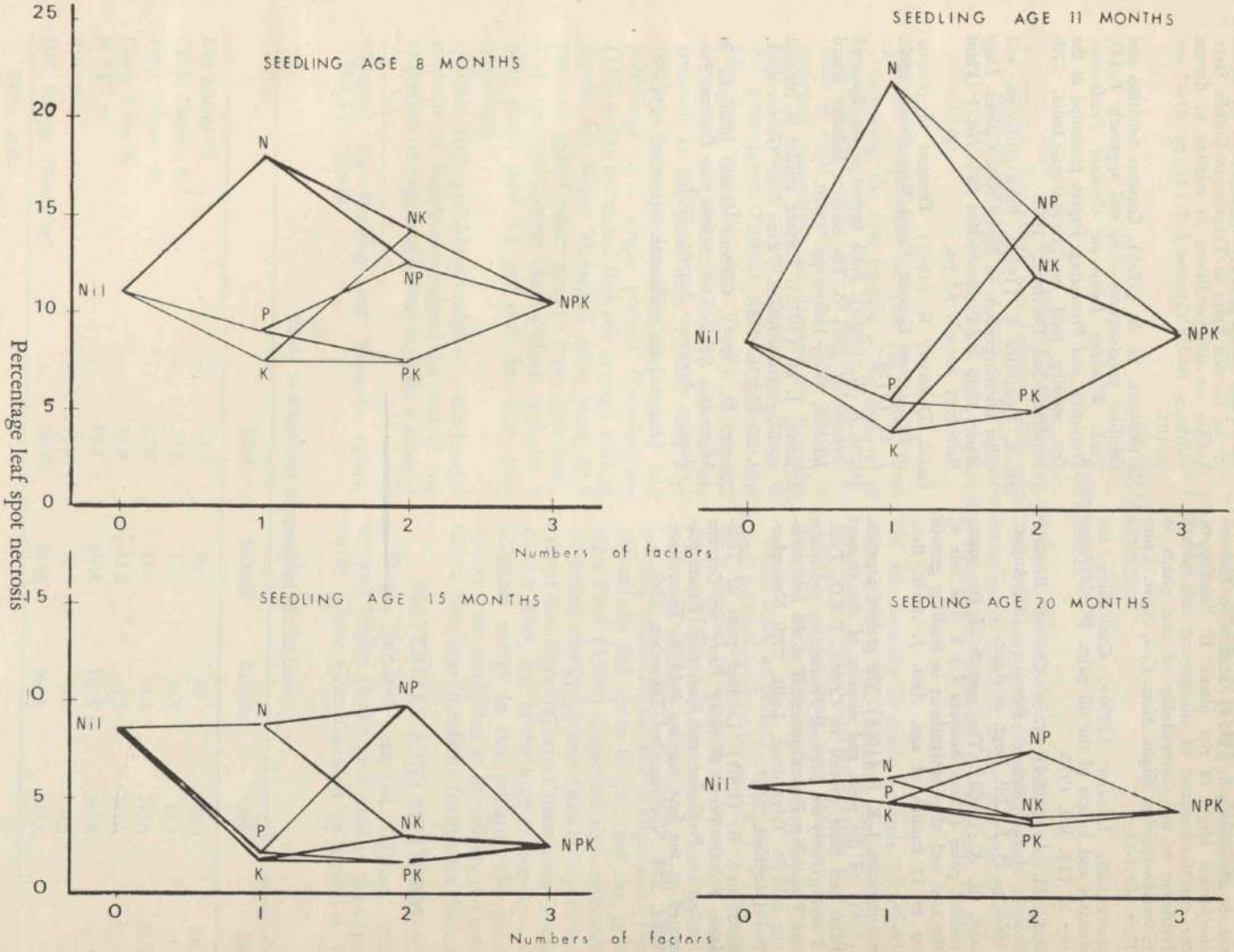

Figure 5—The interaction of nitrogen with potassium and phosph orus in the effect on seedling susceptibility to attack by *D. incurvata* (Experiment 3)

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THE VALUE OF RICE BRAN IN BROILER RATIONS

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ABSTRACT

Rice bran was used to substitute for sorghum and protein concentrate in a broiler ration. The ration was balanced with respect to micro-nutrients. No detrimental effects were observed up to a level of 50 per cent inclusion in the diet, which was the highest level used. Economically, it appears that rice bran could substitute for sorghum in pig rations.

IN the preparation of rice for human consumption, the first process is the removal of the very hard husk. This is essential as it contains a high proportion of silica which, in sufficient quantities, can damage the digestive tract. The kernel which remains is enclosed in the bran layer. Further milling removes the bran layer and the germ. Finally, if the rice is polished, the epicarp, mesocarp and testa are removed as the polishings. (Arnott and Lim 1966a). Some simpler mills remove bran and polishings in a single process. Zwankhuisen (1961) has calculated that the average milling figures for larger Malaysian mills were 63.5 per cent milled white rice, 15.1 per cent husk, 17.1 per cent coarse bran (which includes a little husk) and 4.3 per cent fine bran plus polishings.

Bran and polishings contain considerable amounts of highly unsaturated fat and if fed to poultry or pigs would tend to cause softening of fat deposits in these animals (Arnott and Lim 1966b). The chemical composition of the rice bran used in this experiment is shown in *Table* 1. The bran was obtained from the Bainyik Rice Mill in the East Sepik District.

Rice bran, or pollard, as the mixture of bran and polishings may be called, has been used by a number of workers in rations for poultry. Sidhu (1969) has successfully used up to 25 per cent polishings in starter and finisher rations, whilst Malik and Ichhponani (1969) successfully fed up to 61 per cent rice polishings. Patil (1969) suggested that maintaining a constant energy/protein ratio in experimental rations was more important than using isonitrogenous diets, due to the high content of metabolisable energy in rice pollard. The present studies were conducted to investigate the potential of rice bran in rations for broiler chickens.

MATERIALS AND METHODS

Three hundred day-old Hyline strain unsexed broiler chicks were used in the experiments. These were allocated on arrival at the

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Table 1—Chemical composition of rice bran

	India[1]	Malaysia[2]	Australia[3]	PNG[4]	PNG[4]
Dry Matter %	94.7	89.9	90	86.3	88.4
Crude Protein %	10.9	12.3	13.7	13.1	13.4
Ether Extract %	12.0	12.1	14.6	N/A	N/A
Crude Fibre %	12.0	11.3	4.7	N/A	N/A
N.F.E. %	47.4	N/A	N/A	N/A	N/A
Ash %	12.4	10.2	9.5	6.3	7.4
Met. Energy (Kcals/kg)	29.37	N/A	N/A	N/A	N/A

[1]Sidhu, 1969.
[2]Arnott and Lim, 1966.
[3]Air Dry Basis, Patil, 1969.
[4]Turner, W. J., unpublished, 1971.

Table 2—Composition of rations used to evaluate rice bran for broilers

	RATION NUMBER				
	1	2	3	4	5
Rice Bran (kg)	0	10	25	35	50
Protein Concentrate (kg)	28	27	25	24	23
Sorghum (kg)	72	63	50	31	27
Vitamin/Mineral Mixture[1] (g)	66	68	73	75	77
Coccidiostat[2] (g)	51	51	51	51	51
Anti-oxidant[3] (g)	22	22	22	22	22
Bone Ash (g)	0	121	352	484	704
Salt (g)	0	40	119	158	198

[1]Nutrigain Vitamin-mineral supplement, Nicholas Pty Ltd, contains vitamins A1, D3, E, K, Riboflavine, Pantothenate and Manganese sulphate.
[2]Pancoxin, Merck, Sharp and Dohme, Granville, N.S.W.
[3]Embanox, May & Baker, Dagenham, England.

centre to five groups of 60 in such a way that the mean and standard deviation for each group was quite similar. Groups were allocated at random to kerosene brooders where they remained for three weeks. During this time the chicks were fed one of the five experimental rations whose composition is shown in *Table* 2. Rice bran was used to replace sorghum in the diets which were balanced for levels of protein, vitamins, calcium and phosphorus and salt. A commercial coccidiostat and an anti-oxidant were added at the same level to all diets.

After three weeks each group of 60 was divided into three groups of 20, each subgroup forming a replicate. Housing was provided on a deep litter of coffee hulls in pens measuring 3 x 1.5 metres. The same feed was used from three to nine weeks as had been used in the brooders. Feed and water were provided *ad libitum*. Birds were weighed weekly, food consumption was calculated weekly, and a record kept of all mortalities.

The method used to assess the value of rice bran was the cost of producing 1 kilogram of liveweight gain using the five rations. The prices assumed for sorghum, protein concentrate and rice bran were $80, $250 and $50 per tonne.

RESULTS AND DISCUSSION

The physical results of the experiment are shown in *Tables* 3 and 4. The data for the second part of the experiment were analysed for variance but no significant treatment differences were found for any of the parameters. In both phases of the experiment there was a trend for food consumption to fall with increasing levels of rice bran. This is not unexpected due to the high metabolisable energy content of rice bran, although the increasing crude fibre levels would tend to cancel out this effect. As the differences in weight gain were not large, there was a tendency for feed conversion ratio to improve with higher levels of rice bran.

Table 3—Performance of chicks fed rations containing rice bran—up to three weeks of age

	Level of Rice Bran (%)				
	0	10	25	35	50
Initial weight (g)	39.0	39.3	39.3	38.5	40.0
Mean daily weight gain (g)	10.73	11.03	9.59	12.26	12.76
Mean daily feed consumption (g)	27.12	26.34	23.91	25.48	25.16
Mean feed conversion ratio	2.53	2.39	2.49	2.08	1.97

Table 5 shows the cost of the rations and the feed costs required to produce 1 kilo of liveweight gain. The most economic level of inclusion at the prices studied was 35 per cent. At the present price of $40 per tonne the inclusion of rice bran at levels up to 50 per cent is strongly recommended.

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Table 4—Performance of broilers fed rations containing rice bran—three to nine weeks of age

	Level of Rice Bran (%)				
	0	10	25	35	50
Mean initial weight (g)	228.6	234.8	206.2	261.9	259.4
Mean daily weight gain (g)	25.67	27.50	26.53	27.81	26.41
Mean daily feed consumption (g)	69.75	72.79	71.88	67.30	65.49
Mean feed conversion ratio	2.73	2.65	2.71	2.42	2.48

Table 5—Feed cost of producing one kilo of liveweight gain

	Level of Rice Bran (%)				
	0	10	25	35	50
Cost per kg ration (c)	12.7	12.3	11.5	10.2	10.4
Cost per kg gain (c)	34.7	32.6	31.2	24.8	25.8

AN OUTBREAK OF *TIRACOLA PLAGIATA* (WALKER) (LEPIDOPTERA:NOCTUIDAE) ON COFFEE IN THE WESTERN HIGHLANDS DISTRICT OF PAPUA NEW GUINEA

G. L. BAKER*

ABSTRACT

An outbreak of the Tiracola plagiata *(Walk.) (Lepidoptera:Noctuidae) in the Western Highlands of Papua New Guinea in January,* 1970 *is briefly described.*

Crotalaria semperflorens *Vent. (Leguminosae), a recent illegitimate plant introduction into Papua New Guinea, was implicated as a preferred host of* T. plagiata *and its use as a temporary shade over young coffee is believed to have caused the outbreak.*

Two new ichneumonid pupal parasites of T. plagiata-Lissopimpla scutata *Krieger and* Ichneumon promissorius *Erichson were bred from host pupae collected during the outbreak.*

INTRODUCTION

TIRACOLA PLAGIATA (Walk.) has been recorded from a wide range of host plants in Papua New Guinea (Catley 1962) and from 1961 to 1966, causing serious damage to cacao in the Northern District (Catley 1962, Catley 1963, Dun 1967).

On coffee, *T. plagiata* has occasionally caused economic damage in the Wau area of the Morobe District (D.A.S.F. 1966, 1969, 1971).

THE OUTBREAK

In January, 1970 defoliation of *Coffee arabica* by *T. plagiata* was reported from two plantations in the Wahgi Valley in the Western Highlands.

Large populations of *T. plagiata* larvae were first reported defoliating the coffee and *Crotalaria semperflorens* Vent. on 1st January, 1970. The larvae were reported to be so dense that after defoliating the coffee and *C. semperflorens*, large bands migrated out of the area into adjacent subsistence food gardens, where they fed on *Passiflora edulis*, *Ricinus communis*, *Ipomoea batatas* and *Musa* sp. All these species have been previously recorded as hosts by Catley (1962).

Few larvae were reported on 14th January, most having presumably pupated. Large flights of adults were subsequently reported on 23rd and 24th January.

When the outbreak area was visited on 28th January very few intact pupae were located, as adults had already emerged from the majority.

On one plantation, 16.2 hectares of 2 to 5 month old coffee seedlings and hedgerows of *C. semperflorens* shade between which the coffee was planted had both been completely defoliated (*Plate* I), except for a small area of approximately 0.2 hectare which had been sprayed with a 0.25 per cent solution of DDT (*Plate* II).

On a second plantation, a 10.5 hectares' block of coffee planted under *C. semperflorens* and *Crotalaria anagyroides HBK.* shade had also been attacked. *C. semperflorens* had suffered 90 per cent defoliation whereas the interplanted *C. anagyroides*, which had previously been recorded as a host of *T. plagiata* (Catley 1962) had not been eaten. Also, the coffee seedlings had not been defoliated to the same extent as on the first plantation.

No general build up of *T. plagiata* was evident on other coffee plantations inspected in the Western Highlands. Several of these plantations had coffee growing under *Leucaena leucocephala* (Lamk.) de Wit shade which, in

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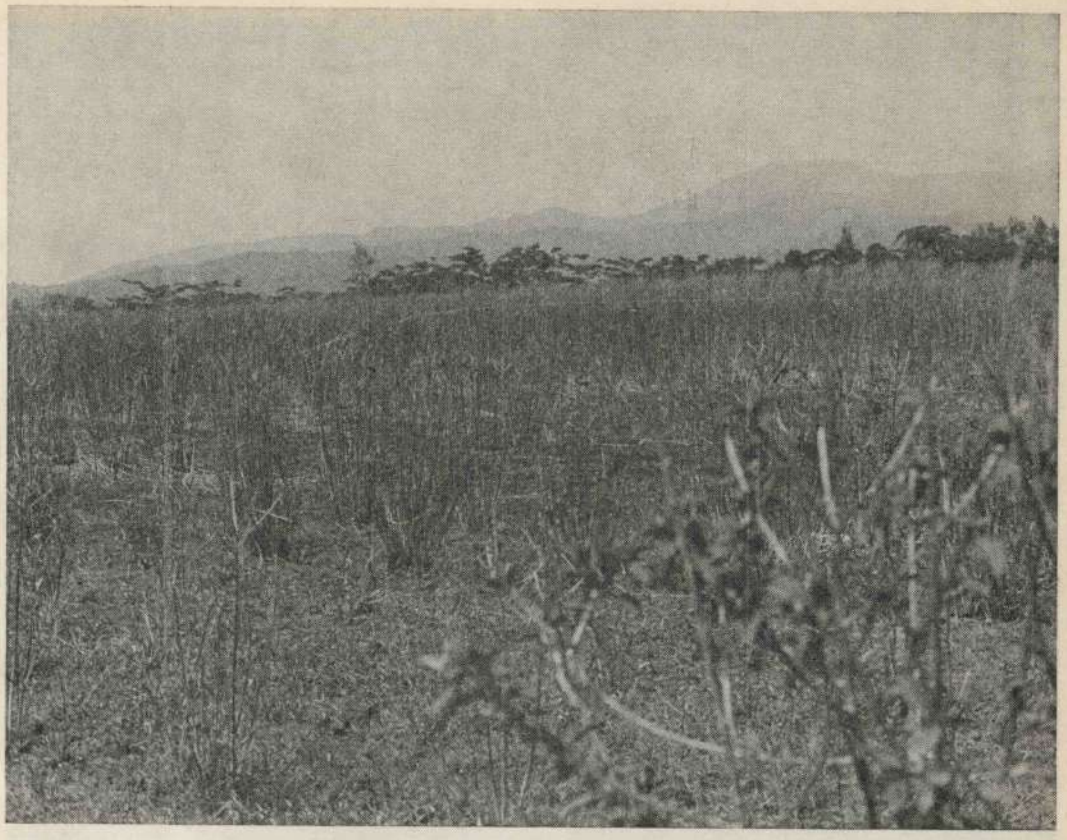

Plate I—Partial view of the 16.2 hectares of *Coffea arabica* under *Crotolaria semperflorens* shade, both of which were completely defoliated during the *Tiracola plagiata* outbreak

the Northern District, is known to favour a build up of *T. plagiata* populations (Catley 1962). However this did not appear to be the case in the Western Highlands.

It is widely believed that prolonged dry weather conditions favour a build up of *T. plagiata* (DASF 1966).

A comparison of rainfall figures for 1969 and the first quarter of 1970 with mean rainfall (*Table* 1), shows that the latter half of 1969 was not an exceptionally dry period which may have contributed to a population build-up leading to the outbreak of January, 1970.

However it is thought that the outbreak was related to the use of *C. semperflorens* as a shade tree for coffee. *C. semperflorens* is a recent illegitimate introduction into Papua New Guinea. It was noted in the Western Highlands at Minj in the early 1960's and was first used as a temporary shade for coffee seedlings in the same area in 1963. By 1966 it made its appearance along roadsides as an ornamental, and its popularity as an ornamental has caused its rapid spread throughout the Western Highlands and Chimbu Districts. As mentioned previously, *C. semperflorens* would appear to be preferred host for *T. plagiata.*

PARASITES

The results of emergences from the *T. plagiata* pupae, collected at the time of inspection, are given in *Table* 2.

The ichneumonid, *Lissopimpla scutata* Krieger was bred from one host pupa and several specimens were collected in the field from the flowers of *C. semperflorens. L. scutata* was also bred by the author from *T. plagiata* pupae collected at Kainantu in the Eastern Highlands in January, 1970. The species is widely distributed throughout Papua New

Plate II—*Coffea arabica* seedlings defoliated by *Tiracola plagiata. Crotalaria semperflorens* on the left was severely defoliated and on the right only partially defoliated due to protection by DDT spray

Table 1—Quarterly and annual rainfall (mm) at Minj and Mt Hagen prior to the outbreak compared with mean

Quarter	Minj			Mount Hagen		
	Mean*	1969†	1970†	Mean*	1969†	1970†
January-March	725	736	748	814	788	738
April-June	495	607		564	503	
July-September	520	464		539	484	
October-December	612	812		639	968	
Annual	2352	2620		2556	2743	
Highest Annual	2819			3283		
Lowest Annual	2021			2099		

* From C.S.I.R.O. (1970). Length of record on which mean based: Minj, 10 years: Mt Hagen, 15 years.
† Bureau of Meteorology, Met. Info. Services, Dept of Interior, Canberra, Australia.

Guinea, having been previously collected at Port Moresby, Wau and Tari. Unfortunately hosts were not recorded from these other areas.

L. scutata larvae feed extensively on the contents of the pupae leaving it filled with small, round, reddish-orange coloured pellets of frass. The parasitic larvae pupate within the pupa of the host. Parasitised host pupae can be distinguished from healthy pupae by their darker colour and dry, rigid integument.

Ten specimens of the ichneumonid *Ichneumon promissorius* Erichson emerged from 43 *T. plagiata* pupae. This gives no indication of the parasitism rate being an inflated value due to the fact that the majority of *T. plagiata* adults had already emerged. Those *T. plagiata* pupae remaining in the soil at the time of collection therefore were more likely to contain the parasite than the host. Some pupae parasitised by *I. promissorius* contained fully formed adult *T. plagiata* which had been partially eaten by the parasitic larvae, indicating that parasitism can occur at a late stage in the host's pupal development.

This is the first record of *I. promissorius* as a parasite of *T. plagiata*. *I. promissorius* has, however, previously been reared from pupae of *Agrotis ipsilon* Hübner in the Eastern Highlands and has since been reared from pupae of *Spodoptera exempta* Walker in the Eastern and Western Highlands.

Pupae parasitised by *I. promissorius* can be readily distinguished from those parasitised by *L. scutata* in that they do not contain frass pellets but instead are full of liquid.

No tachinids were bred from the small sample of *T. plagiata* pupae collected, but two empty tachinid puparia were found in the soil. Tachinid larvae usually emerge from the parasitised lepidopterous host pupae a short time after pupation. This probably accounts for the

Table 2—Emergences from field collected *Tiracola plagiata* pupae

Emergences	Number	Mean Time of Emergence (days after collection)
Host		
Tiracola plagiata	25	2.04
Parasite		
Lissopimpla scutata	1	6.00
Ichneumon promissorius	10	4.90
Non-emergences	7	
Sample Size	43	

fact that no tachinids were bred out for, at the time of sampling, most tachinid larvae would have already abandoned their host. Numerous specimens of a *Drino* sp. were flying around the defoliated *C. semperflorens*. *Drino* sp. adults were abundant on and around the few plants which had escaped defoliation and were flowering. The insects may have emerged from parasitised *T. plagiata* pupae associated with the outbreak.

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