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ERRATUM

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DISCUSSION

Paragraph 4, line 14

The highest yield were obtained where the CODEX were lowest, thus reflecting that metalaxyl controls the disease effectively (Pandotra 1965: Srivastava *et al.* 1991; Gupta and Pandey 1986, Wiles 1992a) they have ...

Should read

The highest yields were obtained where the CODEX were lowest, thus reflecting the efficacy of the test fungicides. Sentence 8 should read "Although manzeb, benomyl, copper oxy choloride and metalaxyl have been reported to control the disease effectively (Pandotra 1965; Srivastava *et al.* 1991; Gupta and Pandey 1986, Wiles 1992a), they have not performed better than the control under Brahman condition".

PAPUA NEW GUINEA

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CONTENTS

THE CONTROL OF BACTERIAL WILT (*Ralstonia solanacearum*) OF POTATO BY CROP ROTATION IN THE HIGHLANDS OF PNG

S. Bang[1] & G.C. Wiles[2]

ABSTRACT

*A trial was conducted to compare the effect of rotation with different crops or fallow treatments and for different durations on the level of bacterial wilt infection in subsequent potato crops. Land severely infected with bacterial wilt (*Ralstonia solanacearum *biovar 2, race 3) at Tambul, Western Highlands Province, was selected for the trial. Potato crops were rotated with maize, sweet potato, bare fallow or weed fallow. Yield and wilt infection in subsequent potato crops were then observed.*

*After one break crop, wilt infection remained high in all treatments. Two or three break crops of maize or bare fallow were effective in reducing wilt incidence. Alternating potato with maize over five crops was just as effective. Sweet potato breaks alone were ineffective in controlling wilt. Weed fallow breaks did not reduce the level of wilting and actually reduced yield of subsequent potato crops. This suggests that weed fallows permit the survival of the pathogen, and raises the possibility that a weed host of *R. solanacearum *may be present.*

Potato yields were significantly higher ($P < 0.01$) after two or three maize crops or bare fallows than after continuous potato or potato following two or three weed fallows. Alternating potato with maize showed similar improvements. Potato crops interspersed with one maize and one sweet potato crop (in either order) also out-yielded continuous potato, but the incidence of wilting was still high.

Keywords: Bacterial wilt, Potato, fallow, weed, sweet potato, maize.

INTRODUCTION

Bacterial wilt (BW) caused by *Ralstonia solanacearum* (Smith) (biovar 2/race 3) causes significant yield losses in potato (*Solanum tuberosum*) in Papua New Guinea (PNG) (Tomlinson and Gunther 1985). Chemical control of this bacterial disease is not a practical option. The bacteria remain dormant in the soil for many years and under PNG conditions this effectively prevents replanting potato on any land which has been infected. Seed tubers can also carry the disease in a latent phase and thereby clean fields can be infected unknowingly.

Two approaches to control bacterial wilt have been studied by researchers in PNG: screening of introduced potato clones for field resistance to BW (Gunther 1992) and control of BW by crop rotation (Bang and Wiles 1994). This paper reports a trial, which was aimed at finding a crop rotation appropriate to the PNG highlands, which can reduce the persistence of *R. solanacearum* to subsequent potato plantings.

MATERIALS AND METHODS

A field was selected at Tambul, Western Highlands Province (5°53'S; 143° 57'E; 2320 meters above sea level). The previous potato crop was heavily infected by BW. The trial was planned to cover a five-crop cycle and lasted for approximately 30 months. There were 14 treatments (Table 1) assigned in a randomized complete block design with four replications. The treatments were selected to compare continuous potato (variety-*Sequoia*) production with potato rotated with maize (variety-*QK hybrid*), sweet potato (variety-*Wanmun*), bare fallow or weed fallow. There were one, two or three break crops of maize, and one or two break crops of sweet potato. Fallow treatments of duration equivalent to one, two or three potato crops were also tested. The other breaks were either sweet potato followed by maize or vice versa.

Each treatment plot was 8 m long and 3 m wide. Potato and sweet potato were spaced 75 cm x 40 cm apart, while maize was spaced at 75 cm x 25 cm between plants. There were 4 rows per plot of

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Table 1. **Crop rotation treatments used in the bacterial wilt control trial.**

Treatment	Crop 1	Crop 2	Crop 3	Crop 4	Crop 5
1	Potato	Potato	Potato	Potato	Potato
2	Potato	Bare fallow	Potato	Bare fallow	Potato
3	Potato	Bare fallow	Bare fallow	Potato	
4	Potato	Bare fallow	Bare fallow	Bare fallow	Potato
5	Potato	Maize	Potato	Maize	Potato
6	Potato	Maize	Maize	Potato	
7	Potato	Maize	Maize	Maize	Potato
8	Potato	Sweet potato*		Potato	
9	Potato	Sweet potato **	Sweet potato		Potato
10	Potato	Weed fallow	Potato	Weed fallow	Potato
11	Potato	Weed fallow	Weed fallow	Potato	
12	Potato	Weed fallow	Weed fallow	Weed fallow	Potato
13	Potato	Maize	Sweet potato*	Sweet Potato	Potato
14	Potato	Sweet potato*		Maize	Potato

* one twelve-month crop
** two nine-month crops

each crop. However only the two center rows of each plot were used for collection of wilt incidence and yield data. All volunteer potato plants and tubers in the weed fallow were uprooted and removed. The dominant grass in the weed fallow was Kikuyu grass (*Pennisetum clandestinum*) (Henty 1969). Fertilizer was applied at 750 kg NPK + Mg (12:12:17+2) and 250 kg triple superphosphate per hectare before planting all crops. This amounted to 90 kg N, 90 kg P and 105 kg K per hectare. No fertilizer was applied to fallow treatments. Weekly applications of acephate (Orthene) and mancozeb (Dithane) were made from crop emergence to senescence for control of pests and diseases.

The first crop (potato in all treatments) was planted in December 1991 and inoculated on 28 January 1992 with local strains of BW to ensure even distribution of infection on the trial site. After harvest, infected tubers were evenly spread on all plots and dug in to produce a uniform level of infection. The dates of planting, harvesting and seed source of all 5 crops are given in Table 2. From Crop 2 to Crop 5, the following records were taken:

Number of plants emerged per plot.

Number of plants with visual BW infection.
Total and marketable yield.
Number of infected tubers at harvest; tubers showing weeping eyes (oozing) were counted as having BW infection. Upon cutting the tubers, browning and oozing of the vascular tissue were observed.

Crop residues were carefully removed from the plots away from trial area. After the weed fallows, all weeds were removed and the land was prepared one week before planting of the next crop. Weeds from all plots were discarded from trial area. Drains 0.75 m wide and 0.50 m deep were dug between each plot to minimize disease spread. Soil samples after crop 5 were taken for nutrient analysis of the ten treatments with potato as the final crop. The samples were a subset of soils collected at random from each plot from a depth of 30 cm.

The trial area was fenced off and access strictly limited to those involved in the trial. All workers were required to wash hands, legs and all tools in a sterilizing (5%) solution of formalin before and after working on each plot, to prevent transmission of BW from one plot to another.

Table 2. **The planting and harvesting dates and seed source of potato crops planted.**

Crop	Planting Date	Harvesting Date	Seed Source
1	December 1991	April 1992	Certified ex Australia
2	15/07/92	21/12/92	Certified ex Australia
3	18/02/93	11/06/93	Tsinsibai – Clean seed
4	18/08/93	29/12/93	Tsinsibai – Clean seed
5	08/03/94	20/07/94	Tsinsibai – Clean seed

In this report the following abbreviations have been used to describe treatments: P = potato; M = maize; SP = sweet potato; BF = bare fallow; WF = weed fallow.

RESULTS

Results are presented on subsequent performance of potato crops after one, two or three break crops. Thus results are compared against the third, fourth or fifth potato crop in the continuous potato treatment.

Crop 3

In crop 3 the percentage of wilted potato plants at 45 and 90 days after planting (DAP) was significantly less (P<0.05) after the bare fallow (P-BF-P) and maize (P-M-P) than in continuous potato (P-P-P) (Table 3). However there were no significant differences in total tuber yield and percentage of marketable tubers (Table 4). In all rotation treatments, a large proportion (>50%) of tubers showed signs of BW infection and marketable yields were reduced accordingly. Although tuber yield was lower in continuous potato and P-WF-P plots, differences were not statistically significant.

***Table 3.* Percentage of wilting potato plants at 45 and 90 DAP in Crop 3 for treatments with one break crop.**

Treatment	45 days	90 days
1. P-P-P	9.8	32.8
2. P-BF-P	0.8	5.0
5. P-M-P	0.0	7.8
10. P-WF-P	9.0	30.5
L.S.D. (5%)	8.4	20.5

***Table 4.* Tuber yield and percentage of marketable tubers in Crop 3 for treatments with one break crop.**

Treatment	Total yield (t/ha)	Percentage marketable (by weight)
1. P-P-P	17.5	29.7
2. P-BF-P	22.7	25.9
5. P-M-P	21.9	28.3
10. P-WF-P	13.6	13.8
L.S.D. (5%)	NS	NS

Crop 4

In Crop 4 the percentage of wilting plants was significantly less (P <0.01) after the maize and bare fallow (Table 5). Yield was significantly higher after the maize rotation compared to continuous potato. The lowest yield and tuber number per plant occurred for potato following weed fallow. The percentage of rotten tubers was also lower after maize than in other rotations, though the difference was not significant at P<0.05.

Crop 5

Total yields in potato crop 5 were much lower than in earlier potato crops. This was probably because of the very small potato seed used for planting this crop. Therefore only total yields are presented in Table 6, as marketable yields were extremely low. In crop 5, emergence was significantly (P<0.01) lower in treatments following weed fallow breaks (P-WF-P-WF-P and P-WF-WF-WF-P) than in continuous potato (P-P-P-P-P). The percentage of wilting plants at 60 DAP was significantly higher (P<0.01) under continuous potato and after interspersed potato crops with weed fallow. The lowest wilting percentage was in potato crops following maize or bare fallow.

Yield was significantly higher (P <0.01) in treatments with maize or sweet potato as a break crop and where potato crops were interspersed with bare fallow than in treatments with continuous potato and where potato crops were interspersed with weed fallows. When maize and sweet potato were used in combination (P-M-SP-P and P-SP-M-P), the yield was significantly increased. While differences in tuber rotting were not significant, the smallest percentage of rots again occurred following the maize break treatment.

In order to assess whether the effect of crop rotations on yield was due to bacterial wilt or to changes in soil fertility, a soil analysis was carried out after the final potato crop (Crop 5). The soil analysis results are shown in Table 7. Following weed fallow, nitrogen levels were depleted and the carbon/nitrogen ratio was extremely high. After maize (and weed fallow), base saturation was improved slightly from a low level. However, cation exchange capacity decreased following maize. Phosphorous levels were similar in all treatments.

Table 5. **The effect of rotation with two break crops on BW and tuber yield of potato Crop 4.**

Treatment	% wilting plants 60 DAP	Tuber number per plant	Marketable yield (t/ha)	Total tuber yield (t/ha)	% rotten tubers by weight
1. P-P-P-P	73.4	11.0	6.2	15.8	32.3
3. P-BF-BF-P	11.0	16.9	6.2	17.6	35.7
6. P-M-M-P	1.4	13.7	17.9	29.0	16.8
8. P-SP-P	32.9	15.8	8.0	18.9	28.3
11. P-WF-WF-P	74.0	6.2	4.1	10.7	42.7
L.S.D. (5%)	15.9	3.8	3.6	4.6	NS

Table 6. **The effect of rotation with three break crops on emergence, BW and tuber yield of potato Crop 5.**

Rotation Treatment	Emergence (plants per plot)	% wilting plants 60 DAP	Tuber number per plant	Total yield (t/ha)	% rotten tubers (by wt)
1. P-P-P-P-P	35.0	28.8	4.1	4.57	32.3
2. P-BF-P-BF-P	33.2	2.2	4.4	4.96	33.8
4. P-BF-BF-BF-P	31.5	4.8	7.1	6.75	38.3
5. P-M-P-M-P	33.2	1.6	5.1	7.54	22.8
7. P-M-M-M-P	32.7	2.4	5.3	8.63	12.7
9. P-SP-SP-P	32.0	31.1	4.1	6.75	24.1
10.P-WF-P-WF-P	28.5	31.0	2.4	2.38	34.2
12. P-WF-WF-WF-P	26.7	14.5	1.7	2.29	44.7
13. P-M-SP-P	32.0	15.5	4.7	9.41	27.6
14. P-SP-M-P	31.0	14.7	5.1	9.12	20.1
L.S.D. (5%)	1.7	10.9	0.9	1.50	NS

Duration of break crop or fallow

In an attempt to assess the effect of the duration of the break crop or fallow on reduction in BW and performance of subsequent potato crops, the relative performance of potato after various break crops has been expressed as a percentage of continuous potato (Table 8).

A maize crop break resulted in the greatest yield increase over continuous potato. Potato yields stabilized at about 180% of continuous potato after two crops of maize. Weed fallow resulted in decreased yield and the percentage decrease in yield was greater with a longer weed fallow. Interspersing potato crops with sweet potato or bare fallow resulted in a smaller yield increase than with a maize crop break.

Maize and bare fallow reduced wilting incidence relative to continuous potato. After two or more maize crops, wilting in the subsequent potato crop was less than 10% of that in continuous potato. Sweet potato or weed fallow breaks failed to consistently reduce incidence of wilting.

The maize crop break was the only treatment, which gave a reduction in tuber rots. The reduction was greater after two or three maize crops than after only one crop. After a weed fallow, the incidence of tuber rots actually increased. However treatment differences in tuber rots were not statistically significant at $P < 0.05$.

Table 7. **Analysis of soil sampled from the five break crop treatments following the 5th (final) crop of potato.**

(a) Extractable bases

Treatment	Rotation	Extractable bases *					CEC	Base
		pH	Ca	Mg	K	Na	me %	Sat %
1	P	4.5	0.9	0.23	0.30	0.01	40.7	3
4	BF	4.5	0.9	0.31	0.23	0.01	42.9	3
7	M	4.7	1.7	0.45	0.34	0.03	24.0	10
9	SP	4.8	1.1	0.22	0.30	0.01	43.5	3
12	WF	4.6	1.5	0.46	0.35	0.04	37.0	6

(b) Carbon, phosphorus and nitrogen

Treatment	Rotation	P ** Mg/kg	Organic Carbon %	Total N %	C/N Ratio
1	P	11.2	14.0	1.03	14
4	BF	8.2	12.8	1.03	12
7	M	11.6	14.6	1.09	13
9	SP	9.4	14.5	1.10	13
12	WF	13.3	12.5	0.74	17

* me %
** Olsen's P method

Table 8. Total yield, percentage wilting and percentage of rotten tubers expressed as a percentage of continuous potato after varying durations of break crops or fallow treatments

	Total yield	% wilting	% rotten tubers
	(percentage of continuous potato)		
Maize break			
1 cycle	148.7	30.1	98.5
2 cycles	183.8	1.4	57.1
3 cycles	195.4	8.4	39.1
Sweet potato break			
2 cycles	120.9	46.4	89.8
3 cycles	150.5	97.4	77.1
Bare fallow break			
1 cycle	148.1	21.9	98.1
2 cycles	112.2	21.3	117.6
3 cycles	151.2	15.5	119.3
Weed fallow break			
1 cycle	84.3	95.6	125.3
2 cycles	68.7	108.7	137.1
3 cycles	49.5	66.0	129.1
L.S.D. (5%)	60.0	61.0	NS

DISCUSSION

In this trial, BW in potato was reduced following rotation with maize or bare fallow. Maize rotation has also been shown to reduce bacterial wilt in potato in other locations (CIP, 1990; Elphinstone and Aley 1992). In the Philippines (CIP, 1990), *R. solanacearum* Race 1 was the causal organism involved. In the present study, Race 2 is believed to be the causal organism (Tomlinson and Gunther 1985). The fact that maize was more effective than even bare fallow, as evidenced by the reduction in rotten tubers (Table 8) suggests that maize may be antagonistic to *R. solanacearum* present in the soil. In South America, Elphinstone and Aley (1992) found that *R. cepacia* in the maize rhizosphere increased at the expense of *R. solanacearum*. It is possible that a similar response is involved here.

After weed fallow, BW incidence was as high as in continuous potato. Thus BW appears to persist in weed fallow. It raises the question as to whether a weed host of *R. solanacearum* is present at Tambul.

The number of rotten tubers remained quite high even after three break crops. Rots were only examined visually and not all rotten tubers were necessarily affected with BW. Tuber rotting actually appeared to increase following weed fallow. It is probable that some other tuber rotting organisms were present in addition to *R. solanacearum*.

The changes in yield observed were not necessarily due to the level of BW infection. After a weed fallow, reduced crop emergence was also a factor in Crop 5. The reason for reduced emergence is not clear, but it may have been related to weed competition. Soil analysis also suggests that low nitrogen and a high C/N ratio may have depressed yields following a weed fallow.

A break of two maize crops was more effective than one crop in bringing bacterial wilt under control (Table 8). However there was no significant improvement following a third maize crop.

This trial was designed to establish how to bring BW under control from an initial high level of infestation. None of the treatments was able to eliminate BW infestation over the duration of this experiment. However there are implications for the current recommendations for potato seed production (Hughes *et al*, 1989) that a four-year break should be allowed between potato crops. Firstly, if this break is to be achieved by weed fallow, there is no evidence from this experiment that it will have the desired effect of ensuring freedom from BW. Secondly, if maize is used as a break crop it may be possible to shorten the rotation as there was no evidence in this experiment of additional benefit when more than two crops of maize followed potato.

Unfortunately sweet potato, which is the traditional staple food crop in the Tambul area, was less effective than maize in reducing BW infection in soils. It is not clear whether farmers will be willing to adopt maize rotation as a strategy for BW control as it is not a common practice to plant maize as a sole crop. There may be a need to examine maize / sweet potato intercrops and their effect on BW persistence in highlands soils.

CONCLUSION

Based on the experimental results described above, it is recommended that maize should be planted following potato crops, which have shown a high level of BW infection, to reduce it to tolerable levels. Where infection is severe, at least two cropping cycles are required before potato is planted again.

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DEMOGRAPHIC STUDY OF PIG MANAGEMENT IN THE SOUTHERN HIGHLANDS PROVINCE OF PAPUA NEW GUINEA

Paul Sillitoe.

ABSTRACT

Pig keeping features prominently in farming systems throughout the Papua New Guinea Highlands, but we know less about it than crop cultivation (the subject of many trials and reports). This paper reports on livestock husbandry, herd structure and demography in the central Southern Highlands Province around Nipa. It reports on a series of surveys conducted over twenty-four years on the pig herd of a Wola speaking community in the Was valley. It describes the pig herding regime, reproduction and growth of animals, pig herd demography and the movement of animals into and out of herds. The livestock regime is predictably different to that seen in commercially managed herds. The demographic data reveal some interesting patterns in herd structure. The paper seeks to account for these by placing them in cultural and environmental context. Pigs not only supply meat they are a measure of social standing too. They feature prominently in the socio-political exchanges that characterise Highlands' life. The high point is the large pig kill staged every few years, which impacts significantly on herd demography. Natural events that cause periodic staple crop shortages may also impact heavily on pig populations, and herds may not contribute significantly to food security at such times. The management regime responds equally to social and political issues, as demographic and environmental ones.

Keywords: *Wola, pigs, herd structure, demography, pig kill.*

INTRODUCTION

The aim of this paper is to report and analyse some data on the demography and management of a pig herd in the Southern Highlands Province collected over a twenty-four year period, situating these data in cultural and environmental context. It is a contribution to a small but important body of literature. If there is one topic of conversation heard throughout New Guinea with all its fabled cultural variety it is pigs. Nearly everyone has something to say about pigs. Yet there is scant literature on the composition of pig herds, with some notable exceptions (see Pospisil 1963:203-218; Rappaport 1968; Malynicz 1976; Hide 1981; Boyd 1984, 1985; Kelly 1988; Dwyer 1993). We have taken pig herds for granted, making assumptions about their structure, ecological relations and their control.

These comments are not new, others have made similar observations since the early 1960s (e.g. Vayda *et al.* 1961, note 15; Hughes 1970:272; Vayda 1972:907; Boyd 1984:27,48; and Lemonnier 1990:143). Highlanders are well known for their sizeable pig herds and colourful festivals at which they periodically slaughter large numbers of animals and distribute pork. The Wola of the Southern Highlands, the subject of this paper, are no exception and, similar to people throughout Papua New Guinea, regularly transact pigs with one another. After researchers elsewhere, I have investigated these activities while paying little attention to the logistics of pig keeping (Sillitoe 1979). When we consider the cultural significance of pigs and the prominent part they play in peoples' lives, the overlooking of herd structure seems a stark omission.

Environmental Background

The Wola, with an estimated population of 60,000, occupy five valleys in the Southern Highlands Province, from the Mendi river in the east to the Augu in the west. The data discussed here come from the Nipa Basin Census Division, notably the Was valley. The country is rugged, comprising sharp-crested mountain ridges, ranging between 1800 and 2200 m a.s.l. Watersheds and some valley areas are heavily forested, other settled parts are under regrowth, notably cane grassland. The Wola are swidden and fallow horticulturalists, their neat gardens dotted about valleys. Sweet potato is the staple, typically cultivated in composted mounds, other crops include bananas, taro, various cucurbits and greens (Bourke *et al.* 1995; Sillitoe 1996). A marked gender division informs activities, men undertaking the initial work of clearing and fencing and woman assuming responsibility largely for routine cultivation. Both humans and pigs depend on garden produce, pigs being fed largely on sweet potato.

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Ethnographic Background

The Wola live in homesteads comprising nuclear or extended families, scattered along the sides of valleys, indistinctly grouped together on territories, to which kinship structures access to land (Sillitoe 1999), resulting in loosely constituted kin corporations. The Wola region is divided up into a large number of territories to which these kin groups, called *sem* 'families', claim rights collectively. In the past, supernatural beliefs centred on ancestor spirits causing sickness and death by 'eating' vital organs, powers of sorcery and 'poison', and malevolent forest spirits. Sometimes people offered pigs to restrain these malicious supernatural powers. Today many people profess to be Christians and attend mission services. The region is peripheral in development terms, although the Highlands Highway runs through Wola territory. Cash crops are few, but with gas and oil finds, the position will change, with the exploitation of these minerals.

The exchange of pigs, with other wealth - including cash today and previously sea-shells and cosmetic oil - between defined categories of kin on specified occasions, is a prominent feature of social life. As Lederman (1986:16-17) elegantly puts it for those in the Mendi valley "pigs are not simply good to eat; they are also a form of wealth and have value in so far as they are made to stand for social relationships. Large pig herds are an artifact of socio-political relations that create high demand for pigs". The transactions remain today a significant force for order in this fiercely egalitarian society with weak central government authority, lawless 'rascal' activity being prevalent throughout the region. Men who excel at exchange achieve local positions of renown and influence, approximating to 'big men' elsewhere. But bigmanship does not extend to authority to direct the actions of others.

Similar to people elsewhere throughout the Highlands; the Wola arrange large pig kills called *showmay tok liy* (literally: pig pole kill) at intervals of every few years; depending on the event, these may involve ten or fewer men, or upwards of one hundred slaughtering pigs on the same day. These large communal events are a highlight of their transaction dominated lives at which many people collect for a massive exchange of pork (see Sillitoe 1979:256-276 for details; also Ryan 1961 and Lederman 1986:174-212). Men kill pigs with heavy wooden clubs fashioned for the purpose (Sillitoe 1988:70-72), hitting animals several times across the bridge of the snout. They singe off their bristles over fires and butcher them following a standard procedure which involves removing a strip of belly pork, breaking open the rib cage to remove internal organs and peeling the chest flesh away to give two sides of pork, each with a front and rear leg attached. They invariably cook pork in earth ovens with tender young tree fern fronds, distributing the cooked meat to relatives and friends.

Pigs

The Papuan Native pig, a relatively short and stocky animal, has a conspicuous coarse bristle coat, the Agouti pattern being the dominant colour, with striped piglets. The bristles are prominent along the spine, frequently standing erect in adults, running mane-like from between the ears down the back and earning the animal the name of 'razorback pig' (Vayda 1972:905). When adult, pigs stand about sixty centimetres tall and may weigh upwards of seventy-five kilograms. The zoological identity of the Papuan Native pig has been subject to taxonomic dispute. The majority of writers identify it as *Sus scrofa*, the widespread 'Common Wild Boar', sometimes adding the subspecies name *papuensis* to differentiate it from its European and Asian cousins (Baldwin 1978:23, 1982:41; Rose 1981, 1982; Hughes 1970:277 - citing Laurie and Hill 1954:86). Following a thorough review of the evidence, including a multivariate analysis of skull data, Groves (1981:66) concludes that the Papuan Native pig is a hybrid of two species *Sus scrofa vittatus*, the 'Banded Pig' and *Sus celebensis*, the 'Sulawesi Warty Pig'. This interpretation of the evidence probably reflects the influence of human activities over the millennia on the island's pig population, people bringing in animals from nearby Indonesia for breeding purposes. The population has not enjoyed the reproductive isolation necessary for species evolution. The wild and domestic pig populations remain today genetically continuous.

The notion of a breed is new, arriving with the introduction of exotic breeds to the Southern Highlands by government agricultural officers (*didiman*), from the 1960s onwards, with a view to stock improvement and commercial production (Malynicz 1971:72 1973a:20; Watt *et al.* 1977:13-14). The Wola call these introduced pigs *susu* (from the Pidgin term *susu pik* 'milk pig'- Malynicz 1973a:17), and point out that they differ from indigenous pigs. They have large ears, short stubby snouts, shorter legs and elongated rounded body profiles. They have a soft muffled grunt compared to the loud squeals of indigenous pigs and they are more sparsely bristled. People are impressed with the size to which these pigs can grow but few have ever owned one, some even seen one. The census data record none in the survey region at any time. They do not do well under local conditions; in Malynicz's

(1973a:20) opinion "the main factors restricting growth are under nutrition of all nutrients". The free-ranging local pig management regime soon results in cross-breeding between any exotic stock introduced into a region and local animals, giving rise to another new class of pig called *aumuw*. The appearance of these pigs varies depending on the proportion of their genetic makeup originating from the foreign breed. They have larger ears than local pigs and less bristly coats with less pronounced 'razorback' mane (no one has ever mentioned teat numbers). In short, the local non-concept of breed reasserts itself, any introduced pigs absorbed into the herd after a few generations without physical trace.

The work involved in herding pigs is not onerous. The daily routine is for a woman to release her pigs in the early morning to forage for the day in neighbouring fallow grassland and forest. Except troublesome pigs, which she may keep penned up or tethered on a rope. Sometimes women put animals in harvested gardens to feed on any remaining tubers and other crops. People say that pigs forage for earthworms mainly, which are necessary to lay down much fat (Rose & Williams 1983/84). In the late afternoon pigs are conditioned to return to the homestead. When they arrive they are fed their tuber ration. They spend the night in stalls, traditionally built at the rear of women's houses, although today many are housed in adjacent lean-to shelters in response to admonitions that living with pigs is dirty and unhealthy. (See Feacham 1973:25 and 1975 on environmental health hazards of pigs, notably to surface water supplies; and Watt *et al*. 1977:23-31 for an example of extension advice about appropriate housing.) Some women regularly manage more pigs than others and are admired for their ability, earning an appellative equivalent to 'big woman'; as with men this title carries no authority.

LITERATURE REVIEW

The Wola pig herding regime is similar to that reported in many other regions of the Highlands (Pospisil 1963; Feacham 1973; Rappaport 1968; Hide 1981; Boyd 1984). The free-ranging arrangement differs from that found in some more densely populated regions such as Chimbu and Tari where people often tether or pen animals during the day (Hide 1981:328; Rose 1976, 1982) and Enga where some communities use river flats enclosed by steep banks (Feacham 1973:27). This review summarises some statistics on pig herds and observations on management practices elsewhere in New Guinea for comparison with the data reported in this paper.

The statistics on pigs per person in New Guinea show considerable variation, probably reflecting to some extent fluctuation in herd sizes over time. Malynicz (1976:202) gave figures of 0.88 to 2.1 for communities in the Eastern and Western Highlands, Waddell (1972) 2.3 pigs per head and Feacham (1973:29) 1.1 to 3.1 per head for the Enga, and Baldwin (1978:23) quoted an upper figure of 2.5 for the Enga region, but Feil (1976:445) reported considerably more at four pigs per person. Rappaport (1968) gave a range of 0.3 to 0.8 for the Simbai valley, Boyd (1984:37) one of 0.55 to 0.7 for the Awa of the Eastern Highlands, and the Chimbu pig population according to Brookfield and Brown (1963:59) is "one grown pig per head: allowing for piglets, we might assume 1.5 adult pigs per head as maximum" (the Sinasina data of Hide (1981:407) agree with these figures). Longhouse communities of the nearby Etolo on the Papuan Plateau had between 0.52 and 1.39 pigs per person (Dwyer 1990:58-59), and among the Anga there are 0.5 pigs per head (Bonnèmere & Lemonnier 1992:140). For further statistics of pig populations in lowland and fringe highlands areas, see Dwyer (1993:134) and Kelly (1988:150, Table 2).

Statistics on size of litters are broadly similar throughout New Guinea. They are all on the low side. Malynicz (1976:204) recorded a range of 3.6 to 4.8. Hide (1981:460) reported that the mean Sinasina litter as 4.8 (for 23 litters), Boyd (1984:42) the mean Awa litter was 4.1 (for 15 litters), Kelly (1988:136) the mean Etolo litter was 5.6 (for 9 litters), and Pospisil (1963:203) the mean Kapauku litter as 6 piglets (for 8 litters). Many reports note high piglet mortality rates. The mortality rate in Kapauku herds is 27% (Pospisil 1963:207). In Sinasina herds it is higher, 42% of piglets dying (Hide 1981:453, 462). Eastern Highlands data suggest piglet mortality rates of 38% to 47% (Malynicz 1976:204). And on the Papuan Plateau, where the pig herding system is more extensive with domestic animals foraging in the forest alongside wild ones, 56% of young pigs die (Kelly 1988:137, 140). Farrowing sows sometimes die too; for example 5% of Etolo sows and 37% of Sinasina ones.

The statistics on growth rates are also on the low side. According to Malynicz (1970:201), the average weight of one year old pigs was 22.7 kgs and they put on 1.8 kg per month. Both Hide's (1981:473) and Rose's (1981) data confirmed these growth rates for Chimbu and Huli pigs; Sinasina pigs for example put on 1.6 kgs per month average in their first year, although their growth rates vary considerably from 0.9 to 2.2 kgs per month. These growth rates are considerably less than those achieved by exotic breeds under commercial conditions. Even when housed and fed under the same regime indigenous pigs grow more slowly, putting on weight at only 0. 47 of the rate of Berkshires and Tamworths (Malynicz 1973b:25, Table 2). As Malynicz (1973b:24) observes "the indigenous pig is significantly slower growing, has a lower food consumption, a worse feed conversion ratio, and smaller eye muscle and back fat dimensions at an equivalent slaughter age". In another publication he suggests that this may confer a selective advantage, writing that "It is interesting to speculate that the low growth potential of native pigs is a fitness characteristic which may increase their survival rate under conditions of nutritional stress" (Malynicz 1973a:17).

Herds comprise animals from a range of sources. The Awa of the Eastern Highlands rely heavily on locally farrowed piglets, which comprised 69% of their herds, they also obtain animals by capturing feral piglets (Boyd 1984:29-34, 38-39). The Sinasina rely more on exchange and trade to supply pigs; one community's herd comprised 49% non-home produced animals, while another had considerably more with 44% coming from trade and 33% in gifts (Hide 1981:433-444). Hide interprets the difference in terms of pig festival cycles, after the work of Vayda *et al.* (1961) and Rappaport (1968), resulting in a system featuring long-term planning of pig production. "Trade plays a major part in rebuilding pig populations at the beginning of the cycle. As the proportion of pigs produced increases from under one quarter to over one half . . . the proportion traded decreases to level off at about one quarter, apparently remaining stable for the rest of the cycle. The interesting feature of the second half of the cycle is the suggested increase in the proportion of pigs acquired by gift exchange at the expense of produced pigs" (Hide 1981:442). The author attributed this difference to men restricting reproduction later in the cycle to ensure herds of large animals for slaughter at festival time: "a co-ordinated cycle of pig management culminating in a pig population composed mainly of large animals . . . implying the restriction, at some stage of the cycle, of reproduction" (Hide 1981:540).

There is a considerable literature on pig killing festivals in the Highlands (e.g. Ryan 1961; Rappaport 1968; Meggitt 1974; Sillitoe 1979; LeRoy 1979; Hide 1981; Feil 1984; Lederman 1986). Most of this literature related pig kill festivals to local politics. An often cited work is Rappaport's (1968) on the Maring, in which he postulates a homeostatic ecological relationship between pig killing, demography and human protein demands. There is no indication in the Wola data, nor has any person ever suggested to me, that there is any correlation between pig kill events and ritual and warfare. (Others have thoroughly criticised this argument and the data on which it depended [McArthur 1974, 1977; Friedman 1974, 1979; Bergmann 1975; Wagner 1977; Hide 1981:549-562], although the author tried to defend it [Rappaport 1977, 1984; Kelly & Rappaport 1975] and others widely cite it in studies of human ecology [e.g. Shantzis & Behrens 1973; Morren 1977; Bayliss-Smith 1982:25-36; Biersack 1999]). Neither is there any evidence in the Wola data of regular 'pig cycles'; Lederman (1986:176) also questions their existence in the Mendi valley. Viewed over several years, Wola pig kills are unpredictable events. The chaotic way in which they schedule them - requiring that a community agrees first that one is due and then featuring considerable wrangling as men strive to reach a consensus over timing - makes cyclic planning difficult (Sillitoe 1979, Rappaport (1968:158-159) on consensus formation among the Maring, and Lederman (1986:187-212) on the political dimension to timing of pig kills).

METHODOLOGY

The data on pig demography discussed here come from a series of surveys conducted periodically over twenty-four years in a part of the Was valley, with a population of 300 and 400 persons, giving a density of about 26 persons km^2. The sample comprised all households resident in the area, which so far as I can judge, is a typical community. The mobility of the population has presented some problems in handling these longitudinal data from one geographical locality. I have had to judge who was resident during any survey period. Some families maintain homesteads on other territories too and I have included their pig herds if they had resided in the survey region sometime during the previous twelve months or so. Beyond this I have counted them as living elsewhere and discounted their herds (some of these families have subsequently moved back into the survey region, others have departed permanently). Regarding men who have migrated elsewhere to work (e.g. Mendi or Hagen), I have counted them in if their families have remained in the region. If they have migrated as a family, I have treated them as families maintaining homesteads in two places and applied the twelve month rule (those who no longer maintain homes in the region and visit regularly I have discounted).

During the surveys all men in their late teens and older were asked a series of standard questions about the pigs in their herds at the time.[1] (The first survey was less detailed on animal size and classification than subsequent ones because I was unaware at the time of the many distinctions people make). The information for each survey

[1] I am grateful to Wenja Neleb for his assistance with these surveys.

results presented here. These data supply a reasonably comprehensive longitudinal picture of pig herd demography.

The men surveyed were asked at the start how many pigs they owned. They were then asked for each of these animals to specify its sex and status (e.g. an *injiy* sow, *saendapow* hog, or whatever). The Wola distinguish between pigs according to their sex and size. Small piglets of both sexes they call *hondba*, a term used for small animals generally. An intact boar is a *tuw* (literally 'testicles'), and a male piglet may be specified as a *tuw-hondba*. A hog or castrated male animal is a *saendapow*. A gilt or female animal that has not farrowed is a *way*, and a female piglet may in turn be designated a *way-hondba*. A sow is an *injiy* (literally 'mother'), again a term used for other animals, including humans. A large mature animal with prominent curling canine tusks is a *himalwaenk* (literally 'tooth-*waenk*'), which people sometimes convey in speech with a bent fore finger hooked into the cheek.

Some of these assessments depend more than others on subjective judgements. There is no clear cut distinction between larger male piglets and sub-adult boars which have not serviced sows, and the same animal may be classed by some people as a *hondba* piglet and by others as a *tuw* boar. There is a similar blurred line between female piglets and gilts, although it is statistically less significant because there are large numbers of animals in both classes, unlike males, very few of which remain intact and capable of servicing females for any time. The classification of large hogs as *himalwaenk* tuskers is also liable to subjective variation, the point at which the canines are sufficiently large and curled to put an animal in this class is debatable (some persons are given to over-exaggerate the status of such pigs).

Respondents were also asked to specify the size of the animals. The Wola have a range of adjectives to indicate size, such as *genk* 'small' and *onda* 'large', or appropriately qualified versions of these, such as *genk ora* 'very small' or *ondasha* 'largish', and so on. During the surveys we used seven descriptive classes to record the size of animals: *onda ora* 'very large', *onda* 'large', *ondasha* 'largish', *genksha* 'smallish', *genk* 'small', *genkden* 'smaller' and *genk ora* 'very small' (newborn piglet). Again these assessments depend on subjective judgements but people were found to give tolerably reliable estimates using these comparative terms. Initially, we tried to survey all herds in the presence of the animals for enumeration purposes but this proved too difficult to arrange. Nonetheless I completed many questionnaires in view of the pigs of an evening as they returned home, and people's estimates accorded well with my own. For analytical purposes I amalgamated the first two size classes into a single large category, the second pair into a medium category, and the last three into a small category.

The Wola also classify pigs according to differences in appearance, largely coat colour plus one or two other features, such as trotter type and tail character. The survey schedule asked about each animal's classification, recorded largely by coat colour (*bombray* 'black', *tindiltoba* 'piebald', and so on). Next respondents were asked how long they had owned each animal, in 'Christmas' years and moons (1977, 1978, 1983 surveys only). Again these data are somewhat subjective, being liable to memory error. But I was able to engage in limited cross-checking with earlier surveys for pigs owned over considerable time periods, memories becoming less reliable the longer the time. The list of questions included the name of the person responsible for herding the animal and her relation to the respondent. Finally, we took down details of how the person had obtained the pig (born to one of his sows, received in an exchange transaction such as a bridewealth or mortuary payment, through purchase, and so on), and for some pigs we were also able to note their subsequent disposal (slaughter, died of sickness, passed on in an exchange payment, and so on).

Between two of the surveys (early 1977 to mid 1978), I attempted to keep a record of pig movements in and out of herds. While I was aware of many of the events that changed pig holdings - such as pigs killed at funerals, pigs presented in exchanges, pigs slaughtered for 'business' (meat sale), and sows farrowing -- there were some that escaped my attention. An attempt was made to cross-check at the second survey and pick up on missed movements.

On one occasion during 1977, all men in the sample community were asked, together with their wives, about all the litters they could remember born to sows in their charge. These data depend heavily on memory recall of respondents, some of them going back in excess of forty years. They were asked for the numbers of piglets per litter, the number that survived to six moons, and whether the sow survived.

RESULTS AND DISCUSSION

Reproduction and Growth

According to the Wola, a sow is pregnant for three moons and farrows during the fourth, called *hondba maeray* (literally: off-spring carries); the gestation period for Highlands pigs being 116 days (Hide 1981:457,citing Malynicz). At the time that she is due to farrow, a sow becomes restless and may wander off, seeking a suitable nesting site. It is usual for sows to build themselves a nest of vegetation, often away in the forest or nearby in a clump of *Miscanthus* cane grass, in which to farrow and suckle their young. Sometimes women lose track of sows at this time and have to search for them. They do not interfere but seek to lure sow and litter back home as soon as practicable with food. These practices are widespread throughout the Highlands (Malynicz 1970:201); the Sinasina for instance are careful not to disturb a sow that has recently farrowed (Hide 1981:460). The number of piglets in a litter varies from between one to eight usually. The average is between four and five (Table 1).[2]

The mortality rate is high with nearly one-quarter of piglets dying, and sometimes, farrowing sows too (according to these data 2.5%), which possibly deters some people from breeding, although they more usually refer to sows losing condition as a discouragement. The number of litters per sow is low. The survey of litters revealed an average of 4.2 litters per man. The numbers understandably increase with age (Table 2), the mean litter intervals suggest that men's herds average two litters a decade. If we assume that a man lives to old age, herding pigs for fifty years, this translates into a mean total of ten litters during his lifetime; the maximum number was a man in his sixties with three wives who had managed 27 litters between them (16 was the maximum number of litters managed by any women). Even allowing for memory failure, particularly for older men, these statistics are low and illustrate people's somewhat reticent attitude to pig production (i.e. the ambivalence that many express to servicing sows, knowing that they will lose condition and surviving piglets take a long time to reach a valuable size).

***Table 1.* Pig litter statistics**

Total No. Litters	Total No. Piglets	Mean Litter Size	S. E.	No. Piglets Surviving to 6 mths	Piglet Death Rate	Sow Death Rate	No. Men Surveyed	No. Men Reporting No Litters	Mean No. Litters Per Man	S. E.
321	1522	4.74	0.10	1189	22%	2.5%	77	12	4.17	0.54

***Table 2.* Pig litters according to men's ages**

Age	No. Men	No. Litters	Mean No. Litters Per Man	S. E.	Total No. Piglets	No. Piglets Surviving	No. Sows Dying
<20 yrs	7	3	0.4	0.3	12	6	
20-29 yrs	26	54	2.1	0.3	278	208	1
30-39 yrs	21	94	4.5	0.9	411	311	
40-49 yrs	17	108	6.4	1.1	522	406	7
50-59 yrs	4	48	12	5.9	240	204	
>60 yrs	2	13	6.5	4.5	58	54	

Difference significant (av. litters): $\chi^2 = 15.50$ (d.f. = 5, $\alpha = 0.05$).

[2] These are low compared to litter rates elsewhere in the tropics, particularly commercial ones

These data suggest a low reproduction rate. The Wola say that some sows make better mothers than others with higher piglet survival rates and larger litters. People may breed more than average – that is, three or more litters - from such sows, hanging on to them until their fertility declines, whereas they dispose more readily of others. The interval between litters is long, sometimes years, for those sows that breed more than once.

The principal concern of pig keepers is to promote animals' rapid and healthy growth. According to the Wola the rate at which pigs grow varies, as does the final size they reach when fully grown, the same as human-beings, they point out. Some piglets grow very rapidly at first but develop more slowly in adolescence, others are slow starters but race away when adolescent, and so on. Some animals remain *dimb* 'diminutive' all their lives and these runts never seem to grow beyond the size others reach during adolescence. Others develop into large *himalwaenk* 'tuskers' with thick fat on their bodies, particularly *saendapow* hogs that not only grow faster than females but also on the whole attain larger sizes when adult. The sexual dimorphism is marked if a female farrows, sows losing weight and condition - Sinasina data show reproducing sows losing 0.2 kg per month (Hide 1981:474). It can take animals some time to regain their weight, which deters people from arranging for them to breed (Malynicz 1976:208 notes the Chimbu prevent breeding to ensure sows grow).

The variation in development makes it difficult to specify growth rates and adult size of animals – the specification of rates would demand the measuring and weighting of a sample of pigs at intervals over several years, data that I have been unable to collect. Sows may have their first litter at about two years when sub-adult (Sinasina pigs likewise do not breed until they are 18 to 24 months old - Hide 1981:452). They attain their final size at about six years (this rate of development compares with that reported by Malynicz (1976:Table III) for Eastern Highlands herds). Sizes and weights of pigs measured ranged from two month old piglets that averaged 45 centimetres long from tip of snout to base of tail and weighed between 3 and 4 kgs, to large males, measuring some 1.4 metres and weighing up to 130 kgs[3]. The natural life span of a pig is twelve to sixteen years, although few live this long, except for good breeding sows that may farrow upwards of three times, which people may be reluctant to slaughter.

Nobody has ever suggested to me that one might take a sow that has grown rapidly into a large adult and cross it with a boar that is growing quickly to breed a litter of fast growing offspring with the potential to achieve heavy adult weights (see Dwyer 1996 for a cross-cultural discussion of pig breeding practices in New Guinea). When I try to discuss the idea of selection, some persons usually point out that the piglets in any litter vary in their rates of development and adult size. There are dominant ones that may grow quickly into large animals and there are runts that fail to develop to full adult size, regardless of parentage. Furthermore, breeding with juvenile boars makes it difficult to select with any certainty a sire according to growth potential, because overall growth rate and final size are difficult to estimate, particularly as castration impacts noticeably on these traits.

Pig Herd Demography

The average size of a man's herd is 4.3 animals, ranging in surveys from one to twenty-seven pigs. The average number of animals in a woman's charge is lower at 3.3 animals, ranging from one to sixteen pigs. Men call on several female relatives, including unmarried and widowed kin, to assist with pig herding. If we take all men in the samples, including those with no pigs, the average size of men's herds falls close to that of women's at 3.4 animals. The composition of these average herds according to size of pigs is as follows:

Table 3. **Mean numbers of pigs owned**

	Large Pigs	S. E.	Medium Pigs	S. E.	Small Pigs	S. E.
Men	1.1	0.09	1.6	0.11	1.6	0.16
Women	0.9	0.12	1.2	0.24	1.2	0.15

These statistics compare with those reported elsewhere; Crittenden (1982:274) for example reports an average of 2.9 to 6.3 pigs per household on the nearby Nembi Plateau, Brookfield and Brown (1963:58-59) an average of 2 to 4.5 animals a family among the Chimbu, and Hide (1981:319) gives an average of 3.5 pigs per household for the neighbouring Sinasina.

These averages conceal the fluctuation that occurs in pig herds. These are in a state of constant flux, not only as animals are born or die or

[3]These weights are estimated from girth measurements, using Hide's (1981:647) very useful conversion table (Dwyer 1993:125 has an equation to estimate pig weights)

the occasional one runs wild, but also as their owners give and receive them in exchanges with one another and intermittently slaughter animals. Figure 1 gives some indication of the fluctuation that occurs in pig numbers. The demographic data suggest that when herds are at their maximum extent they parallel the human population with one pig for every man, woman and child, and fall to nearly 0.5 per capita at their lowest levels. The graph marks the principal events responsible for the falls in numbers, which were large communal pig kills (Sillitoe 1979) and a severe drought. The fluctuation is expected given the numerous reports from across the Highlands of festivals at which people kill large numbers of pigs. Others have documented similar population movements elsewhere (see Hide 1981:405-18 for a sophisticated reconstruction of herd recovery following festival slaughters among the Sinasina). The drought induced fall is also expected given the periodic occurrence of devastating shortfalls in food supply across the region (see Sillitoe 1996:73-102 on the occurrence and consequences of these in the Wola region), although the magnitude is salutary, paralleling a pig kill.

A look at the structure of herds, according to the gender and age status of animals (*injiy* sows, *way* gilts, *saendapow* hogs and so on), reveals that *way* gilts predominate among females and *saendapow* hogs among male animals (Figure 2). The number of piglets of either sex are approximately equal, and similar to the number of *injiy* sows in a herd. Table 4 indicates that while the composition of the herd varies over time, the structure remains broadly constant regarding the proportion of different classes of animals. Gilts predominate among females and hogs among male animals whatever the size of the herd (Table 4). It is the proportion of piglets to adult pigs that shows the most marked variation, which is understandable with the periodic mass culls that characterise pig herd management.

After a pig kill the proportion of *hondba* piglets in the herd goes up by some ten percent, from around one-quarter of the herd to one-third (Table 5). Of the adult animals, it is the number of *injiy* sows that shows the largest proportional change, at seven percent, suggesting that pig

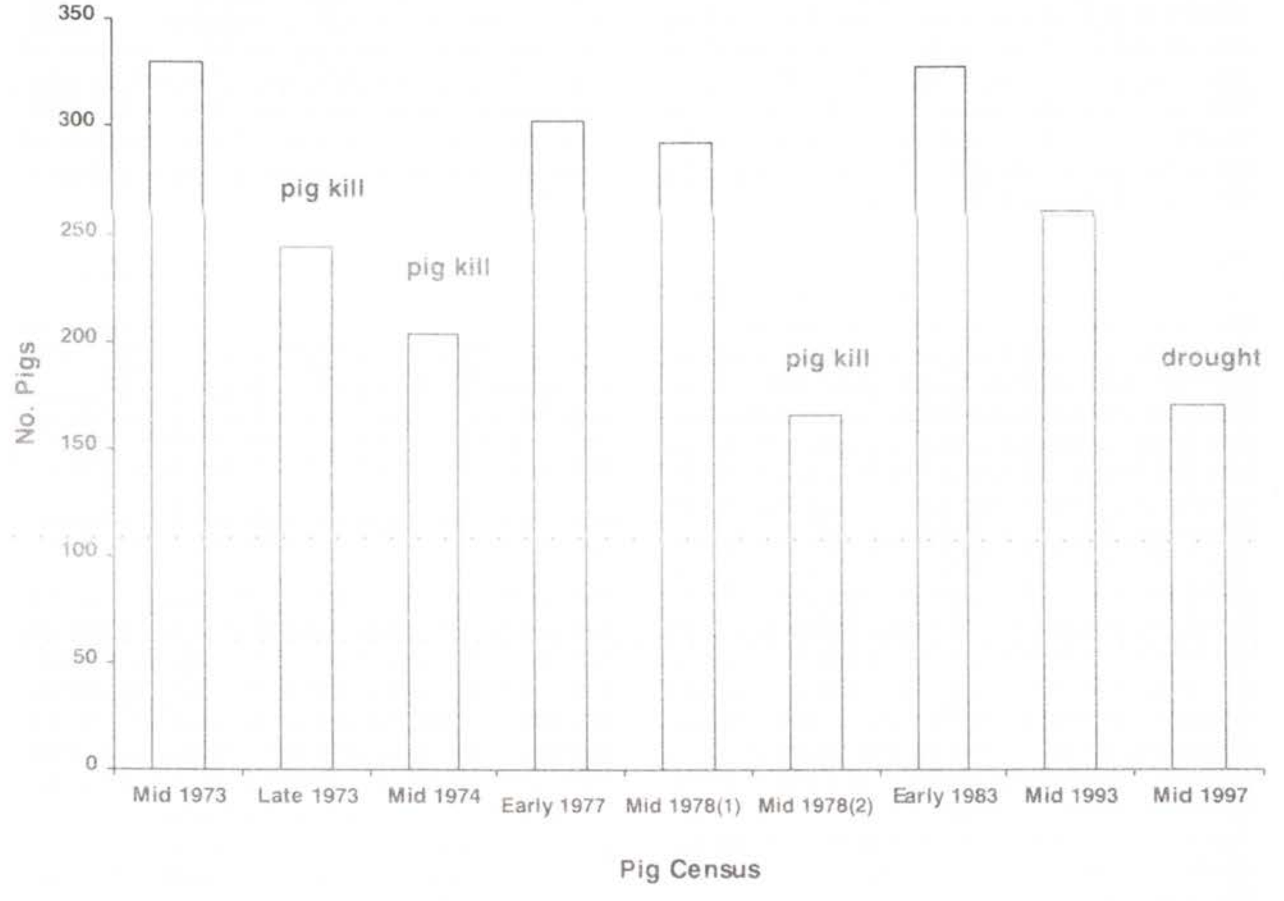
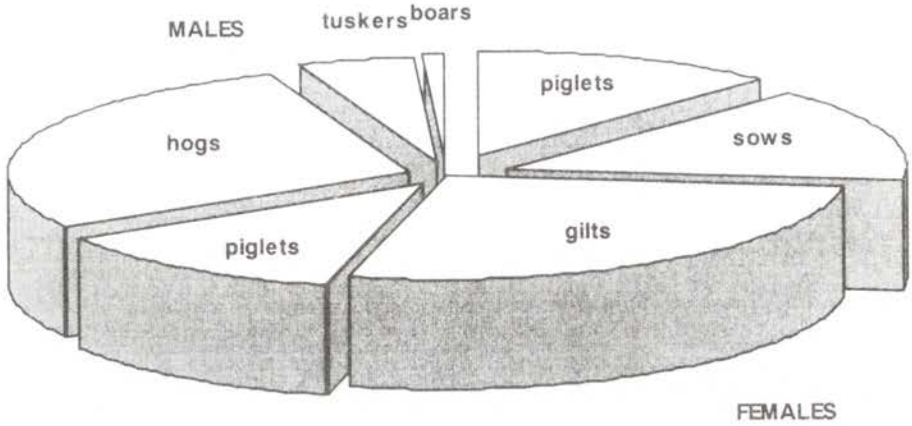


Figure 1. **Pig population at time of survey over twenty-four year period.**

Figure 2. **Mean composition of pig herds according to pig classes (all data ex. 1997)**



kills mark the culling of large numbers of aging sows from a herd. The percentage of *himal-waenk* tuskers killed is also predictably large, although the numbers of animals involved is fewer. None of these changes in herd composition are statistically significant. The proportion of *way* gilts and *saendapow* hogs remains similar at around one-quarter of the herd, although the numbers of these animals slaughtered is large. I estimate that a herd returns to normality within about one to two years. These findings are similar to those reported elsewhere - at a small Sinasina event people "killed almost equal numbers of males and females thus showing no tendency to keep females for breeding" (Hide 1981:487).

The data suggest that a prolonged food shortage, from a drought not only reduces the size of a herd as after a pig kill but also impacts on its structure in a different way, and potentially devastatingly for the recovery of the herd. A review of pig populations according to the size of animals (which predictably parallels the gender-age discriminations) shows graphically the difference (Figure 3, Table 6). After pig kills the number of large animals in a herd declines noticeably. This is expected, people killing many mature animals carrying a lot of fat and meat for distribution. During the El Niño event of 1997 (when the reversal of Pacific currents affected rainfall patterns), the reverse happened and the number of small pigs in the herd declined dramatically. When such a food shortage occurs people say that they reduce the rations fed to pigs, even stop feeding them altogether. The animals come into direct competition with humans for the limited food available (people eating small and sub-standard tubers usually fed to pigs). Small animals, particularly piglets, will be the first to weaken and die as sows dry up. Also during a drought, the low levels of nutrition will contribute to the fall in piglet numbers as the fertility of sows declines.

All pigs lose condition and weight in a severe drought, and many may eventually die. People deny that they systematically kill pigs in these times, although when food is short people may decide to stage a pig kill to reduce the burden (the 1974 kill was prompted in part by such a shortage[3]). This is contrary to the suggestion that pigs may serve as a food store, buffering people against lean times, and that large pig kills serve to take the pressure off when herds burgeon in extended good times (Vayda *et al.* 1961; Vayda 1972; Rappaport 1968:64-68). One of the Sinasina pig populations closely documented by Hide (1981:417) also evidenced an "oddly top-heavy structure" with few young pigs, which the author argues resulted because people stopped pig breeding to allow sows to fatten up for a festival slaughter. "The major husbandry goal prior to a festival is the production of large pigs for slaughter. Continuation of normal reproduction, implying numbers of small animals and thin sows, and the deflection of fodder for their growth to

[3] The food shortage in 1974 that hastened an already planned pig kill (Sillitoe 1979:257) was minor and impacted less on small pigs than the 1997 event when there were no plans for an imminent kill (these events take several months to negotiate, as participants have to settle outstanding exchange commitments).

Table 4. Pig census data according to pig classes.

Class	Wola Term	Mid 1973 (normal)	Late 1973 (kill)	Mid 1974 (kill)	Early 1977 (normal)	Mid 1978(1) (normal)	Mid 1978 (2) (kill)	Early 1983 (normal)	Mid 1993 (normal)	Mid 1997 (drought)	Mean	S.E.
Fe-males:												
Sows	*injiy*	38	24	18	68	58	18	64	33	20	37.9	6.8
Gifts	*way*	85	60	48	75	77	55	70	78	62	67.8	4.1
Piglets	*hondba way*	42	38	40	27	33	31	40	30	3	31.6	3.9
Males:												
Hogs	*san-dapow*	96	73	54	82	85	32	82	72	75	72.3	6.3
Tusker hogs	*himal-wank*	26	12	5	15	14	2	13	10	9	11.8	2.3
Boars	*tuw*	3	1	1	1	4	3	2	1	1	1.9	0.4
Piglets	*hondba tuw*	40	36	38	34	25	25	56	35		32.1	3.3
TOTALS		**330**	**244**	**204**	**302**	**296**	166	327	259	170	255.3	21.3

sizes still well below that sought, would hinder the achievement of this goal". He had no evidence of a fall in piglet numbers, although his fieldwork coincided with the large 1972 pan-Highlands drought – herd structure remained the same throughout (Hide pers. comm.). The Awa pig population reported by Boyd (1984:38,41) also had a top heavy structure at one point, attributed to low natural rates of reproduction due to falling numbers of feral boars in the adjacent forest to inseminate sows.

Pig herds probably recover slowly after a stressful natural event such as a drought, whereas following a pig kill there are many small pigs to bring along and replace the large ones slaughtered (Table 6). After pig kills almost one-half the herd comprises small pigs, whereas normally they make up somewhere around one-third of the herd and in drought considerably less. The proportions of medium sized pigs remain comparable in herds at normal times and herds after pig kills, at 34% to 39% respectively, but they increase in drought to over 60%. The proportions of large pigs are the reverse of the piglet pattern, increasing from 15% following a pig kill to 29% under normal conditions and 37% during a drought. All of these variations are statistically significant with high residual values (Table 7). The standard demographic bar graphs show the situation in normal times and following pig kills (Figures 4 & 5). For comparative demographic pyramids of Sinasina pig herds see Hide (1981:415-416), Awa herds see Boyd (1984:38), and herds in the Eastern and Western Highlands see Malynicz (1976:203). During the interval between pig kills, herds develop an atypical demographic structure which reflects the Wola practice of keeping adult pigs alive for long periods of time once they reach maturity and not, as in commercial farming, killing them for sale and consumption. Instead of the usual demographic pyramid we have a rectangle, with some tendency towards a pyramid on the male side, reflecting the readiness of people to slaughter these animals in preference to breeding females when a pig is required between kills, for example at a funeral feast (a trend noted by Boyd (1984:40) too among the Awa; see also Malynicz (1976:203) whose graph of a Kerowagi pig population evidences a similar structure). Immediately after a pig kill the population structure more closely approximates to a pyramid, particularly on the male side; the difference with the female side again reflecting breeding concerns, people keeping more medium sized females to serve as sows in the immediate future.

Table 5. **Composition of normal pig herd and after pig kill according to pig classes**

	Normal Herd (mid 1973, early 1977, mid 1978 (1), early 1983, mid 1993)			After Pig Kill (late 1973, mid 1974, mid 1978 (2))		
	Mean No. Animals	S. E.	Percent	Mean No. Animals	S. E.	Percent
Females						
Sows	52.2	7.1	17.2	20.0	2.0	9.8
Gilts	77.0	2.3	25.4	54.3	3.5	26.5
Piglets	34.4	2.9	11.4	36.3	2.7	17.8
Males						
Hogs	83.4	3.8	27.5	53.0	11.9	25.9
Tusker hogs	15.6	2.7	5.2	6.3	2.9	3.1
Boars	2.2	0.6	0.7	1.6	0.7	0.8
Piglets	38.0	5.1	12.6	33.0	4.0	16.1

No significant difference: $\chi^2 = 4.47$ (d.f. = 6, $\alpha = 0.05$).

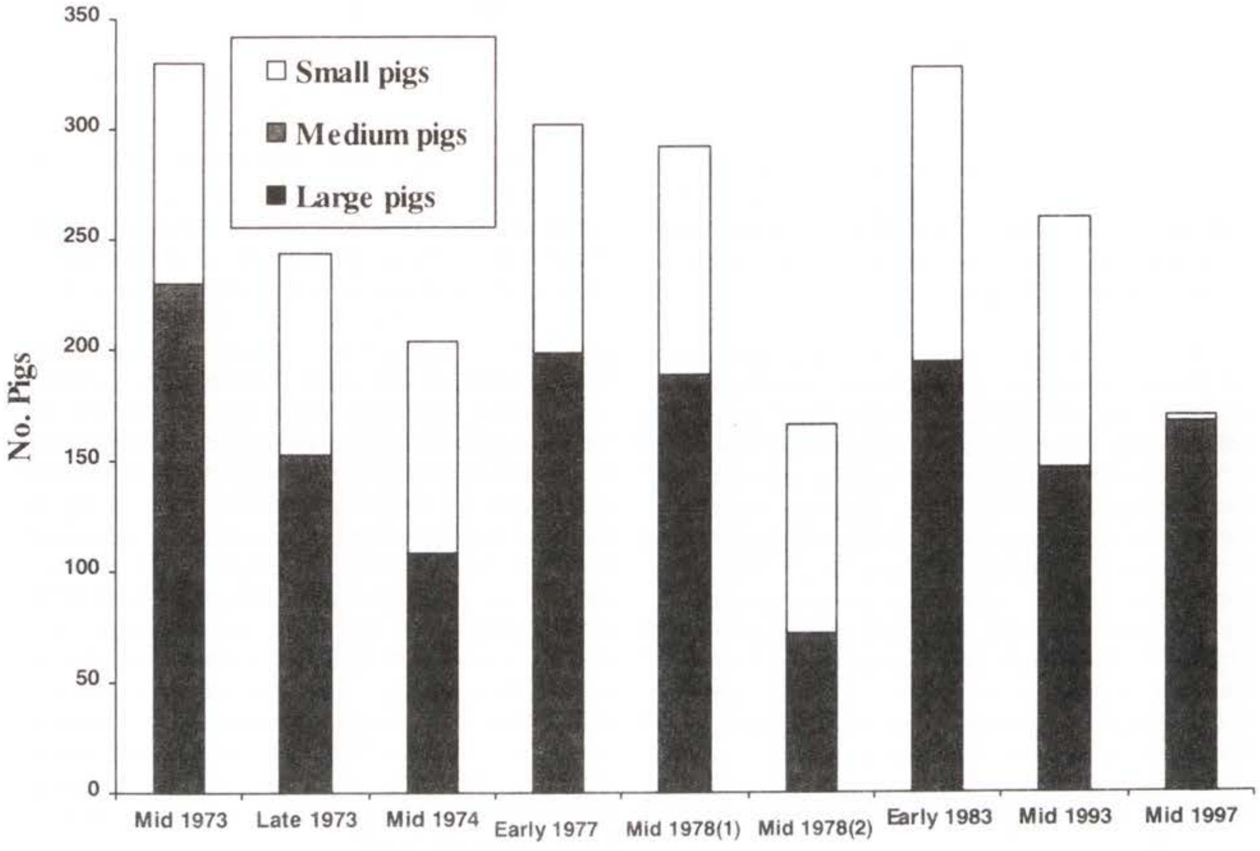


Figure 3. Pig populations by size classes

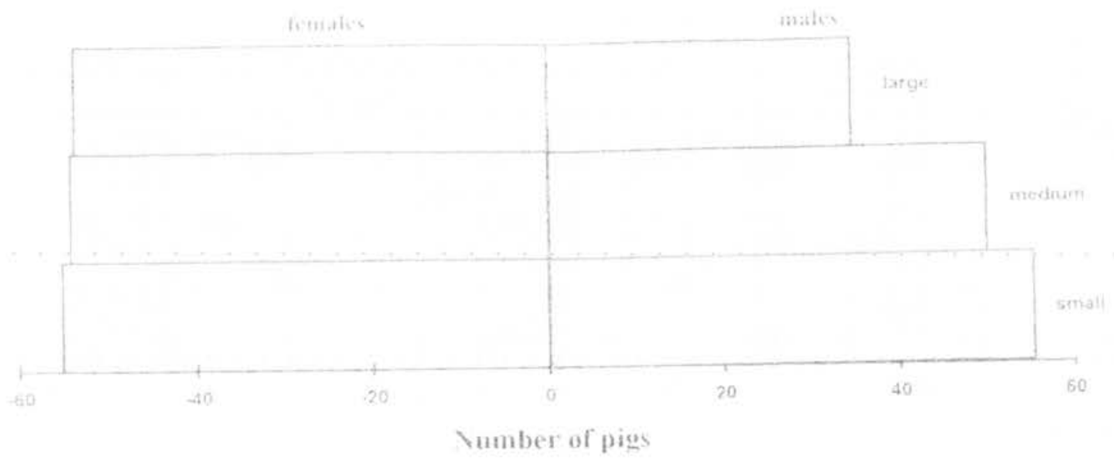


FIGURE 4 Mean demographic structure of pig population (between kills – mid 1973, early 1977, mid 1978 (1), early 1983, mid 1993)

Figure 5. **Mean demographic structure of pig population (after kills - late 1973, mid 1974, mid 1978 (2).**

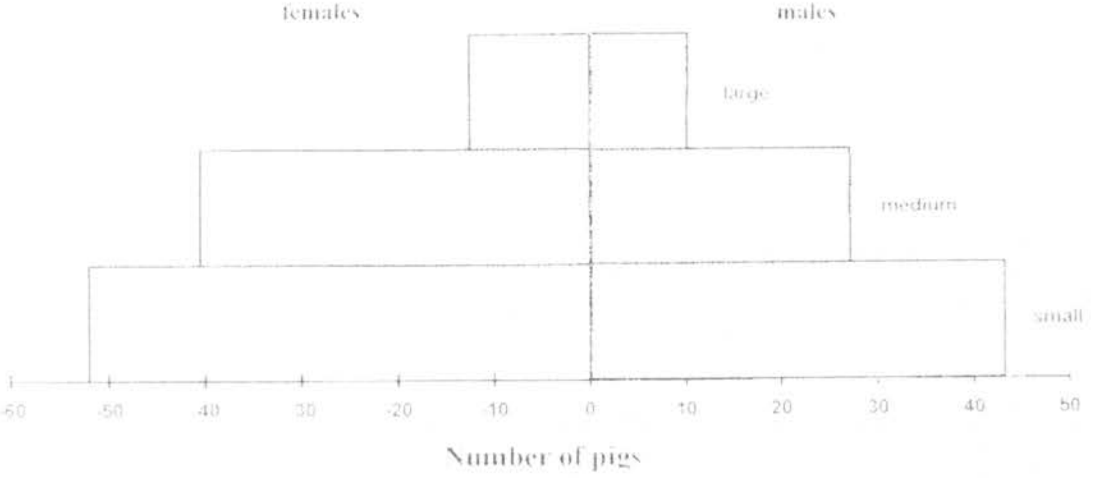


Table 6. **Pig census data according to size of pigs.**

Pig Size Classes	Wola Term		Mid 1973	Late 1973	Mid 1974	Early 1977	Mid 1978 (1)	Mid 1978 (2)	Early 1983	Mid 1993	Mid 1997	Mean	S. E.
Large	*onda ora &*	F	52	25	13	51	48	12	58	60	26	38.3	6.4
	Onda	M	48	25	14	34	40	6	21	30	37	28.3	4.4
Medium	*onda sha &*	F	61	49	43	65	61	38	60	24	56	50.8	4.5
	genk sha	M	69	53	38	49	44	16	55	32	48	44.9	5.0
Small	*genk. Genk-den &*	F	52	48	50	52	59	54	56	57	3	47.9	5.7
	genkora	M	48	44	46	51	44	40	77	56		45.1	3.9
TOTAL			330	244	204	302	296	166	327	259	170	255.3	21.3

Table 7. **Mean composition of normal pig herd, after pig kill and in famine according to size classes.**

Pig Size	Sex	Normal Herd (mid 1973, early 1977, mid 1978 (1), early 1983, mid 1993)			After Pig Kill (late 1973, mid 1974, mid 1978 (2))			Drought	
Classes		Mean No. Animals	S. E.	Percent	Mean No. Animals	S. E.	Percent	Actual No. Animals	Percent
Large	F	53.8	2.3	17.8	16.7	4.2	8.1	26	15.3
	M	34.6	4.6	11.4	15.0	5.5	7.3	37	21.8
Medium	F	54.2	7.6	17.9	43.3	3.2	21.2	56	32.9
	M	49.8	6.1	16.4	35.7	10.7	17.4	48	28.2
Small	F	55.2	1.4	18.2	50.7	1.8	24.8	3	1.8
	M	55.2	5.8	18.2	43.3	1.8	21.2	0	0.0
TOTAL		302.8		100.0	204.7		100.0	170	100.0

Difference significant $\chi^2 = 60.13$ (d.f. = 6, $\alpha = 0.05$).

Pig Movements

It is not only at pig kills that people dispose of animals. The composition of the herd in any community constantly changes as people dispose of animals in various other ways. During an eighteen month period, when I attempted to keep track of pig movements in the herds studied (Table 8), the turnover rate was 55% (i.e. people still had in their herds 45% of the pigs they had at the beginning of the survey period). The total number of animals involved was 525, and of these 229 were disposed of at some time during the eighteen months and 223 were acquired during that period - 28% of these latter were both acquired and disposed of during this period (i.e. they were not owned at either the beginning or end of the survey but passed through the herds).[7] A pig kill occurred within one month of the end of the survey and the turnover rate shot up to 86% (only 14% of the pigs in the herds at the start of the survey remained). And the percentage of animals acquired during the period and subsequently disposed of also increased to 44%, reflecting again the dramatic impact pig kills have on herd composition.

Other data on how long pigs are in herds evidence similar patterns over time to these findings for eighteen months. During an interval of three years between surveys, when pig kills occurred (late 1973 to early 1977), the number of pigs remaining in herds throughout was 11%, and after an interval of four and one-half years (by mid 1978), it was down to 2%. Other data, on the time for which people had owned the pigs in their herds (Table 9), give a further indication of the rate at which their composition changes. (Compare Table 6.1 in Lederman [1986:204] on time pigs owned in Mendi valley.) There is a predictable steady decline with time: some 45% of animals remain in peoples' herds for one year or less; 23% for between one and up to two years; 14% for between two and up to three years; and then 9%, 6% and 2% for the next three years respectively.

It is of interest to consider how people dispose of pigs, other than slaughtering them in large kills, and in what proportions (Table 8, Figure 6 - compare Dwyer [1993:130-132] who gives details of how the Kubo disposed of pigs over a fifteen month period.). The largest proportion, at 18%,

[7] Table 7 documents only the source and disposal of the pigs in herds at the start of the survey, plus those animals acquired and disposed of during the survey period, a total of 365 pigs (it excludes those acquired during the eighteen months and still in herds at the end of this time). The data on herd composition at the start and end of the survey period is comprehensive, but it is probable that I failed to document all the animals that passed through the herds during this period. See Boyd 1984:40-47 for comparable data on an Awa community's herd over a twelve month period.

[8] I use the term foster in preference to agist (cf. Hide 1981:418-33) customarily applied to the pasturing of others' cattle for a sum. (Lederman 1986:211 also points out that agistment is an inappropriate gloss for similar practices in the Mendi valley).

DISPOSAL	SOURCE																					
	Bridgroom	Exchange	Brideweatlh exchange(*injiykab*)	Caught as wild piglet	Compensation for shot pig	Crop harvest payment	Dept payment (*saen*)	Foster pig (*maha*)	Garden clearing payment	Gift	Inherited	Litter	Mortuary exchange (*ol tobway/ol bay*)	Mourning exchange (*gwat*)	Pig herding payment (*hentiya*)	Purchase (*showmay hesay*)	Reimbursment exchange (*haypuw*)	Reparation exchange (*showmay enjay*)	Side of pork payment	Sire payment (*tuwshiy*)	Swapped	**TOTALS**
Bridgroom exchange (*hogol*)			7			1	2						1									**11**
Bridewealth exchange (*injiykab*)							3	3		1		8	3	1		3				1	1	**24**
Compensation payment										1												**1**
Crop harvest payment												1										**1**
Dept payment (*saen*)												1										**1**
Foster pig (*maha*)						1						15	1			2	1					**20**
Foster disputed & reclaimed			1					3				5	1									**10**
Funeral feast (*hombera*)			1					3		1	2	1	1									**9**
Garden clearing payment												1										**1**
Gift (*ponay*)												15										**15**
Inherited														1		1						**2**
Killed & eaten by family								1				2				2						**3**
Killed & pork sold			1					2				2										**7**
Killed by other's sow, sold carcase													1									**1**
Lost at cards												1										**1**
Mission Feast		1						4				3	1									**10**
Mortuary exchange (*ol tobay/olbay*)			4		1		1	1		2		4		1								**15**
Mourning exchange (*gwat*)						1	1	1				4		1		1						**9**
Pig herding payment (*hentiya*)															1	1						**2**
Ran wild & shot for funeral feast													1									**1**
Reimbursement exchange (*haypuw*)			1																			**1**
Remained in hand		3	10			1	3	51	1	3		32	6	4	1	14	1	1	4	1		**136**
Reparation exchange (*komb*)								1			1	1										**3**
Shot damaging garden, pork sold										1			1						1			**2**
Sick, family ate		1					1	3				26	1			1						**34**
Sick, pork sold			2	1																		**3**
Sick, pork buried, feared infected												5		1								**6**
Sire payment												5										**5**
Sold									1			12				3		1				**17**
Swapped					1								1			1						**3**
Unknown								1			2	6	1						1			**11**
TOTALS		5	27	1	2	4	11	74	2	9	5	150	20	9	2	29	3	2	6	3	1	365

Table 8. Source and disposal of pigs during eighteen month period

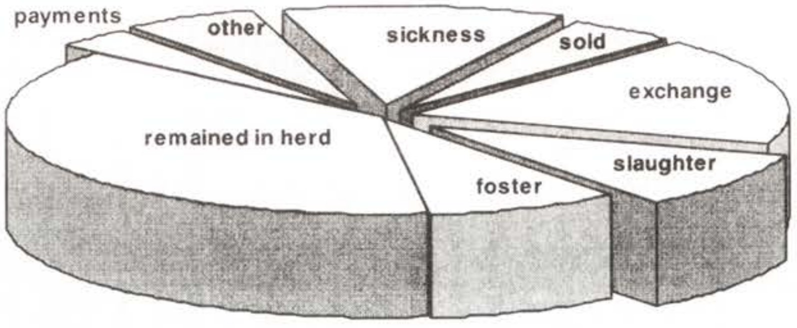


Figure 6. **The disposal of pigs from herds (after Table 8, n=354, ex, unknowns)**

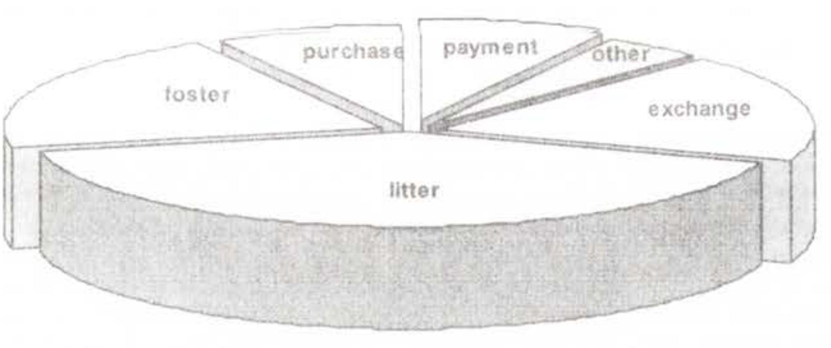


Figure 7. The source of pigs in herds (after Table 8, n=365).

Table 9. **Time pigs owned (1977, 1978, 1983 surveys)**

Months	Total	Percent
<1	36	3.7
1-2	40	4.2
2-3	55	5.7
3-4	72	7.5
4-5	100	10.4
5-6	33	3.4
6-7	49	5.1
7-8	14	1.4
8-9	17	1.8
9-10	4	0.4
10-11	11	1.1
11-12	4	0.4
12-18	136	14.0
18-24	84	8.7
24-30	76	7.9
30-36	63	6.5
36-48	83	8.6
48-60	57	5.9
60-72	18	1.9
>72	14	1.4
Totals	966	100

changed hands at socio-political exchange events (bridewealths, mortuary transactions etc.). The pie-graph indicates that a considerable number of animals -12%, - were lost to sickness either dying or slaughtered when ill. A fair number of pigs, some 9%, people fostered[8] with others, in a customary arrangement called *maha* where the recipient pays the giver when he in turn disposes of the animal (people usually receive such animals while small, commonly as recently weaned piglets, from a wide range of relatives, frequently close affines, and the usual arrangement is that the receiver undertakes in accepting the animal to make a payment to the giver when he gets rid of the animal). People slaughtered a similar – 9%- proportion of their herds, frequently in small feasts such as those that occur at funerals following interment. They sold 5%, and dispersed a further 3% in various payments, including assistance with tasks and debt repayments. And 6% they disposed of in various other contexts, as gifts, inheritance and so on.

The other side to pig movements is the source of animals in herds (Table 8, Figure 7 - compare Hide [1981:510] Figure 8.10 bar graphs of Sinasina pig acquisitions.) These fall into fewer classes. The largest number of pigs in herds - 41% - were 'home grown', coming from litters of sows owned. A considerable proportion of animals were foster pigs received from others, amounting to some 20% of herds. Exchange transactions were the next most common source of animals, these comprising 18% of herds. Next are animals purchased from others at 8% and, comprising a similar percentage, animals received in payment for services rendered and debt repayments. The final 5% came from miscellane-

Table 10. Source of pigs in herds pre- and post- pig kill

Source	Pre-Kill		Immediately Before Kill		Immediately After Kill		Post-Kill	
	No.	%	No.	%	No.	%	No.	%
litter	104	*34*	96	*31*	74	*42*	199	*52*
foster	76	*25*	89	*28*	48	*27*	62	*16*
exchange	63	*21*	69	*22*	28	*16*	51	*13*
purchase	29	*10*	25	*8*	8	*4*	20	*5*
payment	20	*7*	22	*7*	11	*6*	43	*11*
other	10	*3*	3	*4*	9	*5*	9	*3*

*Some of the totals in this table exceed the census counts because they include the herds of men living elsewhere in other communities who chose to come and take part in the pig kill.
Difference significant: $\chi^2 = 61.93$ (d.f. = 15, $\alpha = 0.05$).

ous other sources, including gifts and inheritance. There is no evidence that people prefer to trade for females to increase breeding stock, as Meggitt (1958:288) suggests for the Enga. The reverse is equally plausible, men seeking males that will fatten up more quickly and reach larger final weights. According to the data presented here, 55% of animals purchased in trade were male and 45% female (n=136 animals).

There is possibly some truth in the argument that pig kills effect some deliberate control over porcine demography, and reduce the number of large animals when the burden of their care is inordinately heavy (as Rappaport 1968:160-165 graphically argues for the Maring, where pigs destroy unacceptable numbers of gardens). But among the Wola these stresses appear to be a relatively short-term phenomenon exacerbated, if not precipitated by the promise of a forthcoming pig kill! When the community-wide consensus is that the time for a pig kill approaches, the event taking place maybe in a year or so time, men seek to augment their herds with large animals to slaughter. They rely on exchange opportunities and trade to build up their herds with large animals before a kill. Lederman (1986:204-5) observed the same behaviour in the Mendi valley, putting the case lucidly "people get a substantial number of the pigs they kill at the eleventh hour .... this is not the result of production constraints; it is a systematic social pattern generated by the rules of exchange and is one of the meaningful 'points' or goals of Festival activity". The increase in receipts of pigs through exchange observed by Hide (1981) among the Sinasina and discussed previously, may reflect something similar.

At a large pig kill observed in the Was valley, for example, men had obtained one-third of the 135 animals they slaughtered in only the previous twelve months. Some eighteen months before the kill 34% of herds came from 'home produced' litters and 31% from exchange and trade, and immediately before the kill these percentages had changed little to 31% and 30% respectively, the difference made up largely by foster pigs (Table 10). Immediately after the kill the proportion of 'home produced' animals in herds increased to 42% and those obtained in exchange and trade fell to 20%, as a result of men slaughtering a larger proportion of animals obtained in these transactional contexts than acquired in other ways. Some two years or so after another pig kill 'home produced' litter pigs still dominated. They comprised 52% of herds, an increase largely at the expense of foster pigs, the proportion of animals obtained through exchange and trade remaining nearly constant at 18% of herds. High residual values, for exchange and purchase pre-kill and for litters post-kill, confirm these trends statistically.

CONCLUSION

The people who feature in this paper practise a pig management regime typical of much of the Southern Highlands region. They allow pigs to forage extensively during the day with little or no supervision and return to homesteads of an evening where women usually feed them a sweet potato tuber ration. While people control the reproduction of animals, putting juvenile boars to sows, they do not practice selective breeding of stock. Indeed there is no local idea of breed, although people distinguish between animals, according to morphology and appearance. They maintain that pigs vary in growth rate and final size, including those from the same litter. The analysis of herd survey data reveals some interesting points about the structure and composition of pig herds, confirming many of the findings reported elsewhere. The mean herd size is three to four animals, but this is subject to wide variation. The demographic structure of herds can change considerably due to cultural demands, notably periodic community wide pig kills and pork exchanges, or natural events, notably occasional climatic perturbations resulting in food shortages. Herds may halve in size and the proportion of adult to immature animals change considerably, immature animals increasing following pig kills but falling during droughts. The other source of change in herd populations is the movement of live animals between them. Many pigs are fostered to others and significant numbers change hands in various payments and socio-political exchange transactions. The data suggest that herds turn over about once every five years, including kills. The demographic profile of herds, which is strikingly different to commercially managed herds, reflects the culture's socio-political exchange focus. People hang onto adult pigs for months, even years, commonly waiting for a communal pig kill to cull them.

The logic driving pig herd management and kills is as much transactional as demographic and nutritional. Herds may swell just before a pig kill, particularly with larger animals, and crash immediately afterwards but the evidence suggests that they return to 'normal' levels within a couple of years or so. While the population crashes documented for Wola herds, at between 26% and 44% of pre kill levels, are considerable, they are not as large as those reported elsewhere in the highlands, such as among the Sinasina and Maring where declines of 59% and 56% respectively have been recorded (Hides pers comm. Rappaport 1968:213-15). One explanation for the quick return of populations to 'normal' is that pig kills draw on a wider region than the community staging the event, the movement of large pigs resulting in a 'buffering effect'. After a natural calamity, on the other hand, such as an extended drought, herds recover more slowly because all the communities in a region are affected, unlike after kills which deplete herds in one locality at a time. These exacerbates the demographic effect of losing many young pigs. Pig kills are the high point of the socio-political exchange system. While people are reluctant to dispose of highly valued pigs piecemeal in small events, they willingly slaughter them in large ones to which hundreds of people come. These are truly grand occasions, celebrations of the exchange ethic, at which pork changes hands thousands of times as people repeatedly carve it up, meat sometimes passing between two, three of more persons before consumption.

The demands of exchange critically inform peoples' approach to pig management. They wish to handle many animals in large numbers of transactions, and slaughter several at periodic large pig kills and distribute large amounts of fatty pork. We might assume that these demands would translate into a desire to breed many animals. The requirements of exchange intervene in other ways, modifying any urge to breed pigs. The ready castration of young boars, many of them before they reach sexual maturity, reflects attitudes to breeding, leaving only two or three animals in any locality at a time able to service sows. Men with male piglets are more interested in turning them into rapidly growing and docile *saendapow* hogs than having breeding stock. Regarding *way* gilts and *injiy* sows, we might assume that keeping these as large adults is less wasteful in energetic terms than herding fully grown *saendapow* hogs because they will produce litters. Nevertheless many of these female animals are as unproductive as their large male equivalents because people are often reluctant to allow them to breed. When sows farrow they lose condition and weight, which dramatically reduces their value, and they can take many months to feed up again. A large fat pig now is more desirable for someone with his eye on current exchange commitments, than a skinny sow and litter of piglets that will take years to grow into valuable animals. It deflects men from animal production. The impact of this cultural logic is evident on pig herd demography.

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EVALUATION OF SELECTED FOOD PROPERTIES OF WHITE YAM (*DIOSCOREA ROTUNDATA*) IN PAPUA NEW GUINEA

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ABSTRACT

White yam, Dioscorea rotundata *Poir., has recently been introduced for cultivation in Papua New Guinea to increase yam production and provide varieties for yam consumers and potential processors. Physical, chemical, functional, and sensory properties of the introduced yam species,* TDr-90-1-1 *cultivar, were assessed in relation to popular cultivars,* Takua Yavu *and* Glame, *respectively of* D. alata *and* D. esculenta. D. rotundata *was the most difficult to peel (manually and mechanically) and gave the highest dry matter. The pH of its water-extract was slightly acidic as were for others (5.7 – 6.7) but the extract had the lowest solids content.* D. rotundata *slices (6 mm) absorbed less water but slightly more oil. It exhibited the slowest rehydration behaviour and its 4% slurry was the most viscous at 20 revmin^{-1} in a rotational viscometer as a cold (35°C, 1.56 Nsm^{-2}) or hot (75°C, 0.83 Nsm^{-2}) paste. Sensory evaluation revealed that it was essentially as acceptable as* D. esculenta *when cooked or fried as chips but better than* D. alata. *The perceived bitter after-taste and irritation upon chewing and swallowing products from* D. rotundata *suggested that its content of anti-nutritional (oxalates, tannins and phytic acid) components may be higher than normal and should be quantified for complete acceptability of the yam as a food material. The potential of* D. rotundata *for food production in PNG is good and ought to be pursued.*

Keywords: *Physio-chemical, functional, viscosity, sensory evaluation, water absorption, Dioscorea alata, Dioscorea esculenta.*

INTRODUCTION

Yams (*Dioscorea* spp.) are herbaceous plants with a twining stem belonging to the *Dioscoreaceae* family, which is reported by Kay (1987) to consist of about 60 edible species. Of all, four are widely cultivated and consumed (Kay 1987; Bradbury and Holloway 1988; Udoessien and Ifon 1992). These are *Dioscorea alata* L., water yam; *D. esculenta* (Lour.) Burk., Asiatic yam (often but incorrectly referred to as Chinese yam); *D. cayenensis* Lam., yellow yam; and *D. rotundata* Poir. Increasing taxonomy and composition evidence, however, points to *D. rotundata* and *D. cayenensis* as being the same species (Agbor-Egbe and Treche 1995).

FAO (1993) gives the area and production of yams in PNG as 13,000 hectares and 220,000 tonnes respectively. Yams produce edible starch storage tubers, which are of socio-cultural and economic importance in tropical and subtropical countries (Onwueme and Charles 1994). Nutritionally (Bradbury and Holloway 1988; Ezeh 1992; Udoessien and Ifon 1992), yams are:

- A source of energy.
- Low in protein but contribute to some essential amino acids requirements of the consumers.
- Important sources of pharmaceutical compounds such as saponins and sapogenins, which are precursors of cortisone and steroidal homones.
- Generally low in phytic acid, tannin and cyanide.

Also, yams contribute towards the dietary needs of mineral elements such as calcium, phosphorus and iron, and their soluble oxalates are not high enough to pose a serious threat to calcium (and divalent minerals) availability.

In Papua New Guinea, yam is reportedly the third root crop behind sweet potato and taro but interestingly, PNG is considered to be one of the centres of origin of *D. esculenta* (Kay 1987). While about 1100 accessions of *D. alata* and *D. esculenta* have been recorded in Vanuatu, PNG and Solomon Island, *D. rotundata* is of minor importance generally in the Pacific (Bradbury and Hol-

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loway 1988) in spite of its relatively superior characteristics and dominance of the global yam production. Probably, because of its food uses (Kay 1987; Onwueme and Charles 1994), the cultivation of *D. rotundata* is gradually being encouraged in PNG and it is expected to fit into the farming practice of the target farmers, who are experienced yam producers.

As with any introduced (new or modified) food, the acceptability and hence, sustainability of the food is dependent on many factors, the most important of which are the food properties such as physical, chemical, functional, and sensory. If the introduced food is to withstand the test of time, it must be comparable in properties to or better than existing competitive foods. By instinct, consumers tend to compare foods and modify their patronage accordingly. Hence, the objective of this paper, as a first step in our evaluation of the introduced yam species, was to obtain experimental data on the selected food properties and examine how they compare with the ones for *D. alata* and *D. esculenta*, which are already eaten in PNG.

MATERIALS AND METHODS

Materials

The yam samples were obtained from the storage barn of the National Agricultural Research Institute research station at Bubia and analyses on them started in October, 1998. Several tubers of a promising variety, one each from the three species, were obtained. They were identified as: *D. alata, Takua Yavu; D. esculenta, Glame; D. rotundata, TDr 90-1-1*. *Takua Yavu* was planted in October 1997 and harvested in June 1998, *Glame* was planted in November 1997 and harvested in September 1998 while *TDr 90-1-1* was planted in November 1997 and harvested in August 1998. These crops were planted at Bubia, where the soil is a sandy clay-loam. Fertiliser (Urea) was applied as a basal dressing to the yam plants at about 50 kg nitrogen ha^{-1} at one month after planting. The initial land preparation was done using tractor-mounted implements but all husbandry practices including planting, staking, weeding, and harvesting were carried out manually.

Chemical Property

Moisture content of the fresh tubers were determined by standard procedures – Method 930.15 (AOAC, 1990). The fresh tubers were peeled in an abrasive peeler (Crypto Peerless Ltd., Birmingham B9 4UA, UK; model CC 14) and dried (APV Mitchell (Dryers) Ltd., Carlie CA2 5OU, UK) at 40°C and 2.6 ms^{-1} air flow for about 45 hr after being sliced (AB Halde Maskiner, Sweden) to about 6 mm thickness. Part of the dried slices was ground using a domestic mill and analysed for moisture, crude protein by Kjeldahl procedures (Method 921.32B), crude fat using petroleum either (Method 920.39B) and ash (Method 942.05) following the procedures in AOAC (1990). Carbohydrate was obtained by difference while the procedures in Martin (1979) were used in determining the starch content (acid hydrolysis technique) and the acidity of the yam flours. The pH of the water extract from the acidity determination was measured with a pH meter (TOA Electronics, Japan; model HM-7E). The energy content was calculated using the Atwater factors (kJg^{-1}) on calculated composition of the fresh tubers: protein, 17 and fat, 38 (Bradbury and Holloway 1988) but for the carbohydrate, 16.5 was used being the average of the factors for starch and sugar (Sopade and Koyama 1999).

Physical Property

The ease of and losses from peeling were assessed by peeling about 1.0 kg of each cultivar for up to 4 min. with water in the abrasive peeler. Manual peeling was also done.

Water absorption was measured by incubating 18 g of the yam flour in 2000 ml water at 40°C for 1 hr. The slurry was centrifuged (Kokusan Corp. Tokyo, Japan; model H-103N; radius = 9.5 cm) at 1500 $revmin^{-1}$ for 10 min. The gel was weighed and water absorption index, WAI, was defined as:

$$\frac{W_2 - W_1}{W_1 \{1 - [M/100]\}} \times 100 \quad \text{——— } 1$$

where, W_1 = weight of the flour; W_2 = weight of the gel; M = moisture content of the flour.

The solids content of the decanted solution was determined by evaporating the solution to dryness at 100°C in an oven. Water solubility index, WSI, was defined as:

$$\frac{\text{Total solids in solution}}{W_1 \{1 - [M/100]\}} \times 100 \quad \text{—— } 2$$

The oil absorption index (OAI) was determined an defined as WAI except that copra oil replaced the water.

A 4% solution of the yam flour was brought to boil and simmered for 5 min. before cooling. The evaporated water (110 – 130 g) was added back to the slurry and its viscosity determined at 75°C and 35°C using a rotational viscometer (Brook field Engineering Laboratories, Inc., Stoughton, MA; model RVDV-1+ Version 4.1) at 20 $revmin^{-1}$. Viscosity values were recorded after 3 min. of rotation and no sample rested for less than 3 min. prior to measurement.

Rehydration characteristics of the yam cultivars were assessed at about 22°C by soaking about 5 g dried slices in 60 mL of water for up to 5.5 hr. Periodically, the water was drained and the slices were gently blotted before weighing them. From material balance principles, the moisture content during the soaking was calculated and related to the soaking time.

Sensory Property

Fresh tubers were peeled and divided into two. One lot was thickly (approximately 15 mm x 20 mm x 25 mm) sliced, boiled and simmered in excess water till completely cooked (11 – 20 min.) as judged by the ease of penetration by a cutlery. The cooking water was drained and the cooked slices immediately served for sensory evaluation.

The other lot was thinly (= 1 mm) sliced and deep fried for 3 – 5 min. Frying was stopped when the hot oil stopped bubbling and a golden brown colour was approached. The chips were drained off oil and immediately served for sensory evaluation.

A nine-point hedonic scale was used with 9 representing extremely like and 1 was for an extreme dislike. Ten panellists, four females and six males, who were final year (1998) Food Technology students, conducted the evaluation. Having attended lectures in the principles and procedures of sensory evaluation, and conducted numerous hedonic tests, the panellists were considered trained enough to evaluate the sensory properties of the two yam products. Parameters evaluated included colour, taste, texture, and overall acceptability. Results were subjected to analysis of variance (ANOVA) and Duncan t-test as described elsewhere (Kramer and Twigg 1980).

RESULTS AND DISCUSSION

Table 1 summarises the physico-chemical property of the three yam species. The proximate composition of some popular PNG cultivars of these yam species as reported by Bradbury and Holloway (1988) is included. *D rotundata* was the driest (lowest moisture content) of the fresh tubers despite being in storage for the shortest period. Agbor-Egbe and Treche (1995) noted that, in dry matter, *D. alata* is low (23 – 25%), *D. esculenta* is intermediate (28 – 30%) and *D. rotundata* is high (32 – 37%). Our results follow this trend. Our results also indicate the generally low fat, intermediate protein and high carbohydrate (starch) contents of the yam species. However, the values we obtained for the fat and starch contents are slightly high but close to the range reported by various workers for these species (Table 2).

The chemical compositions of yam (and other root crops) have engaged the attention of many workers, and as shown in Table 2, reported values vary substantially. The following reasons have been advanced (Ekpenyong 1984; Ologhobo 1985; Bradbury and Holloway 1988; Onayemi and Idowu 1988; Faboya and Asagbra 1990) for the differences:

- Environmental conditions.
- Cultural and farming practices.
- Soil fertility.
- Varietal differences.
- Length of storage.
- Degree of maturity

For the *Glame* cultivar of *D. esculenta* planted in different areas of the East Sepik Province of PNG, Bradbury and Holloway (1988) obtained (%) 71.0 – 77.6, moisiture; 1.98 – 2.24, protein; 15.8 – 23.1, starch; 0.07 – 0.09, fat; and 0.66 – 0.83, ash. Storing *D. rotundata* for 150 days, Onayemi and Idowu (1988) recorded (%) 71 – 77, moisture; 0.16 – 0.20, fat; 0.6 – 1.2, protein; 17.0 – 21.8, starch but no change in the ash content. We have only recently initiated this evaluation study and it is planned that as the *D. rotundata* becomes more important in PNG, more cultivars and samples of the yam species in relation to the other two would be evaluated.

The peeling studies revealed that *D. rotundata* was the most resistant to abrasive peeling. Between 1 and 3 min. of peeling, *D. rotundata* lost 16 – 47% weight (63% at 4 min.) while the other two lost more than 60% after only 2 min. of peeling. Manual peeling showed that the peel was between 9 and 16% and *D. alata* was the easiest to peel. However, with mechanical peeling, a higher percent loss can be tolerated but any weight loss greater than 45% could be regarded as indicating excessive loss of yam solids after the peels had been removed. It is, therefore, recommended for potential processors to peel *D. rotundata* for a longer time than normally used for *D. alata* and *D. esculenta*. In the type of the abrasive peeler used in this study, *D. rotundata* may be peeled (1-2 kg) for 3 min. while 1 min is enough for the same weight of *D. alata* and *D. esculenta*. The longer peeling time for *D. rotun-*

Table 1. **Physico-chemical properties of the yam species[a]**

Parameter	D. alata	D. esculenta	D. rotundata
Moisture content[b]	73.4 ± 1.58 (9.0 ± 0.04)[c] [75.2 – 83.8][d]	72.2 ± 0.05 (8.8 ± 0.17) [71.0 – 81.2]	68.5 ± 0.32 (8.6 ± 0.04)
Crude fat	1.3 ± 0.00 [0.3 – 0.5]	1.2 ± 0.05 [0.2 – 0.4]	1.1 ± 0.01
Ash	1.8 ± 0.06 (3.1 – 4.5)	3.1 ± 0.01 (2.0 – 4.2)	2.2 ± 0.06
Protein (N x 6.25)	6.2 ± 0.03 [5.2 – 8.1]	8.2 ± 0.01 [63.1 – 80.9]	5.8 ± 0.06
Carbohydrate by Difference	90.8	87.5	90.9
Starch	90.1 ± 5.21 [74.6 – 87.8]	73.0 ± 3.72 [63.1 – 80.9]	77.8 ± 1.81
Energy ($MJkg^{-1}$)	4.4	4.5	5.2
Energy ratios (%) contributed by: protein	6.3	8.6	6.0
fat	2.9	2.7	2.5
carbohydrate	90.7	88.7	91.5
Acidity (% lactic)	0.4 ± 0.05	0.7 ± 0.05	0.7 ± 0.06
pH	6.7	6.2	5.7
Ease of peeling	Easiest	Easier	Easy
Peeling losses	High	Medium	Low
% Peel (manual)	9	14	16

a: Dried samples were used and values expressed on % dry basis as means ± standard deviations.
b: Values for fresh samples and expressed on % wet basis.
c: The moisture content of the dried samples and expressed on % wet basis.
d: Values in [ ] brackets are for the popular cultivars (including Glame for *D. esculenta*) grown in the East Sepik Province analysed by Bradbury and Holloway (1988).

Table 2. **Chemical composition of the yam species from various references**

Yam species	Parameter	Reference[a]				
		I[b]	II[c]	III[d]	IV[e]	V[f]
D. alata	Moisture	65.73	86.65	69.80	76.79	77.3
	Fat	0.03-0.27	0.1-0.4	0.62-0.93	0.06-0.10	0.08
	Ash	0.67-2.06	0.021-0.044	3.60-4.36	0.75-0.88	
	Protein	1.12-2.78	4.7-15.6	5.61-6.55	1.35-3.05	2.15
	Carbohydrate	22-29		87.00-88.87		17.72
	Starch		60.2-82.1		15.9-17.5	
	Sugars		0.8-18.1		0.77-1.39	
	Crude fibre	0.65-1.40		0.70-1.10	1.19-2.36	1.88
D. esculenta	Moisture	67-81	76-.69	70-82	71-76	74.2
	Fat	0.04-0.29	0.1-0.5	0.42-0.52	0.04-0.07	0.06
	Ash	0.5-1.24	0.016-0.028	2.60-3.18	0.74-0.90	
	Protein	1.29-1.87	4.1-6.5	6.66-8.00	1.77-2.30	2.06
	Carbohydrate	17-25		88.33-88.69		19.85
	Starch		66.3-73.4		17.7-22.2	
	Sugars		3.2-11.6		0.32-0.78	
	Crude fibre	0.18-1.51		0.65-1.15	0.94-1.40	1.15
D. rotundata	Moisture	58-	75.61	67.76	65.7±1.0	65.7
	Fat	0.05-0.12	0.1-0.5	0.30-0.46	0.09±0.01	0.09
	Ash	0.53-2.56	0.014-0.039	2.70-4.00	0.73±0.01	
	Protein	1.02-1.99	3.7-8.9	4.33-4.80	1.42±0.03	1.42
	Carbohydrate	15-23		89.82-90.72		30.52
	Starch		73.5-85.3		30.2±0.7	
	Sugars		2.0-5.5		0.32±0.08	
	Crude fibre	0.35-0.79		1.00-1.45	0.63± 0.10	0.63

a: A blank cell indicates data not available. Reference I = Kay (1987), II = Agbor-Egbe and Treche (1995), III = Ologhobo (1985), IV = Bradbury and Holloway (1988), V = SPC (1995).

b: The upper range for the moisture content of *D. rotundata* was wrongly (typographical) quoted as 33% and, therefore, not included in the table.

c: Apart from the moisture content, other values are on % dry basis.

d: Values are for the head, middle and tail sections of the tuber. Apart from the moisture content, other values are on % dry basis.

e: Values are for the dietary fibre and for *D. rotundata*, figures are means ± standard deviations.

f: Values are for the dietary fibre.

data has an economic implication for potential processors as more energy is used and production cost is increased relative to the cost for the other two yam species.

It has been observed (Kay 1987) that while *D. esculenta* is thin-skinned, *D. alata* and *D. rotundata* are thick-skinned. The higher moisture content of *D. alata*, however, reduces its resistance to peeling when compared to *D. rotundata*. Soaking legumes, which increases their moisture content, have been reported by Sopade *et al.*, 1994 to aid the removal of their hulls, a form of peeling. Apart from this factor, ease of mechanical peeling is dependent on how regular the shape of the tuber is as the tuber surface needs to contact the abrasive surface of the peeler. The *D. rotundata* was the most irregular and heavily distorted while the *D. alata* was essential cylindrical and the *D. esculenta* was basically round or spherical.

Fig. 1 shows the water absorption (WAI), water solubility (WSI) and oil absorption (OAI) indices of the yam species. The absorption indices are related to the ability of the macro-nutrients (starch and protein) to bind a liquid and they have implications for food uses of the materials. A food material with a high WAI is valuable as a food thickener and Ruales *et al.* (1993) observed that the water absorption capacity of an infant food and the amount of water-soluble substances present will affect its palatability in the form of a porridge or a beverage. The whipping ability is related to OAI and it is probably more important in protein-rich foods because OAI increases with an increase in protein content (del Rosario and Flores 1981). It should be noted also that the possibility of a complex between amylose (a starch fraction) and lipids or fats makes the starch content an important parameter in OAI (Deshpande *et al.* 1982). However, the ability to bind fats is important since fats act as flavour retainers and they improve the mouth feel of foods (Rahma and Mostafa 1988). WSI, on the other hand, shows the amount of water-leachable components. For starchy materials, solubility in water increases with polymer degradation through, for example, heat treatment by generating components of low molecular weights (Ruales *et al.* 1993).

Although a high water absorption tends to be accompanied by a low WSI as with *D. esculenta* and *D. rotundata*, the trend with *D. alata* is the opposite (Fig. 1). During peeling, it was observed that *D. alata* was the most slimy implying that it exuded more mucilages, which have been linked to glycoproteins (Onwueme and Charles 1994), than the other two. It was observed that the mucilages accumulated on the surfaces of the yam slices and after drying became solid deposits. This resulted in the high WSI of *D. alata* dispite its intermediate WAI. *D. rotundata* absorbed the most oil (non-polar), the least water (polar) and had the smallest water-soluble components.

An important requirement of any dried food is its reconstituability or rehydration behaviour (Okaka *et al.* 1991). Although root crops are not usually dried as traditional foods in PNG, it seems that the benefits of dehydration or drying have not been properly evaluated in PNG. The lessons from the major drought in 1997 (due to the El-Nino phenomenon) call for an urgent review and modification of the post-harvest strategy for root crops in the country. Food surveys (Harvey and Heywood 1983), for example, have revealed that root crops respectively contribute more than 50% and 30% of the total energy and protein intake in the country, and making these foods available all the year round is a key agro-food task.

The rehydration behaviour of the dried (40°C) yam slices (6 mm) shows (Fig. 2) the normal sorption pattern (Peleg 1988); a sudden increase in absorbed water during the first 50 min. followed by a gradual zone and terminating in a slow phase after 200 min. *D. rotundata* showed a gentle rehydration pattern and absorbed the least irrespective of the duration of soaking.

Sorption patterns are better analysed using sorption equations and the non-exponential Peleg's equation has proved quite useful (Sopade and Kiamur 1999). The equation is:

$$M_t = M_o + \frac{t}{K_1 + K_2 t} \qquad \text{......3}$$

where, M_t = moisture content at time t, M_o = initial moisture content, and K_1 and K_2 = constants. While K_1 defines the temperature dependence of the rehydration behaviour, K_2 is independent of temperature (Sopade and Obekpa 1990) and defines the maximum absorbed water (equilibrium moisture content, M_E) by the food (Peleg 1988):

$$M_E = M_o + \frac{1}{K_2} \qquad \text{......4}$$

Equation [4] is useful in predicting the closeness of the rehydrated dried food to the fresh state and possibly in examining modification of the water binding sites. An application of Eqn. [3] to the rehydration data of the yam species gave a correlation coefficient that ranges from 0.9525 – 0.9780, which shows a good fit. The M_E values (%) for the yams are : *D. alata*, 65.8; *D. esculenta*, 63.8 and *D. rotundata*, 54.1. The differ-

Figure 1. Absorption and solubility indices of the three yams species

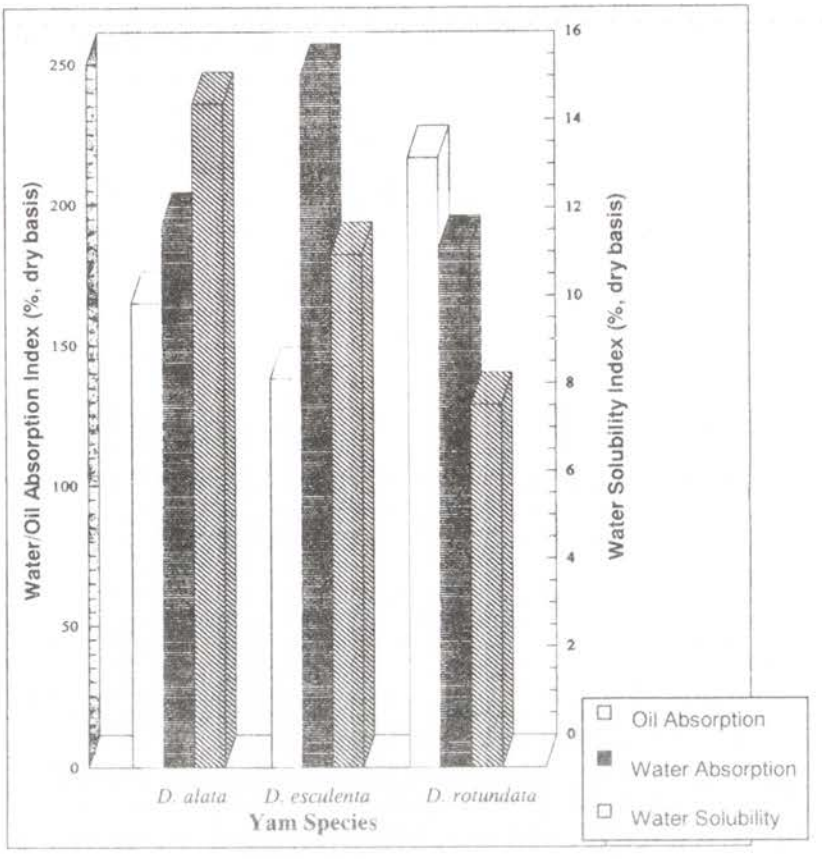
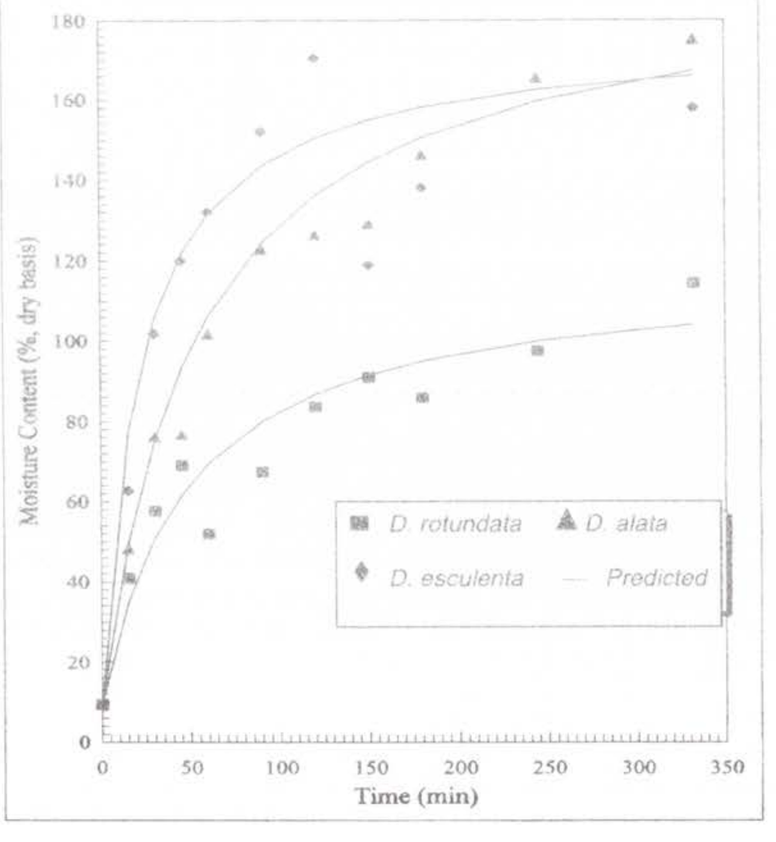


Figure 2. Rehydration behaviour of the three yam species



ences from the fresh state moisture contents (%) are from 7.6 to 14.4 with *D. rotundata* exhibiting the biggest difference. It could be that the drying conditions (40°C, 2.6 ms^{-1}, 45 hr) damaged the water binding sites more in the cultivar but this was not assessed separately; the moisture content of the dried *D. rotundata* slices was the lowest (Table 1). From these observations, it could be that the drying characteristics of *D. rotundata* differ, which is expected, from those of the other species and a study in this direction would be worthwhile.

However, if the cultivars studied here could be subjected to the same treatments as reported in this study, the following equations would predict their water uptake ability on %, dry basis:

D. alata: $$M_t = M_o + \frac{t}{0.29 + 5.47 \times 10^{-3} t} \quad \ldots\ldots 5$$

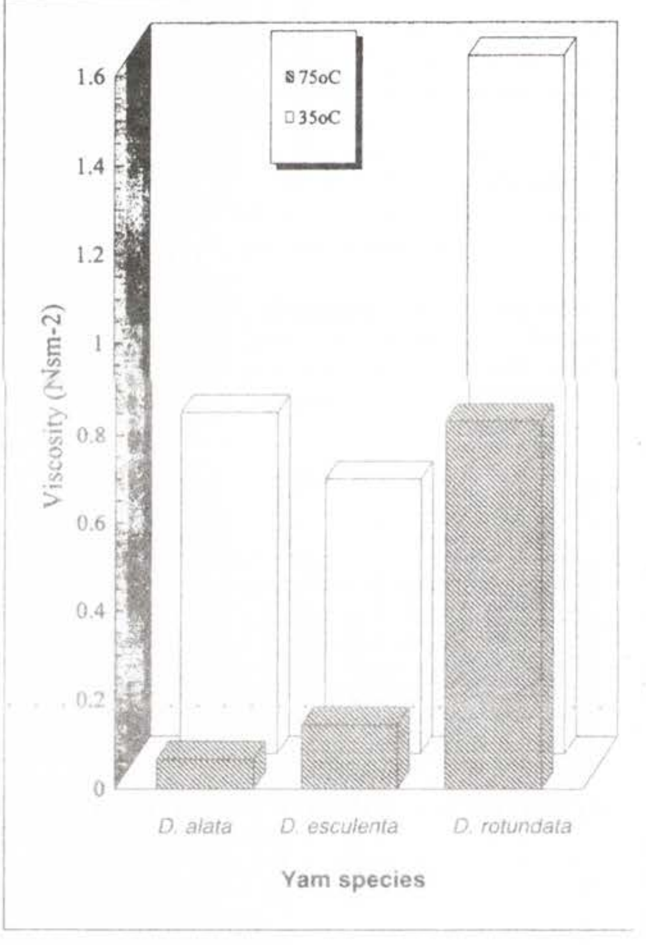
D. esculenta; $$M_t = M_o + \frac{t}{0.13 + 6.00 \times 10^{-3} t} \quad \ldots\ldots 6$$

D. rotundata: $$M_t = M_o + \frac{t}{0.44 + 9.22 \times 10^{-3} t} \quad \ldots\ldots 7$$

These equations [5 – 7] will allow the moisture content to be estimated for a known soaking period as against guessing the time. This is important to the food processor, who is concerned with the economics of the processing package. The equations will also assist in providing the consumers with the knowledge of an appropriate time to obtain defined rehydration levels for various functional uses.

Another functional property is the viscosity of the cultivars. Faboya and Asagbra (1990) have studied, using a Brabender amylograph, the viscous property of five Nigerian cultivars of *D. cayenensis/rotundata* complex and concluded that the starch of *D. rotundata* is a highly viscous one. In the absence of an amylograph, we used a rotational viscometer and the viscosity values at hot and cool temperatures are shown in Fig. 3. All the samples gave higher viscosity values at 35°C than at 75°C, an observation that agrees with the general temperature-viscosity trend (Sopade and Filibus 1995). At either temperature, *D. rotundata* was the most viscous and was 2 – 4 times more viscous than the others. With a starch content lower than that for *D. alata* and comparable to that for *D. esculenta*, the starch of *D. rotundata* must indeed be a highly viscous one for these unique characteristics. Kay (1987) reported that the starch granules of *D. alata* are of sizes 5 – 50 µm, *D. esculenta*, 1 – 15µm and *D. rotundata* 10 – 70 µm and viscosity of *D. alata* starch was quoted as 100 – 200 Brabender units (BU) while Faboya and Asagbra (1990) obtained 360 – 980 BU for that of *D. rotundata* starch. The high viscosity of *D. rotundata* makes it the main raw material for pounded yam in West Africa (Onwueme and Charles 1994). However, it does not seem that there is an identical traditional product in PNG. Rather, the high viscosity of *D. rotundata* can be explored to make a porridge (more watery than pounded yam) that can fall in the same category as cooked sago (*Metroxyln sagu*) starch porridge, which is available in the PNG food system. But sago starch is more viscous (Sopade and Koyama 1999) and more solids of *D. rotundata* have to be used to obtain a close product because viscosity increases with solids content (Sopade and Filibus 1995). Since *D. rotundata* is nutritionally superior to sago starch, consumption of more *D. rotundata* solids brings nutritional benefits.

***Figure 3.* Viscous property of the three yam**



An increase consumption will be dependent on the sensory quality of *D. rotundata* in relation to what the consumers are used to. Since ANOVA what the consumers are used to. Since ANOVA showed no significant difference ($p>0.05$) amongst the panellists, a significant difference ($p<0.05$) amongst the samples was accepted to be entirely due to the inherent differences amongst the samples. Table 3 is a summary of the organoleptic evaluation of the yam cultivars. With respect to the cooked samples, there was no difference ($p>0.05$) in the colour and taste but *D. alata* was the least preferred in terms of the texture (hardness and chewiness) while *D. rotundata* and *D. esculenta* were better preferred in the overall quality (a compound of all sensory parameters). For the fried chips, the samples were found to be significantly different ($p<0.05$) only in the texture (crispiness) with *D. rotundata* being rated essentially the best. Generally, *D. rotundata* was rated the best for the products assessed and this was considered as a positive development for *D. rotundata* as a new yam species in Papua New Guinea.

Table 4 shows the comments of the panellists. Remarkably, the panellists detected a bitter aftertaste in the *D. rotundata* samples and thought that it contained a component that is irritating to the throat. During peeling and washing, we detected that the wash water from *D. rotundata* irritates the skin. Onayemi and Idowu (1988) have reported bitterness in *D. cayenensis/rotundata* complex due to the residual polyphenols and glycoalkaloids. The amount of bitterness compounds increases with the length of storage and are mostly concentrated at the head section. The head section is that part of the tuber to which the vine is attached while the tail is the distal portion with the growing point (Ologhobo 1985). Both sections are watery and are frequently discarded or dried and milled into yam flour. With respect to the effect of storage, Onayemi and Idowu (1988) reported that the yam tubers need not be stored for more than 120 days and that storage for a longer period would yield tubers that are too bitter. The *D. rotundata* tubers that we studied were stored for about 60 days before our analyses started. Irrespective, farmers in PNG, who are being introduced to *D. rotundata*, should be advised accordingly.

Irritants in root crops particularly in taro (*Colocasia*, *Xathosoma* and *Alocasia* spp.) are due to oxalates (Bradbury and Holloway 1988), which are generally considered low in yam (Udoessien and Ifon 1992). It is unknown if the levels of oxalates in the *D. rotundata* cultivar evaluated were higher than normal and consequently, uncomfortable to the panellists. There is a need to analyse the anti-nutritional constituents. The low oxalates in yams grown elsewhere may not be the situation with the *D. rotundata* grown in PNG as environmental and soil factors affect the composition of root crops.

Table 3. **Summary of the organoleptic evaluation of the yam products**

Product	Parameter	D. alata	D. esculenta	D. rotundata
Cooked	Colour	6.4a	7.3a	7.1a
	Taste	5.8a	6.7a	7.6a
	Texture	4.5a	6.4ab	7.8b
	Overall acceptability	5.2a	6.2ab	7.8b
Fried chips	Colour	7.1a	7.0a	7.1a
	Taste	7.0a	7.5a	7.1a
	Texture	6.2a	6.4ab	8.2b
	Overall Acceptability	7.0a	7.1a	7.2a

a: Values within a row followed by a different letter are significantly different at $p<0.05$

Table 4. **Comments from the sensory evaluation of the yam products**

D. alata	*D. esculenta*	*D. rotundata*
Cooked		
Remarkable taste. Tastes sweet with good after-taste. Sticky in the mouth, a bit raw but fair. Tastes better. Sticky when eaten. Texture is hard. Sweeter than the others. No irritating substance but sweet. Colour not quite attractive.	Tastes nice. Soft and powdery feeling. Least white in colour and a bit sweet in the mouth. Feels raw and uncooked. Appealing colour. Produced crunchy sound when chewed. Preferred texture for starchy foods. Tasted nice and acceptable colour. White colour.	Appealing colour but taste is not too good. Good texture. Reasonable chewing texture. Right in taste and colour. Colour not really appealing. Sticky and too soft in texture. Most acceptable. Texture is the most acceptable. Natural yam colour. Nice texture but sticky in the mouth. Seemed to contain an irritating substance. Quite firmer texture. Colour and taste are good but quite bitter when swallowed. Met all the quality attributes. Taste much better. Far more acceptable.
Fried chips		
Appealing colour and remarkable taste. Reasonable flavour. A bit golden brown, soft but tastes nice. Soft and a bit crispy. Have a better light brownish colour. More like stale chips. Texture too soft. Crisp texture for chip making. Best taste. Distinct yam taste still detected. Right texture for chips. Potential as a commercial product	Golden brown in colour. Best taste of all. A bit crispy but feels like unleavened bread. Texture too soft. Crisp texture for chip making. Best sample. Colour needs improvement. A bit too brown. Texture too loose.	Has crispy texture although no pronounced flavour of taste. Has a bitter after-taste upon swallowing. White in colour. Hard and most crispy. Crispier than others. Colour is attractive. A bit crunchy. The best texture, desirable colour and taste. Seems to contain an irritating substance when swallowed. Very hard crispiness. Taste nice but colour not attractive. Has acceptable white colour. A bit too crunchy.

CONCLUSION

Papua New Guinea locally-grown *Dioscorea rotundata* exhibited certain properties that are in line with similar properties of the yam species available elsewhere. It has a high dry matter and produces a porridge that is more viscous than ones from D. alata *and D. esculenta*. When cooked or fried, it was better accepted but left a bitter after-taste and was more irritating to the throat. However, the *D. rotundata* cultivar *TDr 90-1-1* evaluated has not been adversely affected by the environmental and farming practices in the location where it was harvested. This suggests that it can be assimilated into the national agricultural systems. Nevertheless, farmers into its cultivation ought not to store the tubers for more than 120 days. The extent of agricultural extension strategy on *D. rotundata* will depend on the current post-harvest handling practices of *D. alata* and *D. esculenta*, which are the existing popular yam species.

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EFFECT OF DIFFERENT PLANT SPACINGS ON THE YIELD AND YIELD COMPONENTS OF RICE VARIETY NIUPELA UNDER RAINFED UPLAND FIELD CONDITIONS AT ERAP STATION

J. A. Pitala[1]

ABSTRACT

Plant spacings did not have any significant (P<0.05) effect on plant heights, panicle length and number of grains per panicle. However, there were highly significant (P<0.01) differences in panicle weights and number of productive tillers between the different plant spacing treatments.

At the closer plant spacing of 7.5 x 15cm, a significantly (P<0.01) higher paddy yield of 9.50 t/ha was obtained compared to the other plant spacing treatments.

Keywords: *Rice variety Niupela, plant spacing, yield, panicle length, 1000 grain weight.*

INTRODUCTION

In transplanted rice, plant spacing is an important production factor (De Datta, 1981). For example, if rice is planted at closer spacing than necessary, the cost of transplanting and the chances of lodging may increase. Under upland rainfed conditions, wider spacing may contribute to increase in weed population and this may further contribute to the cost of weeding.

In Papua New Guinea (PNG), plant population studies indicated that with higher tillering varieties, higher yields were obtained at closer spacings of 20x10 cm, 20x20 cm and 20x30 cm compared to the wider spacings of 20x40 cm and 20x50 cm (Wohuinangu, 1984). Using the E1 low tillering rice variety, Wohuinangu and Moon Kap (1980) also obtained higher yields at closer spacings of 20x20 cm and 20x30 cm.

This experiment was conducted to examine the effect of different plant spacings on the yield and yield component of rice variety *Niupela*, under rainfed upland field conditions at Erap Station 90 metres above sea level in the Markham Valley, Morobe Province.

MATERIALS AND METHOD

The experiment was conducted from November 1992 to April 1993. Six different plant spacing treatments were used as follows (Table 1).

Table 1. **Plant spacing and number of hills on per hectare basis**

Spacing Treatments	Hills/ha
T1 = 7.5x15 cm	888,889
T2 = 15x15 cm	444,444
T3 = 20x20 cm	250,000
T4 = 25x25 cm	160,000
T5 = 30x30 cm	111,111
T6 = 30x50 cm	66,667

The experiment was a randomised complete block (RCBD) with six plant spacing treatments and replicated four times. The plots were 15 m^2 in size and the rice variety used was *Niupela*. The mixed NPK-fertilizer used contained 12% total N, 12% P_2O_5 and 17% K_2O. At sowing time, a basal application of NPK was applied at the rate of 40:50:50 kg/ha. To obtain the correct doses, 357 kg of mixed NPK-fertilizer + 153.7 kg TSP/ha were applied (535.5 g mixed NPK-fertilizer + 230.6 g TSP/plot). The first and second N top dressings were done 20 and 40 days after planting, respectively. At each top dressing, N was applied at the rate of 30 kg N/ha (65.2 kg Urea/ha or 97.8 g Urea/plot).

At harvest time, ten hills were randomly harvested to determine the yield components. The paddy yield was determined by harvesting the hills within an area of 4 m^2 per treatment and the weights were adjusted to 14% moisture using the formula: "Adjusted Grain Weight = AXW", where A is the adjusted coefficient and W is the weight of harvested grains. The Coefficient A was cal-

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culated as A = 100–M divided by 86, where M is the moisture content (percent) of the grain. For each treatment the following number of hills were harvested (Table 2).

***Table 2.* Number of Hills harvested per plant spacing**

Spacing Treatments	No. of hills harvested/Treatment/4m^2
T1 = 7.5x15 cm	353
T2 = 15x15 cm	177
T3 = 20x20 cm	100
T4 = 25x25 cm	64
T5 = 30x30 cm	44
T6 = 30x50 cm	27

The data collected on the yield and yield components were subjected to the analysis of variance for RCBD and the mean separation for each treatment was determined using the Duncan's Multiple Range Test (DMRT), where treatment effects observed at a probability level of 5% or less are considered significant.

RESULTS

The effect of plant spacings on height, panicle length, panicle weight, 1000 grains weight, filled grains per panicle and the number of productive tillers per hill are presented in Figures 1 to 3. The effect of spacings on paddy yield is shown in Figure 4.

There were no significant (P<0.05) differences in plant heights amongst the different plant spacing treatments. However, there was a significant (P<0.05) difference in plant height between the spacing treatments of 15x15 cm (129.2 cm) and 30x30 cm (143.7 cm). With panicle length, no significant (P<0.05) differences were observed amongst the plant spacings 7.5x15 cm, 15x15 cm, 20x20 cm and 25x25 cm. Amongst the spacings of 25x25 cm, 30x30 cm and 30x50 cm no significant (P<0.05) differences in panicle length were obtained (Figure 1).

There were highly significant (P<0.01) differences in panicle weight between the various plant spacings (Figure 2). Higher significant (P<0.01) panicle weights were observed at the wider plant spacings of 25x25 cm (53.2 g), 30x30 cm (75.2 g) and 30x50 cm (83.3 g) than at the closer plant spacings of 7.5x15 cm (20.3 g) and 15x15 cm (23.9 g).

At thousand grains weight, no significant (P<0.01) differences were observed between the plant spacings 7.5x15 cm, 25x25 cm and 30x30 cm, and between the spacings 15x15 cm, 20x20 cm and 30x50 cm (Figure 2).

No significant (P<0.05) effects were obtained amongst the plant spacings 7.5x15 cm, 15x15 cm and 20x20 cm insofar as the number of filled grains per panicle is concerned. However, there was a significant (P<0.05) difference in the number of filled grains per panicle between the plant spacings of 7.5 x 15 cm and 15x15 cm with those of 25x25 cm, 30cm x 30 cm and 30 cm x 50 cm (Figure 3).

For number of productive tillers per hill although no significant differences in tiller numbers were observed at the wider spacings of 25x25 cm (18), 30x30 cm (19.6) and 30x50 cm (22.8), these were significantly (P<0.01) higher than those at the closer plant spacings of 7.5x15 cm (8.4) and 15x15 cm (10.5) (Figure 3).

For paddy yield, at the closer plant spacing of 7.5x15 cm a highly significant (P<0.05) paddy yield of 9.50 t/ha was observed. No significant (P<0.05) differences in paddy yield were observed amongst the treatments 15x15 cm, 20x20 cm, 25x25 cm and 30x30 cm with paddy yields of 4.3, 3.94, 3.12 and 3.94 t/ha, respectively. Also between the plant spacings of 25x25 cm and 30x50 cm, no significant (P<0.05) difference in paddy yield was obtained (Figure 4).

Though wider spacings have higher numbers of productive tillers (Figure 3), these were not significant to account for the overall yields. It is apparent that at wider plant spacings, the overall paddy yields tend to decrease (Figure 4). However, the only significant yield levels were those between 7.5x15 cm compared to the rest, and that between the widest spacing (30 x 50) to the rest except the 25 x 25 cm spacing.

DISCUSSION

It appears that at the closer plant spacing of 7.5x15 cm, *Niupela* tends to have higher paddy yield (9.50 t/ha) compared with the other spacing treatments (Figure 4). Using the rice variety E1 which is low tillering, Wohuinangu and Moon Kap (1980) reported that at the closer plant spacings of 20x20 cm and 20x30 cm, higher yields were obtained. *Niupela*, which was selected from E1 variety by pureline selection method seems to exhibit the same trend. It also appears that at plant spacings between 15x15 cm and 30x30 cm, the paddy yields of *Niupela* are similar but significantly lower than at 7.5x15 cm plant spacing (Figue 4). De Datta (1981) indicated that at closer plant spacings, the yield per plant is usually small but this is compensated for by greater number of plants per unit area. Therefore, it can be deduced that the higher yield obtained at the

Figure 1. **Effect of spacing on plant height and panicle length of rice variety Niupela.**

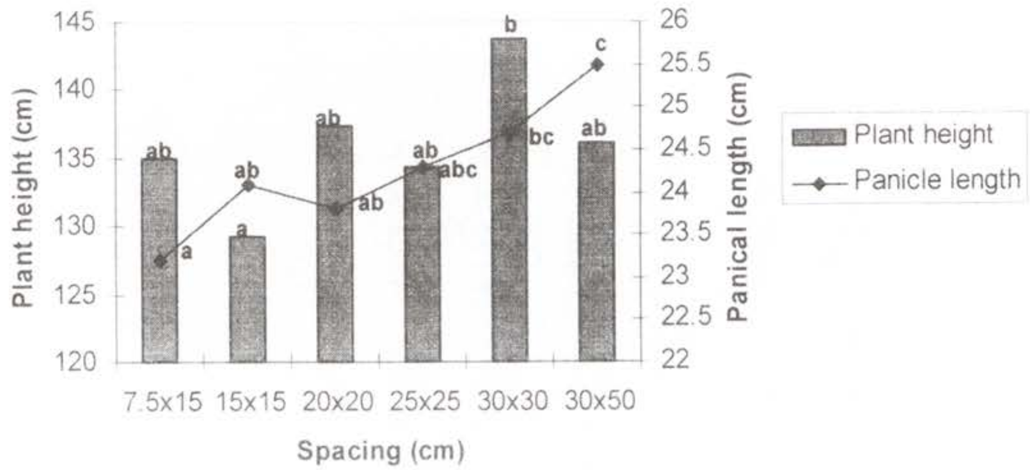


Figure 2. Effect of spacing on panicle weight and 1000 grains weight of rice variety Niupela.

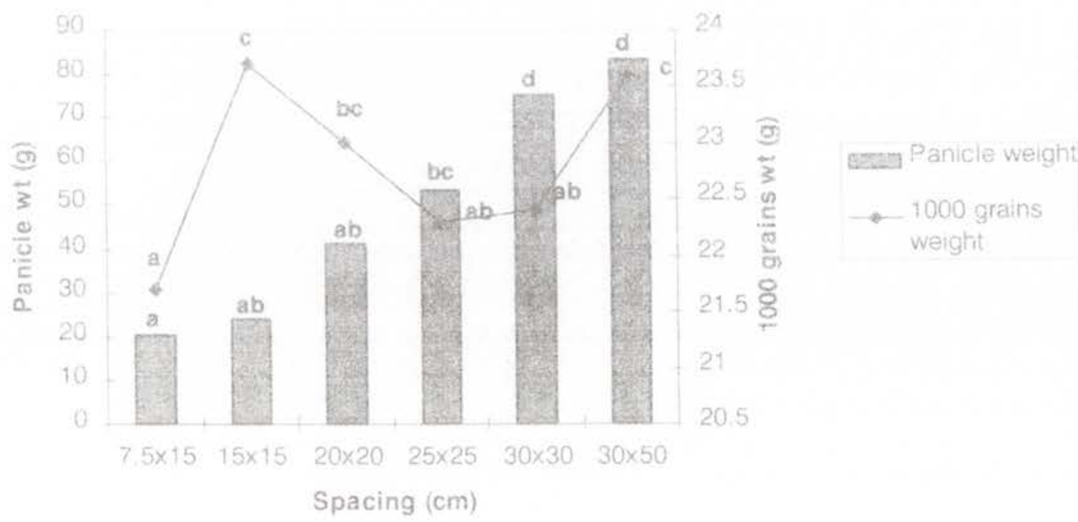


Figure 3. **Effect of spacing on the number of filled grains and number of productive tillers of rice variety Niupela**

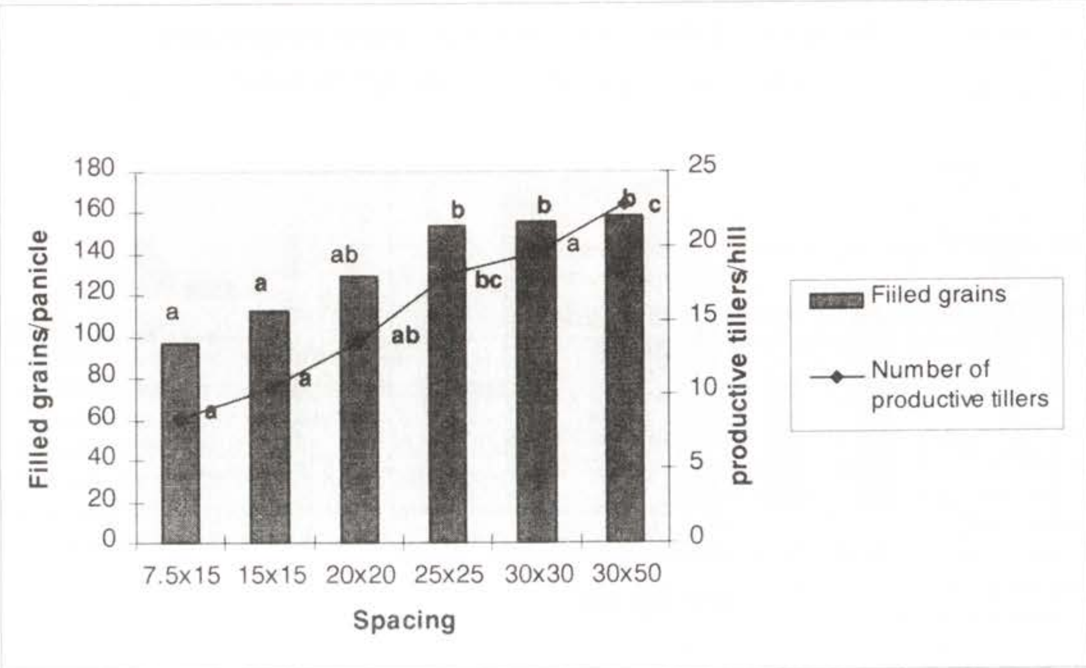
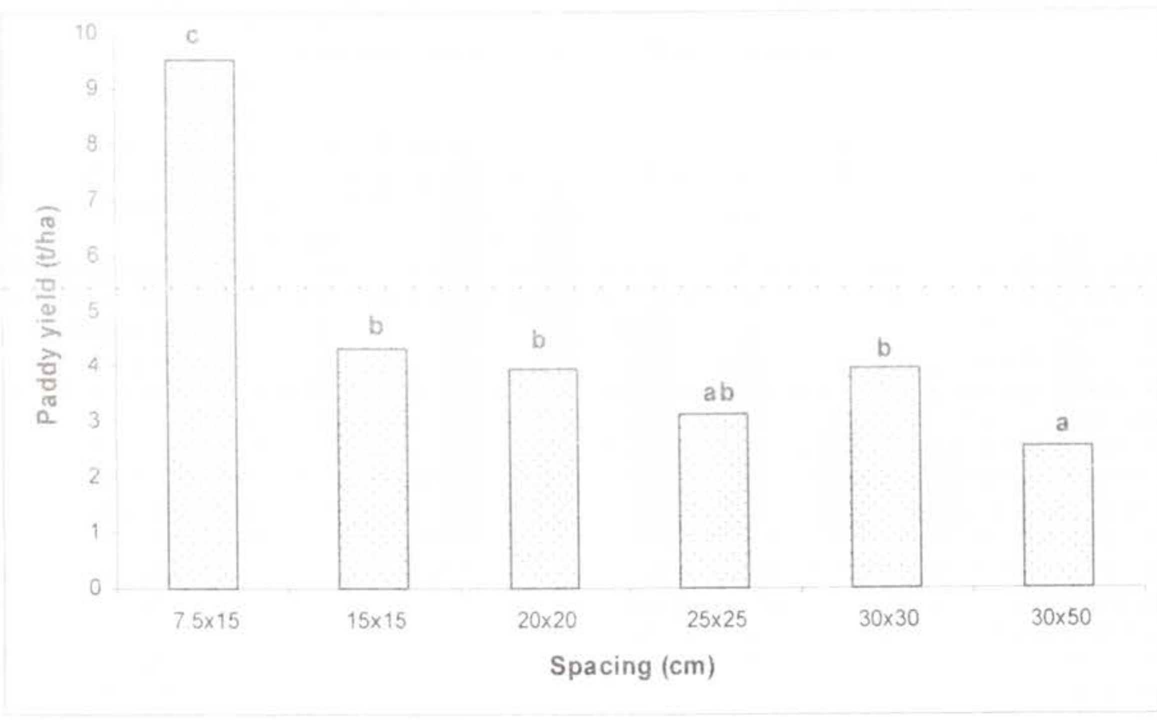


Figure 4. Effect of spacings on the paddy yield of rice variety Niupela.



closer spacing of 7.5x15 cm was due largely to the large number of rice hills harvested. (Table 2).

Despite the higher paddy yield obtained at the closer plant spacing of 7.5x15 cm, the number of filled grains per panicle and the number of productive tillers per hill were lower at this plant spacing as well as at 15x15 cm spacing (Figure 3). This could mean that closer plant spacings have a negative effect on tiller production. This is clearly shown in Figure 3 where under wider spacings, the number of productive tillers were observed to be significantly higher than at closer plant spacing. According to De Datta (1981), the tiller number per unit area in rice population is a function of plant density. The fact that the number of filled grains per panicle was higher at the wider spacings (Figure 3) indicates that the size of individual grains may be bigger. This is shown in Figure 2 where at the wider spacing of 30x50 cm, the 1000 grains weight was higher (23.6 g). However, Yosida (1972) showed that unlike other cereals, grain yields of rice are improved to a very limited degree by increasing grain size, which is largely restricted by the size of hulls. Tanaka (1973), reported that the number of grains per unit area plays a major part in determining the grain yields. He further pointed out that the number of grains per unit area can be raised by either increasing the plant density (closer spacing) or by increasing the number of grains per panicle and panicles per plant. It is obvious that in the current case, increasing the plant density (closure spacing) has contributed significantly to the higher grain yield (Figure 4).

Furthermore during the experimental period it was observed that weed population was very high at the wider spacings than at closer plant spacings. However, weeding was timely and maintained throughout the experimental period. Nevertheless, it must be noted that under large scale commercial situations, increased weed growth could be a demerit of wider plant spacings. This further suggests that it may be undesirable to plant rice at wider spacings as this would promote the problems of weed infestations. However, in a mixed cropping system wider spacings may be desirable.

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INSECTS USED FOR BIOLOGICAL CONTROL OF THE AQUATIC WEED WATER HYACINTH IN PAPUA NEW GUINEA

Mic H. Julien[1] and Warea Orapa[2*]

ABSTRACT

*Water hyacinth (*Eichhornia crassipes*) was first found in PNG in the early 1960s. By the late 1980s, it had spread to a number of locatioins including the Lower Sepik River, East Sepik Province, where it was expanding rapidly and causing serious problems for the Lower Sepik River communities. An AusAID funded biological control programme, from 1993 to 1998, resulted in four biological control agents, the weevils* Neochetina eichhorniae *and* N. bruchi, *and the pyralid moths* Niphograpta albiguttalis *and* Xubida infusellus *being released. The two weevil species caused significant reductions of the weed in PNG while the moth* X. infusellus *established at one site only with no impact. The second moth* N. albiguttalis *did not become established. We review the biology of each insect, the introductions, release strategies and monitoring for these biological control agents, especially the three that are now part of the PNG biota.*

Keywords: *Biological control;* Eichhornia crassipes*; water hyacinth; Papua New Guinea;* Neochetina eichhorniae*;* Neochetina bruchi; Niphograpta albiguttalis; Xubida infusellus*; Sepik River.*

INTRODUCTION

Water hyacinth, *Eichhornia crassipes* (Martius) Solms (Pontederiaceae), is among the world's most serious aquatic weeds (Holm, *et al.* 1977). A native of tropical South America, its invasion of rivers and lakes around the world has rendered waterways useless for utilisation by humans and compromised aquatic ecosystems. Large populations of the free-floating weed can create severe hardships and economic difficulties for humans. In a single growing season the weed can impact on riparian communities by disrupting transportation, interfering with hydroelectric schemes, killing fish and promoting diseases. In agricultural areas such as rice paddies, water hyacinth can become a major weed. The weed can clog irrigation pumps and increase water loss through evapo-transpiration. During flooding, water hyacinth can pile up against bridges, culverts, fences, and barriers, thereby blocking water flow and increasing water levels. Impacts caused by water hyacinth are reviewed in Gopal (1987) and Julien *et al.* (1999).

Water hyacinth was first reported in Papua New Guinea (PNG) during 1962 around the mining town of Bulolo (Mitchell 1979). Despite repeated attempts to have early infestations of the weed eradicated by removal (Fig. 1), it persisted and spread to several towns including Lae, Port Moresby, Rabaul and Goroka where it was sold at the local markets (Mitchell 1979; Laup 1987). The water hyacinth invasion seriously affected the livelihoods of thousands of people in the Lower Sepik area and later in the Middle Sepik, after it was introduced from Madang to a village south of the township of Angoram in 1986 (S. Laup, pers. comm.). It spread rapidly and became a very serious aquatic weed on the Sepik floodplain during the five years following its introduction.

Biological control of water hyacinth has been attempted in many countries since it was started in USA in 1961 (Julien & Griffiths 1998; Julien 2001). Much is known about the natural enemies of water hyacinth through the work of various research teams working in the native range of the weed (Bennett 1970; Conway, *et. al.* 1978; DeLoach 1975; DeLoach & Cordo 1978; Sands & Kassulke 1983; Cordo 1999), and current knowledge has been reviewed by Julien (2001). Of the many natural enemies found in the native range, only five insect species and a mite have been deliberately released and established in at least one major region of the exotic range of water hyacinth (Harley & Wright 1984; Julien 2001). A fungus, *Cercospora rodmanii* Conway, was found established in South Africa. It was field collected and redistributed to other areas in South Africa (M.P. Hill, pers. comm.). Three insect species,

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the weevils *Neochetina eichhorniae* Warner and *N. bruchi* Hustache (Coleoptera: Curculionidae), and the moth *Niphograpta albiguttalis* Warren (Lepidoptera: Pyralidae) have been widely utilised (Julien & Griffiths 1998), and particularly the two weevils have helped control the weed in a number of countries (Julien 2001).

Biological control of water hyacinth in PNG began in June 1985 when 500 adults of the weevil *N. eichhorniae,* imported from Australia, were released at a small infestation near Madang (Laup 1987). The weevils became established, increased in numbers and some were collected and redistributed to Bulolo in July 1986, the Sepik River in March 1989, 1991 and 1992, and to the Lae area in 1992 (P. Pandau, unpubl. report). Prior to these releases, all efforts to address the increasing water hyacinth problem promoted eradication by collection and burning (Mitchell 1979; Laup 1987).

In January 1993, a six-year project to manage water hyacinth commenced. It was supported by AusAID and PNG Department of Agriculture and Livestock (DAL). The project objectives were to locate all infestations of water hyacinth in PNG and instigate manual removal or biological control, reduce spread of the weed by raising public awareness, and increase the capabilities of PNG to undertake future biological control work (Julien & Orapa 1999). The biological control aspects of the project included: the mass rearing and release of *N. eichhorniae*, the collection and redistribution from established field populations, and the introduction, mass rearing and releasing of additional biological control agents. New introductions of *N. bruchi* and the moths *N. albiguttalis* and *Xubida infusellus* Walker (Lepidoptera: Pyralidae) were made between 1993 and 1997 from Australia, where they had been tested and released earlier. Host-specificity testing was conducted in Australia for the leaf-sucking bug *Eccritotarsus catarinensis* (Carvalho) (Hemiptera: Miridae) to assess its biosafety for release in Australia and PNG (Stanley & Julien 1999). It was rejected for release in both countries.

This paper reviews surveys for water hyacinth in PNG and the biology of each of the four insects biological control agents released in PNG on water hyacinth. It also outlines the rearing and releasing strategies for those agents.

Biology and Ecology of Agents

N. bruchi and N. eichhorniae

The two weevils *N. bruchi* and *N. eichhorniae* have been the most widely used biological control agents against water hyacinth (Julien & Griffiths 1998). Their host-specificity has been studied in twelve countries involving 274 plant species in 77 families. In the 32 countries where they have been released and have become established (Julien 2001), no sustained attack on species other than water hyacinth has been observed (Julien *et al.* 1999).

Although *N. bruchi* and *N. eichhorniae* broadly resemble each other, their appearance, life history and behaviour differ in a number of ways. Generally, adults are 4 - 5 mm long and adults of *N. bruchi* are larger than those of *N. eichhorniae*, weighing an average of 4.53 mg compared to 3.49 mg (DeLoach & Cordo 1976). Young adults of *N. bruchi* have a distinctive 'v' shaped pattern on the elytra (wing covers). In *N. eichhorniae* the adults are greyish, lack any pattern on the elytra, and have two parallel tubercles which are longer than those on *N. bruchi*. These tubercles may be of unequal length, and are located closer to the front of the elytra. These differences are illustrated in Julien *et al.* (1999).

Neochetina bruchi prefers high quality plants such as those growing in water bodies replenished regularly with plant nutrients (from sewage, industrial discharge, flooding, agricultural runoff or constant flow that passes nutrients over the roots) (Center 1994; Heard & Winterton 2000). *N. eichhorniae* can tolerate varying foliar nutrient levels. Populations of both species may vary relative to each other temporally and spatially depending on the nutrient quality of the plants on which the populations feed. These adult feeding preferences appear to make the two species complimentary in their attack on water hyacinth over the range of nutritional conditions in which the weed grows.

In both species, the adults are photophobic and nocturnal, feeding preferentially on the soft tissue of unfurled young lamina and upper portions of young petioles. During the day adults move to the base of petioles or remain within the safety of unfurled young leaves, leaf sheaths or among the roots. Center and Wright (1991) found that adults of *N. eichhorniae* are attracted to young leaves by natural plant products that stimulate them to feed, especially at previous sites of injury. The weevils feed by scraping and consuming the epidermal layer leaving characteristic, sub-circular scars, 1 to 2 mm diameter, on the upper surface of laminae and on the upper petioles.

Eggs are small, ovoid, 0.8 mm x 0.6 mm for *N. bruchi* and are slightly smaller and softer for *N. eichhorniae*. They are laid in the aerenchyma tissues in the petioles, singly or in groups by *N. bruchi*, whereas they are usually deposited singly in the epidermis of young or mature leaves and petioles, particularly at adult feeding sites, by *N. eichhorniae* (DeLoach & Cordo, 1976; Center, 1994). Variable numbers of eggs per female have been reported with totals for highly fecund individuals of between 300 and 900 (Center 1994; Julien *et al.* 1999). Incubation period varies from 7 to 8 days at 30°C to 16 days at 20°C (DeLoach & Cordo 1976). Newly hatched larvae (1 mm long) tunnel downwards to the base of the petiole and into the plant crown where they may damage axillary buds. Damage by larvae destroys tissue causing discoloured streaks along the lower petioles. The third and final instar larvae (up to 4 mm long) exit the crown and move to the roots where they construct a dark coloured, circular (2 mm diameter) cocoon of root hairs attached to a larger rootlet under water (Center 1994). On emergence the new adults move up the plant and commence feeding within 24 hours. The development durations varied in different studies (Julien *et al.* 1999), however, development takes longer for *N. eichhorniae* (96 to 120 days) than for *N. bruchi* (72 to 96 days). The optimal temperature for oviposition, feeding and development in both species is around 30°C. Eggs will not develop below 15°C and 20°C in *N. eichhorniae* and *N. bruchi* respectively (Julien *et al.* 1999).

Niphograpta albiguttalis

This moth, previously referred to as *Sameodes albigutallis* (Warren), is the next most widely used biological control agent after the *Neochetina* weevils. It is native to and widespread in South America on water hyacinth. Its host-specificity testing has involved 136 plant species from 60 plant families and the results are detailed in Julien *et al.* (2001). *Niphograpta* is specific to plants in the family Pontederiaceae and has strong preference for water hyacinth. It is established in six of the 13 countries in which it has been released (Julien 2001; Julien *et al.* 2001).

This is a small moth with wingspan of 17 - 25 mm and body length 6 - 10 mm. Colour is variable; wings being golden-yellow to charcoal grey with brown, black and white markings (Center 1994). The body has similar coloured light and dark stripes. The moths rest on the underside of leaves by day and are active at night. Female moths are darker and larger than males. The posterior of the abdomen is more pointed in males and is usually held upwards more than in females. Most eggs are deposited singly or in small groups in lamina and petiole tissues, often injury sites, during the second and third night after emergence (DeLoach & Cordo 1978). Adults live 4 to 9 days and females lay an average of 370 eggs (DeLoach & Cordo 1978; Center 1994). Eggs are 0.3 mm diameter, creamy white, and hatch in 3 to 5 days (Julien *et al.* 2001). Hatchling larvae, ca 1.5 mm long, feed externally initially and then internally causing characteristic 'windows' in the epidermal tissues of petioles. There are five larval instars and as larvae grow older they tunnel deeper into the tissues and eventually into the plant crown. Final instar larvae are about 2 cm long and larval development requires 16 to 21 days (DeLoach & Cordo, 1978; Center, 1994). Severe damage to internal tissues causes leaves to wilt and die. Feeding in the crown area may destroy the apical buds and the entire ramet, causing the plant to rot and sink. Plants may regenerate through the growth of axillary buds. Pupation occurs in a chamber made in the aerenchyma tissues of a petiole, with a tunnel that leads to the petiole surface where a thin layer of epidermal tissue is left intact for protection. Pupae are encased in a white silken cocoon from which the adults emerge after 5 to 7 days and exit the petiole via the tunnel, breaking through the thin 'window'. One generation takes 27 days at 24°C (DeLoach & Cordo$_2$ 1978).

Populations of *Niphograpta* can increase quickly under favourable conditions and rapid dispersion averaging 1 km/day (up to 4 km per day) has been observed (Center$_2$ 1984). *Niphograpta* prefers young, tender plant material, possibly due to young larvae being unable to enter older, tougher petioles (Wright & Bourne$_2$ 1986). Hence larvae and pupae of this moth tend to be found in the small, bulbous petiole form of the weed, characteristic of uncrowded growth at the edge of water hyacinth infestations (Julien *et al.*$_2$ 2001). However, they are not restricted to this plant form (Center$_2$ 1984). Because moths select oviposition sites in healthy, undamaged plants, the damage they cause to water hyacinth is often severe but patchy (Wright & Bourne$_2$ 1986). Damaged plants that are not killed may re-grow from intact buds. Although it has not been possible to quantify the impact of this moth , the moth is considered a valuable control agent because it selectively attacks new growth and appears to reduce the rate of invasion of the weed (Wright 1984; Center$_2$ 1987).

Xubida infusellus

Xubida infusellus was previously referred to as *Acigona infusella* (Walker). It is also widespread on the plant in South America. This moth has undergone host test studies in six countries and tests included 66 plant species in 30 plant families. It is restricted to feeding and developing on plants in the Pontederiaceae family (Bennett & Zwolfer$_2$ 1968; Silveira-Guido$_2$ 1971; DeLoach 1975; DeLoach *et al.*$_2$ 1980). *Xubida* has been released in three countries, Australia, PNG and Thailand and has become established in the first two. It has not been released in USA because it attacks *Pontederia cordata* L., a native of southern USA (Julien *et al.*[2] 2001).

Xubida is a delta-winged moth 20 to 25 mm long and tan to red-brown in colour. Males are smaller than females. Females live 4 to 8 days. By day the moths rest on petioles and they are active at night. Males emerge from pupae before females and mating occurs on the first night with most oviposition occurring over the next - 2 to 4 nights (Julien & Stanley[2] 1999; Julien[2] 2001). Clusters of eggs up to several centimetres long and containing 14 (DeLoach *et al.*[2] 1980) to 171 eggs (Sands & Kassulke[2] 1983) are deposited in white gelatinous masses on leaves and petioles, especially along the grooves where leaves overlap. Individual eggs were 0.8 mm x 0.5 mm and creamy white. Eggs hatch in 6 to 11 days (Sands & Kassulke[2] 1983; Silveira-Guido[2] 1971). Newly hatched larvae, 1 mm long, disperse by lowering themselves on silken threads or walking to a feeding site. They enter the petiole and sometimes cause characteristic damage by girdling and killing the upper portion of the petiole and the entire lamina. Larvae then tunnel downwards to the lower petiole and into the plant crown and rhizome. Larvae developed through 7 to 10 instars taking on average 48 days (Sands & Kassulke[2] 1983). The final instar larva are up to 25 mm long (Julien *et al.*[2] 2001) and they cut a pupation chamber with an exit tunnel to the petiole surface, leaving a thin window of epidermal tissue for protection. There is no pupation cocoon and pupation requires eight days at 25°C. The pupal case may be left projecting from the emergence tunnel as the adult exits the plant (Bennett & Zwolfer[2] 1968). The life cycle requires about two months at 25 - 30°C (Julien *et al.*[2] 2001).

Of all the natural enemies tested for water hyacinth, *X. infusellus* was claimed by DeLoach (1975) to be the most damaging insect. DeLoach *et al.* (1980) observed in Argentina that most *X. infusellus* damaged plants died, reducing the cover from 50% to between 5 and 10% in a lagoon during one year. They prefer the long slender petioles and only occasionally damage the bulbous ones.

METHODS

Surveys for water hyacinth and control strategy decisions

Laup (1987) reported 30 infestations of water hyacinth in 12 provinces in PNG. He included the Sepik River and associated lagoons as one infestation. About half of these required confirmation that they were indeed water hyacinth. Early in the project (early 1993) it was realised that there were many unrecorded infestations in PNG. Information about location of infestations was sought in several ways; through a survey conducted via the agricultural magazine Didimag, displays at agricultural and province shows, radio 'didiman', awareness displays at markets in major centres, and community and individual discussions. Reported infestations were visited to confirm that water hyacinth was present and to decide on and instigate actions to be taken. Follow up visits either implemented actions or assessed their outcomes. To achieve this most infestations were visited a number of times. All water hyacinth infestations were entered into a database that included information on location, date found, the person who confirmed the weed, control action taken, when and which agent(s) were released or if removal had been advised. Follow-up details were also recorded such as dates, confirmation that the agent(s) were established or that removal had been carried out. The very large infestation in the Sepik River catchment was entered into the database as nine locations; lower and middle Sepik, Chambri Lakes, Wom Grasslands and the five main river tributaries; Karawari, Krosmeri, Keram, Pora Pora and Yuat Rivers.

Infestations of water hyacinth that were small and accessible, isolated from other infestations, and threatened catchments that were otherwise free of the weed were considered for eradication. Sites where it was grown as an ornamental or as stock feed were also marked for eradication. At such sites, discussions were held with the landowner, village elders or tenants and advice was given to hand remove, sun-dry and burn the weed. Vigilance and repeated removal of regrowth was also stressed. In the majority of cases this was successful. Where it was not successful, biological control agents were released. The exception was in ornamental situations, such as hotel or household ponds and drains, where reminders of the threat the weed posed to the environment and the illegality of growing the weed always resulted in co-operation.

At all sites where eradication was not feasible biological control was instigated. To do this biological control agents were either reared or collected from the field and released onto the weed at those sites.

Rearing of biological control agents

The *Neochetina* weevils were reared in commercially available above-ground pools. These were constructed on flattened ground and comprised a thin sheet of metal 9.4 m long x 0.6 m wide with ends bolted together to form a circle 3 m diameter x 0.6 m deep and over which was fitted a plastic liner. The pools were filled with water to

20 cm below the top, and Aquasolâ, a soluble complete fertiliser, was mixed into the water at a rate of 200 g per pool. Healthy water hyacinth plants were collected from the field and added to cover the surface of the pools. Two hundred adults of either *N. bruchi* or *N. eichhorniae* were placed on the plants in each pool. Six pools were set up, initially at Saramandi Research Station near Angoram, and later moved to Angoram, on the Sepik River. Similar rearing was conducted at Kila-Kila Agricultural Station, near Port Moresby, using 2.3 m diameter x 1 m deep metal water tanks as well as several of the plastic lined pools.

The fertiliser was added to the pools approximately every month, plants other than water hyacinth, eg. *Salvinia molesta* or *Utricularia*, were removed as required and water levels were maintained. After eight weeks, when the first new generation of *Neochetina* adults began to emerge, adults were harvested. Thereafter, harvesting was carried out approximately every week. To do this, the plants were submerged under steel mesh sheets weighted with stones and adults were collected as they floated to the surface of the water. Harvesting was limited so that sufficient adults remained on the plants to ensure continuation of the population. The collected adults were counted and held in plastic containers on water hyacinth leaves until they were transported and released in the field. Fresh, healthy, water hyacinth plants were added to the pools as required and approximately every 9 - 12 months each pool was emptied, cleaned and set up with new plants and insects to maintain production levels.

Neochetina eichhorniae were reared using insects collected from the field near Angoram in the lower Sepik River in PNG. *N. bruchi* rearing began with insects imported from Australia. In addition, *N. bruchi* adults from Australia were either shipped or hand-carried on direct flights from Brisbane to Port Moresby under PNG import permits. These insects were from healthy colonies maintained in plastic lined pools at CSIRO Long Pocket Laboratories, Brisbane, and none had been field-collected. Adults were transported in plastic food containers 11 cm diameter and 11 cm deep with a piece of damp cloth and up to 250 adult weevils per container. In a laboratory in PNG the weevils were repacked with 100 to 200 adults per container and with water hyacinth leaves collected in PNG. Containers were packed into insulated boxes to protect the insects from heat and direct sunlight during transportation to the field.

Niphograpta albiguttalis was reared in Australia under laboratory conditions using a healthy colony that was regularly checked to ensure that it was free of disease. Attempts to rear in PNG were unsuccessful partly because of poor laboratory facilities. In Australia adult moths were reared in a 3 m diameter x 0.6 m deep plastic lined pool that was surrounded by a 4.5 m square frame covered with shade cloth to prevent the moths escaping. Moths were collected and paired (one or more males to one female) and held in containers on water hyacinth leaves - with grooves made in the upper epidermis. Females laid eggs in the grooves and every 24 hours the moths were provided new grooved leaves. Leaves with eggs were held in a laboratory at 25 to 27°C until they hatched (4 to 5 days) when other leaves were added. Fresh leaves were added and old leaves discarded several times each week until the larvae had developed to about third instar (approximately 1 cm long). At this stage the leaves with larvae were packed into 11 cm diameter x 11 cm deep plastic containers amongst fresh leaves and transported to PNG under appropriate import permits. In PNG the containers were opened in a sealed laboratory and the larvae were transferred to clean containers and fresh water hyacinth leaves. The used containers and plant material from Australia were sealed in plastic bags and immediately burnt.

The larvae were either taken to the field for release or placed on small bulbous water hyacinth plants in rearing pools and some time later the plants with insects were placed in the field. Larvae that were taken directly into the field were either placed on bulbous petioles of field plants or inserted into petioles by cutting a small hole and carefully placing a larva inside the plant and replacing the cut piece of plant. Sometimes the plants with larvae were held in floating screened cages, 0.5 m x 0.5 m 0.5 m high, covered with shade cloth, to prevent emerging moths dispersing before mating. Cages were removed after three weeks on the assumption that larvae would have completed development, and adults would have emerged, mated and laid eggs. At other times, the plants with larvae were held in the same general area by setting up floating logs or bamboo. These techniques held the plants with insects in the same place and permitted post release observations.

Xubida infusellus was reared in Australia and transported to PNG for release and also reared in PNG. In Australia, a population of this moth was maintained in a caged pool from which pupae (which were held in petri dishes until adults emerged) or adults were collected. One female and one or more male adults were placed in an 11 cm diameter x 11 cm deep plastic container with a cover of nylon mesh that was folded to form an overlap groove along which females deposited their eggs masses. New mesh covers were provided daily. Sections of mesh with egg masses were cut out and placed into small containers until eggs hatched; 6 - 7 days at 25°C. The mesh with hatchling larvae was then placed in a plastic container with about ten 5 - 8 cm lengths of freshly cut, slender water hyacinth petioles. The larvae entered and fed on the petioles. As petioles deteriorated, fresh sections were added to the container allowing larvae to move into better material. To complete larval development, each larva required three or four petiole sections. Pupae were carefully extracted from the petiole sections and held in containers. The resulting adults were added to the caged pool or used to obtain eggs and larvae for PNG.

Eggs on mesh or young larvae in petiole sections were transported to PNG with appropriate import permits. In a sealed laboratory, petioles were split open and the larvae were extracted and placed onto sections of petioles collected from PNG water hyacinth. The used containers and Australian plant material were burnt. Some eggs and larvae were added to rearing pools located at Kila-Kila Agricultural Station in Port Moresby. Pupae were collected from the pools and rearing was carried out to obtain egg masses and larvae for release. Eggs and larvae were placed in containers on cut sections of petioles and taken to the field for release. They were transported in containers in insulated boxes for protection. In the field pieces of mesh with eggs were pinned to laminae and petioles of plants. Sections of petiole containing larvae were pinned onto field plants, either directly onto a petiole or rolled into a lamina.

Male moths emerge earlier than females and so repeated releases were made where possible to improve the chances of female moths encountering males, eg., at Magendo No. 1 Lagoon in the Sepik River, releases were made on 21 June, 26 June, 3 July, 10 July and 17 July in 1997.

Releasing and monitoring

Release sites were accessed by foot, vehicle, boat, and, inaccessible locations such as the Wanggoe River in Western Province, by helicopter. Sites were selected for stability so that where possible the plants and insects would not be removed during normal flooding. Surveys for the weed attempted to locate the uppermost infestations in a catchment and initial releases were made at those locations so that any movement of plants downstream would also help spread the insects. All releases were entered into agent specific databases. Included were; site details, agent and numbers released, date(s) of release(s), the origin of the insects (Australia, PNG rearing pools or field collected). There were many more release sites than water hyacinth locations. For example, the locations database included nine locations of water hyacinth in the Sepik River catchment, however, the release site database for the *Neochetina* weevils listed 298 releases at 76 sites in the Sepik River system.

Post release observations were made at regular intervals at selected sites and whenever possible at all other release sites. The weevil species and presence or absence of characteristic *Neochetina* adult feeding scars on the leaves and petioles was noted. For the moths, the presence of characteristic petiole damage and presence of larvae or pupae in the plants was noted. For *Xubida*, Delta traps baited with an artificial pheromone (Stanley *et. al.*,2 2000) were also used to detect presence of adult males.

RESULTS

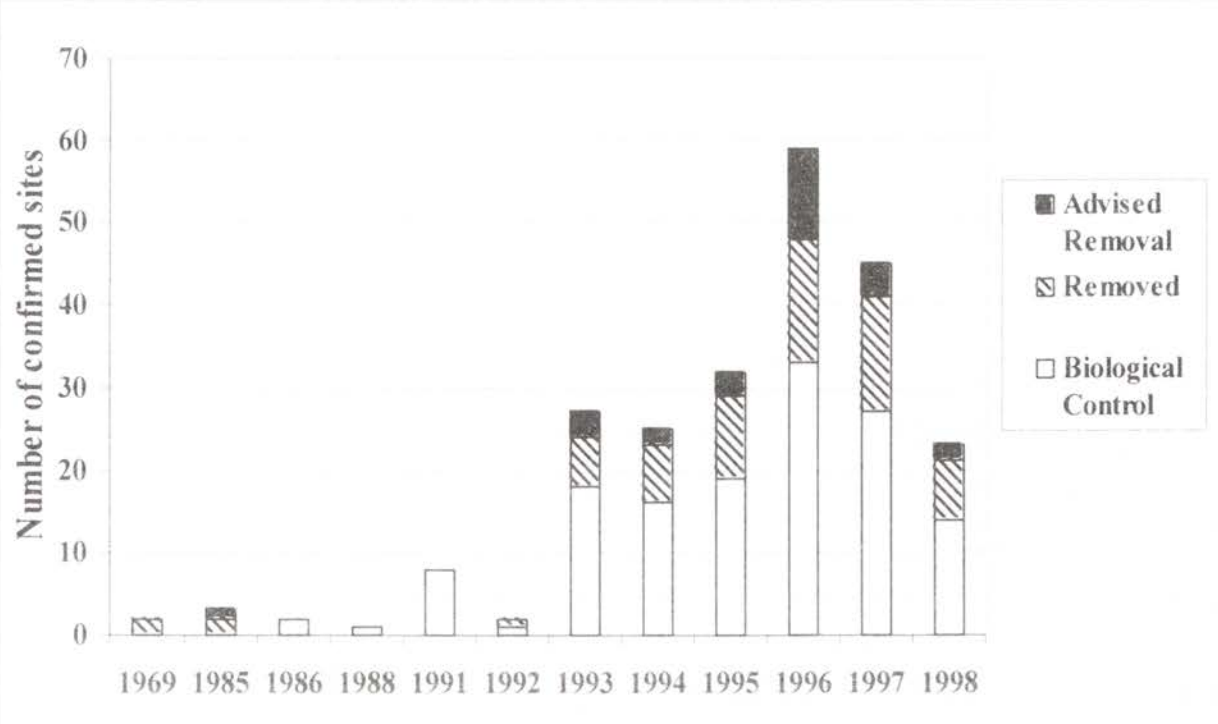
Water hyacinth infestations and their control

Two hundred and twenty nine infestations of water hyacinth were confirmed in PNG with the weed occurring in all provinces. The number of confirmed infestations per year increased dramatically when the project began and again in 1996 when an Information Officer was employed and greater emphasis was placed on public awareness. The data suggests that additional infestations would continue to be identified after 1998 but at a rapidly reducing rate (Figure 1).

Ninety infestations were considered eradicable by removal. At 64 of these the weed had been removed and had not re-grown when checked during follow up visits. The remaining 26 required follow up to determine if removal had been carried out and if it was successful. By the end of December 1998, 139 out of 229 water hyacinth infestations found in PNG had one or all of the biological control agents released on them. There also remained 33 unconfirmed reports of water hyacinth infestations. Some were to be assessed by district officers and others were in restricted locations or those difficult to access, such as parts of Bougainville. An indication of the control actions instigated with respect to the number of reports of water hyacinth in individual provinces in PNG is illustrated in Figure 2. In addition, numerous reported infestations were found to be other plant species, most often *Monochoria hastata* (L.) Solms-Laub., *M. vaginalis* (Burman f.) C. Presl ex Kunth, and *Sagittaria platyphylla* Michaux.

In 1991, 13 lagoons in the Lower Sepik were infested with water hyacinth and the upper most infestation was in a channel leading from the Sepik River into Pesosat Lagoon, west of Timbunke. By 1997, the weed had moved upstream to

Figure 1. **The number of water hyacinth locations identified each year and the control strategy implemented.**



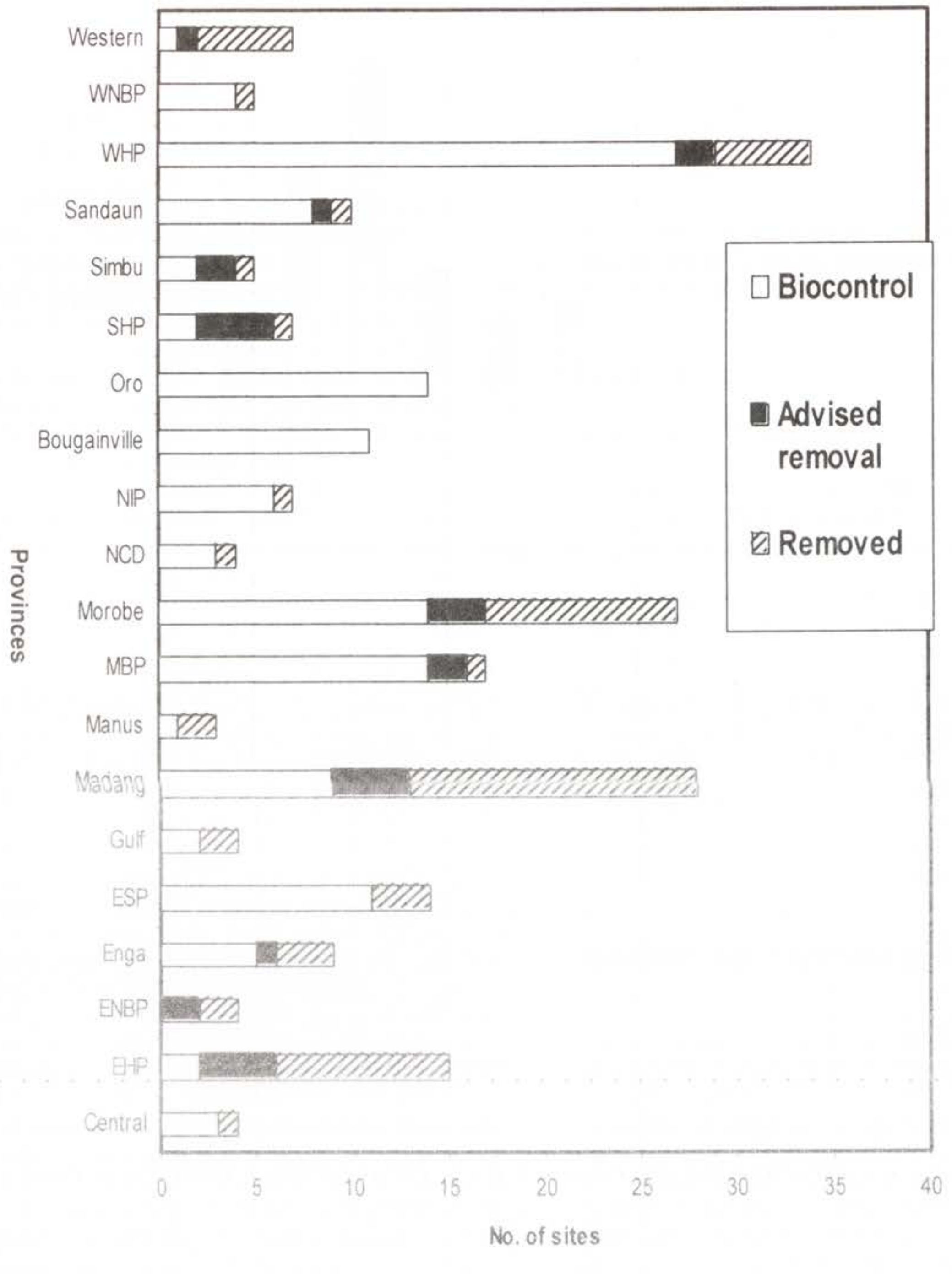
Chambri Lakes and by 1998 it had invaded Kamangawi Lagoon just north of Chambri Lakes. In August 1998, Chambri Lake and 37 other major permanent lagoons, many minor ephemeral water bodies, as well as hundreds of kilometres of the banks on the Sepik River and associated channels and tributaries were invaded by the weed.

Release and establishment of the *Neochetina* weevils

Neochetina eichhorniae was not found on the water hyacinth at the original (June 1985) release sites, an urban drain near Finch Street, Madang, and along the Madang to Bogia Road. This weevil had been established at Finch Street at least temporarily because in July and August 1986 adult *N. eichhorniae* were collected and released at Bulolo and into rearing tanks at Saramandi Research Station near Angoram (P. Pandau, pers. comm.). A further collection was made in September 1988 and these adults were released directly on water hyacinth in the Sepik River near Angoram. This release site was flushed away during the 1988-89 wet season (S. Laup, pers. comm.). The release at Bulolo resulted in control of water hyacinth in several gold mining ponds prior to 1991. In February 1988 weevils collected from Bulolo were released on water hyacinth in Nainkain Creek, Saidor, Madang Province (P. Pandau, pers. comm.), but they failed to establish as no evidence of the weevil was found in 1995. Eight releases at four sites in the Lower Sepik were made between March and August 1989 using adults reared at Saramandi Research Station. These releases averaged 96 (50 to 120) adults. During 1992, adults collected from the field were released at four other locations in the Lower Sepik, and averaged 132 (100 to 230) adults per site (P. Pandau, pers. comm.). In 1993 populations of *N. eichhorniae* were found in lagoons south and west of Angoram town as far as Magendo No.1 Lagoon, Mamu (Kambaramba) Lagoon and Magendo No. 3 Lagoon. No evidence of establishment was found where releases had been made further west near Tambunum Village (Sept. 1992), south along the Keram River (April 1992) or along channels in the Wom Grasslands (Sept. 1992). Hence, despite *N. eichhorniae* being established in parts of the Lower Sepik since 1989, by 1993 they had not spread throughout the areas infested, and some releases had either not survived or had been flushed away during the wet season.

The renewed rearing of *N. eichhorniae* in PNG, which began in early 1993, produced 234,649 adults. Another 100,754 were collected from the field, mostly from the Lower Sepik. Therefore a total of 335,403 adult *N. eichhorniae*

Figure 2. **The number of water hyacinth locations by province in PNG and the management strategies instigated to December 1998.**



were distributed throughout PNG in 429 separate releases, at 191 sites that included all of the 139 water hyacinth locations that received biological control agents. Beginning in late 1993, 93,694 *N. bruchi* adults were reared in PNG, 86,360 others were reared in Australia and transported to PNG for release. After this insect became well established in PNG, another 24,627 adults were collected from the field in PNG and redistributed. Together 339 separate releases of weevils were made at 150 sites throughout PNG. Most release sites received both weevil species. However 45 sites received only *N. eichhorniae* while 16 sites received only *N. bruchi*. The first releases of *N. bruchi* in PNG were made at Tambali Lagoon, Sepik River, on 24 March 1993, and at a Waigani sewage pond, near Port Moresby on 1 April 1993.

The smallest single release of the *Neochetina* weevils was 12 adults, the largest 6,000 and the average was 778. Many sites received multiple releases, eg. six releases at Chambri Lakes comprised 12,175 *N. eichhorniae* and 9,727 *N. bruchi* between Dec 1996 and Nov 1998. Single releases of large numbers were attempted when revisiting was unlikely because of the high cost of accessing sites. For example, during a helicopter survey for the weed in the Wanggoe River area on the border with Indonesia in Western Province, releases were made of 5,490 *N. eichhorniae* and 1,543 *N. bruchi* adults on water hyacinth in two places. Elsewhere, collaborators (usually DAL or quarantine officers) collected air-freighted insects and released them at predetermined locations. This ensured wide distribution of the insects and greatly improved the potential to control the weed throughout PNG.

Where *Neochetina* weevil populations caused consistent damage to the weed over a number of years, e.g. in the Lower Sepik River lagoons, flowering was reduced to practically zero and the overall foliage colour darkened, sometimes developing a coppery sheen. Plants became stunted as new leaves failed to thrive and older leaves died. Leaf and petiole length declined, lamina area, ramet (daughter plant) size and weight decreased and newly produced offshoot ramets were fewer and smaller (Julien & Orapa, unpublished data). Tunneling by one or several larvae led to water logging, which reduced the plants ability to float, and led to invasions by pathogens that caused secondary infections. A result of the combined damage in the Sepik lagoons and channels was that the large mats of water hyacinth that previously clogged waterways either sank or fragmented into much smaller clumps of plants. These were then much easier to navigate between, had a lower tendency to clog channels and were easily flushed out of lagoons and channels into the main river and hence to sea.

Release and establishment of the moths

The first release of *N. albiguttalis* in PNG was at Magendo No. 1 and Pinang lagoons in the Sepik on 16 August 1994 when 89 larvae were inserted into petioles and the plants were placed inside a small screened cage and another 84 larvae were placed on plants in the open. Up to August 1995, a total of 8,332 larvae were released in PNG at 16 locations in the Western Highlands (WHP), East Sepik (ESP), Western, West New Britain, and Central provinces and the National Capital District (NCD). More than half (57%) of the total number of larvae were released at ten sites in the Lower Sepik where, by boat, it was easy to access the young, rapidly growing plants, normally found on the water margins of water hyacinth mats, that are preferred by the moth. The number of larvae per release averaged 269, and ranged from 50 - 1,200. Four releases were made at the same location on the Maramba to Sangriwa channel in the Lower Sepik area at intervals of three to four weeks in an attempt to establish a field population by repeatedly releasing insects to the same site. Post release monitoring found characteristic plant damage and evidence of pupation at several sites soon after releases in the Sepik. However, no further evidence has since been found and it is concluded that this moth failed to establish in PNG.

The first releases of *X. infusellus* in PNG were made at Waigani Lake on 4 May 1997 and on Magendo No. 1 Lagoon in the Lower Sepik, on 11 March 1997. Releases totalling 59,670 larvae and 54 pupae were made at 12 sites in WHP, ESP, Morobe and Madang provinces until February 1999. Monitoring found plant damage on one occasion in the Lower Sepik but no further evidence of this moth. Male moths were found in Delta traps placed at the Waigani Lake release site six months after release. Considering the life cycle of this insect, the moths caught were at least the third field generation, confirming that breeding had occurred in the field. A year later, in September 1998, moths were again caught, this time between 100 and 200 m from the release site, suggesting that the insect was established at Waigani Lake. A week later a characteristic emergence hole in a petiole with the pupal case protruding was found at Gerehu Lake, a smaller lake adjacent to Waigani Lake.

DISCUSSION

This nation-wide project was particularly successful. Initially, the main targets areas were the large water hyacinth infestations on the Sepik River lagoons and on Waigani and Gerehu Lakes, in

National Capital District. Excellent to good control was achieved at those areas (Julien and Orapa unpublished data). In addition, numerous small infestations were found throughout PNG. The fact that these infestations had not yet spread to their full potential suggested that the project began at a time when the weed was still spreading. Elimination of some of the infestations and the instigation of biological control at others may not prevent the eventual invasion of all catchments by the weed. It will, however, help protect catchments from becoming over-run by the weed. The success of the project is attributed not only to the activities of the *Neochetina* weevils but also to an effective management structure, and an adequate period of time (six years) during which appropriate resources (staff, funds and equipment) were available (Julien & $Orapa_2$ 1999). Inadequacies in design, implementation, time and resources are known to limit the success of biological control projects even when control agents with proven capabilities were used (Waterhouse and $Norris_2$ 1987).

The movement of water hyacinth into and within PNG invariably occurred as a result of activities by people. Most movements were deliberate with people growing the weed as an ornamental or as animal food. Movement within a catchment was sometimes accidental or done in ignorance when the weed was caught on boats, fish nets or used to cover freshly caught fish. The awareness component of this project aimed to significantly alter the general perception of the public that water hyacinth was a desirable plant and thus reduced the rate at which it was being spread. From a general change in the public knowledge about the weed we believe that perceptions were changed. However, it has not been possible to quantify this.

Ideally, now that the *Neochetina* weevils are widely established, any plants that are moved will contain adults or immature stages of the weevils and so the weed's potential for growth, flowering, seed-set and expansion will be limited from the outset as the weed enters its new environment. Realistically, there will be a continuing need for the PNG government to monitor water hyacinth growth in some areas and, if necessary, collect and redistribute weevils. For example, the Fly River catchment is thought to be free of the weed after ornamental plantings in Tabubil and Kiunga were destroyed. When water hyacinth eventually invades that catchment, it will be essential to ensure that the weevils are present early in the invasion so that they can reduce growth and rates of seeding to avoid a repeat of the significant sociological and ecological damage that occurred in the Sepik River system.

The impact of *X. infusellus* may become apparent as populations increase but after its initial establishment in 1998 at Waigani Lake, its population remains small and its impact insignificant. Besides the moth *N. albiguttalis*, which failed to become established in PNG, two other agents, the moth *Bellura densa* Walker and the sucking bug *E. catarinensis*, were given initial consideration for release in PNG during the project, but as more information became available they were rejected. Center and Hill (1999) determined that the moth attacked a number of other plants species in the family Pontederiaceae and also the important crop taro, *Colocasia esculenta* L. (Schott). The sucking bug attacked other plant species in the Pontederiaceae, including *Monochoria* species. Its high mobility and short life cycle put *Monochoria* species that are native to Australia and PNG, at possible risk (Julien & Stanley 1999).

Although control has been achieved in some areas, such as the Sepik River and Waigani Lake (Julien & Orapa, unpublished data), the full impact of biological control by the *Neochetina* weevils on water hyacinth in PNG is not known. Assessment is required at many sites where releases were made three or more years ago (1998 or before). The effectiveness of the *Neochetina* weevils is known to be limited by a range of factors (Julien 2001). Low temperatures may limit insect population growth and therefore control. Floods may remove the weed and insect populations periodically disrupting the insect/plant interaction. Invariably, after the floods the remnant weed grows faster than the insects and may clog the waterway until the next clearing flood. Similarly, drought may destroy water hyacinth biomass and hence the insects but a new infestation, without insects, may develop from seeds once wetting occurs. Shallow water may prevent insect damaged water hyacinth from sinking. Roots of water hyacinth embedded in mud may limit pupation by *Neochetina* weevils and so restrict population development. Consequently, efforts to improve biological control have been carried out. Surveys for new natural enemies in South America and the assessment of organisms continues in the search for new safe biological control agents against water hyacinth (Cordo 1999; Julien & Stanley 1999; Center & Hill 1999; Evans & Reeder 2001; Oberholzer & Hill 2001). When proven useful elsewhere, consideration should be given to releasing them in PNG to help in the ongoing management of water hyacinth.

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CONSTRAINTS ANALYSIS OF THE RICE AND GRAIN INDUSTRY IN PAPUA NEW GUINEA.

R. Chris Dekuku[1]

ABSTRACT

***Constraints analysis** of the rice and grain industry was done to give a better view of the problems facing the rice and grain industry in Papua New Guinea. The results of this study discussed below, were used in the testing of a pilot rice program in the Markham Valley and subsequently used in the writing of the current approved National Rice Policy for PNG. The analysis gave a better insight and understanding of the rice and grain industry than before. It is expected that the understanding and utilization of the information in the document together with the salient point of the approved National Rice Policy would go a long way to enhance the rice industry in PNG.*

Keywords: *Constraints analysis, problem analysis, objectives analysis, problem tree, causes and effects, means and end.*

INTRODUCTION

Rice was introduced in Papua New Guinea [PNG] by the German Missionaries over 100 years ago [Sloane Cook *et al* 1993]. But rice production has remained subsistence all these years. However, results of a 24 hours food recall studies in PNG revealed that almost 90 percent of the urban population ate rice the previous day, and one-quarter of the rural population also ate rice the day before the survey [Gibson, J and Rozelle, S. 1998]. Rice has thus become the second staple food, after sweet potato. Currently, PNG imports over K150 Million worth of rice to feed its population.

Since the late 1980's, the Government of PNG set up a Grain and Rice Public Investment Project to oversea grain and rice development. In order to gain a better understanding of the rice and grain industry in PNG, a two day Constraints / goal oriented program planning workshop was conducted at the Forestry Research Institute, Lae in August 1994. Twenty nine participants, made up of university lecturers / professors, rice and grain national and provincial scientific, technical and extension staff from Lae, Unitech and Port Moresby assessed and analyzed on the rice and grain industry in PNG. The results were circulated widely to Rice and Grain Program Managers and staff then. But since most of the constraints still remain today, this report is being published for wider circulation for the benefit of current and future managers, policy makers and participants in rice and grain industry promotion and development in PNG and elsewhere.

MATERIAL AND METHODS

An overview introduction to constraints analysis was done by the moderators. Cards of different colors cut into approximately 8cm by 12cm, and marker pens of different colors were supplied to all participants. Following the methodology of constraints / problem analysis [IRRI 1991, GTZ 1990], candidates were asked to write as many constraints or problems that they know to affect the rice and grain industry in PNG. Only one problem was to be stated per card and each was written boldly for easy reading by all. Participants were encouraged to write as many cards as they wished. All written cards were fixed on the wall and jointly scanned, approved and modified where necessary, and duplications removed. All the approved cards were clustered and clarified into appropriate groups and ranked. Thus causes of the problems were identified and the interrelations among the problems analyzed. In building the problem tree, the means and ends relationships between the individual cards were established. This was followed by solutions identified for evaluation.

The problems were stated in the negative and the corresponding solutions in the positive.

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Figure 1. **PROBLEM ANALYSIS**

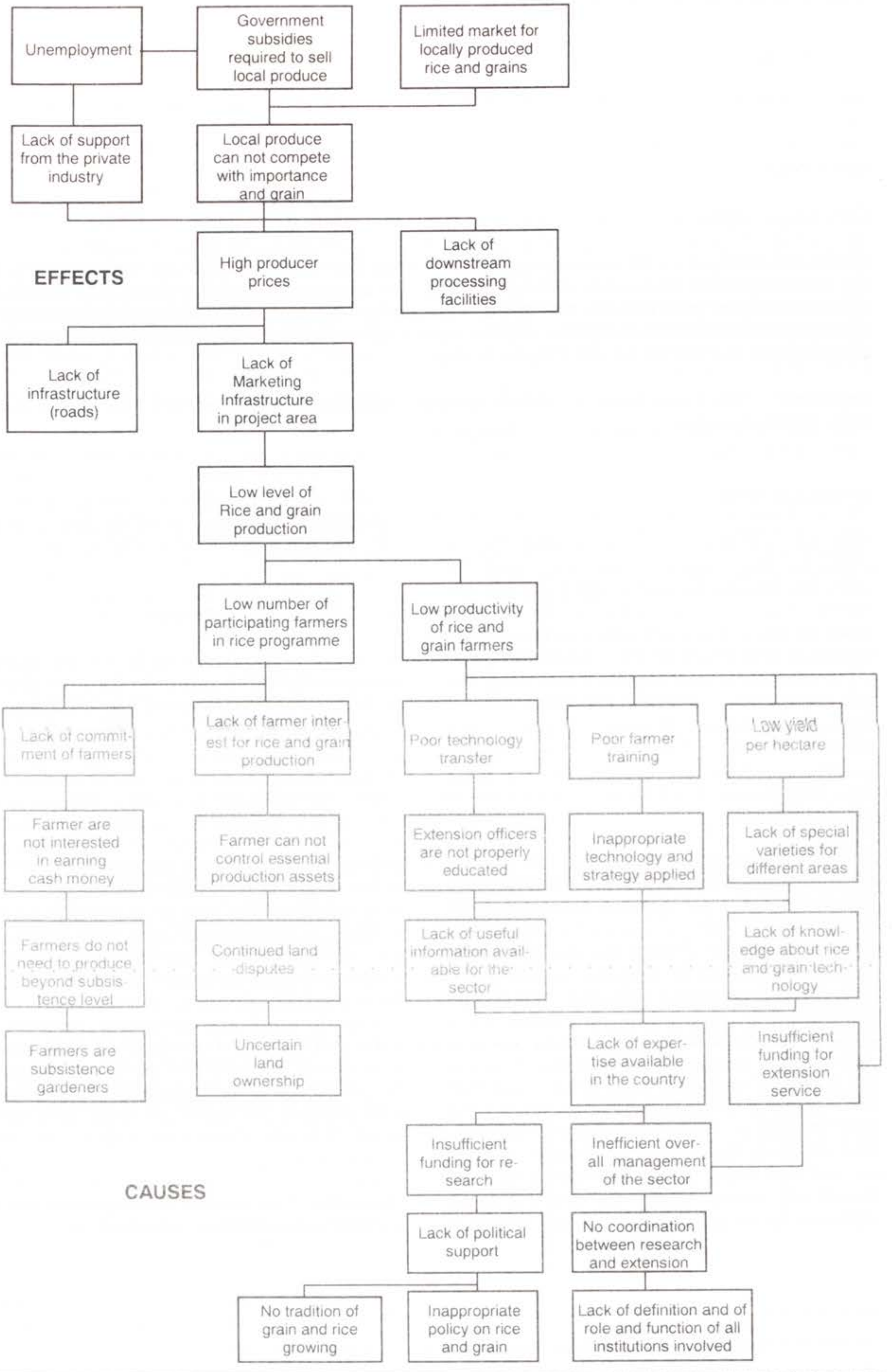
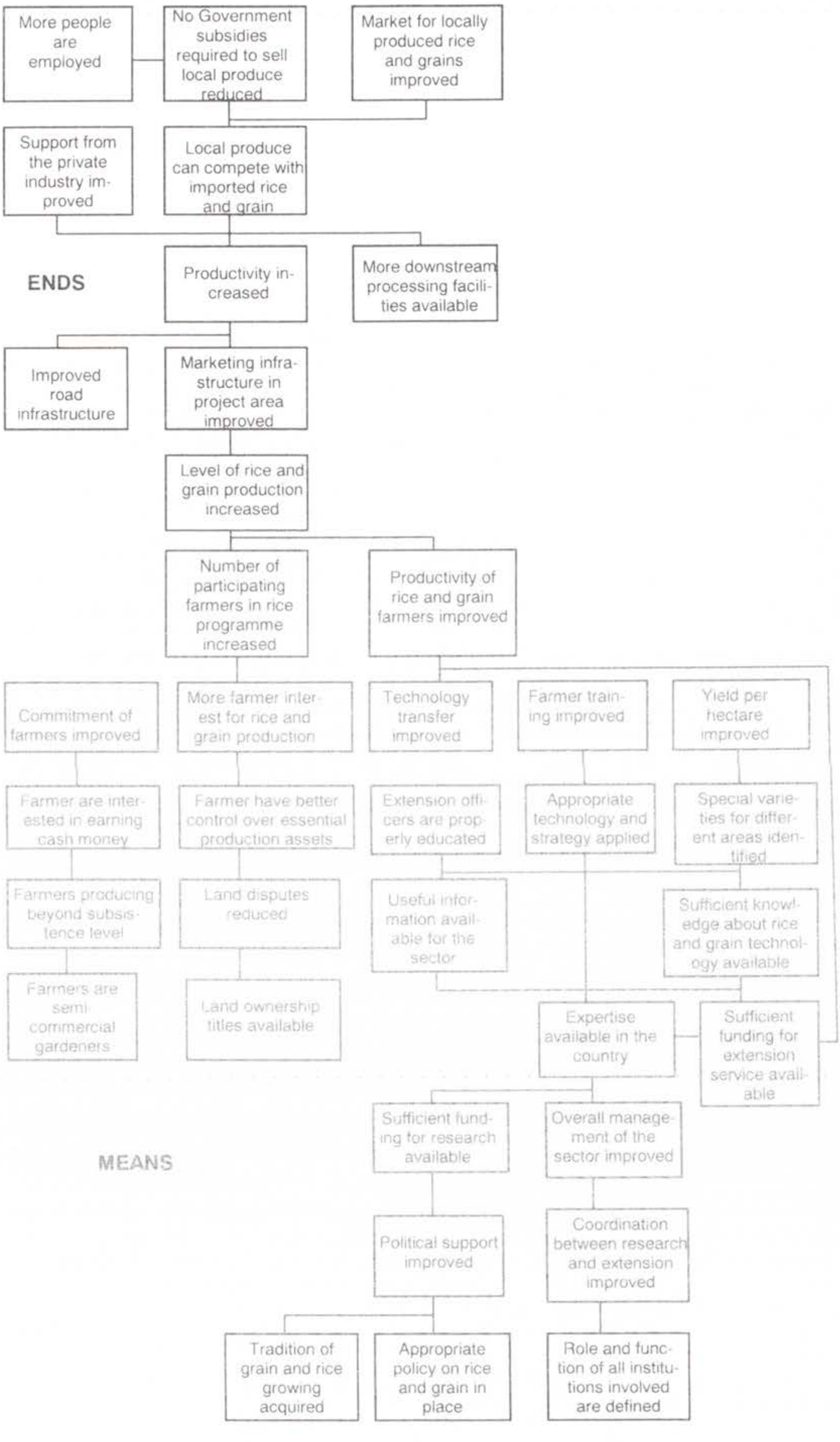


Figure 2. **OBJECTIVES ANALYSIS**



RESULTS

The results of the analysis are presented below [figs 1 and 2]. They indicate that there are many constraints that affect the grain and rice industry, and that by addressing the constraints, positive results would be achieved.

1. **The Constraints / Problems.**

The intermediate causes of failures in the grain and rice industry [fig.1] are due to;

(a). **Low productivity of rice and grain farmers, and [b] Low number of participating farmers in rice and grain programs.**

(a). **Low productivity** of rice and grain farmers results from **poor technology transfer, poor farmer training, low yields per hectare and insufficient funding for extension services**. These in turn are caused by various factors as discussed below;

(i) **Poor technology transfer** results from extension officers not properly educated as a result of lack of useful information for the sector due to lack of expertise available in the country.

(ii). **Poor farmer training** results from inappropriate technology and strategy applied, as a result of lack of expertise in the country, insufficient overall management of the sector, no coordination between research and extension and lack of role and function of all the institutes involved in the industry, insufficient funding for research as a result of lack of political support as influenced by inappropriate policy on rice and grain and no tradition of grain and rice growing.

(iii). **Low yields per hectare** in turn are caused by lack of special varieties for different areas, lack of knowledge about rice and grain technology, also lack of expertise in the country, insufficient funding for research as a result of lack of political support due to inappropriate policy on rice and grain and no tradition of rice and grain growing

(iv). **Insufficient funding for extension services** results from inefficient overall management of the sector, as a result of poor coordination between research and extension which in turn results from lack of role and function of all the institutions involved in the rice and grain industry.

(b). **Low number of participating farmers in rice and grain programs** is caused by **lack of commitment of farmers and lack of farmer interest for grain and rice production**, both of which are influenced by other factors as follows

(i). **Lack of commitment by farmers** results from farmers not interested in earning cash income because farmers do not need to produce beyond subsistence level because they are subsistence gardeners.

(ii). **Lack of farmer interest for rice and grain production** results from farmers not able to control essential production assets due to continued land disputes that result from uncertain land ownerships

(c). The problems of [a] **low number of participating farmers in rice program and [b] low productivity of rice and grain farmers** discussed above, results into **low level of rice and grain production**, which together with **lack of road and marketing infrastructure** in project areas give rise to **high producer prices**. The high production prices coupled with **lack of down stream processing facilities** results in **the local rice and grain produce not being able to compete with the imported rice and grain** and also **lack of support from the private industry**. The ultimate results of these are **limited market for locally produced rice and grains, unemployment and the need for Government subsidy to promote and sell local rice.**

2. By turning all the negatives in Fig 1 to positives in Fig 2 that is by addressing the problems, the end results would be **productivity increase** coupled with **availability of down stream processing facilities**, the **local produce can now compete with imported rice and grain, stimulate private sector support** and gives rise to **reduced unemployment, more market for locally produced rice and grain,** and **no need for government subsidies to produce and sell locally produced rice and grain.**

DISCUSSION

Composition of the team from university, research, development and extension was based on subject matter competence, and thus drew on the knowledge, ideas and experience of the team members and from interdisciplinary points of view. The analysis gave a better understanding of the Rice and Grain Industry in PNG.

The above analysis was used in the design and implementation of a pilot phase rice program in the Markham Valley in 1998 and 1999 [also reported in this issue]. The constraints analysis report and the results of the pilot phase rice study were used in the formulation of the 1999 approved National Rice Policy Document.

The Government of PNG in approving the National Rice Policy pledged to support the rice industry for 10 years at a value of K4.0 Million each year, based on the following salient points addressed in the National Rice policy document;

- Increased research and technology development, by recruiting and training of scientists.
- Promotion of seed production and multiplication to support quality and farmer seed needs
- Called for strong extension component, by recruitment of additional staff also training them to deliver effectively.
- Called for the voluntary mobilization of masses of farmers and therefore also their lands [one ha or less/ farmer] instead of forced mobilization and large acreages that may result in land disputes.
- Called for rice production and promotion as a component of the existing farming systems in the areas.
- Called for the training of farmers to support themselves and the industry
- Backed up the idea of provision of machinery and equipment support at affordable and economical prices in production areas
- Called for small scale irrigation development in favourable sites, to support crop growth and also to extend the cropping season and increase the number of crops per year.
- Supported the need for promotion of down stream processing and packaging in production areas
- Called for a revolving funding and credit scheme to support needy farmers
- Called for the formation of farmer groups for collective decision making implementation and ease of technology transfer, production, processing and marketing, and.
- Called for bilateral collaboration with other partners/countries in developing the Rice and Grain Industry in PNG

Most of the above issues came out clearly, as a result of the constraints analysis done. And it is expected that, by following the issues raised in the constraints analysis as well as in the Approved Rice Policy document, the current Rice and Grain Industry would make better impact. It is recommended that a subsequent follow-up analysis be done after some years, so as to update on this as well as eliminate constraints that would have been solved as well as identify new an emerging ones.

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PILOT PHASE RICE PRODUCTION IN MARKHAM VALLEY OF PAPUA NEW GUINEA SHOWS GREAT PROMISE

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ABSTRACT

Agriculture in the Markham Valley is dominated by moderate intensity of banana cultivation and taro and peanuts in the Upper Markham. Rice was not a crop in the farming systems until 1997, when the FAO/PNG Special Program in Support of Food Security and collaborating partners DAL-Erap Rice and Grain Program, DPI Mutzing Extension Services and R.O.C Taiwan Technical Mission and the Farmers introduced rice to the Villages of Naratumua, Ragiampun, Intoap and Minimian. In introducing the rice to the area, the Team was aware of the constraints of the Rice and Grain Industry as discussed in this volume and took that into consideration in the design and implementation of Pilot Phase Rice Program in the Markham Valley. They also took into account the Initial Farming Systems Analysis in Two Pilot Districts in The Markham Valley, that was done at the start of the Special Program in Support of Food Security in the area in 1996..

The result was that, first time rice farmers in the Markham Valley produced rice under rainfed conditions and obtained yields equal to or better than rice yields in dominant rice producing countries. The result indicated that rice production shows promise in the Markham Valley. Farmers from Naratumua, Ragiampun, Intoap and Minimian have embraced the rice technology and are initially producing and milling rice for home consumption, and saving money for not having to buy rice.

Keywords: *Drilled, Dibbled, Broadcast, Rainfed rice, 14% moisture, Adjustment coefficient, Gross margin, Value addition.*

INTRODUCTION

A Pilot Phase of A Special Program for Food Security [SPFS] was implemented in the Markham Valley in Papua New Guinea [PNG] from 1996 to 2000 as part of a global approach towards food security being sponsored by the Food and Agricultural Organization of the United Nations [FAO] and respective National Governments. This is because PNG is one of the 83 Countries classified as of Low Income and Food Deficit. FAO and Papua New Guinea therefore decided to initiate the SPFS in order to begin addressing the food security needs initially on a Pilot Phase in the Markham Valley of PNG

Markham Valley was selected because of its relatively good infrastructure; road net work, access to market in Lae and even Port Moresby and the Highlands, availability of a range of farming systems, relatively good moisture availability, availability of technical and scientific departments and staff [Department of Agriculture and Livestock, Department of Primary Industry, University of Technology, Fresh Produce Development Corporation, Republic of China on Taiwan Technical Mission and recently the National Agricultural Research Institute] to guide and provide support to the program design, implementation as well as monitoring and evaluation, availability of agro-industries, as well as the possibility of expansion of the Program as a result of land availability [Prodoc 1996].The Program aimed at rapid approach to food security; initially, on a limited scale, and for the success and lessons gained/learnt to be used, to stimulate investment on a wider scale for the extension and expansion of the Program to other parts of PNG.

The vast flatlands of the Markham Valley are usually referred to in political circles as the potential 'bread basket of PNG'. Thus it was logical for the reasons above, to initiate the SPFP in the Markham Valley.

In order to improve on the capacity of the members implementing the program a group training workshop in Farming Systems Development [FSD]; inclusive of Participatory and Rapid Rural Appraisal was conducted from August 11 to September 6, 1996 and documented, published and widely distributed [Bammann *et al* 1996]. Mem-

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bers of the Program Implementation Groups and farmers from the targeted villages in the Huon and Kaiapit Districts of the Program sites were involved right from the constraints analysis stage at the start and they contributed significantly to the program implementation processes.

The SPFS Program had four components, **Constraints Analysis** of the farming systems, **Intensification** of the production systems using improved technologies, **Diversification** of the production systems using new crops and integration of small livestock and **Water control** or small irrigation development and management

The introduction of rice into the area fell within the intensification, diversification and water control components.

MATERIALS AND METHODS

In 1996, the National Grain and Rice Program in Collaboration with the SPFS and the International Rice Research Institute and Trukai Industries provided two month long Rice Farming Systems training at Lae and Erap to 42 Rice Extension Officers from the 19 Provinces of PNG. This was to upgrade extension staff expertise on rice. This included six extension/technical staff in the Markham Valley Program area.

At the start of the in 1996, SPFS in the Markham Valley, the Extension staff and Technical Officers from Erap and Markham Valley were trained and participated in the Farming Systems Analysis in six representative villages. One hundred and twenty farmers also participated. This farming systems analysis gave an additional insight into the farming systems and the constraints faced by the communities. The interaction with the farmers over the period created a better understanding and bond between the farmers and the Program Implementation Groups.

Since rice is a new crop to the farmers, farmers were trained at the Village level; using two earlier established farms. Training followed the operational and growth stage of the rice crop. Village level training allowed many farmers and the children to attend and practice prior to implementing the technologies on their plots.

Farmers were trained to:

1. Plough once and harrow their plots twice at weekly intervals before planting. No ploughing or harrowing down the slope. The weekly intervals allowed for better weed control, than when all operations are done in the same week.

2. Plant or seed their rice directly in lines through drilling in furrows 30 cm apart, or dibble in line into holes 30cm apart or broadcast seeding at 80kg/ha basis. Plot sizes were approximately 0.2 ha for individual farmers and 0.5-1ha for group farmers.

3. Sow and grow rice earlier within the rainy season so as to capture enough moisture and also to avoid drought that normally sets in about May.

4. Apply basal fertilizer, NPK at the rate of 50, 50 50 [kg/ha] of N, P_2O_5 and K_2O respectively, at the last harrowing time so as to have the fertilizer well incorporated into the soil and not left on the surface to be evaporated or washed and eroded out of the plot.

5. Weed on schedule, twice at 3-4th week and 7-8th week respectively.

6. Top-dress the plots [50kg N/ha] soon after the second weeding

7. How to identify maturity stage of rice and to harvest on time so as to avoid too dry of cracked grains that would mill poorly.

8. Taught on how to rouge out off types of rice so as to obtain uniform crop, pure seed and grain, and to save the seed for their next crop

9. How to harvest using the sickle as well as small motorized harvesters.

10. Thresh the harvested rice manually or using the motorized threshers

11. Dry the grain and how not to under or over dry, as that would affect the quality of Milling.

The Program trained the Village Leaders in the running, care, maintenance and management of rice mills.

The farmers on learning each of these operations on the two earlier established farms went to practice them on their own within the same or next few week. Thus they have the knowledge fresh on their minds.

The Farmer Leaders who were trained earlier in addition to the DPI-Mutzing Extension Staff provided the first stop extension advice to the other farmers on daily or twice weekly basis. The Technical team from DAL- Erap and ROC Taiwan provided weekly extension back up.

Clean seed of the recommended rice variety, Taichung Sen 10 with acceptable cooking and eating quality close to the commercial 'Trukai' rice [Amoa *et al*] was provided to the farmers by the DAL-Erap and Taiwain Teams.

Since farmers lacked money because of the 1997 drought which depleted their savings, tractor services, seed and fertilizers were given on credit to the farmers, who subsequently paid for them in kind [by seed] at harvest time. The seed were subsequently extended to other farmers in the area.

Farmers provided their own labor for planting, weeding, fertilizer application, harvesting, threshing and drying. However, this labor was estimated in Kina terms and used in calculating the returns.

Initial training and plantings took place as follows; at Naratumua, in the months of December 1997 to January 1998. At Ragiampun in July/August 1998 under irrigated and rainfed conditions. At Minimian in December 1998, and at Intoap in December 99 to January 2000.

The Rainfed farmers were advised not to plant beyond end of January, so as to avoid cessation of the rains about May that may affect crop growth and yields.

Whole plots instead of sampled plots were harvested, so as to avoid any over or under estimation as normally results from plot sampling. Whole plots were harvested also to show and give the farmers the actual yield of their plots.

After harvest, followed by threshing, cleaning and drying, grains were packed into bags and weighed. At the time of each weighing the moisture contents of the grains were also taken. All weight recorded were later adjusted to a constant moisture content of 14% H_2O and the final weight adjusted to kg per hectare basis. This takes care of variation in moisture and therefore weights between farmers / samples that may give rise to non uniform or standard weight comparison.

Moisture and weight standardization follow after [Gomez 1972], as follows;.

To get the adjustment coefficient factor for each sample to 14% H_2O, we use the formula
$A = [100 - M / 86]$

Where A = Adjustment Coefficient and M is moisture level

And to convert your weight to 14% H_2O, we used

$W = A \times W1$

Where W = Weight at 14 H_2O, W1= the initial weight at moisture level M and A is the adjustment factor.

Thus grains with initial moisture content of 14% would have adjustment factor [A] of 1.0, and would therefore retain the same weight; $W = W1$. Grains with moisture content over 14 H_2O, would have adjustment factor $A < 1.0$, and would have the final weight lower; $W < W1$. While grains with moisture level lower than 14% H_2O would have $A > 1$ and therefore higher weights; $W > W1$.

RESULTS

The 1997 drought had serious effect on the farmers in the Markham Valley. This is because their traditional cash crop is peanut, which they grow, harvest and market at least three times a year. In 1997, because of the poor rainfall and drought caused by El Nino as depicted by the rainfall at Erap [Fig. 1], very few farmers could grow or harvest peanuts after May, and this affected their income levels.

As happened in most area in PNG, including the Makham, farmers were among those that received food aid. And that aid came mostly in the form of rice. In addition to the fact that rice could also be stored over long periods compared to the traditional roots, tuber and vegetables convinced the Markham farmers to accept the rice pilot program

Naratumua

At Naratumua, we investigated simultaneously, the methods of rice planting and overall yield of rice on farmers plots. Harvest samples were taken from six farmers selected randomly from the 51 that participated for evaluation of planting methods, namely; broadcast seeding, drilling and dibbling.

The results indicated that broadcast seeding performed slightly poorly than dribbling and drilling [Fig. 2]. In an interview that followed later, most farmers prefer the dibbling method, which is the same method they are used to in planting peanuts. They view planting of rice the same as their customary peanut, thus the dibbling method of planting rice was easily adopted.

Whole plot rice yields from 50 farmers gave yields on per hectare basis from 1,298 kg/ha to 11,697kg/ha. Majority or highest frequency [76%] of the farmers had yields in the 2,000kg/ha to 5,000 kg/ha range while only 8% had yields in the 1,000kg/ha to 2,000 kg/ha range. And 22% of the farmers had yields above 5,000 kg/ha [Table 2 and Fig. 3]. The actual yield from 10.56 ha was

Fig. 1. Some Aspects of Erap Long Term and 1997 Rainfall

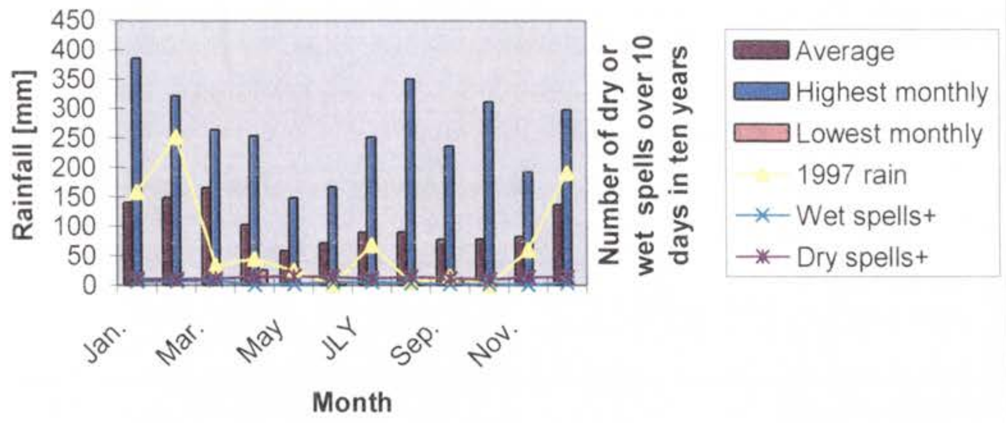


Table 2. Rice planting methods, Naratumua, 1998. Yield and Expected Revenue

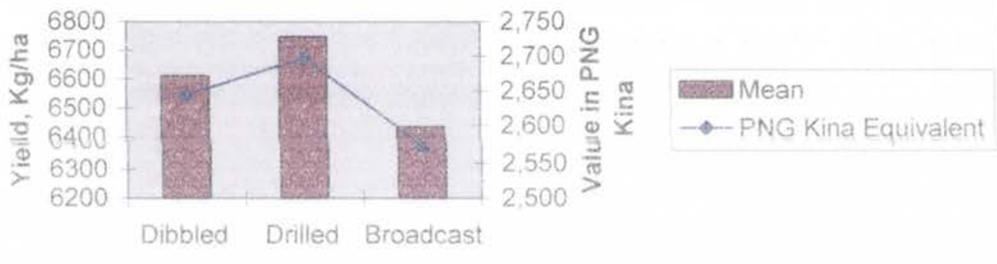
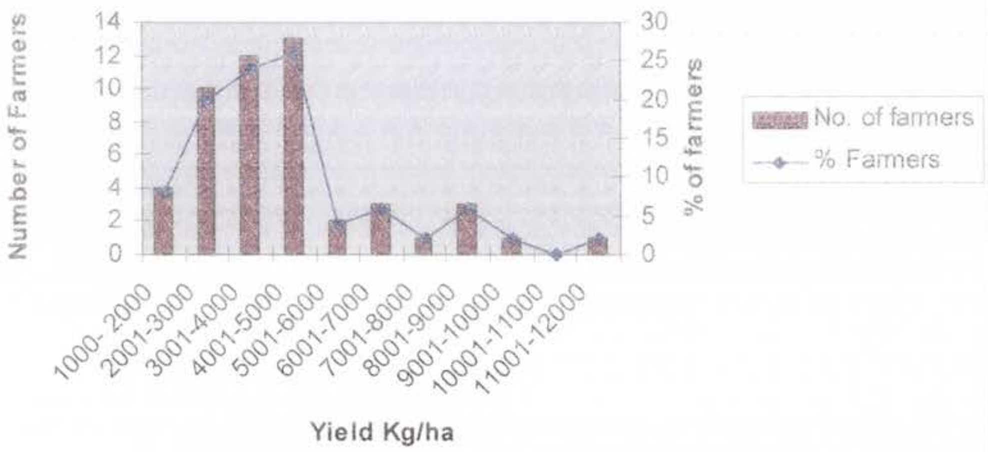


Fig. 3. Naratumua Rice yields kg/ha in 1998



41,838.7 kg/ha at 14% moisture basis, with gave an average yield of 3,960 kg/ha [3.96 tons/ha]. These yields are very high and significant, especially for first time rice farmers.

Gross Margin analysis
Gross margin analysis was done for each of 51 farmers based on;

[a]. Total production cost was calculated, based on; land preparation, seed, fertilizer costs and application, estimated costs for weeding, harvest and post harvest operations

.

[b]. Income was calculated at the equivalent paddy [un-milled rice] price of K400/ ton.

[c]. Profit or net income was calculated as Income less production costs.

Percent Gross Margin was calculated as Profit divided by production costs and multiplied by 100%.

Gross margin % = { [b] – [a] }x 100% **or** { [c] / [a]} x 100%

Gross margin % = { [b] – [a] }x 100% **or** { [c] / [a]} x 100%

The percent Gross Margin analysis indicated [Fig.4] that eight or 16% of the farmers had negative gross margins. Fifteen or 29% of the farmers had gross margins within 1-100%. Twenty or 39% had gross margins of 101 - 200%, six or 12% had gross margins of 201-300%, while 2% had gross margin of 301-400%. Thus overall 84% had positive gross margins. The lower gross margins were due mostly to lateness in applying cultural operations, such as weeding and fertilization by the farmers, while the higher gross margins were due mostly to timely applications of cultural practices

Intoap

During the 1999/2000 crop season, fifty seven farmers from Intoap participated in growing rice using the dibbled method. All other operations were similar to what was described above for Naratumua.

Grain yields ranged from 0.3 to 6.36 tons/ha at 14% H_2O basis [Fig. 5] with a mean of 2.01 tons/ha. Only nineteen percent of farmers had yields below 1ton/ha, While 33% had yields of 1to 2 tons/ha. All others, that is 48% had yields above 2 tons/ha.

The lower rice yields at Intoap compared to Naratumua were due to a 4 –week drought at Intoap in April-May 2000 (personal knowledge).

Ragiampun and Minimian

In Ragiampun and Minimiam farmers collectively cultivate as a group one or two farms at a time. This group farms also gave good yields as indicated in Fig. 6.

Overall rice production in Markham Valley in 1998 to 2000

Fig. 6 gave the overall mean rice yields in Markham valley based on 128 farms at 3060 kg/ha [3.06 tons /ha]. Mean yields per location were in all cases above 2 tons/ha, which is very significant, because mean rice yields in the World's highest rice exporting country, Thailand is only 2 tons/ha [FAO Statistics 1990 – 2000]

K??

Rice Milling

In 1998, thirty tons of paddy rice from Naratumua was carted to DAL-Erap. Part of it was for the refund of costs of inputs supplied to the farmers by the SPFS. The other quantity was purchased from the farmers at the cost of K400/Kg of paddy rice. This was to give the farmers some cash to continue with their lives after the severe 1997 drought, which resulted into lack of income for many of the households due to failures of their traditional income generating peanut crop.In 1999, the SPFS/ROC Taiwan installed one Rice Mill at Mutzing to assist the farmers mill rice for home consumption. The Milling data [Table 2] indicated that acceptable milling recovery from this first time rice growers. Milling recovery ranged from 43 to 74%, with a mean of 59%. The lower milling recovery of May to July 2000 was due to some farmers eagerness to mill and sampled their own rice soon after harvesting and without properly drying them. Milling recovery improves as the grains got dried. Farmers stock paddy rice and mill as and when they need rice for food, and by so doing save money from not buying rice and that money saved or used on other household needs.

Value Addition to rice through processing.

By milling rice instead of selling the paddy [table 2], farmers have value added to their produce, as indicated below;

[A]. The maximum paddy rice value to be gained from selling the 14,180 kg of paddy rice at K0.4/kg = K5,672.

K0.4

[B]. But by milling, even at 59% recovery, the retail gate value for the milled or recovered 8,400 kg x K2.0/kg = K16,800

Fig. 4. Naratumua rice production, percent gross margins

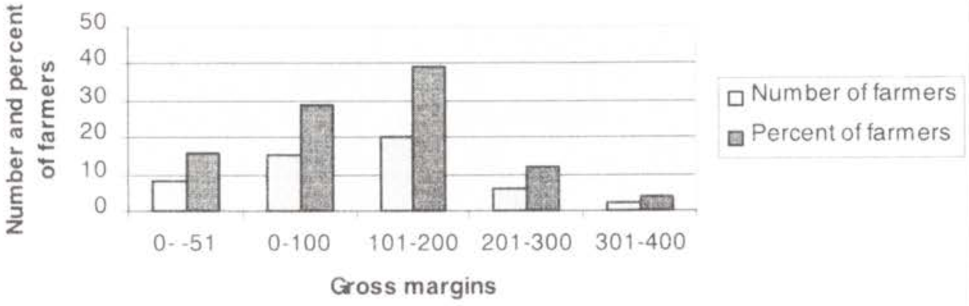


Table 5. Intoap 1999 /2000 Rice Production information [on Kg/ha basis]

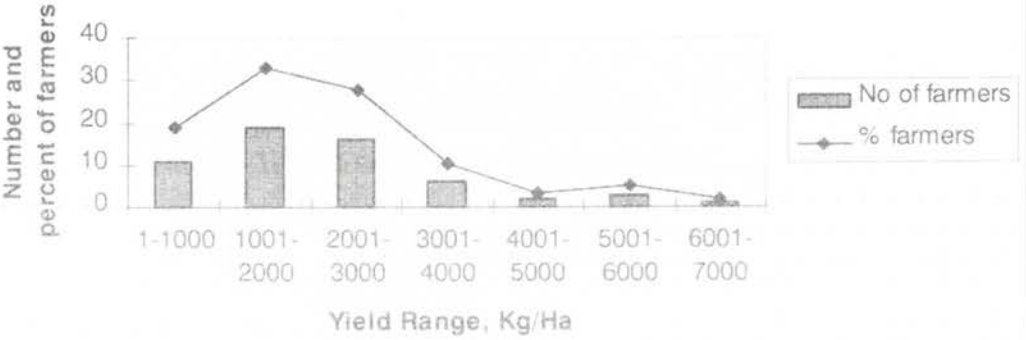
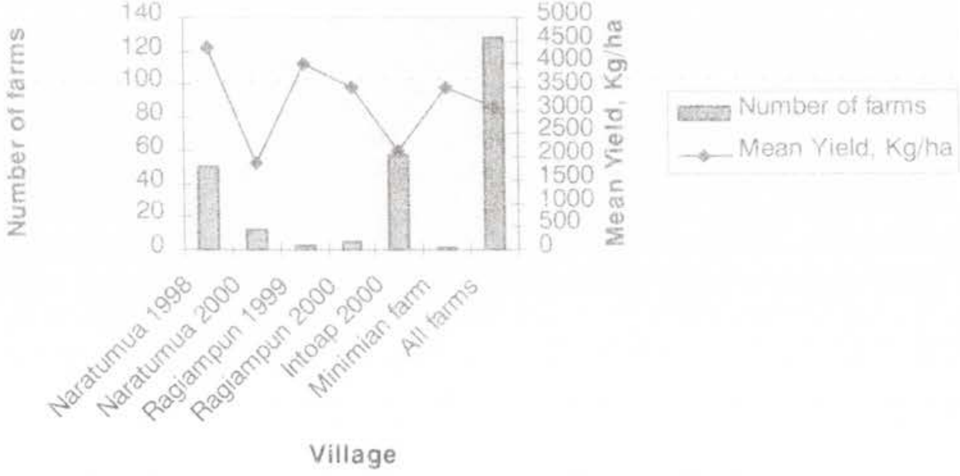


Fig. 6. Mean Rice Yields in Markham Valley, 1998 to 2000



[C]. By taking off the milling cost [K0.2 per kg x 14,180] of K2836 the Net Milled Rice value is K13,964.

[D]. In addition, 5,663 kg of rice bran [a good livestock feed] has been generated at an estimated value of K566.3 or [K0.1/ kg x 5,663]

[E]. The Total Value of rice and bran = K13,964 + K566.3 =K14,530.3

The percent value addition to paddy through milling = {[E – A] / A}x 100%

Value Addition % = {[K14530.3 – K5672] / K5672}x 100% = 156%

Where A = Paddy price value
E = Milled rice + Bran value

Thus by Milling instead of selling rice as paddy we generate % Value Addition of 156%. This in money value for the above milling data = K8858.3 extra over the paddy value of K5672.

Thus, by milling rice, the farmers saved K14,530, which could be used to meet other household needs.

In order to promote not only rice production, but also milling and possible future packaging in production areas, the SPFS has since donated 4 rice mills to the area, and the mills are cited at Erap, Intoap, Chivasing and Naratumua in the Markham Valley.

DISCUSSIONS

Our results, based on data from 128 farms within the period 1998 to 2000; indicated that, even without irrigation, average yield of 2.000 - 3000 kg/ha could be obtained, and yield equivalents above 5 tons/ha are common This is very high for rainfed rices world wide, which indicated a high quality of adaptation/adoption of the optimum production process by the Markham Farmers.

Dibbled and drilled rice were preferred and gave higher yields as compared to broadcast seeded rice.

Gross margins indicated that small scale rainfed rice production is economical with highest gross margin of 300-400%.

By milling rice instead of selling paddy, the farmers or the community would gain value addition through processing. In the above case value addition of 156% was obtained at even a relatively moderate milling recovery of 59%. The Value addition would increase further as farmers gain experience in their production, post harvest management and processing.

The results of rice production in the Markham Valley indicated that small grower rice production could be sustainable.

By using information from the Constraints analysis of the rice and grain industry the Team and the farmers were able to address issues of lack

Naratumua farmers celebrating their bumper rice harvest.

Table 1. **Naratumua rice yields in 1998 on plot and ha basis**

No	NAME	Rice Area, m^2	Yield 14% H_2O, Kg/plot	Calculated Yield, Kg/ha
1	Aisaia Jonah	1716	222.8	1298
2	Simion Yagi	1440	241	1674
3	Ruben Erias	1344	249.6	1857
4	Wilson Abel Ken	880	175.7	1997
5	Lawrence James	3300	694.4	2104
6	Giame Binuai	1716	364.8	2126
7	Yaing Tamat*	5434	1199.1	2207
8	Tani Mura	2394	552.1	2306
9	Max John	8724	2034.5	2332
10	Francis Giame	1716	427.5	2491
11	David Jonah	1716	430.2	2505
12	Fangkis Muri	3024	794.8	2628
13	Eric Amu	2063	559.5	2712
14	Yaru Banabas	3300	950.1	2879
15	Saif Bing.	957	299.5	3130
16	Brown Pania	2698	894.2	3314
17	Boni Yamin Afa	1572	529.7	3370
18	Anu Murur	2142	740.3	3456
19	Tom Ufi	3000	1055.1	3517
20	Martha Kais	1890	670.4	3547
21	Simion Yana	2268	807.2	3559
22	Tirimail Buni	1786	653.7	3660
23	Ketumbing G. Ufi	2684	995	3707
24	Gidisa Y	588	229.7	3906
25	Andrew Yaking	2331	929.5	3988
26	Kikingai Pumu	1998	792.6	3997
27	Daniel Yawing	1625	659.2	4057
28	William Balob	2520	1072.3	4132
29	Caspar Y. Gurunts	1512	657	4345
30	Giam Nanu	1984	874.1	4406
31	Teddy Yaku	2470	1129.4	4571
32	Henry Nabri	1302	598.5	4597
33	Maino Steven	2295	1065.9	4644
34	Yaku Ufi	3564	1685.2	4728
35	Sammy S. Mathew	1360	651.6	4791
36	Steven Yaing	1380	661.4	4793
37	Steven Philip	2232	1071.4	4800
38	Simion Afa	1210	596.2	4927
39	Warabum Mura	2140	1056.6	4973
40	Sinur Simon	1520	841.9	5539
41	Maik Yaing	2142	1216.6	5680
42	Giring Yaramu	2460	1479.3	6013
43	Utunan Yana	1808	1096.2	6063
44	Zakia Pania-Paps	1428	979	6856
45	Judah Marabuman	1440	1039.4	7218
46	Simon Mesa	1159	930.6	8029
47	Sakias Pania	1200	966.6	8055
48	Andrew Yaring	1184	1020.9	8622
49	Anna Max	2106	1915.7	9096
50	Ripus Yana	924	1080.7	11696
Total		105,646	41,838.7	
In hectare & tons		10.56 ha	41.84 tons	
Mean		3960 Kg/ha or	3.96 tons/ha	

Table 2. **SPFS Assisted Small Scale Farmers Rice Milling Statistics at Mutzing, Markham Valley 1999-2000.**

Period	Number of Farmers	Rice Variety	Weight of rice(kg)		% milling recovery	Bran and Husks
			Rough	Polished		
Sep-1999	25	TSC10	2810	2166	77.1	642
Oct-99	11	TSC10	698	471	67.5	228
Nov-99	17	TSC10	1648	864	52.4	732
Dec-99	7	TSC10	459	256	55.7	203
Feb-2000	10	TSC10	983	553	56.3	430
Mar-00	2	TSC10	202	130	64.4	72
Apr-00	5	TSC10	968	719	74.3	308
May-00	4	TSC10	1741	750	43.1	866
Jun-00	24	TSC10	1396	671	48.1	725
Jul-00	29	TSC10	1241	595	48.0	658
Aug-00	34	TSC10	1304	776	59.6	518
Sep-00	12	TCS 10	459	263	57.2	196
Oct-00	9	TCS 10	271	186	68.6	85
Totals	**189**		**14,180**	**8,400**	**59%**	**5,663**
Price/Kg basis			**K 0.40**	**K 2 . 0**		**K0.1**
Expected Value			**K5,672.0**	**K16,800. 0**		**K566.3**

1. **Mean Milling Recovery = [Milled rice /Total paddy rice]x 100% = 8400/14180 X 100% = 59.2%**
2. **Milling cost is K0.2 /Kg, and price for rice bran is K0.1/kg**

of extension, by training farmer leaders and farmers in rice production technologies. Voluntary mobilization of people with their lands was resulted to, where farmers use their own lands, without any force. Expertise and extension support were available to the farmers all season round, from the Mutzing District, DAL-Erap and ROC Taiwan. This collaboration and team working and pooling of resources resulted in the high productivity achieved at the field level. The Trained Farmer Leaders and other Farmers have become the on site extension providers to the other new farmers in their localities, Thus farmers now rely on their trained Leader unlike before where every one was an 'illiterate in rice cultivation'. Thus rice knowledge is now available at the grass roots level to ensure the long term sustainability.

The provision of processing infrastructure, rice Mill and shed and the training of four staff from each village on the running, management and maintenance of the machinery, and giving the complete management of the Mills to the Village Farmers Group, have further increased the interest of the communities in growing and milling rice for food as and when they need to.

Contrary to other reports [Gibson J. 1992, Hanson L.W. *et al* 2001] that seem to suggest that rice production in PNG could not be viable, this pilot phase study in the Markham Valley in PNG indicated that small scale rice production is promising.

ACKNOWLEDGEMENTS

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THE PERFORMANCE OF GRANOLA POTATO AT FOUR SITES IN THE HIGHLANDS OF PNG

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ABSTRACT

Cultivar trials were conducted during September to December 1998 to compare the yield of three varieties of potato; Granola (ware), Sequoia (ware) and Kennebec (processing). The trials were conducted at four sites in the Highlands over an altitude range of 1700 – 2500 m.a.s.l.

There was no G x E interaction for yield or any of the other parameters measured. There were significant ($p<0.01$) yield differences between sites. The cooler sites of Kotuni (1800 m), Tambul (2300 m) and Ialibu (2500 m) yielded better, with the highest total yield (26.3 t/ha) obtained in Tambul and the lowest total yield (13.5 t/ha) from Keluwa (1700 m). Marketable yield was significantly ($p<0.01$) higher in Kotuni (18.2 t/ha), followed by Ialibu (11.3 t/ha).

The total yield of Granola (21.0 t/ha) was as good as Sequoia (21.6 t/ha) and Kennebec (20.6 t/ha). The yield of Kennebec was higher than that reported earlier. It was noted that Kennebec produced bigger sized tubers, resulting in more marketable yield.

Keywords: *Potato variety, Sequoia, Granola, Kennebec, performance, fertilizer*

INTRODUCTION

In PNG, potato has become a cash crop for farmers in high altitude areas. The annual demand is about 10,500 tonnes of which 85 % is for ware or cooking potato. On average there is an annual shipment of 1600 tonnes from the Highlands to Port Moresby (FPDC, 2000). The main areas of production are Tambul / Tomba (WHP), Sirunki (EP), Ialibu (SHP), Gembogl (SP) and Kotuni / Okapa (EHP).

The two recommended commercial potato varieties are Sequoia (ware or cooking) and Kennebec (processing) (Sawanga 1991). Following the 1997 drought, the variety Granola was introduced as a stopgap measure, since Sequoia seed was not available. Granola is a ware potato and was reported by highland farmers to have yielded well ('Fresh Produce News No.144', FPDC', 1999). It is a common variety in the highlands of the Philippines.

This multi-location trial was carried out to compare the yield of Granola with that of Sequoia and Kennebec. Past research had not found a variety superior in yield to Sequoia.

MATERIALS AND METHODS

The trials were conducted at four Highlands sites, namely Tambul, Keluwa, Ialibu and Kotuni in (Table 1). Trial details are as follows.

A randomised complete block design with six replications was adopted at each trial site. Generation 5 seeds were used for all varieties. There were five rows in each plot with 12 seed tubers planted in each row. Tubers were planted 10 cm deep. The inter- and intra- row spacings were 80 cm and 40 cm respectively. The rate of fertiliser application was 1,200 kg NPK (10,25,12 + $2.5B_2O_5$) per hectare (120 kg N, 131 kg P, 119 kg K and 9.3 kg B per hectare), applied before planting. Weekly sprays of mancozeb and orthene or karate were applied to control diseases and insect pests.

Data was collected from the middle three rows of each plot, and the outer two rows were treated as guard rows. The following parameters were recorded per plot: emergence, total tuber number and tuber weight at harvest; marketable tuber (> 60 g) number and weight; and number and weight of rotten tubers. Performance of each vari-

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Table 1. **Site characteristics to Potato Trial**

Site	Altitude (m)	Planting Date	Growing Periods (days)
Tambul, WHP	2,300	09/9/98	102
Keluwa, WHP	1,700	15/9/98	99
Ialibu, SHP	2,500	16/9/98	103
Kotuni, EHP	1,800	14/9/98	101

ety at each site was analysed and this data was also used to investigate G x E interactions.

RESULTS

There was no variety or genotype by site (G x E) interaction for any parameter, so only main effects of site and variety are presented.

There were significant differences between sites in emergence and yield characters ($p<0.01$) (Table 2). Total tuber yields were significantly higher at Tambul (26.3 t/ha), Kotuni (22.9 t/ha) and Ialibu (21.6 t/ha) than at Keluwa (13.5 t/ha). Mean tuber weight (hence marketable yield) was greater at Kotuni and Ialibu than at Keluwa and Tambul ($p<0.01$).

There were significant differences between the varieties in total tuber number per plant, marketable tuber weight per plant and mean tuber size ($p<0.01$). Emergence, total tuber weight per plant, marketable tuber number per plant and marketable and total tuber yield were not significantly different between varieties. Granola produced the most tubers per plant and Kennebec produced significantly bigger tubers ($p<0.01$).

DISCUSSIONS

The main objective of the trial was to evaluate the performance of Granola against Sequoia and Kennebec, the established ware and processing varieties respectively. Furthermore, it encompassed a multi-location comparison to determine whether Granola yield would differ from other varieties in different parts of the Highlands.

The analysis showed that there was no G x E interaction ($p>0.05$). However, between the trial locations, there were significant differences in emergence and yield parameters ($p<0.01$). Emergence was good in Keluwa but yield was substantially lower than other sites due to infection by bacterial wilt and late blight. At Tambul, there were significantly more tubers produced but they were smaller in size ($p<0.01$).

Total tuber number, tuber weight per plant and total yield were significantly ($p<0.01$) greater in Tambul, but the tubers were small, probably because the trial had been infected with black scurf (*Rhizoctonia solani*). The site with the best performance overall was Kotuni, which produced significantly ($p<0.01$) bigger tubers and greater marketable yield, followed by Ialibu. Generally, the higher and cooler sites of Tambul, Ialibu and Kotuni produced better yields. There was a lower incidence of bacterial wilt (*Ralstonia* solanacearum) and early blight (*Alternaria solani*)at Ialibu and Kotuni than the other two sites.

Granola produced significantly ($p<0.01$) more tubers per plant than Kennebec but not significantly more than Sequoia. Granola tubers were smaller than Sequoia. Kennebec had fewer, but larger tubers than either Granola or Sequoia. However, the marketable and total yields obtained for Kennebec were not significantly different ($p>0.05$) from the other varieties.

The results showed that the yield performance of Granola as a ware potato was as good as Sequoia and Kennebec at the four highland sites tested. The lack of a G x E interaction means that Granola yielded well at all the sites tested. In these trials the yield of Kennebec was similar to Sequoia.

However the potential for Granola to be accepted as an alternative ware potato is also influenced by tuber quality. Granola tubers were generally smaller than either Sequoia or Kennebec and their yellow flesh colour may be a disadvantage in some markets. Granola tubers are also roundish, unlike Sequoia which has flattened oval tubers. Farmers in the highlands of PNG tend to prefer flattened oval tubers that are white fleshed.

Table 2: **The emergence and yield components obtained from each potato variety at the four highlands sites.**

Treatment	Emergence (plants per plot)	Total tuber number per plant	Marketable tuber number per plant	Mean tuber weight (g/tuber)	Marketable yield (tonnes/ha)	Total yield (tonnes/ha)
Site						
Tambul	32.8	22.3	2.3	46.7	7.7	26.3
Keluwa	34.9	8.0	2.6	58.7	8.0	13.5
Ialibu	29.4	11.0	3.0	81.6	11.3	21.6
Kotuni	30.0	10.9	6.1	85.7	18.2	22.9
LSD (5%)	3.7	3.5	0.9	16.6	3.7	3.2
Variety						
Sequoia	32.2	13.3	3.3	66.3	11.0	21.6
Kennebec	30.5	11.1	3.3	84.7	12.4	20.6
Granola	32.7	14.8	3.9	53.6	10.5	21.0
LSD (5%)	NS	1.9	NS	9.2	NS	NS
CV (%)	10	24	35	23	39	18
Interactions (Site x Variety)	NS	NS	NS	NS	NS	NS

NS = Not significant ($p>0.05$)

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7. Text - Papers should be concise. Extensive introductions referring to the work of earlier authors should be avoided. Lengthy discussions and detailed descriptions should be reduced by the use of tables and diagrams. The text should not repeat in detail what is apparent from a table or diagram.

Names of countries or organizations may be abbreviated to capitals without full stops but must be given in full at the first mention.

Numbers under 11 should be spelt out unless qualifying a unit of measurement. If a number over 10 and a number under 11 appear in the same sentence, both are written as numerals. Do not begin a sentence with a numeral. Fractions should be given as decimals or spelt out. All decimal numbers less than unity should have a zero before the decimal marker, e.g. 0.25. All units should be in the S.I. System.

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Common or local names may be used but the scientific name should be quoted on the first occasion. An agricultural chemical must be referred to by its generic or common name when it is first quoted.

8. Tables - Numerical results should be displayed as means with relevant standard errors rather than as detailed data. Standard errors should be given to one place of decimals more than the means to which they refer and the number of degrees of freedom should also be quoted. Tables should be complete in themselves so that they can be understood without reference ot accompanying text. Each table should have a brief and self explanatory title. The presentation of the same data in tabular and graphic form is not permitted.

9. Figures and photographs - Line drawings should be drawn in black water-proof ink on smooth tough paper. Labeling should be clear and always produced with stencils using black water-proof ink and should be legible when reduced. No alterations or additions to artwork can be made by the editors. Figures should be no larger than an A3 page, and no smaller than final published size. Photographs should be glossy prints of good quality and must make a definite contribution to the value of the paper. Indicate the top of the figures and photographs on the back: the plate number of each figure and photographs, the author's name, and the title of the paper. Do not write on the back of photographs: use an adhesive label with the data previously written on it. Artwork should be of appropriate proportions for the final dimensions.

10. Acknowledgements - The names, initials and place of work of those the author wishes to mention may be included. It is unnecessary to mention everyone who has been marginally involved in the work.

11. References - These should be cited in the text by the author's name and data as follows:

"Moran and Brown (1965) showed or "Various works" (Miller and Smith 1956; Adams *et al.* 1960; Wilson 1978, 1979 a) found ..." The term *et al.* should be used when there are more than two authors. The letters a,b,c, should be used to distinguish several papers by the same author in one year.

All references in the bibliography should be given in full and in alphabetical order. For a journal the reference should include surname and initials of all author(s), (year), title of paper, full title of the journal, volume, (part) and full page numbers. For a book the reference should include author(s) surnames and initials, (year), title of chapter and page numbers if appropriate, full title of book, published and city and total page numbers. Conference proceedings should include the year and place of the conference. The title of the journal or book is underlined to be printed in italics. Examples:

BOWET, C.M. and **SMITH, L.N.** (1950). Measurement of phosphorus. *Methods of Soil Analysis*. C.A. Lack. Ed. Department of Primary Industry, Port Moresby.

SANDERS, A.J. (1940). Plant responses to Molybdenum. *Papua New Guinea Agricultural Journal* 48(4): 981-995.

TROBEN, M.M. (1973). Genetic fine structure in *Drosophila. Department of Primary Industry Research Bulletin* No. 102: 196-197.

VANCE, P.N. (1976). Maize in the Markham Valley. Pp. 215-220. *In: 1975 Papua New Guinea Food Crops Conference Proceedings*. K. Wilson and R.M. Bourke (Ed.). Department of Primary Industry, Port Moresby.

Internal reports, communications and memoranda are not valid references. The criteria for valid publications (in the scientific world) are that publications are distributed widely among those interested in the subject and are available to the international public in major libraries and from the publisher. This therefore excludes reports circulated only within a department and to a few outsiders and conference documents available only to those who attended the conference and the like.

Work that has not been accepted for publication (unpublished data) and personal communications are not included in the list of references buy may be refereed to in the text. References cited in an appendix should be included in the list of references at the end of the paper.

Special care should be take to see that every reference in the text is included in the list of references and vice versa, and that there is consistency in the spelling of author's names and the citation of the dates throughout the paper.

12. Review of papers - All papers will be submitted to suitable professional referees. Major changes will be referred to the author for consideration. Minor editorial changes will be made without consultation but will be presented to the author(s) at proof stage. The final decision to accept or reject a paper, rests with the Editor.

13 Offprints - Twenty-five free off-prints are given to the author. Where there are several authors, the first author will be sent the off-prints. Extra off-prints may be ordered at the time the galley proofs are returned to the editor. Costs will be determined at the time of printing.

14. Recognised abbreviations in this journal are:

g	- gram
kg	- kilogram
t	- tonne
l	- litre
ml	- millilitre
ha	- hectare
mm	- millimetre
cm	- centimeter
M	- metre
a.s.l.	- above sea level
yr	- year
wk	- week

h - hour
min - minute
s - second
k - kina
n.a. - not applicable or not available
n.r. - not recorded
var - variance
s.d. - standard deviation
s.e.m.- standard error of difference
d.f. - degrees of freedom

Levels of significance

n.s. - not significant
* - $0.01 \le p < 0.05$
** - $0.001 \le p < 0.01$
*** - $p < 0.001$

Either kg/ha or kg.ha is acceptable, but large combinations of units should be in the form kg.ha to avoid possible mathematical ambiguity.

15. Submission of manuscripts - All correspondence should be addressed to: Editor, PNG Journal of Agriculture, Forestry and Fisheries, Agricultural Information Branch, Publication Section, Department of Agriculture and Livestock, P.O. Box 417, Konedobu, Papua New Guinea.