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CONTENTS

ADDITION OF COPRA MEAL TO COMMERCIAL FEED FOR BROILER CHICKEN PRODUCTION.

Janet Pandi[1]

ABSTRACT

Commercial hybrid broiler chickens were fed from three weeks to 53 days of age on diets in which various levels of copra meal were added to commercial finisher feed. The findings confirm that a finisher feed of commercial broiler pellets with 20-60 percent added copra meal can make a satisfactory low density feed for broiler chickens in the finishing stages. A diet of 60 percent copra meal with 40 percent broiler finisher can be fed to broilers for an additional week for them to reach a marketable weight of two kilograms. There is an economic advantage in favour of the lower intensity system as long as the ratio of the actual prices of the copra meal and commercial feed is above the calculated threshold ratio.

Keywords: *Commercial, broiler chickens, copra meal, ratio.*

INTRODUCTION

Lowering the cost of feeding or using local feeds, mainly for commercial broiler chicken production, were identified as being of high priority in Papua New Guinea (PNG) by the National Agricultural Research Institute (NARI) in its regional research prioritisation consultations (NARI 2004). Due to the need to assist smallholder broiler farmers, NARI has been doing research on the use of low nutrient density feed with increased use of local ingredients for feeding broiler chickens during the finishing stage.

Work was conducted using proportions of copra meal along with the commercial broiler finisher pellet for a lower intensity feed. The treatment rations were given to the birds during the finishing stage from day 21 to 53.

Copra meal is the by-product of the oil extracting industry done currently in two mills located in East New Britain and Madang provinces. This by-product is used in the manufacture of commercial feeds at a low rate of inclusion. It can be utilized either as a protein or energy source or both.

General recommendations propose that copra meal can be included in the diet economically up to 40 percent in poultry rations (CAB International 1987).

This project was designed to test whether copra meal can be further included in broiler finisher rations up to 80 percent, economically, without affecting overall production in a low cost feeding system. Such a low cost production system would be beneficial to poultry farmers where copra meal is available locally such as in the Madang and East New Britain provinces.

Moreover, it may also be profitable to include or substitute higher levels of copra meal as an energy or protein source in the production of low intensity feeds elsewhere leading to low cost production systems.

MATERIAL AND METHODS

Birds, feeds and management

One hundred and forty (140) hybrid broiler chickens hatched by Nuigini Tablebirds Company were used in the trial. During the first three weeks, all birds were fed commercial starter ration as a group. The treatment diets were introduced at 21 days and continued until 53 days.

There were five diets with four replicates and each experimental pen housed seven birds.

The design was a completely randomised design with the five treatment diets having the compositions shown in Table 1. Feed was offered *ad libitum*.

Live weights, feed intakes and feed residues were measured on a weekly basis and the collected data subjected to analysis of variance.

Costs

The method used for calculating the average total cost per bird per diet is illustrated by an example for the

[1] Papua New Guinea National Agricultural Research Institute

Table 1. **Chemical composition of the treatment diets used in the experiment.**

Diet	Composition	Percentage on Dry matter basis					
		Protein	Energy	Crude fibre	Moisture	Ash	Fat
1	100% BF	23.30	51.54	11.77	23.3	6.2	7.5
2	80% BF + 20% CM	20.11	51.42	15.31	19.5	6.7	5.1
3	60% BF + 40% CM	19.57	50.50	17.06	18.3	7.1	6.5
4	40% BF + 60% CM	18.88	54.21	24.20	17.2	7.1	7.0
5	20% BF + 80% CM	19.31	54.65	27.19	16.3	6.8	8.9
	Copra meal	18.03	50.41	40.80	18.4	8.4	13.0

BF = Broiler Finisher; CM = Copra Meal

100 percent broiler finisher diet. For this diet, the average finisher feed intake per bird was 4.199 kg with the diet costing K2.57 per kilogram. Each day-old chicken cost K1.78, and starter feed cost K0.95 per bird. Thus the cost of rearing a 53 day old broiler on this diet is K1.78 + K0.95 + (4.199 x K2.57) = K13.52

Threshold ratio of costs

The price (cost of feed) ratio between the high intensity (100% Broiler Finisher) feed and the lower intensity feed was determined such that the feed cost of producing a kilogram of live weight during the finishing period of a bird would be equal. This can be considered as the break-even or the threshold ratio.

Any value of the ratio of actual feed prices above the threshold would indicate an economic advantage in favour of the lower intensity system. An increase in the actual ratio would occur if the high intensity feed price rose or the cost of the lower intensity feed could be reduced relatively.

The threshold ratio is calculated as follows and is independent of the actual feed prices (Ignatius and Quartermain, 2002).

Cost of 1kg of live weight gain on the high intensity feed = $\frac{(\text{Intake H})(\text{Price H})}{(\text{Gain H})}$

Cost of 1kg of live weight gain on the low intensity feed = $\frac{(\text{Intake L})(\text{Price L})}{(\text{Gain L})}$

At the threshold,

$$\frac{(\text{Intake H})(\text{Price H})}{(\text{Gain H})} = \frac{(\text{Intake L})(\text{Price L})}{(\text{Gain L})}$$

and the ratio is $\frac{(\text{Price H})}{(\text{Price L})} = \frac{(\text{Intake L})\ (\text{Gain H})}{(\text{Intake H})\ (\text{Gain L})}$

Figure 1. **Weekly average weights of birds over the experimental phase (21-53 days)**

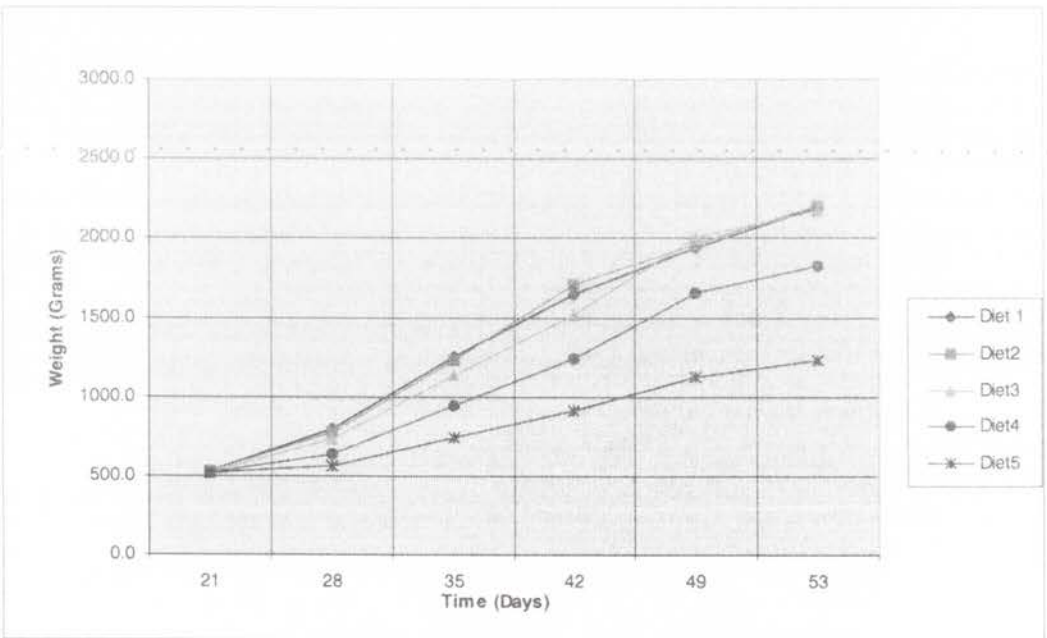

Table 2. **Live weights, overall gain, total intake and food conversion ratio per bird over the experimental phase**

Diet	Treatment diets	Initial weight	Final weight	Weight gain	Intake	FCR
1	100 % BF	0.526	2.191a	1.665a	4.199a	2.53ab
2	80% BF	0.527	2.208a	1.681a	4.024b	2.40a
3	60% BF	0.523	2.168a	1.645a	4.025b	2.45a
4	40% BF	0.524	1.823b	1.300b	3.387c	2.61b
5	20% BF	0.524	1.226c	0.702c	2.483d	3.55c
LSD		0.011	0.104	0.102	0.169	0.157

Means with the same subscript are not significantly different at the 5% level

RESULTS

Weekly weights, overall gain, intakes and feed conversion ratios

Weights

There were no significant differences between initial weights of birds. However, there were some clear distinctions between the live weights of birds on the different treatment diets in subsequent weeks. Birds on the 100, 80 and 60 percent BF diets had significantly ($p<0.05$) higher final live weights than those on the 40 and 20 percent BF diets. In turn, birds on the 40 percent BF diet had significantly ($p<0.05$) higher weights than the ones on the 20 percent BF diets (Figure 1 and Table 2). There were no differences between the final weights of birds on the 100, 80 and 60 percent BF diets.

Gains

The overall gains showed a similar trend to that observed in the final live weights. Birds on the 20 and 40 percent BF diets had significantly ($p<0.05$) lower weight gains compared to those on the 60, 80 and 100 percent BF diets. However, the birds on the 40 percent BF diet gained more than those on the 20 percent BF diet.

Intakes

The total intakes of birds showed that birds on the 20 percent BF diets had significantly ($p<0.05$) lower intakes than those on the 40 percent BF diet. These two groups in turn had significantly ($p<0.05$) lower intakes than birds on the 60, 80 and 100 percent BF diets.

Feed Conversion Efficiency

Feed conversion efficiency is measured by the ratio of feed intake to liveweight gain. Birds on 80 and 60 percent BF diets had feed conversion ratios of 2.40 and 2.45 which are lower than those on the other diets with added CM. The ones on the 20 percent BF (80 percent CM) diet had a higher ratio of 3.55. These results show that birds on the 80 percent CM diets had to eat over one kilogram of feed more to gain one kilogram of live weight than birds on the 100 percent BF and 20 and 40 percent CM diets.

Table 3. **The total production cost of a bird and the cost per kilogram of live weight**

Diets	Treatment diet	Cost	Cost per Kg
1	100 % BF	13.52a	6.18a
2	80 % BF	11.29b	5.12b
3	60 % BF	9.51c	4.39c
4	40 % BF	6.94d	3.81d
5	20 % BF	4.72e	3.85d
LSD		0.336	0.227

Means with the same subscript are not significantly different at 5% level

Costs

At the current prices for BF and CM, the birds on the 100 percent BF diet were significantly ($p<0.05$) more expensive to produce than the ones on the 20 percent BF diet (Table 3). The costs of production of birds on the other diets ranked according to the proportion of CM in the diet. It is significantly cheaper per kilogram of live weight to produce birds using the 60 and 80 percent CM diets than any of the other diets.

DISCUSSION

The results of this study indicate that broiler finisher diets which already contain some CM can have added a further 20-40 percent CM without productivity loss and with economic gain. Even birds on a 60 percent CM diet can perform quite well and should be able to reach a marketable weight of two kilograms at considerably lower cost if raised for an additional week or two as inferred from the results of this trial.

The chemical compositions of the diets on a dry matter basis in Table 1 show that the energy and crude fiber values for diets with 60 and 80 percent CM were high compared to those of the other diets. The low intakes of birds fed the 60 and 80 percent CM diets may be attributed to the high percentage of fiber in these diets or the higher energy content and possibly the palatability of the diets themselves. Palatability may be a factor affecting intakes of these diets since the CM was not pelleted and the feed was dusty. Also the oil content of the CM may have become rancid during the trial.

Even so, a diet combination of 60 percent CM with 40 percent BF can be economical and profitable as a low intensity feed ration for a small scale broiler farmer constrained by the high prices of commercial broiler finisher feed.

CONCLUSIONS

Birds on the 20 and 40 percent copra meal diets performed as well as those on the 100 percent broiler finisher diets. Production costs were inversely proportional to the percentage inclusion of the copra meal. The higher the percentage inclusion of copra meal in the diet, the lower the costs involved in raising a bird to market weights.

An inclusion rate of 50-60 percent copra meal in the diet to give a low-density feed for broiler chickens during the finishing stage is nutritionally viable and economical for a small-scale broiler chicken farmer.

A diet of 80 percent copra meal, although cheaper compared to the other diets, may not be economical as birds did not perform as well on this diet and may take too long to reach a marketable weight.

RECOMMENDATIONS

Farmers can use any diet combinations used in this experiment, except for the 80 percent copra meal diet, as long as the ratios of the actual feed prices are above the threshold ratios, indicating an economic advantage in favour of the lower intensity system. The ratios calculated from the feed intake and weight gain data for each diet are as follows:

Diet	Treatment diets	Threshold Ratio
2	80% BF + 20% CM	0.95
3	60% BF + 40% CM	0.97
4	40% BF + 60% CM	1.03
5	20% BF + 80% CM	1.40

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A REVIEW OF BANANA PSEUDO-STEM FIBRE REINFORCED COMPOSITES

E.S. Zainudin[1] and S.M. Sapuan[1]

ABSTRACT

The use of banana pseudo-stem fibre as reinforcing agent in polymer based composites is reviewed from viewpoints of status and future expectations of natural fibres in general, composition and physical properties of banana pseudo-stem fibre, fibre surface modifications, and mechanical properties of banana pseudo-stem fibre based polymer composites. The use of banana pseudo-stem fibres as a source of raw material in plastic industry not only provides a renewable resource, but could also generate a non-food source of economic development for farming and rural areas.

Keywords: *Banana pseudo-stem fibres, fibre-matrix interaction, mechanical properties*

INTRODUCTION

Economic and other related factors in many developing countries where natural fibres are abundant demand that scientists and engineers apply appropriate technology to utilize these natural fibres as effectively and economically as possible to produce good quality fibre reinforced polymer composites for housing and other needs. Among the various natural fibres, banana *Musa sapientum* (L) pseudo-stem is of particular interest; in that its composites have high impact strength besides having moderate tensile and flexural properties compared to other lignocellulosic fibres. The present paper surveys the research work published in the field of banana pseudo-stem fibre reinforced polymer composites with special reference to the structure and properties of banana pseudo-stem fibre, processing techniques, and the physical and mechanical properties of the composites.

Cellulosic fibres like banana pseudo-stem, sisal, palms, bamboo, wood in their natural condition, as well as several waste cellulosic products such as shell flour, wood flour and pulp have been used as reinforcement agents of different thermosetting and thermoplastic resins (George *et al.* 2001, Pothan *et al.* 2003, Varghese *et al.* 1994, Mi *et al.* 1997). During the transformation of the raw fibres into cordage, approximately 10% of waste fibres are produced. These waste fibres can be profitably used in the manufacture of fibre polymer reinforced composites because they posses attractive physical and mechanical properties (Coutinho *et al.* 1997). They impart the composite high specific stiffness and strength, a desirable fibre aspect ratio; they are biodegradable and are readily available from natural sources and, more importantly, they have a low cost per unit volume.

Unlike the traditional engineering fibres, e.g. glass and carbon fibres, along with mineral fillers, these lignocellulosic fibres are able to impart to the composite certain benefits such as: low density; less machine wear than that produced by mineral reinforcements; minimal health hazards; easily biodegradable and a high degree of flexibility. The latter is especially true because these fibres, unlike glass fibres will bend rather than fracture during processing. Whole natural fibres undergo some breakage while being intensively mixed with the polymeric matrix, but this is not as notorious as with brittle or mineral fibres (Wambua *et al.* 2003).

The present work in the field of banana pseudo-stem fibre reinforced composites with special reference to the composition and physical properties of banana pseudo-stem fibre, fibre surface modifications, and mechanical properties of banana pseudo-stem fibre polymer composites would be initiated.

Research background

Natural fibres like sisal, jute, coir, oil palm fibre have all been proved to be good reinforcement in thermoset and thermoplastic matrices (Joseph *et al.* 1996, Nishinoa *et al.* 2003, Geethamma et al. 1998). The idea of using natural fibres as reinforcement in composite materials is not a new or recent one. Man has used this idea, since the beginning of our civilization when grass and straw were used to strengthen mud bricks. During the seventies and eighties, these cellulose fibres were gradually substituted by newly developed synthetic fibres

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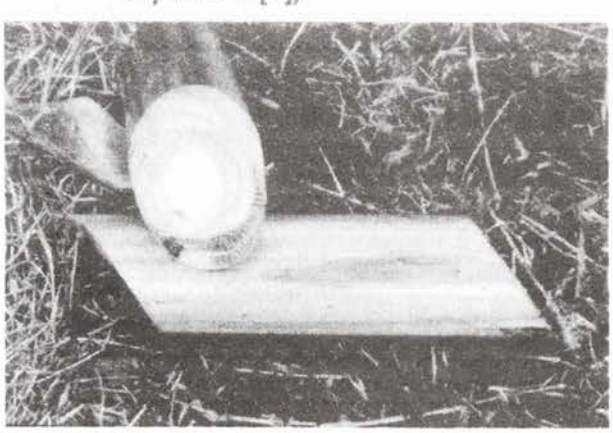
because of their better performance (Bledzki and Gassan 1999). Then, the use of cellulose fibres has been limited to the production of rope, string, clothing, carpets and other decorative products (Joseph *et al.* 1999). However, over the past few years, there has been a renewed interest in using these fibres as reinforcement materials to some extent in the plastics industry. This resurgence of interest is due to the increasing cost of plastics, and also because of environmental concerns for using renewable and biodegradable materials (Sapuan *et al.* 2001, Muhammad 2004).

Among the various natural fibres, banana pseudo-stem is of particular interest in that its composites have high impact strength besides having moderate tensile and flexural properties compared to other lignocelluloses fibres (Pothan *et al.* 2003). This agricultural activity generates a large amount of residues, because each plant produces only one bunch of banana, after its harvesting the bare pseudo-stems are cut and usually left to decompose. Thus, it could be estimated that few tons per hectare are produced annually (Sinha 1982). These crops could be utilized as a source of cellulosic fibres in papermaking and as reinforcing fibres in composite materials.

Structure and properties of banana pseudo-stem fibre

The cellulosic fibres obtained from the pseudo-stem (Figure 1) of banana plant is a bast fibre with relatively good mechanical properties. Banana contains fibres in the pseudo stem which may be extracted by scraping with a blunt knife or by using an extractor machine. The fiber is coarser than jute, has a non-mesh structure and long filaments with good strength and greater extension than those of jute (Paul 1980). Drying of fibres before processing is an important factor, because water on the fibre surface acts likes a separating agent in the fibre–matrix interface. This phenomena lead to a decrease of mechanical properties of natural fibre reinforced composites if it is not properly controlled. Therefore, fibre drying can be done in a vacuum stove at different temperatures. This results in different degrees of loss of humidity (Bledzki and Gassan 1999).

Figure 1. **Banana pseudo-stem (*Musa sepientum*[L])**



The properties and performance of a given agro-based fiber depends on chemical composition and the physical properties (Table 1 and 2). What part of the plant the fiber came from, the age of the plant, and how the fiber was isolated, are some of the factors which affect the performance of those fibres in a composite. Even with the data available, it has been collected under different laboratory conditions and, therefore, it is impossible to compare one set of data with another set. This information is critical before agro-based fibres will reach their highest potential (Joseph *et al.* 1999)

The importance of research

Sapuan *et al.* (2001) observed that plant based fibre reinforced composites to be potentially good alternative to conventional fibre reinforced composites. The fibre which serves as a reinforcement in reinforced plastics may be synthetic or natural. Although glass and other synthetic fibre-reinforced plastics possess high specific strength, their fields of application are very limited because of their inherent higher cost of

Table 1. **Details of composition analysis of banana pseudo-stem fibres (Sinha 1982)**

Composition	Banana-fibre
Major constituents (% of dry fibre)	
Holocelulose	88.7
α-cellulose	61.5
Lignin	9.7
Pentosan	14.9
Uronic anhydride	5.3
Pectin	1.6
Acetyl content	2.8
Minor constituents (% dry fibre)	
Fat and wax	1.3
Nitrogen matter	1.6
Ash	4.7
Other parameters	
Loss on water boiling	2.5
Loss on 1% alkali boiling	28.6
DP of α-cellulose	1300
Ultimate all length (mm)	0.9-4.0
Ultimate all diameter 10^{-4} cm	12-33
L/B ratio	100

Table 2. **Physical properties of banana pseudo-stem fibres (Sinha 1982)**

Physical characteristics	Banana fibre
Single fibre tenacity (gf per tex)	50 (17.0-78.8)
Single fibre extension at Break (%)	2.5 (1.5-3.4)
Fibre bundle tenacity (gf per tex)	28.4 (22.0-33.4)
True density (g cm^{-3}	1.31
Apparent density (g cm^{-3}	0.62
Fibre porosity (%)	53
Uncombed linear density (tex) of 2 mm cut length	10.5 (30-12.0)
Flexural rigidity (dyn cm-2)	33 (20-50)
Moisture regain at 65% Relative humidity (%)	15-2
Length of raw fibre (cm)	85 (45-100)

production. Some of these natural fibres are not only strong and lightweight but also relatively cheap (Paramastvam and Kalam 1974).

These fibres, which are available in bulk due to the increasing cultivation of banana needs immediate attention for their exploitation. Investigations on banana pseudo-stem fibre clearly indicate that these agro wastes can be suitably processed into useful products. Banana pseudo-stem fibre can also be used, as is evident from its chemical nature, as a cellulosic raw material for paper, board, cellulose derivatives, etc.

Their proper use will improve the economy of cultivation of the fruits and benefit farmers. They will also satisfy the need of plastic product based industries for raw materials or supplement the growing demand for industrial fibres and do away with the necessity of bringing in additional land for their production. The prerequisites for channelling the fibres to industry are: (i) the optimisation of the properties of the fibre, as well as its yield, by following improved techniques of fibre extraction; (ii) a steady bulk supply; (iii) development of a processing technology for the fibres; (iv) and development of a market for the products (Sinha 1982).

Research on banana pseudo-stem fibres composites

The mechanical properties of the natural fibre composites tested were found to compare favourably with the corresponding properties of glass fiber polypropylene composites. The specific properties of the natural fibre composites were in some cases better than those of glass (Table 3). This suggests that natural fibre composites have a potential to replace glass in many applications that do not require very high load bearing capabilities.

Banana pseudo-stem fibre is comparable to fibres of other agricultural crops, such as sisa and pineapple

Table 3. **Comparison between natural and glass fibres (Wambua *et al.* 2003)**

Properties	Natural fibres	Glass fibres
Density	Low	Twice that of natural fibres
Cost	Low	Low, but higher than NF
Renew-ability	Yes	No
Recycle-ability	Yes	No
Energy consumption	Low	High
Distribution	Wide	wide
CO2 neutral	Yes	No
Abrasion to machines	No	Yes
Health risk when inhaled	No	Yes
Disposal	Biodegra-dable	Not biodegradable

(Table 4). The influence of fibre content and fibre length from banana pseudo-stem fibres epoxy composites were examined by Bledzki and Gassan (1999) and it was found that in glass-fibre-reinforced polypropylene, the impact strength increases with increasing fibre length.

Fibre-matrix interaction

Franco and Gonzalez (2004) studied the mechanical behavior of continuous natural fiber reinforced composite and found that the fiber-matrix interaction were changed by modifying the surface properties of the fiber. Firstly, the area of contact was increased, then the cellulose microfibrils were exposed to improve fibre wetting and impregnation. To improve the adhesion between the cellulosic fibres and the polymer, different authors have suggested various chemical modifications (Botaro and Gandini 1998).

However, plant based fibre reinforced composites require surface treatment (fibre surface treatment by bonding/coupling agent) for better performance, especially fibre resin interfacial bonding. Pothan and Thomas (2003) concluded that composites with better modulus and low damping ideal for use as a substitute

Table 4. **Mechanical properties of natural fibres and work of fracture of their composites Joseph *et al.* 1999).**

	Fibre Properties			Composite Properties	
Fibre Type	Tensile Strength	Elongation (%)	Toughness (MM m^{-2})	Fibre Pull-out Layer (mm)	Work of (KJ m^{-2})
Sisal	580	4-3	1250	3.5	98.7
Pineapple	640	2.4	970	2.2	79.5
Banana	540	3.0	816	1.9	51.6

for building material can be developed from banana pseudo-stem fibre and polyester resins by the judicious control of the interphase chemistry. Silane A174 was found to be an ideal coupling agent for improving fibre-matrix adhesion in banana-polyester system. Joseph *et al.* also (2002) found that interfacial shear strength values obtained from single fibre pull out test reveal that the interlocking between banana pseudo-stem fibre and phenol formaldehyde resin is much higher than that between glass and phenol formaldehyde resin.

Mechanical properties

Pothan *et al.* (2003) found that the dynamic mechanical properties of short banana pseudo-stem fibre reinforced composites are greatly dependent on the volume fraction of the fibre. The maximum improvement in properties is observed for composites with 40% fibre loading, which is chosen as the critical fibre loading. Another study leaded by O'Donnell *et al.* (2004) found that natural composites were found to have mechanical strength suitable for applications such as housing and automotive. It is also suggested that this composites study still need further investigation in order to monitor the post-curing behaviour and degradation over a long period of time (aging).

The stress relaxation behaviours of banana pseudo-stem fibre-reinforced polyester composites have been found to be dependent on the amount of banana pseudo-stem fibre. The rate of stress relaxation was found to be at a maximum during the initial stages. Incorporation of fibre reduced the rate of stress relaxation and the highest reduction was observed in the case of composites with the highest fibre loading (Pothan *et al.* 2004).

Zhu and Tobias (1994) found that a pulped banana fibre is a satisfactory fibre for incorporation into a cement matrix suitable for use as building material. In term of design, Sapuan and Maleque (2005) employed a systematic approach of total design process in the fabrication of natural woven fabric reinforced epoxy composite for household telephone stand.

Mechanical analysis of short randomly oriented intimately mixed banana/sisal hybrid fibre reinforced polyester composites was investigated by Idicula *et al.* (2005) with special reference to the total volume fraction of the fibre and varying the relative volume fraction of the two fibres. The tensile strength, tensile modulus, flexural, strength, flexural modulus and impact strength of the composites at different volume fraction of fibres are outlined in Table 5. All this behaviour shows that effective stress-transfer and fibre/

Table 5. **Mechanical properties of banana/sisal hybrid composites having different volume fraction of the fibres (Idicula *et al.* 2005).**

Volume fraction of The fibre (banana + sisal).	Tensile strength (MPa)	Tensile Modules (MPa)	Flexural Strength (MPa)	Flexural Modules (MPa)	Impact Strength (MPa)
0.19	39	1347	48	2247	16
0.32	51	1443	53	2376	32
0.40	57	1601	62	2842	36
0.48	58	1597	56	2950	38

matrix interaction takes place at a fibre loading of 0.40 volume fraction.

CONCLUSION

Mechanical properties of short banana pseudo-stem fibre reinforced composites are greatly dependent on the volume fraction of the fibre. The optimum improvement in properties is observed for composites with 40% fibre loading, which is chosen as the critical fibre loading. The mechanical properties of composites are influenced mainly by the adhesion between matrix and fibres. As in the case of glass-fibres, the adhesion properties can be changed by pretreating the fibres. So, special processings, such as chemical and physical modification methods should be developed. Banana Pseudo-stem Fibre Polymer Composites With And Without Hybridization Should Be Developed And Characterized So As To Arrive At A Series Of Composites Which May Find Use In Several Areas Such as Structural, Consumer Articles and Industrials Applications.

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REACTION TO DISEASES BY FOUR RICE VARIETIES IN TWO AGRO-ECOLOGICAL LOCATIONS IN MOROBE PROVINCE, PAPUA NEW GUINEA

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ABSTRACT

Four rice varieties were evaluated for their reaction to diseases in two agro-ecological locations in Morobe Province of Papua New Guinea. Brown spot, sheath rot, bacterial leaf blight, narrow brown leaf spot, sheath blotch and grain spot diseases were of common occurrence. Two of those, sheath blotch caused by Pyrenochaeta oryzae *and bacterial leaf blight caused by* Xanthomonas oryzae pv. oryzae *are recorded for the first time in PNG. There were significant differences among the varieties with respect to bacterial blight and brown spot severity. Disease severity was significantly higher ($p \leq 0.05$) in the second year of trials in both the locations. The epidemiological aspects of these diseases, their implications on yield and management strategies are also discussed.*

Key words: *Rice, disease index, epidemiology, control*

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important cereals in the world. Rice was introduced to Papua New Guinea (PNG) in 1891 by the Filipino Catholic missionaries (Mills 2002). Despite the introduction a century ago, rice industry is still at its infancy. However, rice has quickly become a vital staple for many Papua New Guineans, particularly those in the urban areas and the per capita consumption rose to about 32 kg per annum (Mills 2002). PNG imports about 140,000 tons of rice annually with a retail value of K350 million (Sajjad *et al.* 2003). Successive PNG governments have encouraged domestic production but it never exceeded 2% of the country's requirements (Mills 2002).

Rice importation has been seen as expensive and a high cost to the balance of payment. The National Executive Council of PNG government in 1998 approved the Rice and Grain Policy with the aim to gradually reverse the trend of rice imports through domestic production (Anonymous 2003).

In the recent past, research on rice production has strengthened. A lot of work is being done on rice varietal selection (Sajjad 1995a; Sajjad *et al.* 2003), agronomy of rice production (Pitala 2001; Sajjad 1994, 1998; Sumbak 1977; Wohunangu and Kap 1982), fertilizer management (Sajjad 1995b), consumer preference and physico-chemical studies (Amoa *et al.* 1995, 1996) and studies on the constraints of rice cultivation (Dekuku 2001a, b). However, hardly any systematic research is done on rice diseases, particularly on varietal reactions, spread, distribution, epidemiology except for noting the occurrence of some diseases in different areas.

Knowledge of plant disease incidence, severity and spatial pattern is becoming increasingly important, as the economics of agriculture require more critical decisions at all levels. Government, public and private institutions use this information to evaluate their long-term research goals and resource allocations. Growers and agricultural advisors use it to make pest management decisions. Occurrence of diseases varies in different agro-ecological zones depending on factors such as climate, soil, crop varieties and acreage under cultivation. Crop varieties differ with respect to disease resistance/susceptibility. Prior knowledge of the varietal reactions to diseases is one of the key factors in selecting the variety (-ies) suitable for a particular area. Rice is being grown in the country on a very small scale for long but no systematic work is done in PNG about the rice disease occurrence in different agro-ecological zones. The objectives of this research were to identify the various diseases and determine their severity in four-rice varieties/lines under rain-fed condition at PNG University of Technology (Unitech) farm, representing the wet costal regions and Trukai farm at Clean Water in Markham valley of Morobe Province, representing the drier interior valleys.

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MATERIALS AND METHODS

Site Description

Unitech site: The experimental site was located in the Agricultural Farm of the PNG University of Technology, Lae, Morobe Province and is situated at 6°45' S and 147° E at an altitude of 65 m.a.s.l. The site represents the wet coastal areas with unimodal rainfall distribution with the peak during May to July. The mean annual rainfall is higher than 3500 mm and evaporation is about 1800 mm. Mean annual maximum and minimum temperatures are 30°C and 23°C respectively (Gurnah 1992)

Clean Water site: Trukai Clean Water farm at Erap in the Markham valley, Morobe Province is situated at 7°S, 147°E and 90m above sea level. This site represents the dry lowland sub-humid zones. Mean annual rainfall is 1000 – 1500 mm with marked seasonality and a long dry season which occurs from May to November. Temperatures range from 20°C to 30°C. Evaporation is 2200 mm and the ratio of rainfall to evaporation is less than 1 (Gurnah 1992).

Rice Varieties (Treatments)

The rice varieties tested were Taichung Sen 10 (TCS 10), Finchs, BG 379-2 and IR 19661-23-3-2-2 (NR1). The first two varieties have been commonly cultivated in many parts of PNG as upland varieties. The later two are promising lines resistant to BPH. The National Agricultural Research Institute has recently released IR 19661-23-3-2-2 as 'NARI RICE 1' (NR1).

Experimental Design

The trials were laid out in Randomized Complete Block Design (RCBD) in each location and year with four replications. Each of the plots was 3m x 5m and was separated by 1m foot path.

Field Establishment and Maintenance

Land preparation: At Unitech farm, plots were ploughed and harrowed twice to incorporate any primary growth/stubble and establish a reasonable seedbed. At the time of land preparation and 15 days before planting, Glyphosate (Round up), a pre-planting herbicide was applied at 4L/ha. Dried dead weeds were ploughed under and a seedbed was established. In the second trial at Unitech farm no herbicide was used.

At Clean Water site, the experimental plot was sprayed with Glyphosate at 1.5 L/ha a few weeks after the harvest of the previous crop. About a month before planting, the plot was ploughed with the tractor and left open. Three to four days after ploughing, the plot was rotovated twice and was ready for the sowing of rice seeds.

Fertilizer rate and application time: Fifty kilograms of NPK (12:12:17) per hectare was applied as a basal dose. Additional nitrogen fertilizer was applied as urea at 20 kg N/ha in two splits during early and late tillering stages.

Seed rate: Four to five seeds were planted in each hole, that is equivalent to a seeding rate of 90kg per hectare.

Sowing time and method: A total of four trials were conducted, two in each site of Unitech Farm and Clean Water.

The first trial at Unitech site was seeded on 18 May 2001. The second trial in the same site was planted on 10 May 2002. Seeds were sown in holes at 25 cm X 25 cm. Seeding was done with a dibbler at 4 cm depth. The trials were harvested during October of the respective years.

The first trial at Clean Water was planted on 10 December 2001 and was harvested in April, 2002. The second trial in the same location was planted on 12 December 2002 and was harvested during April-May 2003. The differences in the planting times in two locations are due to the differences in the main wet season.

The treatments and the design remained the same at both sites over the period of the trials. All the intercultural operations were also similar for all the trials.

Disease Recording

Disease record was taken from seedling to maturity stages. Narrow brown leaf spot caused by *Cercospora oryzae* was observed in all the varieties at both locations and years throughout the growing seasons, but the severity was very low (less than 1%). As a result no severity was recorded but the occurrence was noted for the varieties. Sheath blotch caused by *Pyrenochaeta oryzae*, which is a new report in the country does not have any standardized scale. Occurrence of sheath blotch was recorded as low, moderate or severe. Disease severity of the three most commonly occurring diseases, brown spot caused by *Drechslera oryzae*, bacterial leaf blight caused by *Xanthomonas oryzae* pv. *oryzae* (which is also the first report in PNG), and sheath rot caused by *Sarocladium oryzae* were recorded before harvest following the Standard Evaluation Systems (SES) of IRRI (IRRI 2002).

Data Analyses

Disease index (DI) data for brown spot, bacterial blight and sheath rot over the sites and years were analyzed using appropriate statistical package. Disease severity data were analyzed using analysis of variance (ANOVA). The ANOVA over the years in a site indicated non-significant interactions ($p>0.05$) between the treatments (varieties) and years. However, significant interactions ($p \leq 0.05$) were found between the treatments and sites.

RESULTS

Unitech site

Five diseases, namely brown spot, narrow brown leaf spot, sheath rot, bacterial leaf blight and sheath blotch were recorded at Unitech site. The severity of Narrow brown leaf spot was very low (< 1%), thus, only the occurrence of the disease was noted. All the varieties were more or less equally infected by Narrow brown leaf spot. In the first trial, low level of infection of sheath blotch was observed only on NR1.

Brown spot severity ranged from 1.83 to 4.50. The highest severity was observed on NR1 and the lowest on TCS10. Brown spot severity on NR1 was significantly higher ($p \leq 0.05$) than the TCS10, BG379-2 and Finchs. There was no significant difference among TCS10, BG379-2 and Finchs (Table 1). The brown spot severity in the 2002 was significantly higher ($p \leq 0.05$) than the first trial in 2001 by 56.80% (Table 2).

Bacterial blight severity ranged from 2.75 on TCS10 to 6.25 (more than 50% leaf area infection) on Finchs. Disease on Finchs was significantly higher ($p \leq 0.05$) than the other three varieties. The bacterial blight infection on NR1 was significantly higher than TCS10 but was not significantly different from BG379-2 (Table 1). Bacterial blight severity differed insignificantly by only 1.5% between the trials in two seasons (Table 2).

Severity of Sheath rot was found to be low on all the varieties. Sheath rot severity ranged from 2.25 on BG379-2 to 3.0 on TCS10 but the differences were not significant among the varieties (Table 1). However, overall sheath rot severity was significantly higher ($p \leq 0.05$) in year 2002 compared to year 2001 by 75.26% (Table 2).

Clean Water site

Six diseases were observed at Clean Water. Data for the three most commonly occurring diseases are presented in Table1.

Narrow brown leaf spot infection was low (about 1%) in all the rice varieties at Clean Water. However, the disease level on Finchs was a bit higher compared to the other three varieties.

A moderate level of sheath blotch infection was also observed on all four rice varieties in both years. Severity level appeared to be a bit higher on Finchs and NR1 compared to TCS10 and BG379-2.

Brown spot severity in clean water was low to moderate. Highest severity of 3.0 was observed on NR1 and the lowest being 1.13 on Finchs and this difference was significant at $p \leq 0.05$. Finchs and TCS10 did not differ significantly their disease levels were significantly lower than BG379-2. The overall brown spot severity level was also significantly higher

Table 1. **Severity of different rice diseases at the Papua New Guinea University of Technology and Clean Water, Markham Valley, Morobe Province, Papua New Guinea for two years.**

Variety	Disease Index (DI)					
	Sites					
	Unitech Farm			Clean Water Farm		
	Brown spot	Bacterial blight	Sheath rot	Brown spot	Bacterial blight	Sheath rot
TCS10	1.83 b	2.75 c	3.00 a	1.38 c	3.00 b	3.00 a
Finch	1.88 b	6.25 a	2.42 a	1.13 c	4.75 a	1.75 b
BG 379-2	2.38 b	3.13 bc	2.25 a	2.25 b	2.75 b	1.88 b
NR1	4.50 a	4.00 b	3.00 a	3.00 a	4.75 a	3.63 a

All the numbers are the means of four replications. Means followed by the same letter in a column are not significantly different at $p \leq 0.05$ (LSD)

($p \leq 0.05$) in the 2002 trial over the 2001 trial by 81.16% (Table 2).

Low to moderate level of bacterial blight was observed on all four rice varieties. Bacterial blight severity of 4.75 was observed on both Finchs and NR1 followed by TCS10 with 3.0 and BG 379-2 being the lowest with 2.75. Finchs and NR1 had significantly higher disease than TCS10 and BG379-2 and the latter two did not differ significantly. The overall disease level was significantly higher ($p \leq 0.05$) in 2002 over 2001 by 77.45% (Table 2).

Sheath rot severity was low to moderate among the rice varieties. Highest severity level of 3.63 was observed on NR1 followed by TCS10, BG379-2 and Finchs. Severity of on NR1 and TCS10 was significantly higher than BG379-2 and Finchs but the former two are not significantly different. Non-significant difference in disease level was also found between Finchs and BG379-2. Overall, sheath rot severity level was significantly higher ($p \leq 0.05$) during the second year of trial over the 1st trial by 72.87% (Table 2).

Grain discoloration of moderate severity was observed only on NR1 in the second year of trial. This grain discoloration could be due to many pathogens including brown spot and sheath rot.

DISCUSION

Six diseases were recorded with varying level of severity on four rice varieties tested at two sites in two different agro-ecological zones over two successive years. Among these, Sheath blotch and Bacterial leaf blight were reported for the first time in PNG.

Narrow brown leaf spot was observed from seedling to maturity stage and the severity was quite low (d" 1%). This level of disease does not seem to have any impact on yield, although the severity level was slightly higher in the case of Finchs.

Sheath blotch was reported for the first time in PNG (Akanda *et al.* 2003). The disease infects the leaf sheaths during tillering to maturity stages. Due to severe infection, leaf sheaths become dead, making the plant weaker and susceptible to lodging. At the Unitech site, only NR1 was infected during the first trial (2001). But during the second trial, all of the four rice varieties had low to moderate level of infections. On the contrary, a moderate level of infections was observed in Clean Water on all the varieties in both years. The severity level was also a bit higher in Clean Water. The difference in the disease level between the two sites might be due to the fact that rice has been cultivated in Clean Water for several years compared to only two years at Unitech. It is also worth mentioning that at the Unitech farm the experimental site has never been under rice cultivation. There might have been higher pathogen population at Clean Water, perpetuated and accumulated over the years due to continuous rice cultivation. It was also evident that at Unitech site, even though in the first trial (the very first crop in that site), only NR1 was infected with sheath blotch. During the second year of trial, all the varieties were infected. This might be due to infected straws left in the soil. The pathogen population increased and spread to all other areas because of ploughing during the land preparation. From this it is evident that with continuous rice cultivation over the years in the same land, the severity of sheath blotch might be quite severe. Burning of infected straws could be beneficial in reducing the inoculum level in the soil and in turn the disease level.

Brown spot disease was observed from seedling to maturity stages with low to moderate level of infection on all the varieties in both years and sites. Overall, brown spot severity was significantly higher on NR1 in all the location and years. The highest severity (DI)

Table 2. **Differences in the severity of rice diseases in two successive years at the Papua New Guinea University of Technology and Clean Water, Markham Valley, Morobe Province in Papua New Guinea.**

Site	Name of disease	Disease Severity		Percent severity increase over 2001
		2001	2002	
Unitech Farm	Brown spot	2.06 b	3.23 a	56.80
	Bacterial blight	4.00 a	4.06 a	1.50
	Sheath rot	1.94 b	3.40 a	75.26
Clean Water Farm	Brown spot	1.38 b	2.50 a	81.16
	Bacterial blight	2.75 b	4.88 a	77.45
	Sheath rot	1.88 b	3.25 a	72.87

All the numbers are the means of four replications. Means followed by the same letter in a row are not significantly different at $p < 0.05$ (LSD)

of 5.50 (about 15-25% leaf area infected) was observed at Clean Water during the second trial. Among other factors, the drought period during flowering period could have contributed to the increase in brown spot severity, particularly, if the plants suffer from water stress during the flowering and/or grain filling periods.

Brown spot of rice is also regarded as the "poor man's disease" as the severity is enhanced by infertile soil due to the deficiency of nitrogen and potash (Havlin *et al.* 1999; Miah and Shahjahan, 1987; Misawa 1955; Sato *et al.* 1959). The soil, particularly in the Unitech farm is lighter, sandy with low water holding capacity and also deficient in potassium (personal observation) in both locations. This could have had some effect on the severity of brown spot on different varieties. As a leaf disease, brown spot reduces the photosynthetic area and affects grain filling. With moderate level of infection, the grain yield can be reduced by 12% and with severe infection yield loss could be as high as 30-40% (Aluko 1975). Brown spot was also responsible for Bengal famine in 1942, when yield losses up to 90% were recorded (Ghose *et al.* 1960; Agrios 1997). Another major impact of brown spot is the reduction in grain quality; due to increase in grain spotting and/or discoloration. During milling, most of the grains are broken and provide black and lower quality rice. Brown spot is a seed borne disease and if the severely infected seeds are used for planting, it can cause germination failure and seedling blight with about 10-58% seedling mortality (Ocfemia 1924).

As Brown spot is a seed borne disease, un-infested areas could easily be contaminated with the distribution of infected seeds. Care should be taken so that seeds are collected only from the un-infected areas for multiplication purposes. Seed treatment with hot water (53-54°C) for 10-12 minutes also reduces the pathogen level. Presoaking the seeds for 8 hours increases the effectiveness of the treatment. The hot water treatment reduces the initial inoculum in the seeds and in turn reduces the chances of germination failure. However, this does not guarantee that there would be no disease, particularly, at the later stages because of the spore dispersal from the neighboring plants or even from the collateral hosts. Chemical control of the disease is possible, but may not be economically profitable, environmentally unfriendly, and may increase the probability of pathogen resistance. Use of resistant varieties and cultural practices could be the easiest options. In this aspect, in terms of brown spot, probably TCS10 is a bit better than the other varieties and is also higher yielding. Field sanitation, crop rotation, adjustment of planting dates to avoid water stress during the later stages of life cycle, good water management and proper soil nutrition are effective in reducing brown spot (Ou 1985).

Sheath rot disease affects rice plants at the booting stage and in severe cases, the panicles cannot emerge. The varieties did not differ significantly at $p \leq 0.05$ with respect to sheath rot. The boot stage is the most vulnerable stage of the rice plants for sheath rot. The disease is aggravated by heavy application of nitrogenous fertilizers (Akanda *et al.* 1984). Moreover, the severity gets higher when the plants are weakened by any stress and/or by tungro disease and stem borers. Sheath rot a seed borne disease, not only affect grain yield, but also reduces the grain quality by causing discolouration. A severity level of seven (DI 7) or above could lead to zero yield, suggesting that the disease has high potential for decreasing yield (Shahjahan *et al.* 1994).

Bacterial blight is a new record for PNG (Akanda 2002) and was significantly higher ($p \leq 0.05$) on Finch than in other rice varieties. The disease severity on the other three rice varieties was moderate to low but not significantly ($p \leq 0.05$) different (Table1). Bacterial blight occurs during the panicle initiation to boot stage and affects the leaves and is more severe and destructive when infection takes place at paincle initiation to boot stage. The high temperature in the tropics accompanied by high humidity is favourable for the growth of the bacteria and development of the disease. Torrential rain and high wind further aggravates the disease condition as these not only disseminate the bacteria but also cause wounds on the leaves making it easier for the bacterial penetration. It is advisable not to apply nitrogenous fertilizers immediately after torrential rain and/or wind. By reducing the photosynthetic leaf area, it reduces the yield by affecting the grain filling. Bacterial blight is aggravated when the rice crop is grown under high nitrogenous fertilizers and yield loss could be as high as 20 to 30% in severely infected fields (Srivastava 1967). Use of resistant variety (-ies) is the most important option for the management of bacterial leaf blight. The TCS10 could probably be better than the other three varieties.

As these trials were conducted under natural disease condition and the level of diseases were not that high, these varieties need to be tested with artificial inoculations to determine and confirm their genetic resistance/susceptibility.

Disease level was considerably higher in the second year of the trials in both locations. Similar trials need to be conducted in other agro-ecological zones over several years to monitor the disease buildup and to devise appropriate control measures to reduce the buildup of diseases in the subsequent years of rice mono-culture.

Gradual intensification of rice cultivation in PNG will increase the number and severity of more new diseases over time and some of these diseases may become a major threat to the emerging rice industry. It is probable that many of the diseases are already in existence but not recognized and identified until now. So far, no systematic and proper survey is done to identify different rice diseases and to determine the status and destructive potential of these diseases under PNG conditions. This is of utmost importance not only for the management purposes but also to decide on what variety (-ies) to grow in those areas. A systematic survey is essential to identify the different diseases in different rice growing areas, determine their status, pathogenic variability, environmental condition including soil and related farmer practices, so that proper and sustainable, environmentally friendly management practices could be developed for the rice industry in PNG.

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ANALYSIS OF THE VOLATILE CHEMICAL CONSTITUENTS OF TUMERIC (*CURCUMA LONGA* LINN: ZINGIBERACEAE)

Stewart W Wossa[1], Topul Rali[1*] and David N Leach[2]

ABSTRACT

The volatile oil constituents of tumeric were extracted through exhaustive hydro-distillation and the individual chemical components identified using a gas chromatograph coupled with a mass spectrometer (GC/MS). Eleven components were identified, representing 87.2 % of the total oil composition with the tumerones comprising 80 % of the oil. It was found that ar-tumerone (33.6 %); â-tumerone (30.0 %) and á-tumerone (16.4 %) were the main constituents in the volatile oil extracts of tumeric while the other terpenes made up the balance.

Keywords: *Curcuma longa*; Zingiberaceae; tumeric; spice; essential oil; tumerone; curcumin.

INTRODUCTION

Tumeric (*Curcuma longa* Linn.; Zingiberaceae) is a perennial herb that grows up to a height of about 1 meter with comparably shorter stems and large oblong leaves. It bears short-branched rhizomes that are brownish-yellow in color and possess a distinct aromatic note. It is native to southern India but is now grown in most tropical and subtropical climatic zones of the world, and its distribution has been observed throughout Asia, Africa and South America. It has been the subject of extensive studies due to its medicinal and economic importance.

The rhizomes of tumeric have had a long tradition of use as food flavour, additive, preservative and colouring agent as well as in the Chinese and the Ayurvedic systems of medicine (Araujo and Leon 2001). Such preference for medicinal and condimental uses has been attributed to the presence of certain chemical constituents in the rhizome extracts. The main component of commercial interest in tumeric is curcumin and it's other derivatives. Curcumin is the principal chemical compound responsible for the yellow colour of tumeric and is also the active ingredient in the commercially available curry powder. It has been reported to show anti-inflammatory (Such 2002; Brag *et al*. 2003; Chainani 2003; Huang *et al*. 1992), anti-oxidant (Sacchetti *et al*. 2005; Unnikrishnan and Rao 1995; Reddy and Lokesh 1992; Sreejayan Rao 1994), anti-protozoan (Araujo *et al*. 1998, 1999), anti-bacterial (Chopra *et al*. 1941; Bhavani Shankar and Murthy 1979), anti-HIV (Mazumber *et al*. 1995; Eigner and Scholz 1999), anti-tumor (Kuttan *et al*. 1985; Kuttan *et al*. 1987; Huang *et al*. 1988, 1991; Narayan 2004; Lai and Roy 2004; Ji *et al*. 2004; Duvoix *et al*. 2005; Aratanechemuge *et al*. 2005; Hanif *et al*. 1997; Aggarwal *et al*. 2003) and hosts of other potent biological activities. The other curcumin derivatives ar-tumerone is anti-venom (Ferreira *et al*. 1992), demethoxycurcumin and bisdemethoxycurcumin have anti-oxidant properties (Unnikrishnan and Rao 1995) and sodium curcuminate is anti-inflammatory (Ghatak and Basu 1972).

The volatile constituents from the rhizomes of tumeric have been reported from different regions of the world to contain different chemical constituents as the main components. Such reports indicate the main constituents of the tumeric rhizomes to be á-curcumene and á-zingiberene (Hu *et al*. 1998), 1,8-cineole (Raina *et al*., 2002) and the à- and â-tumerones (McCarron *et al*. 1995; Bansal *et al*., 2002, Raina *et al*. 2002; Leela *et al*. 2002). The leaf essential oils of tumeric have also been extensively studied and reported to be composed of ñ-cymene (Garg *et al*. 2002), terpinolene (Oguntimein *et al*. 1990, Raina *et al*. 2002), myrcene (Bansal *et al*. 2002) and á-phellandrene (Leela *et al*. 2002; Behura *et al*. 2002) as the main constituents.

In an ongoing study to establish the volatile chemical constituents from the spice products of Papua New Guinea (PNG) (Rali *et al*. 2003; Wossa *et al*. 2005),

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we report herein the chemical constituents in the rhizome oil of tumeric obtained from the East New Britain Province.

MATERIALS AND METHODS

Representative tumeric rhizomes were obtained from Rabaul in the East New Britain Province of PNG. The essential oils from these samples were extracted by exhaustive hydro-distillation at the University of PNG laboratory using a modified all-glass standard distillation apparatus, and the pure oils obtained were dried over anhydrous magnesium sulphate. The oil was analyzed using a gas chromatograph coupled to a mass spectrometer (GC/MS) and the individual components identified.

The analyses of the oil constituents were as previously described (Wossa *et al.* 2005). The individual oil constituents were identified by their respective retention indices and confirmed by comparison to the mass spectral data of the authentic reference compounds or with the library of the published data (Adams 1995).

RESULTS AND DISCUSSIONS

The volatile oil from the fresh rhizomes of *Curcuma longa* afforded colorless oil in 0.61 % yield. The major constituents of the volatile oil were predominantly sesquiterpenes as outlined in Table 1, with ar-tumerone (33.6 %), â-tumerone (30.0 %) and á-tumerone (16.4 %) as the major constituent of the tumeric oil while other components made up the balance.

These results compliment the work previously reported (McCarron *et al.* 1995; Bansal *et al.* 2002; Leela *et al.* 2002; Raina *et al.* 2002) where tumerones are the main constituents. It further indicates that the tumerone contents from the tumeric obtained from Rabaul are higher (80.0 %) than that reported in literature from other regions of the world.

We also note, however, that some of the volatile components of *C. longa* reported in literature as major constituents but found to be in lesser amounts in our study include á-phellandrene, 1,8-cineole, ar-curcumene, á-zingiberene and â-sesquiphellandrene. Such variability in the composition of the essential oil constituents of tumeric further confirm an earlier postulation that the chemical compositions differ within species from different geographical localities due to the climatic and geographical conditions as well as the soil types and the age at harvest (Miyazaki and Taki 1955). An important factor that may also contribute to such variation in the chemical composition is the type of cultivars used and its unique genotypes that are further influenced by the local environmental conditions in which the cultivars are grown.

Our results indicate that the cultivars used in Rabaul produce high tumerone yields in the volatile oil and are therefore of commercial significance. Such high yields suggest the potential for large-scale cultivation and commercialization of this particular cultivar of tumeric as an agricultural commodity. Further, downstream processing of the rhizomes of tumeric to obtain these chemicals of importance through appropriate technology will increase market value, hence high economic returns. In realizing these prospects, it is worthy that further research are undertaken towards value added production of commodities.

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Table 1. Chemical composition in the volatile oil distillates of *Curcuma longa* L.

Chemical constituents	Retention indices	% Composition
á-phellandrene	1027	0.7
1,8-cineole	1058	1.7
ar-curcumene	1507	1.2
á-zingiberene	1519	1.2
â-sesquiphellandrene	1555	1.4
2-methyl-6-ñ-tolyl-2-hepten-4-ol	1659	1.0
â-tumerone	1703	30.0
ar-tumerone	1708	33.6
á-tumerone	1747	16.4

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LIVE WEIGHT GAINS OF BRAHMAN BEEF ENTIRE MALES COMPARED WITH STEERS IMPLANTED WITH COMPUDOSE®.

Gariba Danbaro[1]

ABSTRACT

Liveweight gains (LWG) of 58 Brahman steers and 66 entire males raised under similar conditions in the Markham Valley, a hot dry area of Papua New Guinea were compared. The steers were implanted with Compudose 400® containing synthetic oestradiol 17â and the measurement period was 120d starting from 112d after weaning. LWG of steers was found to be slightly lower than for entire males but the difference was not significant. This result, together with the costs and risks of castration necessitates careful consideration of the practice of raising steers rather than entire males under certain conditions in Papua New Guinea.

Keywords: *Growth, growth promotant, tropics, Brahman, beef cattle, Papua New Guinea.*

INTRODUCTION

In Papua New Guinea (PNG) about 80% of beef cattle are kept on large-holder ranches (Vincent and Low 2000) and are sold on mature liveweight basis. One important management practice on these ranches is castration of young beef males which are then implanted with synthetic growth promoters in the hope of improving their growth rates and feed efficiency. This practice is almost absent on small holder ranches probably due to high initial costs and lack of equipment, trained manpower and understanding.

Castration, among other uses, is believed to reduce wildness in cattle on ranches where human contact is minimal and also prevent undesirable pregnancies in mixed herds. However, castration deprives the animals of their natural sex hormones produced in the testes, which stimulate growth and affect other important production characters. Synthetic growth promotants such as Compudose 400® are therefore usually administered to the steers either as implants or injections to improve their performance. A number of studies have reported desirable effects of these synthetic hormones such as increased growth rate, feed efficiency and decreased fat deposition in steers (Minish and Fox 1982; Mathison and Stobbs 1983; Stobbs *et al*. 1987). According to its manufacturers, each Compudose 400® silicone rubber implant contains the same oestradiol 17â found in mammals including cattle and this compound is released in a controlled manner over a period of 400 days. Oestradiol 17â stimulates the pituitary gland resulting in the release of the animal's own natural growth hormone. The growth response of steers to growth promotants has however, been reported in the literature to depend on genotype of the animal and other environmental factors such as age and the plane of nutrition of the animal (Song and Choi 2001). Generally growth performance of steers on synthetic growth promotants are enhanced in more intensive systems such as feedlots where the plane of nutrition is often higher and other environmental challenges are minimal.

In PNG, however, most beef cattle are kept under range conditions where the availability of grazed pastures and their nutritional status depend on the season. In the rainy season pasture conditions and nutrient supply from pastures are usually better than in the dry season. Supplementary feeds such as molasses and copra meal are also used but the supply of these also varies in composition and availability. Furthermore there are inherent costs and risks of castration and use of synthetic growth promotants. Under these conditions a further re-examination of performance of beef steers under ranching conditions in PNG is necessary.

The objective of this study was to compare live weight gains (LWG) of Brahman entire beef males with those of steers implanted with Compudose 400®, in the Markham Valley, a hot dry tropical area of Papua New Guinea (PNG).

MATERIALS AND METHODS

The cattle used in this study were kept at the Sulikon cattle ranch of Trukai Farms, at Erap located 7°S, 147°E and 90m above sea level. Mean annual rainfall on the ranch is 1260mm with most of it falling between November and March while May is usually the driest

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month. Temperatures range from 20°C to 30°C. Cattle on the ranch were of the Brahman breed with a small amount of Javanese zebu inheritance introduced to improve reproductive performance. The breeding herd is usually mated to calve during a single calving period each year, from December to April, which corresponded to the wet season.

Calves used in this study were weaned in February 2001 and consisted of 142 beef males. The animals were randomly assigned to two treatment groups of equal size: entire males and steers. Steers were castrated, dewormed and implanted in June with Compudose 400®, under the skin of the earflap, about 112d after weaning. Liveweight of the cattle were measured on the day of implantation and, 120d later, at the end of the testing period.

All experimental animals received similar management practices usually employed on the ranch. Weaned cattle were rotationally grazed in paddocks containing both improved and native pasture species such as *Dichanthium* sp., *Bothriochloa* sp., *Imperata cylindrica*, *Brachiaria* sp., *Urochloa* sp., *Macroptilium atropurpureum* and *Stylosanthes* sp. at about 1.5 beasts/ha. Cattle were given supplements of copra meal and molasses and had access to drinking water and mineral and salt licks freely on the ranch.

The data analysed was on 124 cattle weaned between three and six months of age. Age at weaning, was included as a covariate in the fitted linear model, which, in statistical notation was:

$$Y = \mu + T + \beta X + \varepsilon$$

Where: Y is a liveweight gain (LWT) observation on a calf calculated as the difference between liveweight just before implantation of compudose and at the end of the test period; μ is a general mean; T is the treatment group of calve (entire males or steers); X is the age of the calf at weaning and used as a covariate; β is a regression coefficient and ε is a random residual term. The computations were run in the analysis of variance (unbalanced treatment structures) procedures of GENSTAT (2003).

RESULTS AND DISCUSSION

Table 1 shows the results of the analysis of variance of LWG of calves from time of implantation of Compudose 400® to the end of the test period. The treatment effect did not contribute significantly to variation in LWG among calves ($P<0.05$) indicating that both steers and entire males would perform similarly with respect to LWG and any differences among them could arise simply by chance. The mean LWG for entire males and steers were estimated to be 91.8kg and 86.1kg respectively (Table 2). Thus

Table 1. **Analysis of variance of liveweight gain of beef calves**

Source of variation	Degrees of freedom.	Sum of squares	F value
Age at weaning	1	4507.9	0.016*
Treatment group	1	986.8	0.254 ns
Residual	121	90748.1	
Total	123	96242.7	

* Significant
ns Not significant

Table 2. **Estimates of mean liveweight gain of beef calves.**

Factor	Subclass	Number of observations	Estimated mean LWG ± s.e. (kg)
Treatment	Entire males	58	91.8 ± 3.60
	Steers	66	86.1 ± 3.37

steers grew slightly less than entire males but the difference was not important. It is known that males generally grow faster than steers not implanted with synthetic growth promotants however only few reports have compared entire males with steers implanted with compudose.

LWG is known to have high positive phenotypic correlations with mature market weights (Koots *et al.* 1994), the trait by which cattle are sold in PNG. Thus this result suggests that steers may not produce extra profits from sold cattle as compared with entire males on the basis of mature market weights under the conditions of this study. This is more so because the domestic market for high quality meat associated with beef from steers (e.g. better texture, flavour, juiciness and tenderness) is limited. Other disadvantages associated with raising steers are the cost of castration and synthetic growth promoters and the risks of calf mortality from infections. On the other hand meat from bulls are known to be leaner, a quality which is now becoming an important public health consideration. Moreover beef males on the ranch are usually sold at relatively young ages where carcass quality would not be affected by the development of secondary sexual characters in the entire males. This result therefore suggests that beef cattle enterprises need to re-evaluate the practice of raising steers rather than entire males for the domestic market in PNG under the conditions mentioned in this study.

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BANANA VARIETIES TESTED FOR SIGATOKA DISEASE RESISTANCE UNDER IRRIGATED CONDITIONS IN PAPUA NEW GUINEA

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ABSTRACT

Fourteen introduced varieties of banana were tested for their resistance to Sigatoka disease and yield potential under irrigated conditions in the seasonally dry lowlands of Papua New Guinea. Varieties FHIA 02 and FHIA 18 showed extreme resistance to Sigatoka disease while the Australian common variety Williams was highly susceptible to the disease. FHIA 25 showed high resistance to the disease and produced the highest yield of 38 kg/bunch. Other good yielding varieties with high resistance to Sigatoka disease were FHIA 17 and SH 3436 with 20-21kg/bunch. The varieties most preferred by tasters as dessert bananas were SH 3436, Pisang Ceylan and Yangambi. Pisang Ceylan and Yangambi had bunch yields of 17kg and 13kg respectively and also showed high resistance to Sigatoka disease. The disease resistant varieties that are most prefered by the tasters will establish well in the country once introduced into farm production. These high yielding varieties will greatly boost banana production in the country and thus contribute to food security and income earning opportunities for the rural people.

Keywords: *Banana, varieties, Sigatoka, resistance, susceptible, consumer preference*

INTRODUCTION

Bananas is important source of energy and is a major food crop for millions of people in the tropical world. Most people in West and Central Africa obtain their food energy requirements from banana. Banana is essential export commodity for countries of Central and South America, and the West Indies. In Papua New Guinea (PNG), banana is the second most important staple food crop in terms of consumption and ranks third only to sweet potato and taro in production (Kambuou 2001). It is grown widely throughout the country and is a dominant staple crop in the Amele area of Madang, the Gazelle Peninsula of East New Britain, the Markham valley of Morobe and the coastal areas of Central Province. Stover (1987) reported a serious threat to banana production throughout the world from the Sigatoka leaf-spot disease complex, especially black Sigatoka caused by the fungus *Mycosphaerella fijiensis*. The disease complex is present in PNG and can cause up to 40 percent yield reduction in banana production, especially in high rainfall areas. The purpose of this study was to investigate resistance to Sigatoka disease, the re-infestation rates and yield potentials under irrigated conditions at Laloki, Central Province, of eight newly created hybrid varieties[2] from breeding programmes and six international common varieties of banana introduced from Queensland, Australia. Consumer preferences for these bananas were also assessed.

MATERIALS AND METHODS

Study Site

The study was conducted at the Dry Lowlands Research Programme, Laloki Station of the PNG National Agricultural Research Institute from 30th November 1998 to November 2001. Laloki Station is situated 25 kms from Port Moresby and located at an altitude of 30 m.a.s.l. The local climate is characterized by a marked dry season with day SE winds from May to October. The wet season with variable NW winds extends from December to April. The average annual rainfall is 1,100.00 mm. The soil is mostly allivial clay and the topography of the area varies from slightly rolling to flat. The tested varieties were planted adjacent to the PNG National Banana Germplasm field collection for easy access to Sigatoka spore inoculation.

Sigatoka Resistant Banana Varieties under Investigation

Table 1 gives the Sigatoka resistant hybrids derived from international breeding programmes and the

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[2] The term varieties is used here in a wide sense to cover both newly created hybrids for testng and established international varieties.

international common varieties of bananas that were used in the study. Variety Williams is a common commercial variety in Australia, susceptible to sigatoka disease but most favored as a dessert banana. It was included in the study as a control and on-going source of inoculation by the fungal spores.

The main variants measured were total bunch weight, number of hands per bunch, number of fingers per hand, finger diameter, finger length and pest and disease scores. Other variants recorded were number of days to flowering and to harvest of the first crop, and plant heights at the flowering and harvesting

Table 1. **List of Sigatoka Resistant International Banana Varieties**

Assigned Numbers	Varieties Derived from Breeding Programmes	Common Varieties
V88		Kluai Khai Bonng
V529	SH 3640	
V548	FHIA 03	
V549	FHIA 23	
V550	FHIA 17	
V560		Pisang Lilum
V601	SH 3436	
V621	FHIA 18	
V827		Pisang Berlin
V904		Williams
V905		Pisang Ceylan
V934	FHIA 02	
V944	FHIA 25	
V1030		Yangambi

Banana Plantlets in the Nursery

The banana materials were introduced as tissue cultured plantlets with 10 vials of each variety. The cultured plantlets were de-flasked on arrival, washed in tap water to separate the small plantlets, then sown into peat moss media in seedling trays. The trays were maintained under humid conditions in the nursery for one month to harden the plantlets. After a month the plantlets were transplanted into polythene bags and maintained in the nursery for another two months before they were planted out in the field. The seedlings were hand watered three times a week during the hardening stage in the nursery.

Design, Field Planting and Data Collection

The study had a randomized complete block design with four replicates and the 14 banana varieties as treatments. Plants were planted 1.5 m within rows and 2 m between rows. The gross plot area was 24 m^2 (6 m x 4 m) and the net plot area of 9 m^2 (4.5 m x 2 m) was harvested for analysis. Each plot contained 28 plants of which, 10 plants were harvested for analysis.

stages. Pest and disease scores, ranging from 0 (no infection) to 5 (severely infected) were recorded at monthly intervals after one month from planting through to harvest. Detailed recording of number and area of leaves infected with fungal spores was also done but results are not reported here. Data on finger lengths were obtained from the average of ten fingers from the third oldest hand of the bunch. Finger diameter measurements were taken from cross section cuts of the middle fingers of the third oldest hands.

Consumer Preference Test

After banana bunches were weighed they were allowed to ripen. The ripe banana fruits were given to 20 programme staff to taste for consumer preference. Tasters were able to express their like or dislike of the banana according to their individual taste. A scale of 1 - 5 was used for taste preference; score of 1 for 'dislike alot' and 5 for 'like very much'.

RESULTS

Results from the analysis of variance showed differences between the bunch yields of the varieties.

FHIA 25 gave the highest yield of 38 kg/bunch while Pisang Lilum, a common variety, gave the lowest yield of less than 2 kg/bunch. All hybrids from the breeding programmes yielded over 10 kg/bunch. The only two common varieties that yielded over 10 kg/bunch were Pisang Ceylan and Yangambi. The overall results of the yield performance are presented in Table 2 and Figure 1.

Table 2. **Banana Varieties and Bunch Yields**

Varieties	Mean Bunch Yield (kg/bunch)
Pisang Lilum	1.53 a
Kluai Khai Bonng	4.18 a
Pisang Berlin	7.97 b
Williams	8.55 b
SH 3640	10.40 bc
Yangambi	12.65 cd
FHIA 23	15.95 de
FHIA 02	16.90 ef
FHIA 18	17.10 ef
Pisang Ceylan	17.17 ef
SH 3436	19.52 fg
FHIA 17	20.72 g
FHIA 03	24.25 h
FHIA 25	37.57 i

Means with the same subscript are not significantly different from each other at P<0.05. LSD = 3.447.

susceptible. The resistant varieties did not show any sign of disease re-infestation in the ratoon suckers (Table 3).

Consumer preference tests showed that more people like the taste of varieties Pisang Ceylon, Yangambi and SH 3436 when these are ripened as dessert bananas. The least liked banana was FHIA 18. A summary of the findings of the consumer preference test is given in Table 3 and Figure 2.

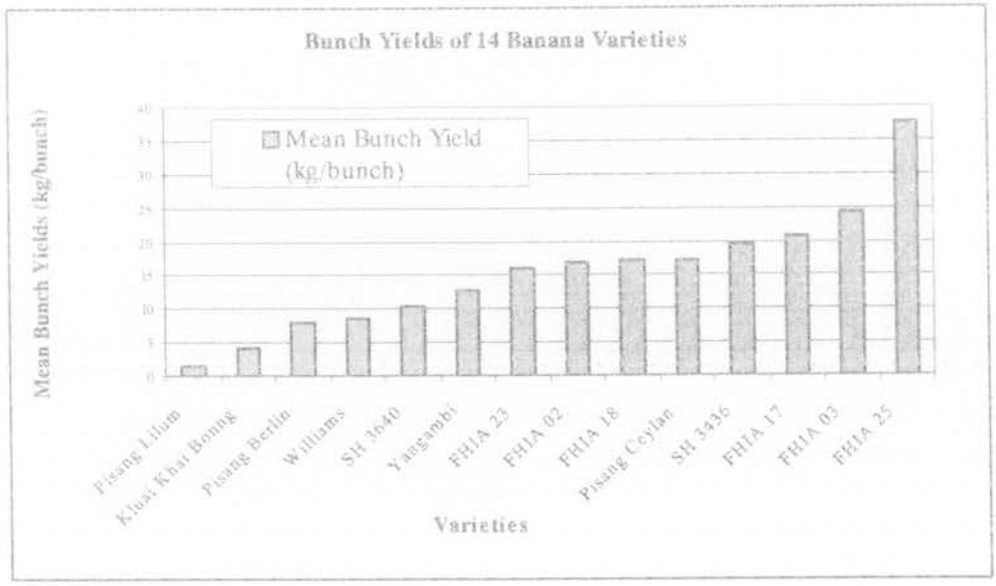
Varieties Kluai Khai, Pisang Lilum, Pisang Ceylan and SH 3640 are early maturing types while most breeding programme hybrids are medium to late maturing.

DISCUSSION

Yield Performance and Sigatoka Resistant Varieties

Results of bunch yields Table 2 showed that hybrids from the breeding programmes produce higher yields than most common international varieties under irrigated conditions at Laloki. FHIA 25 produced the highest yield of 37.6 kg/bunch, which is statistically higher than the other varieties. FHIA 03 and FHIA 17 yielded significantly higher than the remaining varieties with 24.3 and 20.7 kg/bunch respectively. FHIA 25

Figure 1.



FHIA 02 and FHIA 18 showed extreme resistance to Sigatoka disease. The other breeding programme hybrids showed high resistance to the disease as well. Variety Williams showed high susceptibility to the disease. Pisang Berlin and SH 3640 were also

and FHIA 03 are both medium maturing hybrids, a trait that farmers would prefer. FHIA 17 is a good yielder but has a late maturing habit. There was no statistical difference between the yields of the two common varieties Pisang Ceylan and Yangambi and

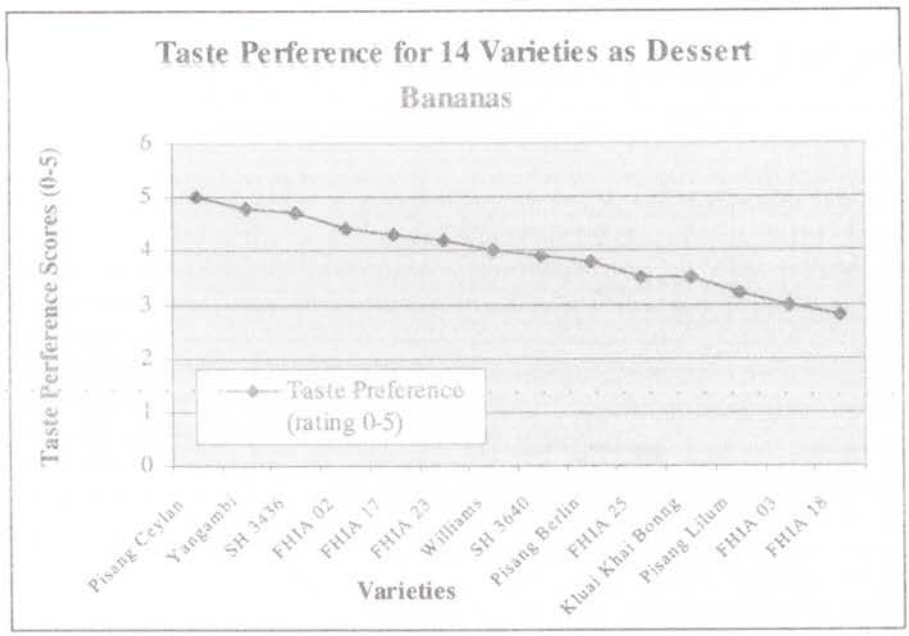
Table 3. **Reaction to Sigatoka Disease, Consumer Taste Preference, Bunch Yields and time to Maturity**

Variety	Sigatoka Resistance	Taste Preference (rating 0-5)	Yield/bunch (kg)	Time to Maturity
Pisang Ceylan	HR	**5.0**	17.2	E
Yangambi	HR	4.8	12.7	M
SH 3436	HR	4.7	19.5	M
FHIA 02	ER	4.4	16.9	M
FHIA 17	HR	4.3	20.7	L
FHIA 23	HR	4.2	16.0	L
Williams	HS	4.0	8.6	L
SH 3640	S	3.9	10.4	E
Pisang Berlin	S	3.8	8.0	L
FHIA 25	HR	3.5	37.6	M
Kluai Khai Bonng	-	3.5	4.2	E
Pisang Lilum	-	3.2	1.5	E
FHIA 03	R	3.0	24.3	M
FHIA 18	ER	2.8	17.1	M

Keys: ER = extremely resistant
HR = highly resistant
R = resistant
HS = high susceptibility
S = susceptible

E = early maturity
M = medium maturity
L = late maturity

Figure 2.



the other four recent hybrids (FHIA 23, 02, 18 and SH 3436). The two common varieties also showed high resistance to Sigatoka disease. The Australian commercial variety Williams from the Cavendish subgroup ranked fourth last (8.6 kg) in terms of bunch yield and showed high susceptibility to Sigatoka disease. Studies conducted in North Queensland, Australia, also showed higher bunch yields from FHIA 03 (31.5 kg/bunch), FHIA 17 (41.3 kg/bunch) and FHIA 23 (35.1 kg/bunch) as compared to variety Williams with 29.1 kg/bunch (Daniells and Bryde 2001). It is likely that the recent hybrids yielded much higher than

the common varieties due to hybrid vigor and their resistance to Sigatoka disease. These hybrids are tetraploids (AAAA /AAAB/AABB) with robust pseudostems and are capable of producing heavy bunches.

Relationship between Bunch Yields and Sigatoka Resistance

Table 3 showed some relationship between high yields and resistance to Sigatoka disease. Highly resistant varieties produce higher bunch yields than those susceptible to the disease. The trend showed that Sigatoka disease contributes to the lower bunch yields of the susceptible banana varieties. This finding is confirmed by a study conducted in the Democratic Republic of the Congo in 1996 that reported yield loss of 76 percent in plantain bananas due to Sigatoka disease (Ngongo 2002).

Panelists Taste Response

The high yielding hybrid varieties FHIA 03 and FHIA 25 were disliked by 30 percent of the 20 panelists. They were disliked as sweet table bananas. They may taste better if cooked or fried but this would reduce versatility of use. Results from studies carried out by the international collaborators in the International Network for the Improvement of Bananas and Plantains (INIBAP) indicated that FHIA 03 produced good texture and excellent taste when fried as chips (Dadzie 1998). Variety Pisang Ceylan was most liked by all tasters who suggested its release to the farming community. The other banana that was liked by 95 percent of the panelists was variety Yangambi. SH 3436, FHIA 02, FHIA 17 and FHIA 23 were liked by 70-80 percent of the panelists. The FHIA hybrid that was most disliked by the panelists was FHIA 18 (90% of the people). Daniells (2001) reported FHIA 18 to be a dessert banana which may not be suitable for cooking or frying purposes.

Re-infestation Rate of the Disease

Visual observations showed no signs of re-infestation by the disease of ratoon suckers of varieties that are resistant to Sigatoka disease. However, these varieties were cropped for one season only and under irrigated conditions that may not have been conducive to disease development. At this stage it may be too early to draw any meaningful conclusions as to re-infestation rates.

CONCLUSIONS

This investigation gave new insight into the yield performance under irrigated conditions in the seasonally dry Laloki lowlands of PNG of some international varieties of bananas that had been bred for Sigatoka resistance. Most of these varieties out yielded the common international varieties and also showed high resistance to the disease that is capable of reducing bunch yield by up to 70 percent. Banana is the second most important staple food crop and the introduction of high yielding Sigatoka resistant hybrids into the production systems of the country would greatly boost household banana production, thus contributing to food security and income generating opportunities for the rural population.

The high yielding disease resistant international varieties that are liked by the panelists would become established once introduced into local production. These promising introduced banana varieties will also enrich or further broaden the already rich genetic resource base of PNG bananas.

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3. Author's name - First names or initials can be used according to the preference of the author. However, authors are strongly advised to use the same style for their name in all publications to avoid giving the impression that they are two or more different authors. The address of each author at the place where the work was done is given in a footnote. If there has been a change of address, the present address is also given for the first author.

4. Abstract - An informative abstract suitable for use by abstracting services should precede the introductory paragraph. Because it is not a part of the paper, an abstract should be intelligible on its own and should summarise the contents and conclusions of the paper. It should be written as simply as possible to assist people who are not specialists. It should not include unfamiliar terms, acronyms, trade names, abbreviations of symbols without explanation. The abstract should not exceed 2% of the total extent of the contribution, maximum 300 words.

5. Key words - A short list of key words should be provided for rapid scanning of the contents of the paper and use by abstracting agencies/journals.

6. Headings - In experimental papers the general order of headings is: Abstract, Introduction, Materials and Methods, Results, Discussion, Acknowledgements, References, Appendix. In descriptive, or other types of papers, as far as possible, a similar format should be followed. No headings should be underlined.

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.

All scientific names of animals and plants must be underline to indicate that they should be set in italic type or written in italics. The authority should be cited in full on the first occasion a scientific name is used. Where the same name is used repeatedly, the genus may be abbreviated to a capital letter after the first citation. For example, use *Homo sapiens* Linnaeus on the first occasion and *H. sapiens* thereafter.

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
* - $0.01 \leq p < 0.05$
** - $0.001 \leq p < 0.01$
*** - $p < 0.001$

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.