YIELD OF FOUR VARIETIES OF RICE (*Oryza Sativa* L.) IN TWO SOIL TYPES AND CONTRASTING AGROECOLOGICAL ZONES

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ABSTRACT

Field experiments were conducted to evaluate soil properties and the yield performance of rice in two agro-ecological zones of Morobe province, Papua New Guinea. Study show that with the current practice of low input and subsistence farming of the province, soil nutrients was not a major impediment for rice cultivation. However, yield had been affected by the moisture supply as a result of different mechanical and physical properties of soils in these two agro-ecological zones. The average grain yield of 2.8- 4.7 t/ha suggests that both regions have the potential to grow rice and is capable to meet the current demand of the province.

Keywords: *Rice, soil types, agro-ecological, zones, Markham valley.*

INTRODUCTION

Morobe province is one of the twenty provinces of Papua New Guinea (PNG) that occupies 33,525 km^2 in the north of the country (Fig. 1). Population of the province is 3, 07, 000 where banana (*Musa* cultivars), sweet potato (*Ipomoea batatas*), and taro (*Colocassia*) are the major staples. While these are the most important crops consumed, rice has quickly become popular for many people, both in the rural and urban areas of the province. Despite the demand, very little rice is produced locally and almost all the rice consumed is imported from overseas, resulting in the spending of large amounts of foreign exchange by the government (Manning 1998). Therefore, government of PNG and many non-governmental organizations are promoting domestic production of rice in order to become self reliant and to ensure food security for the households. This has achieved limited success and has never exceeded 2% of the country's requirements (FAO 2000).

In the province two kinds of cropping systems are practiced, namely the cash crops like coffee (*Coffea spp.*), cocoa (*Theobroma cacao*), coconut palm (*Cocos nuerfera*), and the subsistence agriculture which produce staple crops. Almost all of the 25% of the arable land of the province is being used to produce both the cash and traditional food crops where yield is depended on the inherent soil fertility and available moisture supply (Hanson *et al.* 2001). With this system of agriculture, however, yield is low. Therefore, to increase yield, since 1950, much of the research carried out was focused on the land use and nutrient status of cash crops (Baseden 1960; van Wijk 1959; Fahmy 1977). Significant research on nutrient deficiencies in traditional food crops started only in the 1970s (Hartemink and Bourke 2000; Hartemink *et al.* 2000). As rice was not considered a major staple it received little or no attention and is cultivated only in a few isolated locations.

It is well known that crop growth and yield would largely be determined by the climate, biological, and edaphic factors of the region. This study investigated soil properties, particularly soil chemical properties on the yield performance of four rice cultivars under low input conditions in two agro-ecological zones in Morobe province. Soil properties have been used to provide an overall assessment of soil fertility, noting any apparent deficiency of nutrient elements that might affect crop growth and yield. In evaluating rice yield, rainfall which is one of the dominant characterists of the region also was taken into consideration. It is hoped that findings of this investigation would entail the land manager's, particularly smallholder farmers, to understand the soil's potential and limitations, and the role of climate on rice yield.

MATERIALS AND METHODS

Climate of the experimental sites

Two sites were selected for the study where agriculture is dominated by the traditional food crops. One is at the University of Technology (Unitech) experimental farm (6°39¢ S, 147°00¢E and

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65 m.a.s.l), Lae the capital of Morobe province and the other in Trukai experimental farm at Markham valley (6°31¢ S, 146°29¢ E and 112 m.a.s.l.) which is about 60 km North West of Lae (Fig. 1). Unitech represents wet coastal areas and Markham valley represents the drier interior valley of the province.

The climate of both experimental sites is tropical humid and classified broadly as Koeppen Af (Ford 1974) i.e. rainy tropical climate. It has two main rainy seasons with short but important transition periods between them. The north-west season, influenced by the perturbation belt and occurring from December to late March. The south-east season, which occurs from May to October, when south-east trade winds dominate the weather.

Unitech receive rainfall in south-east season and have the greatest incidence of long wet spells unlike other wet places in the province. Whereas, Markham valley receives most of its rainfall during north-west season. The annual rainfall at Unitech and at Markham valley is about 3452 mm and 1139 mm respectively (five year average) (Figs. 2 and 3). Annual evaporation (US Class A pan) is 2139 mm at Unitech and 2200 mm at Markham valley. At Unitech rainfall exceeds evaporation whereas at Markham valley evaporation exceeds rainfall. Temperature at both experimental sites are constantly high, with mean maximum readings of 28-34 °C and mean minimum readings of 20-25 °C. Temperature range throughout the year is usually small, 1-4 °C for the mean and 3-9 °C for the extreme of monthly maxima and minima. Daily range is usually at least double that of the average monthly range (Bleeker 1983a).

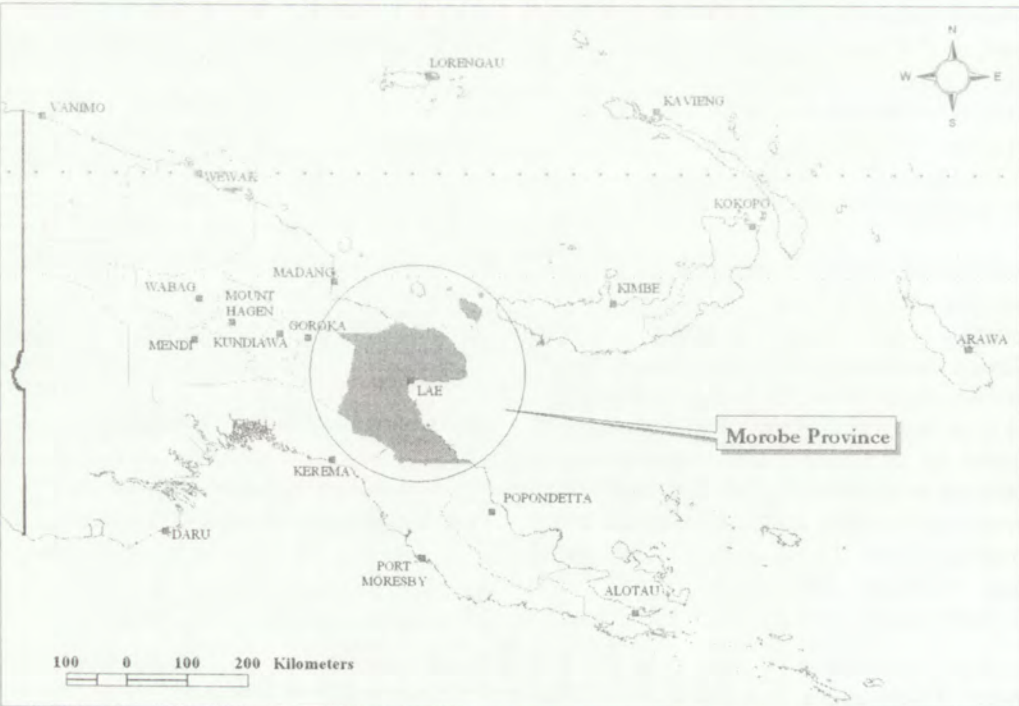
Soil and land use of the experimental sites

Soil at Unitech is derived from alluvial deposits whereas at Markham valley it is derived from colluvial and alluvial deposits (Bleeker 1983b). According to USDA Soil Taxonomy (1999) and FAO/UNESCO (1988) Unitech soil is classified as *Typic Tropofluvents* and *Eutric Fluvisol* whereas Markham valley soil is classified as *Typic Troporthents* and *Haplic Phaeozems* respectively. Soil at Unitech is well drained and has moderate slope 10-20°, whereas, soil at Markham valley is moderately to poorly drain and is steeply sloping > 20°. The natural vegetation at Unitech farm is mainly savanna grassland (*Imperata cylindrica*) with scattered shrubs while Markham valley has predominantly grassland vegetation (*Themeda austrailis*) with scattered trees. Taro is the dominant crop grown at the farm, whereas, banana and sweet potatoes are common at Markham valley.

Field Establishment and Maintenance

A total of four experiments were conducted over 3 year period having two at each location. At Unitech, experiments were conducted during May to October in 2001 and 2002 whereas at Markham valley during December to May in 2002 and 2003. Land was kept fallow between the trials. Four rice cultivars were used. These are Taichung Sen-10

Figure1. **Location of Morobe Province in Papua New Guinea**



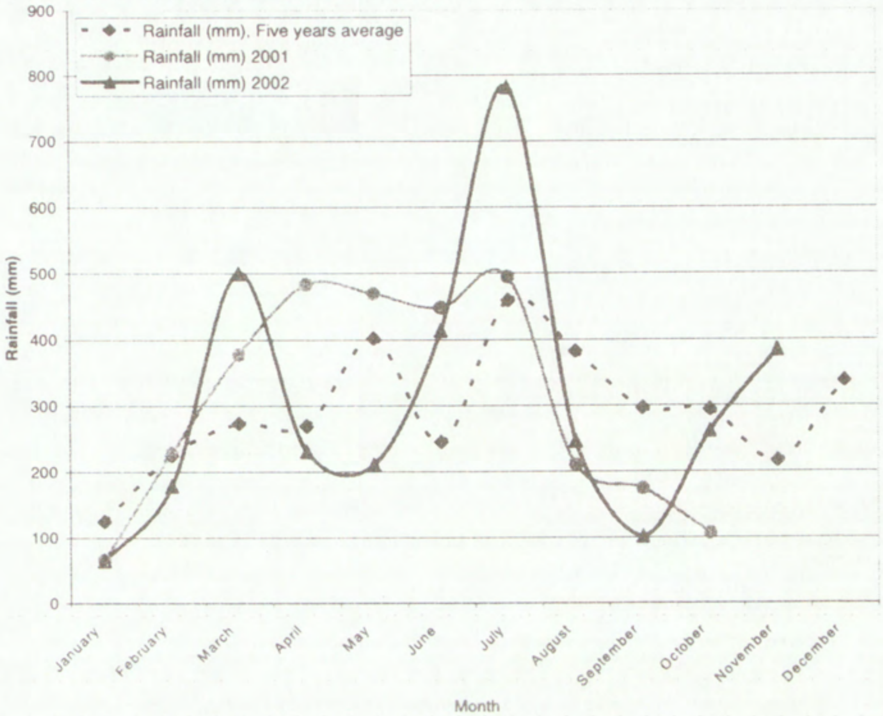


Figure.2. Rainfall at the University of Technology agriculture farm in 2001, 2002 and five year's average

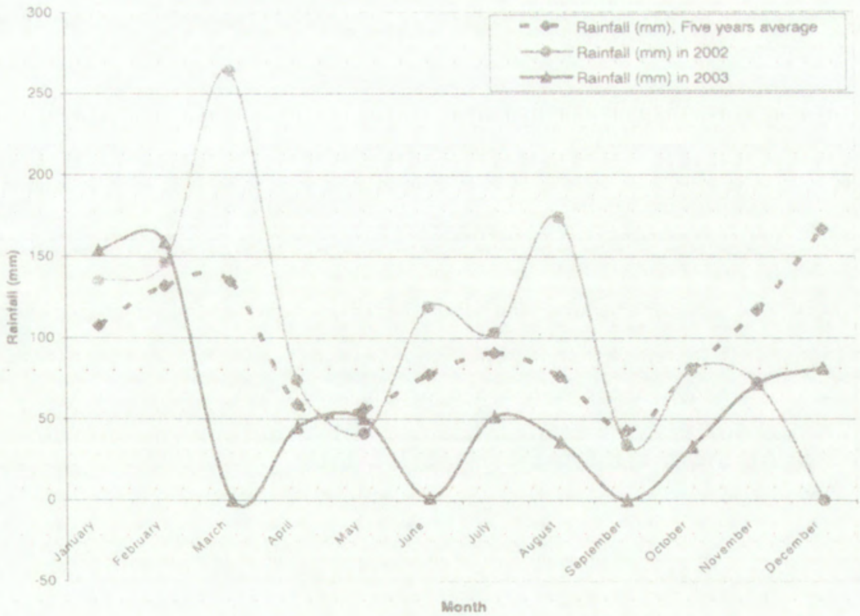


Figure 3. Rainfall at Markham valley experimental site in 2002, 2003 and five year's average

(TCS 10), IR 19661-23-3-2-2 (IR 19661), BG 379-2, and Finsch. Finsch is known to exist in PNG for over one hundred years while other three are exotic varieties imported from overseas. At the time of land preparation, Glyphosate (Round up) a pre-planting herbicide was applied (4L/ha). Seedbed was established by ploughing and harrowing twice to incorporate any primary growth/ stubble. The trial was laid out in a Randomized Complete Block Design, with four replications. The plot size was 3m x 5m with one meter clearance between them. Seeds were planted by dibble stick method. In this method a pointed stick was pushed to the ground to make a hole for 3-5 seeds at a depth of about 4 cm. The holes were spaced about 25 cm apart. Experimental field received 50 kgs of NPK (12:5:17) per hectare as a basal dose. Additional nitrogen fertilizer (20 kg/ha) was applied as urea in two splits during early and late tillering stages. Fertilizer was broadcast manually. At Unitech three manual weeding was done at seedling, early and late tillering stages. There was very little infestation of weeds at Markham valley which were weeded manually at seedling stage only. Harvesting was carried out at Unitech site in October 2001, 2002 and at Markham valley in April 2002, April-May 2003 for the first and second trial respectively. Harvesting was done manually with a knife (sickle). After harvest each of the treatment plots was threshed separately by beating on a wooden block. Grains were cleaned, sun dried and weighted along with the moisture content (Satake Moisture, Model SS-5). The yield data was adjusted to 14% moisture content. The above treatments and management practices remained the same in all trials.

Soil properties measurement

Measurement of soil physical properties included particle size distribution, bulk density, field moisture capacity, and saturated hydraulic conductivity. Soil particle size distribution was determined by hydrometer method (Gee and Bauder 1986). Soil bulk density was determined using the core method (Blake and Hartge 1986). Field moisture capacity (*in situ*) was determined by the method as described by Cassel and Nielsen (1986). Soil saturated hydraulic conductivity *(Ks)* measurements were carried out by ring infiltration method (Rowell 1994). At the beginning of each trial three soil samples were taken from each site for chemical analysis. Each soil sample consisted of a mixture of four subsamples taken from the top 20cm depth of the soil. Soil samples collected were air dried and then ground lightly with a mortar and pestle to pass through a 2 mm round-hole sieve. Soil chemical analysis was carried out by the following methods as described by Rayment and Higginson (1992). The procedures were as follows. Total Nitogen-semimicro Kjeldahl, steam distillation (reference: 7A1); Organic carbon-Walkley and Black (reference: 6A1); Exchangeable bases and CEC-1M ammonium acetate at pH 7.0 (reference: 15D1); Olsen-extractable phosphorus (reference: 9C1). The data presented here is the average of three measurements.

Statistical Analysis

The data were analyzed using the standard procedure of randomized block design to compare means for grain yield. Analysis of variance (ANOVA) was used to test the difference in yield. Treatment means were compared using the least significant difference (LSD) procedure and Duncan Multiple Test Range (DMRT) at the 5% probability level. Yield among and between the varieties and the yields obtained in two trials were computed.

RESULTS AND DISCUSSION

Rice yield obtained at Unitech and Markham valley trials are given in Table 1. In the first trial at Unitech highest yield obtained was in TCS 10 (3.8 t/ha) and at Markham valley it was in IR 19661 (5.6 t/ ha). In both experimental sites BG 379-2 have produced the lowest yield. The yield obtained in BG 379-2 was 1.9 t/ha and 3.3 t/ha at Unitech and Markham valley respectively.

The results of selected chemical and physical analysis of Unitech and Markham valley soils are

Table 1. **Rice yield (t/ha) at the Unitech in 2001 and 2002, and at Markham valley in 2002 and 2003 trials**

Rice variety	Unitech agriculture farm		Markham valley	
	2001	2002	2002	2003
TCS 10	3.81a	3.21b	5.63ab	5.89ab
Finsch	3.08b	2.76c	5.03bc	3.82c
BG 379-2	1.96c	1.68b	3.38d	2.75d
IR 19661	3.17b	3.04b	6.77a	4.87bc

Means followed by the same letter in the vertical column are not significantly different according to Duncan's Multiple Range Test (pd" 0.5).

given in Table 2. Analysis of soil collected on the onset of first trial show that the contents of nutrients at Markham valley and Unitech soil were not different significantly except organic carbon, available P and CEC. At Markham valley the content of organic carbon was 2.24% whereas it was 1.6% at Unitech. At Markham valley the levels of available P (Olsen- P) was 24 mg/kg compared to 11 mg/kg at Unitech soil. Soil CEC was 30 coml. /kg and 49 cmol. /kg at Unitech and Markham valley respectively. It is postulated that yield difference between these two sites was primarily due to the differences in nutrient contents particularly in organic carbon, available P and CEC (Ponnamperuma *et al.* 1981; Yamaguchi 1997; Pandey 1998). However, yield difference among the varieties was expected as cultivars respond differently to the available water and nutrients because of genetic variations (Hedley *et al.* 1994; Ladha *et al* 1998; Wade *et al* 1999).

In the second trial at Unitech yield has declined significantly ($p < 0.05$) in TCS 10, Finsch, and BG 379-2 varieties. Whereas, there was no significant difference in soil nutrient contents between the trials (Table 2). However, in the second trial at Markham valley there was a significant loss of organic carbon and available phosphorus but yield has declined in IR 19661 only. Therefore, it is assumed that apart from plant nutrients other factors might have involved in the variation of yield at both experimental sites. The loss of organic carbon at Markham valley may decrease biomass, organic matter turnover, and increase mineralization of added organic matter (Juo and Lal 1977, 1979; Jaiyeoba 2003). Organic matter affects CEC (Bernal *et al.* 1992; Tisdale *et al.* 1993). Even though there was a significant loss of organic matter at Markham valley soil, but it did not show any effect on CEC probably due to the valley charged clay particles (Ca^{2+}, Mg^{2+}, K^{+} etc.). The decrease in available P in the valley soil after the cropping was expected (Parfitt and Thomas 1975; Parfitt and Mavo 1975).

In rainfed rice ecosystems apart from plant nutrients the availability of water is considered to be very important to the productivity of rice (IRRI 1993). The total rainfall at Unitech 2001, 2002 trials was 3057 mm and 3828 mm, and at Markham valley 2002, 2003 trials it was 1612 mm and 898 mm respectively (Fig. 2 and 3). Rainfall data show that the amount of rainfall that Unitech have received in both trials was more than double than that of Markham valley. But in two consecutive trials all the variety have produced higher yield at Markham valley (Table 1). Mechanical analysis show that Unitech soil was a loamy sand, whereas, Markham valley was a clay loam (Table 2). The hydraulic conductivity (*Ks*) and field moisture capacity at Unitech soil was 45 mm/h and 22% and at Markham valley it was 15 mm/h and 52% respectively. It is postulated that due to the high hydraulic conductivity and low field moisture capacity of Unitech soil, plants could not use moisture and nutrients efficiently and hence low in yield (Lal 1979; Singh *et al.* 2000; Saleh *et al.* 2000; Oberthur and Kam 2000). In each experimental site the yield difference between the trials is presumed due to the pattern of rainfall of the site. In both experimental sites the pattern of rainfall was very erratic. Therefore, it is assumed

Table 2. **Some chemical and physical properties of Unitech and Markham valley soil.**

	Unitech		Markham valley	
	2001	2002	2002	2003
pH (1:5 w/v)	6.5	6.5	6.8	6.7
Organic Carbon (g/kg)	16.0±0.33	13.0±0.23	22.4±0.24	13.9±0.23*
Total Nitrogen (g/kg)	2.0±0.02	1.9±0.01	2.1±0.01	1.8±0.02
Available P Olsen (mg/kg)	11.0±2.65	11.0±3.35	24.0±6.51	10.0±7.33*
CEC pH7 NH_4OAc (cmol/kg)	29.0±3.00	30.0±3.51	49.0±4.58	5 3.0±1.00
Exchangeable cations (cmol/kg)				
Ca	21±2.73	19±1.00	57±6.63	56±5.77
Mg	3±0.90	3±0.76	9±1.35	9±1.32
K	0.91±0.19	0.7±0.29	2±0.31	2±0.29
Sand content (g/kg)	840	-	380	-
Silt content (g/kg)	140	-	340	-
Clay content (g/kg)	20	-	280	-
Bulk density (Mg/m3)	1.26	-	1.14	-
Field moisture capacity (g/kg)	260	-	530	-
Ks (mm/h)	45	-	15	-

(-) not determined
* indicates significance at $p<0.05$

that it is not the amount of rainfall but the extreme variability both within and between the years have affected rice yield (Craig and Pisone 1985; Patil *et al* 1998; Fukai *et al*. 2000).

CONCLUSIONS

The average grain yield obtained at Unitech 2001 and 2002 trials was 3 t/ha and 2.6 t/ha and at Markham valley 2002 and 2003 trials it was 5.2 t/ha and 4.3 t/ha respectively. In rainfed rice cropping system the global average yield of rice is 1-3 t/ha (Dobermann and Fairhurst, 2000). This suggests that under current practice of low input and low intensity agriculture of the province soil nutrients was not a major limiting factor for rice cultivation. However, hydraulic conductivity and moisture holding capacity of soil could influence the available moisture to plants and hence yield. It was also observed that there was no simple relationship between rainfall and grain yield.

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