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CONTENTS

ELEMENTAL SULFUR COATED FERTILIZER MATERIALS AS SULFUR SOURCES FOR RICE UNDER FLOODED AND NON-FLOODED CONDITIONS

Joachim A. Pitala,[1,2] Graeme J. Blair[1] and Ray A. Till[1]

ABSTRACT

A study was undertaken to investigate the effectiveness of a range of elemental sulfur (S^0) coated TSP fertilizer materials in rice under flooded and non-flooded conditions.

The experiment was conducted in a glasshouse at the University of New England, Armidale, N.S.W., Australia, using a factorial combination of 6 sources of S^0 coated fertilizer materials [Gold-phos 10 (GP10), UNE511, UNE1, TSP+S^0f (fine), TSP+S^0m (medium), TSP+S^0c (coarse)], and a Control, 2 water regimes and 3 replications. The soil used in the study was an S-deficient Aquic Haplustalf. The treatments were arranged in a randomized complete Block design (RCBD). P and S from the different S^0 coated materials were applied at the rates of 46 kg P/ha and 10 kg S/ha, respectively.

The use of ^{35}S labeled soil and the employment of the Reverse Dilution Technique enabled the estimation of the recovery of the fertilizer S in the various components derived from the different S sources.

Mean percentage recovery of fertilizer S in the straw and grain, and mean total S recovered in the rice tops were significantly lower in the GP10 and UNE511 fertilizer treatments.

Based on the results, it was concluded that UNE1, TSP+S^0f, TSP+S^0m and TSP+S^0c were effective S sources for rice under flooded and non-flooded conditions.

Keywords: *elemental S, rice, coated fertilizers, radioactive S, tiller, grain.*

INTRODUCTION

Sulfur (S) is one of the major nutrients required by plants for their growth. It is a major constituent of the amino acids – cysteine and methionine, and various other compounds in plants (Russell 1973; Anderson 1975; Thomson *et al.* 1986).

Despite its importance as an essential plant nutrient, it has received little attention compared to nitrogen (N), phosphorus (P) and potassium (K) and only in the recent past, has its significance been recognized. The incidence of S deficiency is becoming widespread and has now been widely recognized in many countries (Morris 1987). S deficiency is widespread in most rice growing regions, particularly in Southeast Asia (Blair 1983; Ismunadji *et al.* 1983; Mamaril *et al.* 1983; Hoult *et al.* 1983), Latin America (Wang *et al.* 1976), and Africa (Osiname and Kang 1975).

In the past, the so-called "low analysis" fertilizers such as single superphosphate and ammonium sulfate were the principal sources of S for most agricultural crops. Recently, however, there has been a growing shift away from the use of these fertilizers to the so-called "high analysis" fertilizers such as urea, triple superphosphate (TSP), mono- and di- ammonium phosphates which contain little or no S (Blair 1979; Morris 1987).

As the need for S increases to counter the S deficiencies resulting from the use of high analysis fertilizers, many attempts have been made to use elemental S (S^0) to supply crop demand (Fisher *et al.* 1984). However, since plants use only SO_4^{2-} - S, S^0 needs to be oxidized before a plant can utilize the S. Coating of fertilizer materials with S^0 has been introduced to deliberately supply S to plants and this employ finely ground S^0 to granular products with various binders such as lignosulfonate, formaldehyde, etc. Most of these materials contain 10 – 100 % S (Tandon 1987).

The experiment was conducted under glasshouse conditions to investigate the effectiveness of some

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of the S° – coated TSP fertilizer materials as S sources for rice in terms of yield, S content and the recovery of fertilizer S in the straw and grain components, under flooded and non-flooded conditions.

MATERIALS AND METHODS

Location

The experiment was conducted from January to May 1997 in a glasshouse at the Department of Agronomy and Soil Science of the University of New England, Armidale, N.S.W. Australia.

Experimental Design

The experiment consisted of a factorial combination of 6 S° coated fertilizer materials [Gold-phos 10 (GP10), UNE511, UNE1, TSP+S°f (fine), TSP+S°m (medium), TSP+S°c (coarse)], and a Control, 2 water regimes (flooded and non-flooded) and 3 replications. These treatments were arranged in a randomized complete block design (RCBD).

Soil Sampling and Preparation

Surface layer (0-15 cm) of an S-deficient Aquic Haplustalf (Anderson, 1988; Dana, 1992) soil from Uralla, N.S.W., was collected from a natural pasture site, air-dried, processed through a soil shredder and passed through a 2 mm sieve to obtain a uniform soil particle size, before being used in the experiment.

Coating of TSP Granules with Elemental S

Three different S° particle sizes were used to coat the TSP granules. These included 53-154 µm (fine), 154-263 µm (medium) and 263-328 µm (coarse). Coating of TSP granules with S° was done by weighing 20g each of the three S° particle sizes and mixing them thoroughly with 10 ml of calcium lignosulfonate to make a paste. TSP granules of 2-2.8 mm diameter were then added to the S°/lignosulfonate mixture and mixed thoroughly with a glass rod. To get a good coated material, the mixture was transferred to a rotating drum and a slightly warm air blown over the granules. The S° coated TSP materials with the 3 different particle sizes were then air-dried and stored in three different plastic jars.

Measurement of the S content of each of the coated materials was done by using the Combined Phosphorus and Sulfur Digest Method for Soils and Fertilizers by Till *et al.* (1984). The P and S rates used in the experiment (46 kg P/ha and 10 kg S/ha) were thus calculated based on the P and S contents of the coated TSP materials as obtained from the analysis and the surface area of the pots (183 cm²).

^{35}S Labeling of the Soil Samples

Prior to potting, 42 lots of 1.85 kg of soil were weighed and put in plastic bags. ^{35}S was then used to labeled the soil samples. This was done by using a syringe to apply 5 ml of the radioactive solution ($K_2{}^{35}SO_4$) to the soil surface in the bags. Immediately after the application of the radioactive solution, 50 ml of deionized water was added and mixed thoroughly with the soil in the plastic bags. The labeled soil samples were then kept in a storage room to incubate for 3 weeks. Incubation allows the equilibration of ^{35}S with the native sulfate and rapidly turning over organic S in the soil (Dana, 1992). After the incubation period, the sample in the plastic bag was placed inside a second plastic bag so that there were two plastic bags/pot as inner linings. These were then transferred to the glasshouse, manually irrigated with deionized water to field capacity and were ready for basal nutrients application, which was done a day later.

Basal Nutrients and Treatment Applications

Only N and K were applied as basal nutrients and these were mixed thoroughly with the soils. The nutrients were applied as Urea (400 mg urea/pot) and KCl (35.2 mg KCl/pot), respectively. A day after the basal applications, 6 two weeks old rice (variety IR30) seedlings which were grown in quartz sand were transplanted per pot.

After the adjustment period of 1 week, 6 different S° coated TSP fertilizer materials and 2 water regimes (flooded and non-flooded) were applied. The 6 different coated TSP fertilizer materials include Gold-phos 10 (GP10), UNE511, UNE1, TSP+S°f, TSP+S°m and TSP+S°c. Description of the coated TSP material UNE1 is given by Dana *et al.* (1994a). UNE511 was made in a similar manner as UNE1, but its coat was hardened during the drying process. Golphos 10 is a commercial S° coated TSP fertilizer which contains 18 % P and 10 % S. It is manufactured by Hi-Fert Pty Ltd, Australia. For the latter three S° coated TSP, refer to the section on coating of TSP granules above.

All these S° coated fertilizer materials were applied by placing the granules uniformly on the soil surface. The flooded treatments were imposed by adding deionized water to a level of 4 cm above the soil surface and maintained at that level until the ripening period when watering was terminated. For the non-flooded treatments, watering was maintained at or near field capacity by weighing until the ripening period when watering ceased. Table 1 indicates the

Table 1. **Application rates (mg/pot) of P and S of the elemental S coated fertilizer materials.**

Coated material	% P	% S	Coated TSP mg/pot for 10 kg S/ha	P added in coated TSP (mg/pot)	Extra P needed to make 84.18 mg/pot for 46 kg P/ha	Uncoated TSP to make up P level (mg/pot)
GP10	18.0	10.0	183.0	32.9	51.2	222.5
UNE511	17.4	9.7	189.0	32.9	51.2	222.5
UNE1	20.0	10.0	183.0	36.6	47.6	206.6
TSP+S°f (53-154μm)	20.7	10.3	177.5	36.7	47.5	206.2
TSP+S°m (154-263μm)	20.3	11.3	162.1	33.0	51.2	222.5
TSP+S°c (263-328μm)	20.3	11.6	158.2	32.0	52.2	226.2

application rates of P and S of the S^0 coated fertilizer materials.

Tiller Count and Leaf Sampling

Twenty days after transplanting (DAT), the first tiller count was made and at 27 DAT, a second tiller count was carried out and repeated at 2 weeks intervals. The first leaf sampling was made during the second tiller count (27 DAT) with the subsequent tiller counts and leaf samplings carried out at 41 DAT, 55 DAT and 69 DAT. Hence, a total of 5 tiller counts and 4 leaf samplings were conducted.

To sample the leaves, the first step was to dry the digestion bottles (50 ml borosilicate screw-top) without the caps, in an oven at 80 °C for 24 hours. After cooling, the dry bottles were weighed and taken to the glasshouse.

Sampling of the leaves for each treatment was done by clipping at the leaf base, the youngest fully expanded leaf from the top of the main tiller with a pair of scissors. Since there were 6 rice plants/pot, leaves were sampled from the first three plants and at the next sampling, the samples were taken from the other three plants, alternating at the subsequent samplings.

Immediately after the leaves were harvested, they were cut into small pieces of about 5 mm in length and put in the appropriate digestion bottles. The bottles with the fresh leaves samples were then taken to the laboratory and their fresh weights taken. These were then dried in the oven at 80 °C for 48 hours. After cooling, the bottles with the dry samples were weighed to determine the dry sample weights for each treatment.

Panicle, Grain and Straw Harvest

At harvest, the number of productive panicles were counted and recorded. The grains were harvested by stripping them from the panicles and sorted out into filled and unfilled grains. These were counted and recorded. The straw was harvested by cutting approximately 1 cm above the soil. The unfilled and filled grains, and straw were then dried at the oven at 80 °C for 48 hours and weighed after cooling. Each straw and filled grain sample was then ground to pass a 1 mm screen.

Laboratory Analyses

Laboratory analyses of the leaf samples for each harvest was done following the procedures outlined by Anderson and Henderson (1986) for Sealed Chamber Digest for P, S, K, Na, Mg, Ca and trace elements determination. Total S in the leaves for each sampling times (27 DAT, 41 DAT, 55 DAT and 69 DAT), was measured by the ICP spectrometry (ICP-AES) and ^{35}S content was measured by Liquid Scintillation Counting (Till *et al.* 1984). The Reverse Dilution Technique of Shedley *et al.* (1979) was used to calculate the recovery of fertilizer S by the rice plants whereby the radioactivity data were converted to specific radioactivity ratio (SRR). SRR is the ratio of the treatment to the Control specific radioactivity (SR) and SR is the activity of ^{35}S in becquerel per gram of dry matter (Bq/g DM) expressed per unit of total S content of the plant leaves (μg/g). Therefore, the amounts of sulfur derived from the fertilizers were estimated as (1-SRR) x 100%.

For analysis of total S in the straw and grain, a sub-sample of 0.20 g for each treatment and plant component was taken and digested using the same procedure as outlined for leaf analyses, and measured by ICP Spectrometry. ^{35}S content was measured by Liquid Scintillation Counting (Till *et al.* 1984) and fertilizer S recovery was calculated using the Reverse Dilution Technique of Shedley *et al.* (1979).

Statistical Analysis of Data

The data collected for the different parameters measured were analyzed by the analysis of variance (ANOVA) using the NEVA Version 3.3 computer program (Burr, 1982). Mean separation for each treatment was determined using the Duncan's Multiple Range Test (DMRT), where treatment effects observed at the probability level of 5% or less are treated as significant.

RESULTS

Yield Components

(i) Tiller numbers

The effects of the different S^0 coated fertilizer sources on tiller numbers were significant at 20 and 27 DAT (Table 2). At 20 DAT, higher tiller numbers were observed in the TSP+S^0f, TSP+S^0m, TSP+S^0c, UNE1 and UNE511 S^0 fertilizer sources, which were similar.

At 27 DAT, application of UNE511 resulted in a significantly lower tiller numbers, which was similar to the Control treatment. No significant differences in tiller numbers were observed between the different S^0 coated fertilizer sources at 55 and 69 DAT.

There were significant differences in tiller numbers observed at different counting times (Figure 1). At 20 DAT, the tiller numbers produced in the non-flooded treatment was significantly lower than that of the flooded treatment. The highest tiller numbers produced in the flooded treatment was observed at 27 DAT, although this was similar to the non-flooded treatment with the means of 3.84 and 3.98 tillers/plant for the non-flooded and flooded treatments, respectively. At 69 DAT, the till numbers under flooding, declined dramatically as compared to the tiller numbers under non-flooding. Figure 1 also shows that tiller numbers under flooding were consistently lower after the second tiller count (27 DAT) compared to the non-flooded treatment.

(ii) Filled grain numbers

There was no significant water regime x S^0 fertilizer source interaction (Appendix 1) on the number of filled grains. However, the application of the different S^0 fertilizer sources resulted in significant differences in the mean number of filled grains (Table 3). The mean filled grain numbers in the Control and GP10 treatments were similar but significantly lower as compared to the mean filled grain numbers in the other S^0 fertilizer sources.

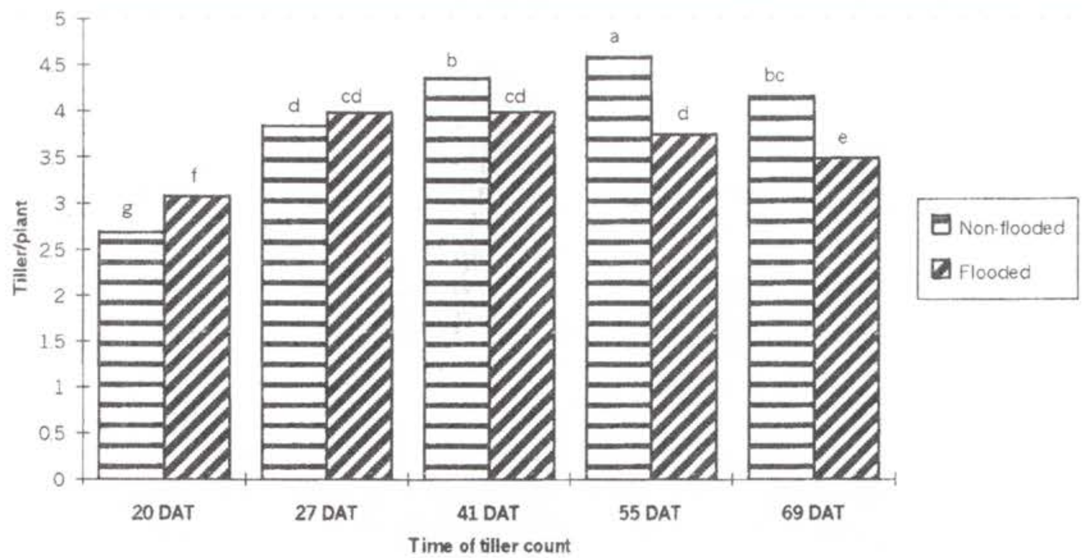
No significant differences in mean filled grain numbers were recorded in the UNE1, TSP+S^0f, TSP+S^0m and TSP+S^0c, and between UNE511, UNE1 and TSP+S^0f S^0 fertilizer sources (Table 3). Application of the different S^0 coated fertilizer sources did not have any significant effects on the number of unfilled grains, and panicle numbers were neither

Table 2. **Tiller numbers (tiller/plant) counted at different times as influenced by different S fertilizer sources.**

	S^0 coated fertilizer materials						
Harvest time	Control	GP10	UNE511	UNE1	TSP+S^0f	TSP+S^0m	TSP+S^0c
20 DAT	2.2 c	2.8 b	2.9 ab	3.0 ab	3.2 a	3.0 ab	3.0 ab
27 DAT	3.2 c	4.2 a	3.4 c	4.1 ab	3.9 ab	4.1 ab	3.8 ab
41 DAT	3.6 b	4.1 a	4.2 a	4.4 a	4.3 a	4.2 a	4.4 a
55 DAT	3.9 b	4.1 ab	4.1 ab	4.2 ab	4.4 a	4.2 ab	4.2 ab
69 DAT	3.8 a	3.5 a	3.8 a	3.9 a	4.0 a	3.8 a	3.9 a

Numbers followed by the same letter in a row within each harvest time do not differ significantly at the 5% level by DMRT.

***Figure 1.* Tiller numbers (tiller/plant) counted at various times for the non-flooded and flooded rice.**



Columns headed by the same letter do not differ significantly at the 5% level by DMRT.

influenced by the imposition of the water regimes or application of the different S^0 fertilizer sources (data not presented).

The number of filled and unfilled grains were significantly influenced by water regime (Figure 2). The filled grain numbers in the flooded treatment (F) were significantly higher than that of the non-flooded treatment (NF) with the means of 578 grains/pot and 372 grains/pot, respectively (Table 3 and Figure 2).

Yield Parameters

(i) Straw and filled grain dry weights

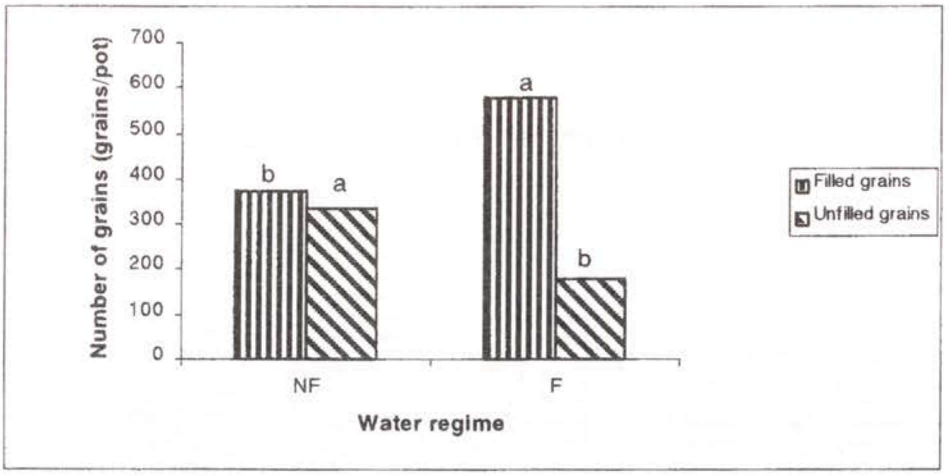
There was no significant water regime x S^0 fertilizer source interaction (Appendix 2) on straw dry weight (DW). However, application of the different S^0 coated fertilizer sources resulted in significant differences in mean straw DW (Table 4). A higher mean straw DW was recorded in the TSP+S^0f treatment with a

***Table 3.* Effects of the application of the different S^0 coated fertilizer sources on the number of filled grains of rice under flooded and non-flooded conditions.**

Filled grain numbers (grains/pot)			
S^0 fertilizer source	Flooded	Non-Flooded	Mean
Control	387	203	295 c
GP10	443	254	348 c
UNE511	645	297	471 b
UNE1	623	442	532 ab
TSP+S^0f	669	421	545 ab
TSP+S^0m	645	478	561 a
TSP+S^0c	636	514	575 a
Mean	578 a	372 b	

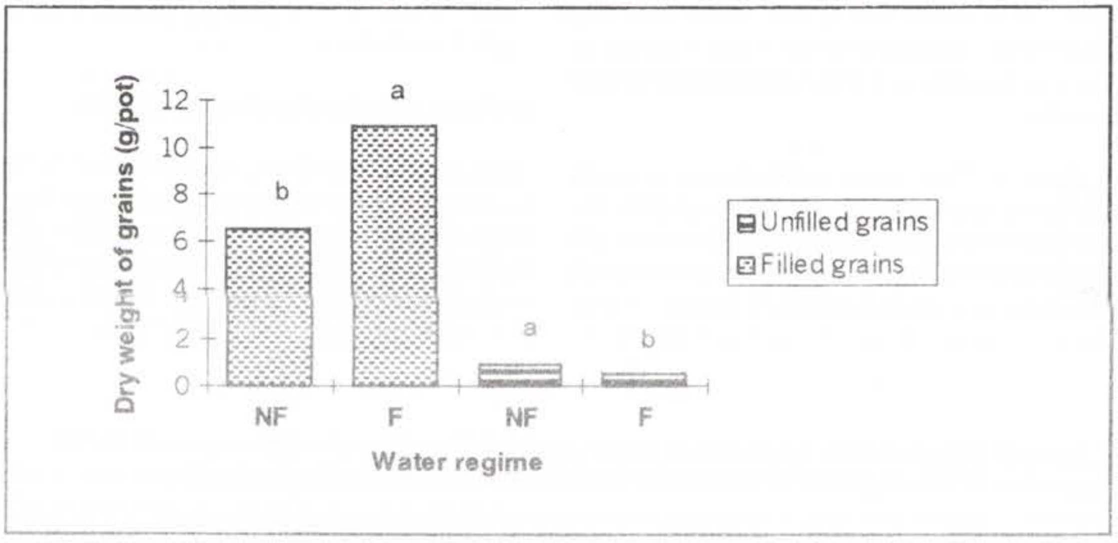
Mean values followed by the same letters in a column or row, are not significantly different at the 5% level by DMRT.

Figure 2. **Effects of water regimes on the number of filled and unfilled grains of rice.**



Columns headed by different letters within the two respective grain categories (filled and unfilled) differ significantly at the 5% level by DMRT.

Figure 3. **Effects of water regime on the dry weight of filled and unfilled grains of rice.**



Columns headed by different letters within the two respective grain categories (filled and unfilled) differ significantly at the 5% level by DMRT.

mean DW of 13 g/pot which was similar to that of UNE1, TSP+S°m, TSP+S°c and UNE511. Application of GP10 resulted in a lower mean straw DW (11.8 g/pot), but this did not differ significantly from that of UNE511, UNE1, TSP+S°m and TSP+S°c. The lowest straw DW was observed in the Control treatment with a mean of 7.2 g/pot.

The mean dry weights of filled grains were significantly influenced as a result of the applications of the different S° coated fertilizer sources (Table 4). Higher but similar mean dry weights of filled grains were observed in the coated fertilizers TSP+S°m, TSP+S°c, TSP+S°f and UNE1 with the means of 10.4, 10.3, 10.1 and 9.9 g/pot, respectively (Table 4). GP10 had the lowest mean DW of filled grains. There was no significant difference observed between the GP10 and the Control treatment.

The imposition of the two water regimes resulted in significant differences in mean DW of filled and unfilled grains (Figure 3 and Table 4). Flooding of the soils resulted in significantly increased DW of filled grains from a mean DW of 6.5 g/pot without flooding to a mean of 10.9 g/pot with flooding. In the case of unfilled grains, there were significantly lower unfilled grain mean dry weights in the flooded treatment (Figure 3 and Table 4).

Table 4. **Dry weight of rice straw and grain, and total dry weight of tops as influenced by the application of the different S fertilizer sources under flooded and non-flooded conditions.**

S material	Straw DW (g/pot)			Filled grain DW (g/pot			Total DW (g/pot)		
	F	NF	Mean	F	NF	Mean	F	NF	Mean
Control	6.9	7.4	7.2c	7.1	3.3	5.2c	14.0	10.7	12.4d
GP10	11.7	11.8	11.8b	8.3	4.4	6.4c	20.0	16.2	18.1c
UNE511	12.6	12.3	12.5ab	12.1	5.3	8.7b	24.7	17.6	21.2b
UNE1	13.4	12.2	12.8ab	11.7	8.0	9.9ab	25.1	20.2	22.7a
TSP+S^0f	13.3	12.7	13.0a	12.7	7.5	10.1ab	26.0	20.2	23.1a
TSP+S^0m	12.8	11.7	12.3ab	12.2	8.6	10.4a	25.0	20.3	22.7a
TSP+S^0c	13.2	12.0	12.6ab	12.0	8.7	10.3a	25.2	20.7	22.9a
Mean	11.9 a	11.4 a		10.9 a	6.5 b		22.9 a	18.0 b	

Mean values followed by the same letter in a column or row within each rice component are not significantly different at the 5% level by DMRT.

(ii) Total dry weight of tops (straw + grain)

Table 4 indicates that the lowest mean total DW of tops was recorded in the Control treatment followed by GP10, which recorded a significantly lower mean total DW of tops compared to the UNE511 S^0 fertilizer source. UNE1, TSP+S^0f, TSP+S^0m and TSP+S^0c recorded higher but similar mean total DW of tops. Flooding of soils significantly increased the mean total DW of tops from a mean of 18.0 g/pot without flooding to a mean of 22.9 g/pot with flooding (Table 4).

Sulfur Content and the Recovery of Fertilizer S in Leaves at each Leaf Harvest

(i) S content of leaves

Water regimes had a significant effect on S content of leaves only at 27 DAT, where the mean S content averaged over fertilizers was 0.25 and 0.30 mg/pot in the flooded and non-flooded treatments respectively. Application of the different S^0 coated fertilizer sources did not have any significant effects on S content of leaves at 27 DAT (Table 5). The Control treatment recorded a significantly lower S content of leaves compared to the S^0 coated fertilizer sources. A similar trend was observed at 41 DAT, where the lowest S content of leaves was recorded in the Control treatment, which was significantly lower than that of GP10 and UNE511 S^0 fertilizer sources. Lower and similar S contents of leaves were observed in the Control and GP10 treatments at 55 DAT. At 69 DAT, higher but similar S contents of leaves were observed in the TSP+S^0m and TSP+S^0c S^0 coated fertilizer sources.

(ii) Fertilizer S recovery in the leaves

Table 6 shows that at 27 DAT, flooding of soils significantly increased the mean percentage recovery of the fertilizer S from a mean percentage S recovery of 18% without flooding to a mean of 41% with flooding. Application of TSP+ S^0c fertilizer resulted in a significantly higher recovery of fertilizer S in the rice leaves at the first leaf harvest (27 DAT) with a mean of 40%, although this was similar to that of the UNE1 (35%), TSP+S^0m (34%) and TSP+S^0f (31%) S^0 coated fertilizer sources. The lowest fertilizer S recovery in the rice leaves was recorded in the UNE511 S^0 fertilizer source.

There was a significant interaction between water regime and S^0 fertilizer source on the percentage fertilizer S recovery in the rice leaves at 41 DAT. That is, in the presence of floodwater, most of the fertilizers significantly improved their performances as far as recovery of the fertilizer S is concerned. At 55 DAT, the S^0 fertilizer sources UNE1, TSP+S^0f, TSP+S^0m, TSP+S^0c recorded high but similar mean percentage fertilizer S recoveries. Flooding of soils also significantly increased the mean fertilizer S recovery. At 69 DAT, a similar trend was observed. Application of GP10 and UNE511 resulted in

Table 5. **Effect of S^0 coated fertilizer sources on S content (mg/pot) of rice leaves at different leaf harvest times.**

	S^0 Coated fertilizer materials						
Leaf harvest time	Control	GP10	UNE511	UNE1	TSP+S^0f	TSP+S^0m	TSP+S^0c
				S content			
27 DAT	0.22 b	0.30 a	0.27 a	0.28 a	0.30 a	0.30 a	0.30 a
41 DAT	0.15 d	0.22 c	0.24 bc	0.29 a	0.29 a	0.27 ab	0.28 ab
55 DAT	0.18 c	0.21 c	0.30 b	0.37 a	0.31 ab	0.32 ab	0.33 ab
69 DAT	0.15 c	0.18 de	0.22 cd	0.25 bc	0.26 bc	0.29 ab	0.31 a

Values followed by the same letter in a row within each harvest time do not differ significantly at the 5% level by DMRT.

Table 6. **Percentage fertilizer S recovery (%) in rice leaves from the different S^0 coated fertilizer sources measured at each harvest under flooded (F) and non-flooded (NF) conditions.**

	S^0 coated fertilizer materials						
Water regime	GP10	UNE511	UNE1	TSP+S^0f	TSP+S^0m	TSP+S^0c	**Mean**
			27DAT				
F	41	27	36	50	39	52	**41 a**
NF	0	5	34	11	28	27	**18 b**
Mean	**21 bc**	**16 c**	**35 ab**	**31 abc**	**34 ab**	**40 a**	
			41DAT				
F	34 abc	38 ab	50 a	43 ab	19 bcd	52 a	
NF	9 cd	0 d	29 abc	37 ab	29 abc	18 bcd	
			55DAT				
F	25	30	56	51	46	52	**43 a**
NF	0	7	32	26	19	28	**19 b**
Mean	**13 b**	**19 b**	**44 a**	**39 a**	**33 a**	**40 a**	
			69DAT				
F	13	28	60	57	45	47	**47 a**
NF	1	3	36	31	31	41	**24 b**
Mean	**7 b**	**16 b**	**48 a**	**44 a**	**38 a**	**44 a**	

Values followed by the same letter in a column or row within each harvest time are not significantly different at the 5% level by DMRT.

significantly lower mean percentage fertilizer S recovery at 69 DAT.

Sulfur Content and Recovery of Fertilizer S in the Straw and Grain Components

(i) S content of straw and grain

Flooding of the soils resulted in significant increases in the mean S content of straw and grain with the means of 7.5 mg/pot with flooding and 6.4 mg/pot without flooding for the straws, and 9.8 mg/pot with flooding and 5.7 mg/pot without flooding for the grains (Table 7). Application of the different S^0 coated fertilizer materials resulted in significant differences in the mean S content of straw and grain, and the mean total S content (Table 7).

Higher but similar mean S contents of straw were recorded in the S^0 coated fertilizers UNE1, TSP+S^0f and TSP+S^0c, followed by TSP+S^0m and UNE511, which were significantly lower. The lowest mean S content of straw was observed in the Control treatment, which was significantly lower than that of the GP10 S^0 coated fertilizer source (Table 7).

A similar trend was observed for the S contents of grain where higher but similar mean S contents were recorded in the UNE1, TSP+S^0f, TSP+S^0m and TSP+S^0c S^0 coated fertilizers. The Control and GP10 treatments recorded the lowest mean S contents of grain (Table 7).

(ii) Total S content of the tops (straw + grain)

When the S content of straw and grain was summed, a higher mean total S content in the rice tops was obtained in the UNE1 fertilizer treatment, but, this did not differ significantly from those of TSP+S^0f and TSP+S^0c S^0 coated fertilizer sources (Table 7). UNE511 recorded a significantly lower mean total S content in the rice tops, although this was significantly higher than that of the GP10 fertilizer treatment. The lowest mean total S content in the rice tops was observed in the Control treatment. Flooding of soils significantly increased the total S content in the rice tops from a mean of 12.1 mg/pot without flooding to a mean of 17.3 mg/pot with flooding (Table 7).

(iii) Fertilizer S recovery in the straw and grain

There was no significant water regime x S^0 coated fertilizer source interaction on the recovery of fertilizer S in the straw and grain components. Higher fertilizer S recovery was recorded in the UNE1 treatment with a mean percentage S recovery of 38.6% (Table 8), although this was not significantly different from those of TSP+S^0f and TSP+S^0c S^0 coated fertilizer sources.

The mean percentage fertilizer S recoveries in the straw were significantly lower in the UNE511 (13.7%) and GP10 (5.6%) S^0 coated fertilizer materials, which were similar.

The mean percentage recovery of fertilizer S in the grain (Table 8) shows a similar trend as has occurred

Table 7. **S contents of straw and grain, and the total S content as influenced by the application of the different S fertilizer sources under flooded and non-flooded conditions.**

S material	S content of straw (mg/pot)			S content of grain (mg/pot)			Total S content (mg/pot)		
	F	NF	Mean	F	NF	Mean	F	NF	Mean
Control	3.0	3.4	3.2d	5.0	2.5	3.7c	8.0	5.9	6.9e
GP10	6.0	5.6	5.8c	5.7	3.3	4.5c	11.8	8.9	10.4d
UNE511	7.2	6.6	6.9b	10.5	3.7	7.1b	17.7	10.3	14.0c
UNE1	10.3	7.9	9.1a	12.1	8.2	10.2a	22.4	16.1	19.3a
TSP+S^0f	9.2	7.4	8.3a	12.3	6.7	9.5a	21.5	14.1	17.8a
TSP+S^0m	7.4	6.6	7.0b	10.6	7.4	9.0a	18.0	14.0	16.0b
TSP+S^0c	9.7	7.4	8.6a	12.0	7.8	9.9a	21.7	15.2	18.5a
Mean	7.5 a	6.4 b		9.8 a	5.7 b		17.3 a	12.1 b	

Values followed by the same letter in column or row within each rice component do not differ significantly at the 5% level by DMRT.

in the straw, where application of UNE511 had a lower grain S recovery compared to the other S° coated fertilizer materials followed by GP10 which recorded the lowest (4%) S recovery in the grain (Table 8).

(iv) Total fertilizer S recovery in the rice tops

Higher but similar mean total fertilizer S recoveries were obtained in the treatments TSP+S°c, UNE1 and TSP+S°f with the means of 82.7%, 82.1% and 68.4%, respectively (Table 8). The lowest mean total recovery of fertilizer S in the rice tops was observed in the GP10 fertilizer treatment with a mean of 9.6%, which was significantly lower than that of the UNE511 (38.8%) treatment. Flooding of the soils significantly increased the mean total recovery of fertilizer S from 38.7% without flooding to 75.4% with flooding.

DISCUSSION

Number of Tillers and Grains

Applications of the different S° fertilizer sources under flooding appear to have contributed to the rapid increase in tiller numbers, thus, higher grain number (Table 2 and Figure 1). Visual observations during the course of the study, showed stunted growth and less tiller numbers in the Control treatment particularly in the early growth stages (Table 2), which are symptoms of S deficiency (Yosida and Chaudhry, 1979; Blair *et al*., 1979b). This is clearly shown in Table 3, where applications of the different S° fertilizer sources under flooding resulted in higher grain numbers than when they were applied to non-flooded conditions.

The number of tillers is approximately constant for any one variety under comparable conditions, however, tillering can be influenced by cultural conditions, plant spacings, amount of fertilizer applied, weeds and water availability (Grist, 1986). According to Grist (1986), if tiller numbers are few in number and produced within a short period of time, the ripening period of all is about equal. However, if tillers are numerous or produced over a lengthy period of time, a variable number of unproductive tillers can occur. Hence, a large number of tillers is not necessarily conducive to higher grain yield, because it is possible that unequal ripening may result.

In the current study, tiller numbers in the flooded condition, increased rapidly from 3.1 tillers/plant at 20 DAT to almost 4.0 tillers/plant at 27 DAT (Figure 1). Under non-flooding, tiller numbers increased slowly from 2.7 tillers/plant at 20 DAT to 4.6 tillers/plant at 55 DAT (Figure 1). De Datta *et al*. (1970), indicated that tiller number increases as the depth of water decreases and as the soil dries, but, when the soil drying reaches a relatively extreme level, the tiller number reduces sharply. In the present study, under flooding, water was maintained at a depth of about 4 cm at all times whereas under non-flooding, water was maintained at or near field capacity. The consistently lower tiller number under flooding after 27 DAT, may thus be due to the above phenomenon. However, despite the lower tiller numbers under the flooded conditions, the filled grain

Table 8. **Effect of application of the different S fertilizer sources on recovery of fertilizer S in rice straw and grain, and total recovery of fertilizer S in the tops under flooded and non-flooded conditions.**

S material	Percentage S recovery (%)								
	Straw			Grain			Total		
	F	NF	Mean	F	NF	Mean	F	NF	Mean
GP10	11.1	0	5.6c	8	0	4.0d	19.1	0	9.6d
UNE511	27.4	0	13.7c	37.8	12.3	25.1c	65.2	12.3	38.8c
UNE1	46.3	30.9	38.6a	50.4	36.5	43.5ab	96.7	67.4	82.1a
TSP+S°f	44.7	18.8	31.7ab	46.4	26.9	36.7abc	91.1	45.7	68.4ab
TSP+S°m	33.6	23.7	28.7b	39.9	24.6	32.3bc	73.5	48.3	60.9b
TSP+S°c	44.5	26.0	35.2ab	62.2	32.7	47.5a	106.7	58.7	82.7a
Mean	34.6 a	16.7 b		40.8 a	22.2 b		75.4 a	38.7 b	

Values followed by the same letter in column or row within each rice component do not differ significantly at the 5% level by DMRT.

number was significantly higher than under non-flooding (Table 3 and Figure 2). This implies that the rapid increase in tiller numbers and the early attainment of maximum tillering under flooding, had a positive influence on grain production. Furthermore, the higher number of unfilled grains under non-flooding (Figure 2) appears to be the direct result of the slow increase and late attainment of maximum tillering. This seems to be in conformity with Grist (1986), where he indicated that tillers produced over a longer period of time may result in the production of a variable number of unproductive tillers or unequal grain ripening.

Straw and Grain Yields

In relation to straw yield, it is apparent that applications of the different S° fertilizer sources increased the DW of straws, however, there were non-significant differences in straw DW amongst the different S° fertilizer sources (Table 4). However, grain yield was significantly influenced by the application of the different S° fertilizer sources. Application of GP10 and UNE511 fertilizer treatments resulted in lower grain yields (Table 4). The data on the total dry weight of tops (Table 4) show that the applications of GP10 and UNE511 resulted in significantly lower total dry weight of tops. Flooding of the soils resulted in higher total DW of tops (22.9 g/pot) compared to the non-flooded treatment, which recorded 18.0 g/pot. The Control treatment recorded the lowest total dry weight of tops under both water regimes. Similar results were also found by Dana *et al.* (1994a) and Blair *et al.* (1994), who found that the application of GP10 (HF) resulted in significantly lower relative whole plant and grain yields.

Sulfur is required early in the growth of rice plants and if it is limiting during early growth, the final yield will be reduced (Blair *et al.* 1979b). Dana *et al.* (1994a) and Blair *et al.* (1994) found that the application of UNE1 gave consistently higher yields irrespective of the water regimes (non-flooded and flooded) employed. In the current study, non-significant differences in straw and grain yields amongst the S° fertilizer sources TSP+S°f (fine), TSP+S°m (medium) and TSP+S°c (coarse) were obtained. This means that the different S° particle sizes bound onto the surfaces of TSP granules had a similar effect on the straw and grain yields. Dana *et al.* (1994a), attributed the different responses principally to the different techniques employed in the production of the products, resulting in different coat strengths. According to Dana *et al.* (1994a), UNE1 was produced using a rotating drum-seed coating device by binding S° (particle size <0.1 mm or <100 µm) onto the surface of 2-4 mm diameter TSP granules with polyvinyl alcohol as a binder. In the present study, TSP+S°f, TSP+S°m and TSP+S°c were prepared in the similar manner as UNE1, but different S° particle sizes were used (fine = 53-154 µm; medium = 154-263 µm and coarse = 263-328 µm). Calcium lignosulfonate was used to bind S° particles onto the surfaces of TSP granules of 2-2.8 mm diameter. The information booklet (No.8) on Gold-phos by Hi-Fert Pty Ltd (1997) indicated that the Gold-phos product (GP10) is made by milling S° to an agronomically available size (<250 µm) and chemically bonding it onto TSP granules. The lower yields obtained in both the UNE511 and GP10 products seem to be related primarily to the way these products were prepared and not necessarily due to the different S° particle sizes or coating materials used. It is possible therefore, to suggest that these products (UNE511 and GP10) were prepared in such a way that impairment of water penetration into the granules was increased thereby, inhibiting the dispersion of S° in the soil.

The imposition of the two water regimes also influenced straw and grain yields. Grain yield under non-flooded condition was significantly lower with a mean of 6.5 g/pot than that under flooded condition with a mean grain weight of 10.9 g/pot (Figure 3). Similar results were also reported by Dana *et al.* (1994a) and Ismunadji (1985), who found higher grain yields under flooded conditions than under non-flooded conditions. However, these authors found higher straw yields under non-flooded than under flooded conditions whereas in the current study, a non-significant difference in straw yield between non-flooded and flooded conditions was observed. Visual observations during the course of the experiment, showed that under the non-flooded condition, the rice plants were generally shorter but had more tillers particularly at the later growth stages (Figure 1). On the other hand, under the flooded condition, the plants were generally taller but had less number of tillers (Figure 1). The non-significant difference in straw yield under these two water regimes may be due to the compensatory effect of higher tiller numbers under non-flooded and taller plants under flooded conditions. That is, it is possible for the generally shorter plants under the non-flooded condition to have lower straw yield if it were not for the higher tiller numbers. Similarly, it is possible to suggest that although the plants under the flooded condition had less number of tillers, which may contribute to lower straw yield, the fact that they were generally taller may have compensated for any decrease in straw yield that may have eventuated if the plants were shorter as under the non-flooded condition.

Sulfur Content and Recovery of Fertilizer S in the Leaves, Straw and Grain

Sulfur content of leaves in the Control and GP10 treatments tend to decline with each leaf harvest (Table 5) whereas with the other S° fertilizer sources the S contents of leaves were generally higher and constant at each leaf harvest. Similarly, the data on percentage fertilizer S recovery (Table 6) indicate that the percentage fertilizer S recovered in the leaves from the GP10 and UNE511 treatments were significantly lower at each leaf harvest compared to the other S^0 fertilizer sources.

The fact that the higher S content of leaves were observed in the GP10 and UNE511 treatments at the early growth stages (27 DAT), is because the rice plants in the early growth stages were relatively smaller, thus the amounts of S released from the GP10 and UNE511 fertilizer sources were sufficient to be recovered in the leaves at the higher amounts even though they were releasing little S. However, as the rice plants mature the S released from these two fertilizer sources was distributed to other leaves or plant parts and because the fertilizers were releasing little S, less amount of fertilizer S was recovered in the leaves, hence, the generally lower S contents in the leaves at the later growth stages (Table 5). On the other hand, the other S^0 fertilizer sources were able to release higher amounts of S at a sustained level, therefore the S contents in the leaves (Table 5) and the percentage fertilizer S recovered in the leaves from the respective S sources (UNE1, TSP+S^0f, TSP+S^0m and TSP+S^0c) were generally high at each leaf harvest (Table 6).

The data on S contents of straw and grain, and the total S content (Table 7) indicate that the GP10 and UNE511 treatments recorded lower straw and grain S contents. This may be attributed to lack of S as a result of little S being released by these particular fertilizer materials. Table 8 shows that the mean percentage recovery of fertilizer S in the straw and grain, and the mean total S recovered in the rice tops (total) were significantly lower in the GP10 and UNE511 fertilizer materials. These results further support the assertion that both GP10 and UNE511 released little S in comparison to the other S fertilizer sources and it is in agreement with the results of Dana *et al.* (1994b), who found that the release of S from UNE1 (polyvinyl alcohol) and UNE3 (calcium lignosulfonate) products were similar and greater than the release from HF (GP10) product. Blair *et al.* (1994), found a higher amount of fertilizer S recovered in the organic S pool from HF (GP10), and they attributed this to the slower release of S from HF, which resulted in the poor growth of pastures. They also found that the immobilization of S, which was released from this product was the main reason for the higher S transformation into the organic S fraction.

Flooding of the soils significantly increased the total S content in the rice tops from a mean of 12.1 mg/pot without flooding to a mean of 17.3 mg/pot with flooding, and the mean total recovery of fertilizer S from 38.7% without flooding to 75.4% with flooding (Table 8). This means that oxidation of S^0 was greater under the flooded condition. However, this is in contrast to studies, which demonstrated the S^0 oxidation is favored at field moisture capacity (Janzen and Bettany 1987c; Nevell and Wainright 1987). However, Dana *et al.* (1994a), found that oxidation of S^0 was rapid under both flooded and non-flooded conditions. Within a flooded soil, there are aerobic and anaerobic zones, therefore, oxidation and reduction reactions can occur at the same time in the different parts of the flooded soil (Blair and Lefroy 1987). Rice plants generally occupy a large volume of the planted soil so that oxidized zones occur which allow for the growth and metabolism of aerobic microorganisms (Freney *et al.* 1982). As part of the experiment, these S^0 coated products were placed under water in petri- dishes for a period of 5 days. It was observed that UNE1, TSP+S^0f, TSP+S^0m and TSP+S^0c disintegrated and dispersed faster after a day (data not presented), which would mean that oxidation of S^0 by the S oxidizing microorganisms took place quickly.

Many factors influence the oxidation of S^0 and these include soil temperature (Parker and Prisk 1953; Nor and Tabatabai 1977; Janzen and Bettany 1987b; Germida and Janzen 1993), soil moisture and aeration (Burns 1968; Janzen and Bettany 1987c; Germida and Janzen 1993), soil pH (Nor and Tabatabi 1977; McCready and Krouse 1982); nutrient availability (Burns 1968; Lawrence and Germida 1988), sulfur oxidizing microorganisms (Vitolins and Swaby 1969; Konopka *et al.* 1986) and particle size of the S^0 (Li and Caldwell 1966; Weir 1975; Koehler and Roberts 1983; Janzen and Bettany 1986; Germida and Janzen 1993).

In the present study, the different S^0 particle sizes used did not have any significant influences on the dry weight of straw and grain irrespective of the 2 water regimes imposed. Koehler and Roberts (1983), observed that S^0 particle size of 250-350 μm provided some increase in lucerne yield when applied at higher rates, but when applied at lower rates very little effect on lucerne yield was obtained. Santoso *et al.* (1995), found no significant difference in S^0 (150-250 μm) oxidation when S^0 was applied at 10 mg/g soil. In a similar study, Lefroy *et al.* (1997), found higher S^0 oxidation when S^0 was applied at 35.2 mg/g soil (» 20 kg S/ha). In the current study, the rate of S^0 applied at 10 kg/ha with the coarse particle size (263-328 μm) would have had a lower specific surface area and amount of S, resulting in lower oxidation (Lefroy *et al.* 1997) thus, contributing to the non-significant effects of the different S^0 particle sizes on the total dry weights of rice tops and the S content and recovery of fertilizer S in the straw and grain.

As indicated earlier, the different S responses obtained in the current study seem to be due largely to the way the individual product was prepared. For example, in the case of UNE511, although the coating material used was the same as that in UNE1, because it was prepared differently, the results obtained differ significantly to that of UNE1. Hence, it may be suggested that selection of the right coating material should be accompanied by the precise following of the right procedures in the preparation of each individual product to realize the full potential of a coated fertilizer product.

Comparison of the different Elemental S Coated Fertilizer Sources

In general, the results in the current study clearly demonstrated that amongst the S^0 coated fertilizer sources, UNE1 and the TSP+S^0 products with the fine, medium and coarse S^0 particle sizes were more effective than the other sources. This was due principally to the use of water-soluble adhesives (polyvinyl alcohol and calcium lignosulfonate) to bind S^0 to the TSP granules. However, it has also been observed that the way each individual product was prepared contributed partly to its effectiveness. This is clearly shown in the case of UNE511, that although it has the same coating material as UNE1, because it was subjected to excessive warm air during its preparation, the coat was extra hardened which tended to impede water penetration into the granules and the consequent dispersion of S^0 into the soil. The application of GP10 also generally resulted in poorer S response than UNE1 and the TSP+S^0 products. It has been highlighted previously that this particular product was prepared by milling S^0 to <250 μm and chemically bonding it on the TSP granules. It is most probable that during this process the coat strength could have been consolidated, which, resulted in the impairment of water penetration into the granules thus preventing the dispersion of S^0 into the soil. It seems obvious, therefore, that the choice of a suitable coating material should be accompanied by the proper preparation techniques of the product, so that not only it can release its nutrient content but also release them when they are required by plants at the optimum.

The rate of nutrient release from slow release fertilizers was described by a number of researchers as being controlled by the slow diffusion of the nutrient ions through the membrane to the soil (Lunt and Oertli, 1962; Ahmed *et al.* 1963). Kochba *et al.* (1990), proposed that the mechanism responsible for nutrient release is the diffusion of water vapor into the granule through the hydrophobic membrane (coat material) and the subsequent bursting or expansion of the membrane, which lead to an accelerated outward flow of the saturated solution from the coated granules. In addition, they proposed that timing of the nutrient release of the individual granules was a random phenomenon, similar to radioactive decay. This proposition assumes that the release process follows first order kinetics. That is, the granule population is considered to be uniform and that the likelihood of the bursting of any given granule is the same throughout the release process. However, Kochba *et al.* (1994) reported that studies on slow release rate and individual granules and population behavior showed that individual granules within a given population of a slow-release fertilizer have a different release pattern. They found that some granules released their nutrient content within a few days, whilst others released their nutrient contents in a period of 100 days. Furthermore, the authors observed that the release process contains a delay mechanism that has a different duration for different individual granules and that a "starter" fraction reacts soon after the exposure to water while others react later. Studies on N release from polyolefin-coated urea (POCU) (Takahashi and Ono 1996), indicated that individual granules of POCU had different weights and N release rates. Also, they found that an increase in individual weights of POCU resulted in a decrease in the N release and they attributed this relationship to the coating thickness.

From the above discussions on nutrient release as described by the various authors, it is apparent that for a coated fertilizer to be more effective, the coating material must allow water to diffuse through it into the granules and because individual granules within a population have a different release pattern (Kochba *et al.* 1994), maximum penetration of water through the coat into most granules should be facilitated, so that each individual granule may release its nutrient content according to its release pattern or behavior. It is pertinent, therefore, that in the process of coating fertilizer granules, the water-soluble nature or characteristics of the coating material should be maintained so that water penetration into the granules, which is the beginning of the entire process of fertilizer nutrient release, cannot be impeded.

CONCLUSION

On the basis of the results discussed above, it is clear that UNE1, TSP+S^0f (fine), TSP+S^0m (medium) and TSP+S^0c (coarse) are effective S fertilizer sources for rice under non-flooded and flooded conditions compared to GP10 and UNE511 S^0 fertilizer sources. It is also evident that the use of water-soluble adhesives such as polyvinyl alcohol and calcium lignosulfonate to bind S^0 particles on to TSP products contributed significantly to the effectiveness of these products. Moreover, the results indicated that the way a product is prepared has a strong influence on its effectiveness. The use of the different S^0 particle sizes of 53-154μm, 154-

263µm and 263-328µm did not result in any significant differences, and these could be considered as agronomically suitable in respect of providing S nutrition to rice plants under non-flooded and flooded conditions.

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Appendix 1. Anova for filled grain numbers

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB
GRAND MEAN	1	9499064.00000	9499064.00000	2212.1680	0.00000***
R	2	0024776.38000	0012388.19000	0002.8850	0.07386-
W	1	0443520.80000	0443520.80000	0103.2883	0.00000***
F	6	0445365.30000	0074227.55000	0017.2863	0.00000***
WF	6	0047750.09000	0007958.34900	0001.8534	0.12756
RWF/	26	0111644.20000	0004294.00700		

Appendix 2. **Anova for the straw (tops) dry weights**

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB
GRAND MEAN	1	5765.30400000	5765.30400000	7267.3840	0.00000***
R	2	0001.58370500	0000.79185270	0000.9982	0.38224
W	1	0003.12537200	0003.12537200	0003.9396	0.05781-
F	6	0149.62500000	0024.93750000	0031.4347	0.00000***
WF	6	0004.14248500	0000.69041420	0000.8703	0.52796
RWF/	26	0020.62612000	0000.79331210		

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CONSTRAINTS AND RESULTS ANALYSIS OF THE SPICE INDUSTRY IN PAPUA NEW GUINEA

R. Chris Dekuku and Anton K. Benjamin

ABSTRACT

*Most of the currently cultivated spice crops in Papua New Guinea [PNG] were introduced in the 1960's and 1970's, but to date, there is no spice industry plan, despite the approval of a Spice Industry Act in 1989. This report is a component of the outcome of the PNG Spice Industry Workshop, held on the 18th and 19th of September 2003, at the Gateway Hotel, and DAL – Konedobu Conference Room respectively to to initiate discussions towards the formulation of PNG Spice Development Plan. It is by understanding the issues that constraints the industry, then only would appropriate solutions be formulated to address them. The **ineffectiveness of the Spice Industry in Papua New Guinea** could be classified broadly into two **inter linked** sub – components, namely; **Ineffective management** and **Poor operational** components. As such, improvements in the management and operational components would help boost the efficiency and effectiveness of the spice industry in PNG. It is expected that, the information in this report would be useful to the planners and people in the Spice Industry for the formulation of the PNG Spice Industry Plan[s] for the future.*

Key words: *Spice, vanilla, cardamom, ineffective management, poor operational component*

INTRODUCTION

The loss of over 80 percent of Madagascar vanilla plantations through cyclone damages has contributed to decline in world production of natural vanilla in late 1990s to 2000. This has seen vanilla prices souring in the world-wide. PNG farmers are taking advantage of the improved world prices through increased production and exports of vanilla. From less than one tonne production in 1998, vanilla exports is on the increase, reaching 46 tons in 2001, 70 tons in 2002 for a value of K23 million. [Spice Industry Board data]. The major production areas are; Wewak, Lae, Vanimo, Rabaul, Manus, Madang, and the National Capital District.

Other spices reported to be exported besides vanilla are; cardamom, and chillies, but the exports of these have been fluctuating over the years.

The spices, especially vanilla are now being considered as high impact crops that must be promoted alongside the major export tree crops; coffee, tea, cocoa and coconut. For the first time since the approval of the Spice Industry Act in 1989 and the inauguration of the Spice Board, the PNG Government in 2003 allocated K1.0 million to support capacity strengthening and operations in the spice industry.

Spice workshop and constraints analyses were subsequently held in September 2003, to deliberate on issues affecting the industry, and to plan for the future. The constraints and results analysis component is presented here for guidance and further deliberation by people in the spice industry.

MATERIALS AND METHODS

A cross section of personnel with association and knowledge in the spice industry who participated in the workshop also took part in the constraints analysis component, following the methodology of constraints / problem analysis [IRRI 1991, GTZ 1999 and Dekuku 2002]. The constraints were identified and written; one per each card. These were pinned on the wall, re-written, if necessary, and duplications eliminated, and finally grouped and arranged in a problem tree based on causes and effects scenario. Re-writing each of the constraints cards into positive statements led to the results tree, which also corresponds to means and ends scenario. The participants are acknowledged at the end of this report.

RESULTS AND DISCUSSIONS

The analysis indicated for the spice industry to be successful, some key issues must be addressed, and suggested also how those should be done [Figs 1 to 6]. These are highlighted below;

[1] Department of Agriculture and Livestock, P. O. Box 2033, Port Moresby.

2. Constraints Component of the PNG Spice Industry.

The identification of the constraints in the Spice Industry is an essential step in understanding the weaknesses in the industry, which in itself leads to a better understanding of the factors that are contributing to failures or stagnation in the industry.

The **ineffectiveness of the Spice Industry in Papua New Guinea** could be classified broadly into two **inter linked** sub – components, namely; **Ineffective management** and **Poor operational** components **[Fig 1]. Note that both components are inter-linked and must be addressed jointly.**

2.1. The Ineffective Management Component results from; **Ineffective Spice Board Leadership, Insufficient Funds, Frustrating Interests and Lack of Down Stream Processing [Fig. 2],** as discussed below;

2.1.1. Ineffective leadership in the industry is compounded by **lack of management and technical capacity** and **lack of coordination,** Other factors are; **lack of Spice Development Plans** which means there is **lack of Policy** and **Corporate plan** for spice development. As a result, the industry **lacks rules and regulation to regulate and guide the industry**, which **leads to poor linkages with Provinces and Stakeholders.** All these cumulatively **led to lack of coordination** and the subsequent **Ineffective Board Leadership [Fig 3].**

2.1.2. Insufficient funds for spice development, Government financial support to the spice industry is insufficient at the moment, and **Private sector investment is also limited.** In addition, there are **no credit facilities attuned to the spice industry**. Due to these, there is **lack of funds and credit** thus resulting into **insufficient funds for spice industry development**.

2.1.3. Frustrating interests in the industry, There is **stealing of spice beans in the field** as well as **on the way to market through hijacking**, and these are attributed to the **lack of control in spice exports, too many export licenses/ exporters, and lack of effective farmer associations or cooperatives.** The resulting **law and order problems** lead to **frustrating interest in the spice industry** [by producers and marketing agents].

2.1.4. Lack of down stream processing in the spice industry results from **lack of collaboration between Spice Industry Board and relevant Departments. Lack of expertise in down stream processing of some of the spices** and **lack of processing facilities** [this is interrelated to low production base under operational component].

2.2. The Poor Operational Component results from; **Low production base for most spices** [also influenced by lack of down stream processing], **inadequate information to guide the industry** and **poor market access for some of the spices [Fig. 3]**, as discussed below;

2.2.1. Low production base for most spices, results from **poor spice production systems**, which in turn is a result of **poor spice farm management practices, lack of good varieties and planting materials.**

The poor spice farm management practices results from **poor farmer training,** due to **poor extension information and poor extension services. Poor extension information** results from **spices not being part of the curriculum in schools** and subsequent **failure to train farmers. Poor extension service** is a consequence **of lack of training and re-training of extension staff and** therefore resulting in **inadequate extension staff performances.**

The lack of planting materials results from; **lack of seed and planting material multiplication centers.** While **Lack of good varieties is due to inadequate research on some spices,** which also results from **slow transfer of research technologies and insufficient research information** to the population.

2.2.2. Lack of adequate information to guide the industry, Lack of proper reporting and information systems and **lack of baseline data** in the Spice industry are causes of **inadequate extension, research, processing and market information on most spices**. This in turn leads to **lack of adequate information** [this directly contributes towards the low production base of most spices as well as poor marker access for some spices].

2.2.3. Poor market access for some of the spices results from **insufficient market outlet for most spices,** which is a consequence of **high marketing costs, inconsistency in supply** and **variable and mostly low prices for some spices.**

The high marketing costs result from **poor road, transport and marketing infrastructure and high freight costs. Variable and low prices for most spices** also result from **inconsistency in quality,** which in turn is a result of **lack of inspection and certification** resulting due to **inadequate regulations and mechanisms to enforce quality control.**

Fig. 1 Constraints Analysis of the Spice Industry in Papua New Guinea

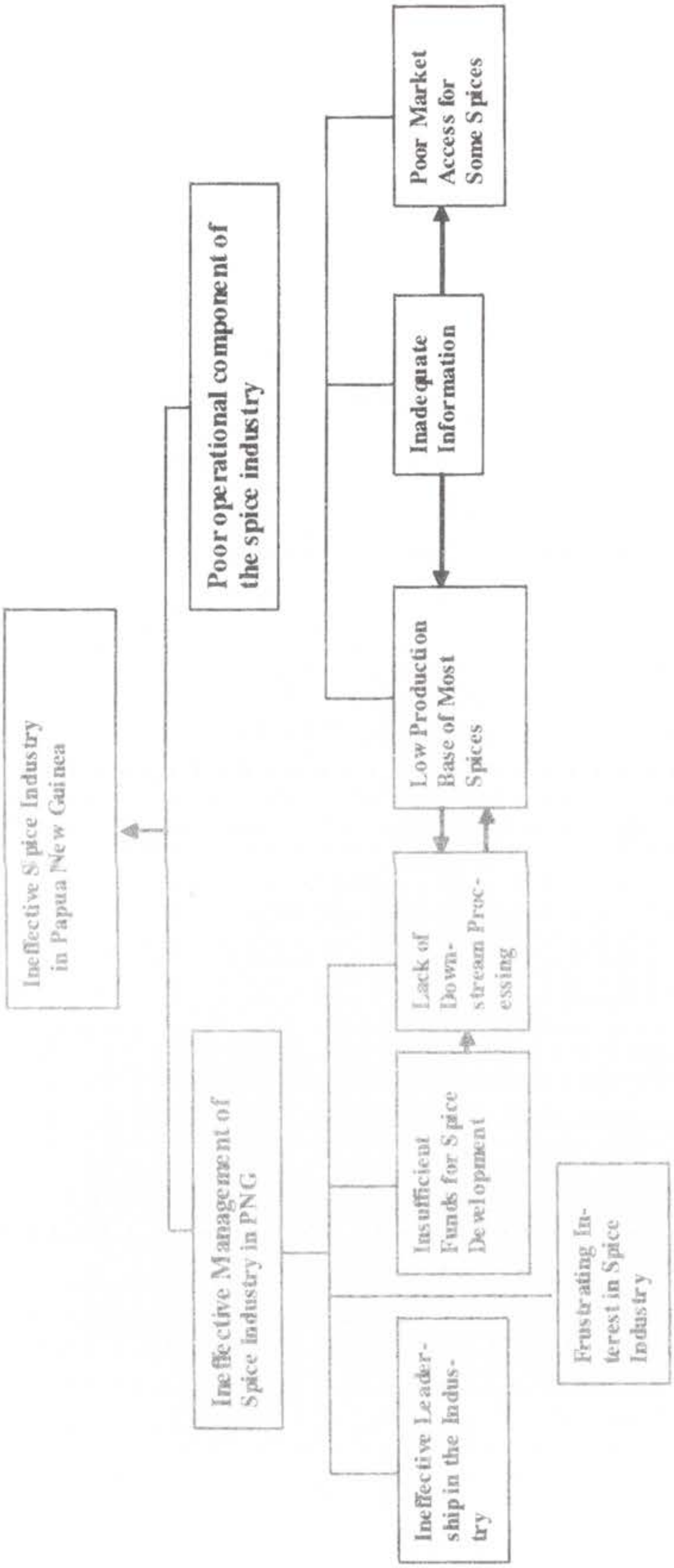


Fig 2. Management Constraints of the Spice Industry in Papua New Guinea

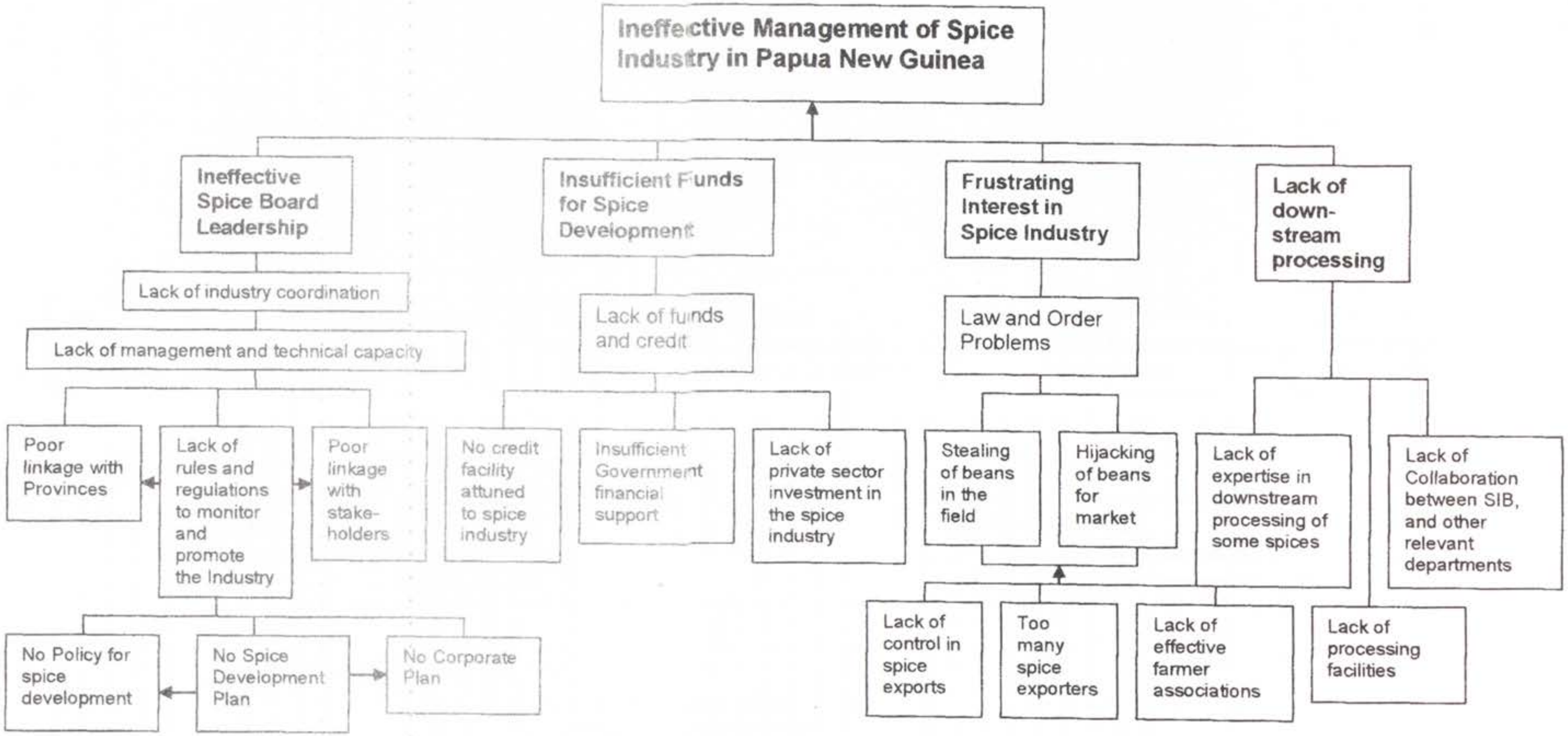
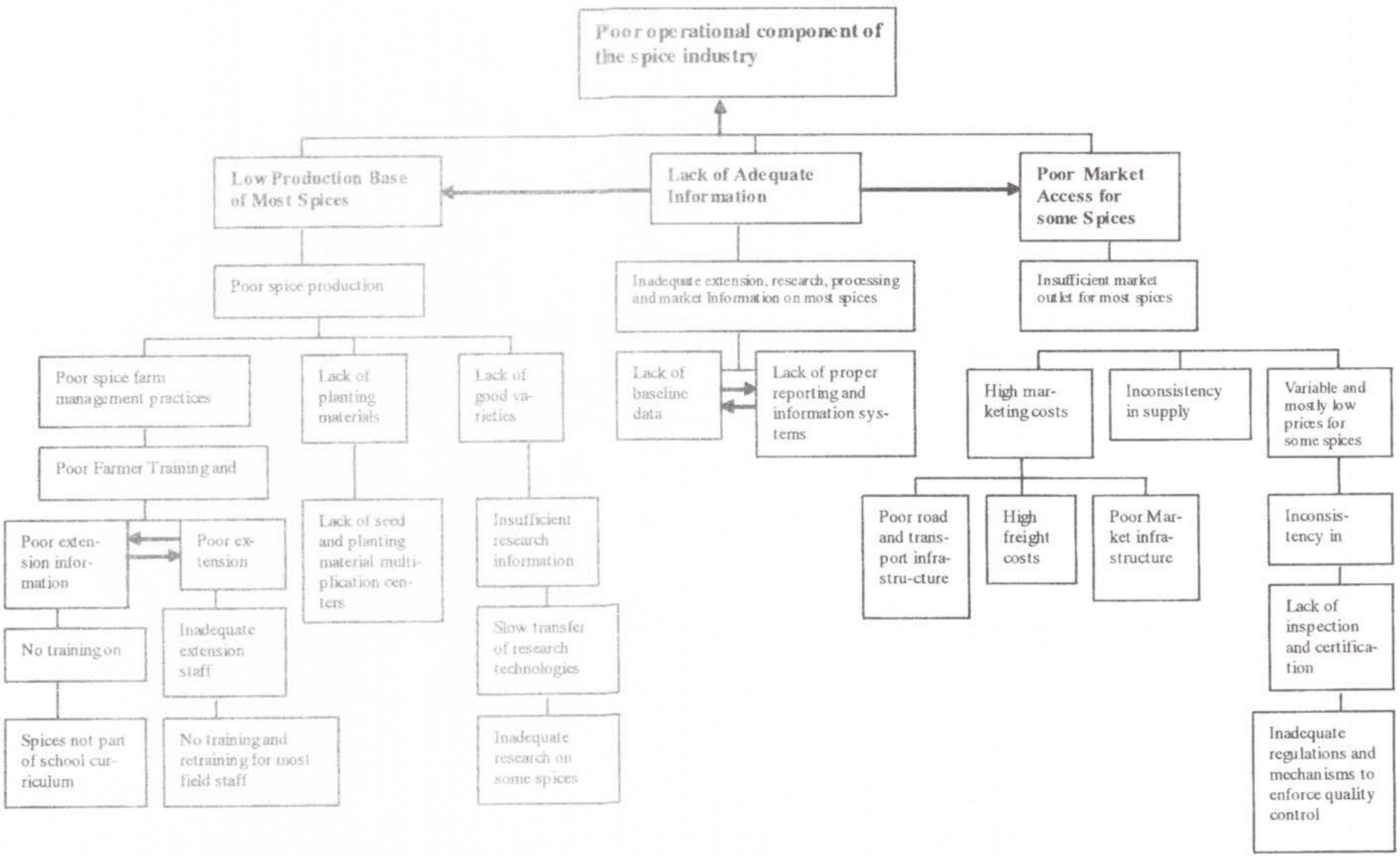


Fig. 3. Operational Constraints of the Spice Industry in Papua New Guinea



3. Results /Objective Analysis of the PNG Spice Industry.

The identified constraints in the Spice Industry, which are factors contributing to failures or stagnation in the industry, must be addressed, for the Industry to make progress, as discussed below;

An **Effective Spice Industry in Papua New Guinea** would result from **effective management** and **adequate operational components [Fig 4]. Since both components are inter-linked, the optimum operation of each sub - component is essential for the overall success of the industry.**

3.1. Effective Management Component would result from; **Effective Spice Board Leadership, Adequate Funding, Stimulating Interests and Promotion of Down Stream Processing [Fig. 5]**, further discussed below;

3.1.1. Effective spice board leadership in the industry would result from **management and technical capacity building** and **improved coordination of the industry,** Other factors are; the formulation of **Spice Development Plans** including **Policy** and **Corporate plan**. With **rules and regulation to regulate and guide the industry, linkages with Provinces and Stakeholders would improve.** All these subsequently would lead to **Improved Coordination in the Industry** and therefore promote **Effective Spice Board Leadership [Fig 6].**

3.1.2. Adequate funds for spice development, **Adequate Government financial support to the spice industry, increased private sector investment** as well as **availability of credit attuned to the spice industry** would **improve access to funds and credit** thus facilitating **adequate funds for spice industry development.**

3.1.3. Frustrating interests in the industry. The **reduction in stealing of spice beans in the field** as well as **on the way to market through hijacking** would result from **better control in spice exports, reduction in and monitoring of export licenses/ exporters** and **effective farmer associations or cooperatives in producing areas.** These would lead to **less law and order problems** and therefore **stimulate interest in the spice industry** [by producers and marketing agents].

3.1.4. Promotion of down stream processing in the spice industry would result from increased collaboration between SIB and relevant departments [such as the Department of Trade and Industry, and the Private sector], promotion of **adequate expertise in down stream processing of more spices** and **facilitating for needed processing facilities** [and promoting increased production base under operational component].

3.2. Improved Operational Component results from; **Increased production base for most spices** [also influenced by promotion of down stream processing], **adequate information to guide the industry** and **improved market access for more spices [Fig. 6]**, as discussed below;

3.2.1. Increased production base for most spices [relates to promotion of down stream processing], results from **better spice production systems**, which in turn is a result of **better spice farm management practices, access to good varieties and availability of planting materials.**

Better farm management practices would result from **better farmer training,** due to **improved extension information and improved extension services. Improved extension information** results from **adequate extension services, training of farmers on spices and spices being part of the curriculum in schools. Adequate extension service** results from **adequate extension staff performances** due to **training and re-training of extension staff.**

The availability of planting materials results from; the **establishment and promotion of seed and planting material multiplication centers.** While **availability of good varieties is due to adequate research on most spices**, which also results from increased **transfer of research technologies and sufficient research information** to the population.

3.2.2. Adequate information to guide the industry, Adequate reporting and information systems and **availability of baseline data** in the Spice industry would result in **adequate extension, research, processing and market information on most spices**. This in turn would lead to **availability of adequate information** [and also directly contributes towards the **increased production base of most spices** as well as **improved market access for most spices**].

3.2.3. Improved market access for most of the spices would result from **sufficient market outlet for most spices,** which is a consequence of **affordable marketing costs, consistency in supply** and **better prices for most spices.**

The affordable marketing costs would result from **improved road, transport and marketing infrastructure and lower freight costs** in major spice producing areas. **Better prices for most spices** would result from **consistency in quality,**

Fig. 4. Results Analysis of the Spice Industry in Papua New Guinea

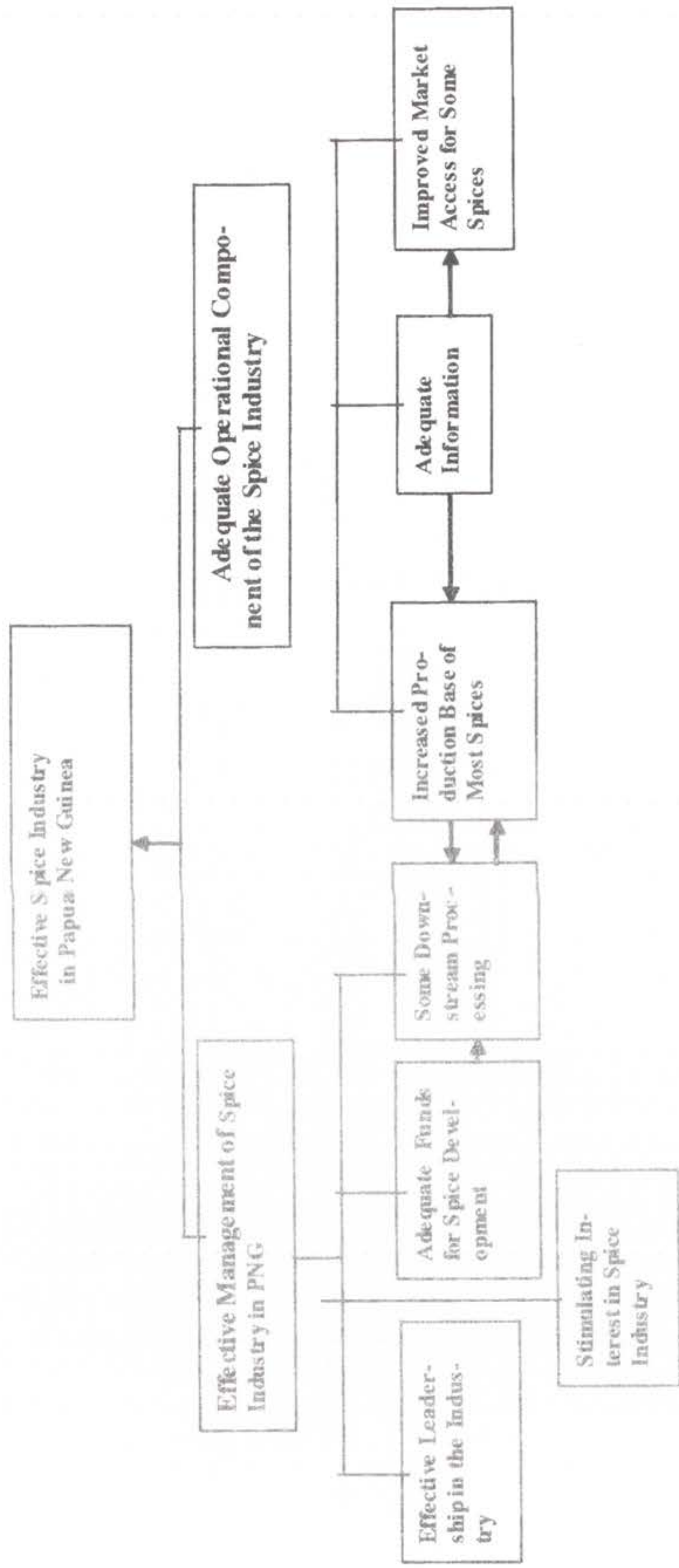


Fig 5. Management Results of the Spice Industry in Papua New Guinea

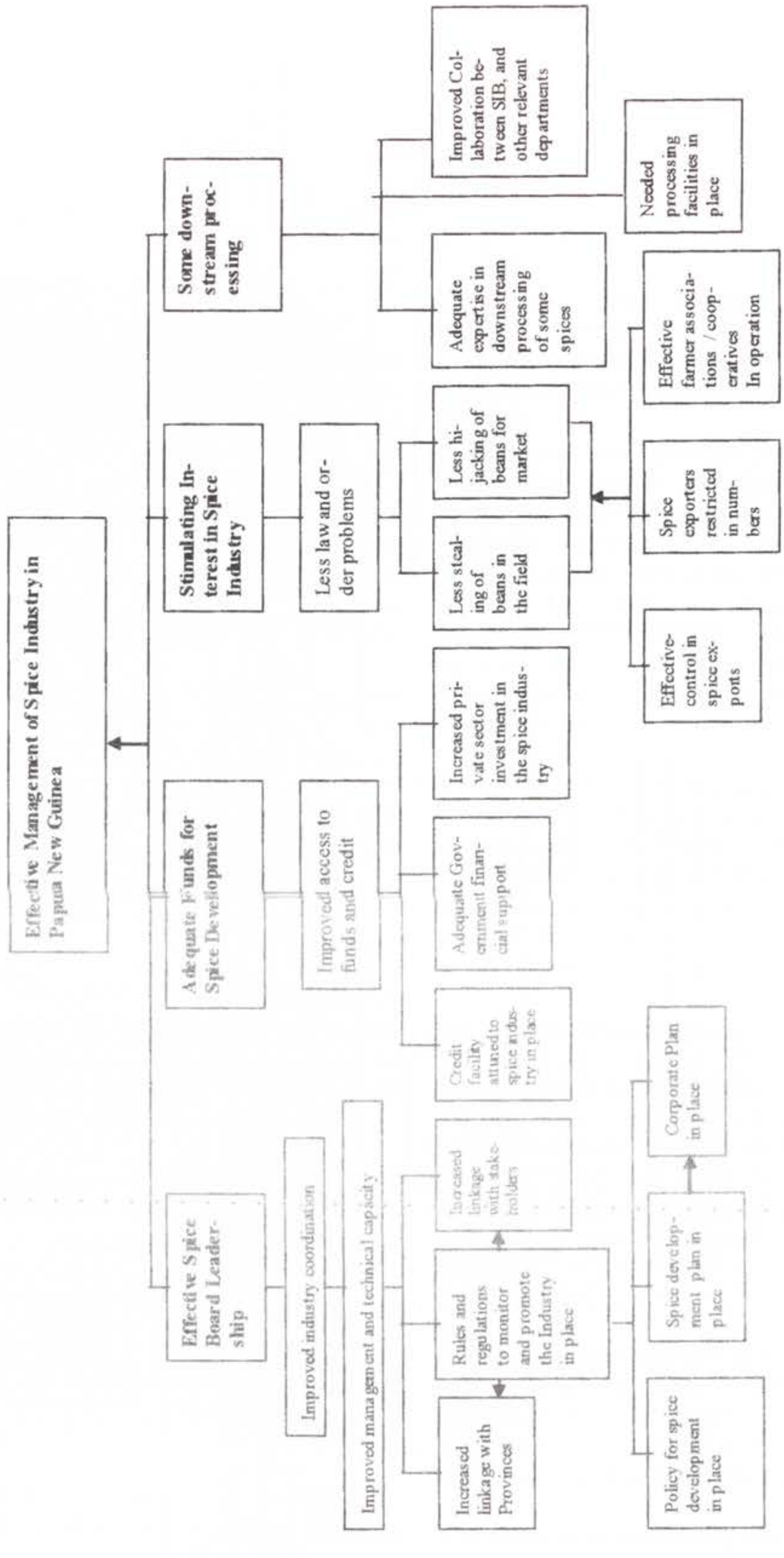
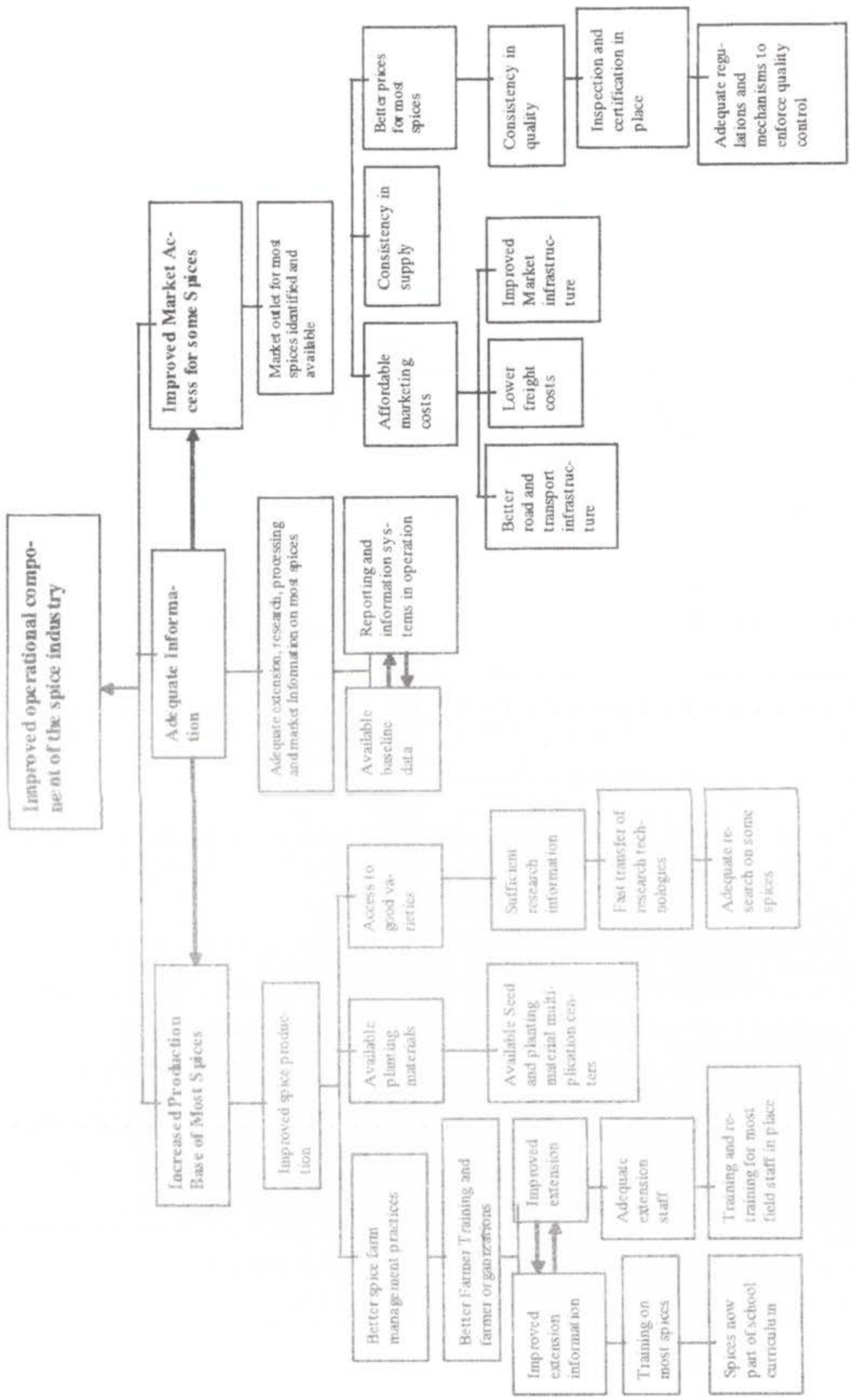


Fig. 6. Operational Results of the Spice Industry in Papua New Guinea



which in turn is a result of **adequate inspection and certification** due to **adequate regulations and mechanisms to enforce quality control.**

CONCLUSIONS

The PNG Spice Industry could be revitalized, if issues raised in this report are addressed. It has taken over 40 years and the loss of vanilla production base in Madagascar; and the corresponding hike in world vanilla prices for the PNG Spice Industry to begin showing some significant financial gains. It is expected that, the high vanilla export prices may be short-lived. Thus PNG Spice Industry would need to make significant efforts in terms of economic and quality spice production for spice produce/products from PNG to remain competitive in the World Market. We believe that, by implementing the suggestions in this report, the PNG Spice Industry would be taking great strides toward the promotion of economic, quality and competitive spice industry, for the long term sustainability and benefit to participants in the spice industry.

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ATTEMPTS AT GAINING SOME UNDERSTANDING OF THE POSSIBLE FACTORS THAT PROMOTE HIV/AIDS SPREAD IN PAPUA NEW GUINEA

R. Chris Dekuku[1] and Joseph Anang[2]

ABSTRACT

Program identification and analysis methods used in agricultural program analysis, namely; Participatory / Rapid Rural Appraisal (PRRA) were applied as methods to gain an understanding of the possibility of the spread of AIDS/HIV in two districts in Papua New Guinea [PNG]. Based on this preliminary analysis, some occupational groups and certain social activities were suggested as more prone to the spread of AIDS/HIV. These are discussed below.

Keywords: *participatory/ rapid rural appraisal, HIV/AIDS, Trobriand Islands., Kakar Island, pair wise analysis*

INTRODUCTION

HIV/AIDS is an issue of international importance of which no country in the world and no occupation is immune from. In PNG, spread of HIV/AIDS is now being recognized as an issue that demands attention, as a result of its increasing incidence and deaths recently. HIV/AIDS affects all types of people irrespective of profession

This study employs the method of Participatory Rapid Rural Appraisal [PRRA] and others in trying to gain some understanding of factors or circumstances that may encourage the spread of HIV/AIDS in PNG. The analysis presented here is a result of a two-day workshop involving seven Research Assistants, three each from Trobriand Islands in Milne Bay and Karkar Island in Madang Provinces and one from Port Moresby. It was assumed that these staff, who are health and HIV/AIDS workers may have information on AIDS/HIV in their areas. The staff from these areas come to Port Moresby for a short training on HIV/AIDS, and participated in this exercise / study as component of their training. The study was used as training for the participants as well as for the organizers to explore the local knowledge base of the participants; in an attempt to gain better understanding of their rural community activities and behaviors that may encourage and promote HIV/ AIDS spread in these parts of PNG.

Brief Information on Human immunodeficiency virus (HIV, giving rise to AIDS)

Humans inherited HIV from chimpanzees and mangabeys and since doing so, HIV has diversified and continues to do so. HIV parasitises T-helper cells of the immune system and uses their genetic machinery to produce new copies of itself. The end result is that it kills these infected cells and also reduces the body's ability to produce new cells to replace them. The depletion of these T-helper cells reduces a person's ability to fight off disease and when the number of T-helper cells drops to below 200 per mm^3 a person is regarded as having AIDS. He or she becomes particularly vulnerable to the opportunistic infections and cancers that typify AIDS, the end stage of HIV disease (NIAID).

People with AIDS often suffer infections of the intestinal tract, lungs, brain, eyes and other organs, as well as debilitating weight loss, diarrheal, neurologic conditions and cancers such as Kaposi's sarcoma and lymphomas. Most scientists think that HIV causes AIDS by directly killing $CD4^+$ T cells or interfering with their normal function, and by triggering other events that weaken a person's immune function. For example, the network of signalling molecules that normally regulates a person's immune response is disrupted during HIV disease, impairing a person's ability to fight other infections. The HIV-mediated destruction of the lymph nodes and related immunologic organs also plays a major role in causing the immunosuppression seen in people with AIDS. [*Fact Sheet* of National Institute of Allergy and Infectious Diseases (*NIAID*), *Piot et al. 2001*]

Background information on Trobriand and Karkar Islands

The Trobriand Islands consist of a group of sixteen (16) small islands or atolls situated at the south eastern tip of PNG. The population of the island is approximately 25,000 people of Austronesian origin.

[1] Department of Agriculture and Livestock, Port Moresby and
[2] United Nation's Children's Fund, Port Moresby

(1990 National Census, Milne Bay) The main language spoken by the people is Kilivila. (Weiner 1976.) PNG pidgin is not popularly spoken, and only few inhabitants who attended schools outside the Trobriand Islands or on the main land of PNG, speak pidgin. There is very little outside influence on the lifestyles of people in the Trobriand Islands. This is because only few outsiders live in there. The Trobrians practise matrilineal clan system, and there are four main clans, namely: Malasi, Lukwasisiga, Lukulabuta and Lukuba on the Island. Every indigenous Trobriand Islander belongs to one of these clans. Customary laws prohibit marriages between the clan members, but sometimes people flout these laws and marry within clans. Chieftaincy is the main traditional hierarchy system practiced on the Islands. The Paramount Chief is the chief of chiefs who has jurisdiction over lesser chiefs on the Islands. (Malinowski 1929). In Trobriand Islands women play special roles during funeral celebrations that give them some recognition in society (Weiner 1976).

Modern Trobriand Islanders hold firm beliefs in cultural practices and seasonal celebrations that have been practiced for many years. Promiscuity is rife and sexual freedom among the youth and the use of magic and love potions to attract partners for sexual pleasure are widely practiced and culturally accepted by the elders, even in this era of the AIDS epidemic. Marriage at a very young age is practiced and extra marital sex especially among teenagers is common. Teenage sex is regarded as one of the developmental stages that every young man or woman should experience, before finally settling down to marry. Group dating 'ula-tila', 'kapugula' between male teenagers from one village and female teenagers from another village, for sexual pleasure, as observed by Malinowski in 1920s, is still practised in all villages in the Trobriand Islands. (Malinowski 1929). These factors put the people of Trobriand Islands at a greater risk of acquiring STI and HIV.

Karkar is an Island situated at the north-eastern part of mainland PNG. It is east of Madang town. The population of the Island is between 25,000 to 30,000. Two ethnic groups, the Takias and the Waskias reside on the Island. Unlike the Trobriand Islands many people speak pidgin. Karkar society presents a similar picture as many other societies in PNG, in terms of male dominance and control over women and the patrilineal system of inheritance is practiced. Mixed marriage between the two main ethnic groups is practiced. There are also marriages between Karkar Islanders and people from other areas in PNG. Unlike the Trobriand Islands, people from the highlands region of Papua New Guinea have settled on the Karkar island and work as plantation labourers in coconut plantations. The 'Big Man' system of community hierarchy is practiced. Although elected local level government councilors and village court magistrates exercise more power in the Island than the 'Big Men', when it comes to cultural matters the Big Men's advice are sought and their directives are always followed. The Lutheran and the Catholic Churches have stronghold and with many followers on the Island. There are also Apostolic Churches, which are making their presence felt in some villages on the Island (Mgone C., Oyang G., Yeka W., Anang J. unpublished).

Anecdotal reports from Karkar islanders living in Port Moresby and Goroka suggest that promiscuity and teenage pregnancies are rife on the island. Sexually transmitted infections are common. Many young girls and boys are sexually active and in the absence of employment opportunities on the Island, young girls are drawn into the sex trade.

Interestingly, whilst among the elite circles in PNG, the Trobriand Islands are called the 'Island of love' probably due to the practice of sexual freedom among the youth, Karkar Island is known as the 'Island of No Return', probably due to fact that, young men and women who visit the Island do not want to go back to their place of origin once they fall in love with a member of the opposite sex, residing on the island (Mgone C. *et al.* unpublished).

These revelations also make Karkar Island a potential ground, where HIV and STIs can take their toll on the lives of people; if adequate preparations are not made to help community members stem the flow of HIV and STIs.

MATERIALS AND METHODS

White board markers, pens, cards and wall papers were used in this study.

The study explored the knowledge base of the participants on HIV/AIDS and followed on by asking participants to;

1. Name or indicate places where sexual activities take place in the two sites.
2. Name traditional practices that could promote HIV/AIDS in the country
3. Name the various groups in each community, and using pair-wise analysis, to rank them according to possible risks groups in relation to HIV/Aids spread

In the pair-wise analysis, you compare one group at a time against each of the other groups, and indicate in the appropriate cell, the name or number of the group, that in the opinion of the participants is more at risk than the other. At the end of the group comparison, you count the number of times a group appears. That gives the frequency. This frequency can then be expressed in percentage of the total number of groups (less one).

An exercise in PRRA was done, to highlight the possible contributing factors to HIV/AIDS spread and as to how best to address the issue to reduce or contain future spread.

In the PRRA, participants were first introduced to the method, and were asked to write as many cards on factors that could promote HIV/AIDS; one factor per card. Cards were pinned on the board, duplicated cards were removed and cards not understood were clarified and re-written. The interrelationship and hierarchy between the cards were established. The issues that help promote HIV/AIDS were stated in the negative and the possible solutions identified in the positive following standard procedures in constraints analysis (Dekuku 2001, GTZ 1990 and IRRI 1991)

The exercise was on 8-9[th] of August 2001 at the Institute of Medical Research Office in Port Moresby.

RESULTS

Places and traditional practices that may promote HIV/AIDS spread.

Based on answers provided by the groups, it was identified that illegal sexual activities take place in the two communities. The Karkar Team names the following as the places of illegal sex; video and disco places, sports venues, market places, plantations, schools and private sector workers compounds. The Trobriand Island Team named Market places, shops, Guest houses, Kebutu plantation and gardens (Table 1).

Table 1. **Places where 'illegal' sexual activities take place.**

Karkar Team [Madang]	Trobriand Islands Team
Video Places Disco places Sport venues Market places Plantations Schools Private sector workers compounds	Market places Shops Guest Houses Kebutu Plantation Gardens

Traditional Practices that may promote the spread of AIDS.

On traditional practices that may lead to the rise in HIV/AIDS, mentioned were; Traditional sing-sing, traditional circumcision and initiations, traditional marriage ceremonies and funeral practices (Table 2).

Table 2 . **Some traditional practices that can lead to rise in HIV.**

1. Traditional sing-sing
2. Traditional Circumcision/ initiation
3. Traditional Marriage ceremonies
4. Funeral practices

Pair –wise analysis in comparing groups to each other.

The groups of people by occupation in each locality were listed by the participants. The Trobriand team identified 19, while the Karkar team identified 20 groups (Tables 3 and 4).

By ranking groups against each other for perceived risk to HIV/AIDS, the various risk groups identified for Trobiland are as follows (Table 3);

Very Highly at risk: 50 – 100% score; Youth, Sailors, PMV Drivers, Public Servants, Dingy Drivers, Beach Dina Divers, Town Drifters, Canteen Owners, and Carvers.

High Risk: 25 – 49% score; Betel nut Sellers, Husbands, Fish Sellers, Gamblers and Kula Sellers

Medium risk: 10 – 24% score; Students, Widowers and Wives.

Low risk : <10% score; Widows and Church worker.

For the Karkar Group, the various risk groups are (Table 4);

Very Highly at risk: 50 -100 % score; Two-Kina sex workers, Private sector workers, Male plantation workers, Female plantation workers, Settlers and Dingy operators Public servants, Drug bodies, Husbands, Widowers and Male sport groups.

High Risk: 25 – 49% score: Female sport groups, Wives and Male School Leavers and Male village teenagers.

Medium risk: 10-24% score: Female village teenagers, Widows, Female school leavers and Youth groups.

***Table 3.* Pairwise analysis of the various groups in Trobriand Islands in relation to HIV/AIDS risk**

Group*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1. Betel nut sellers		2	3	4	1	1	7	1	1	10	1	12	13	1	1	1	17	18	19
2. Sailors			2	2	2	2	2	2	2	10	2	2	2	2	2	2	2	2	2
3. Kula traders				4	5	6	7	3	9	10	11	12	3	14	3	16	17	18	3
4. Beach dina divers					4	4	7	4	4	10	4	4	4	4	4	4	4	18	4
5. Fish sellers						5	7	5	5	10	5	12	5	14	5	16	17	18	5
6. Husbands							7	6	6	10	6	12	6	14	6	16	17	18	6
7. Public servants								7	7	10	7	7	7	7	7	7	17	18	7
8. Wives									9	10	11	12	8	14	8	16	17	18	19
9. Students										10	11	12	9	14	9	16	17	18	9
10. Youth											10	10	10	10	10	10	10	10	10
11. Gamblers												12	11	14	11	16	17	18	11
12. Town Drifters													12	12	12	12	17	18	12
13. Widows														14	15	16	17	18	19
14. Carvers															14	16	17	18	14
15. Church workers																16	17	18	19
16. Canteen owners																	17	18	16
17. Dingy owners																		18	17
18. PMV drivers																			18
19. Widowers																			

* Note; The numbers in row 1 correspond to group names in column 1, and interpretation is that the number in the body of the table is more at risk than the corresponding number in row 1 or column 1.

Low risk: < 10 % score: Women groups.

Constraints Analysis of HIV/AIDS in PNG.

The constraints analysis tree (Figure 1) indicated that increasing **HIV/AIDS infection rate** is a result of Lack of Protection. The lack of protection results from; **Ignorance about causes and dangers of HIV/AIDS, Women feeling shy to negotiate for safer sex,** some people **having unprotected sex for fun, lack of condom, forced unsafe sex and sex for money.** Some of these are consequence of other factors as explained below;

Cultural taboos prevent sex education and this leads in some cases to the **lack of awareness about HIV /AIDS and its prevention**, and these result in **Ignorance about causes and dangers of HIV/AIDS by some individuals.**

Inadequate laws to protect sexual partners, night clubs promoting sex and **overcrowded settlements** contribute to **no restriction on sexual activities in the society** as well as the proliferation of **multiple sexual partners**. These in combination with **drugs and alcohol abuse** lead to **unprotected sex** in most cases.

Drugs and alcohol abuse also **contribute to increasing rape cases**, which in addition to **forced marriages** often leads to **forced and unsafe sex** in these circumstances.

Some individuals turn to indulge in **sex for money** as a result of **lack of food** or **income** to support the family and self. These in turn are due to **lack of employment** which in itself is due to **lack of education, lack of employment avenues, lack of**

Table 4. **Pair-wise analysis of the various groups in Karkar [Madang] in relation to HIV/AIDS risk**

Group*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. Pubic servants		1	1	1	1	1	1	1	1	10	1	12	13	14	1	1	1	18	19	20
2. Drug bodies			2	2	2	2	2	2	2	10	2	12	13	14	2	2	2	2	19	20
3. Male school leavers				3	3	3	3	3	9	10	3	12	13	14	15	16	17	18	19	20
4. Female school leavers					5	6	4	4	9	10	11	12	13	14	15	16	17	18	19	20
5. Male village tenagers						6	5	5	5	10	5	5	13	14	15	16	17	18	19	20
6. Female village tenagers							6	6	9	10	11	12	13	14	15	16	17	18	19	20
7.Women Groups								8	9	10	11	12	13	14	15	16	17	18	19	20
8. Youth Groups									9	10	8	12	13	14	15	16	17	18	19	20
9. Wives										10	9	9	13	14	15	16	17	18	19	20
10. Husbands											10	12	13	14	10	16	10	18	19	20
11. Widows												12	13	14	15	16	17	18	19	20
12. Widowers													13	14	15	12	12	18	19	20
13. Male plantation workers														13	15	13	13	18	19	20
14. Female plantation workers															15	14	14	18	19	14
15. Settlers																15	15	15	19	15
16. Male sport groups																	16	18	19	20
17. Female sport groups																		18	19	20
18. Dingy operators																			19	20
19. Two Kina sex workers																				20
20. Private sector workers																				

* Note; The numbers in row 1 correspond to group names in column 1.

Table 5. **Summary of Pair-wise analysis of various groups for HIV/AIDS risk from two locations in Papua New Guinea**

Risk position	Trobriands Group Milne Bay Province	Trobriands Risk Score	Karkar Group Madang Province	Karkar Risk Score
	Very high risk		**Very high risk**	
1	10. Youth	18 [100%]	19. Two Kina sex workers	19 [100%]
2	2. Sailors	17 [94.4%]	20. Private sector workers	17 [89.5%]
3	18. PMV Drivers	16 [88.9%]	13. Male plantation workers	15 [78.9%]
4	7. Public Servants	15 [88.3%]	14. Female plantation workers	15 [78.9%]
5	17. Dingy Owners	14 [77.8%]	15. Settlers	15 [78.9%]
6	4. Beach Dina diver	14 [77.8%]	18. Dingy operators	15 [78.9%]
7	12. Town Drifters	12 [66.7%]	1. Public servants	12 [63.2%]
8	16. Canteen Owners	11 [61.1%]	2. Drug bodies	12 [63.2%]
9	14. Carvers	9 [50.0%]	10. Husbands	12 [63.2%]
	High risk		12. Widowers	11 [57.9%]
10	1. Betel nut Sellers	8 [44.4%]	16. Male sport groups	10 [52.6%]
11	6. Husbands	8 [44.4%]	**High risk**	
12	5. Fish sellers	8 [44.4%]	17. Female sport groups	8 [42.1%]
13	11.Gamblers	6 [33.3%]	9. Wives	7 [36.8%]
14	3. Kula Sellers	5 [27.8%]	3. Male school leavers	6 [31.6%]
	Medium risk		5.Male village teenagers	6 [31.6%]
15	9. Students	4 [22.2%]	**Medium risk**	
16	19. Widowers	4 [22.2%]	6. Female village teenagers	4 [21.1%]
17	8. Wives	2 [11.1%]	11. Widows	3 [15.8%]
	Low risk		4. Female school leavers	2 [10.5%]
18	13. Widows	1 [5.6%]	8. Youth groups	2 [10.5%]
19	15. Church workers	1 [5.6%]	**Low risk**	
20			7. Women groups	0 [0.0%]

Across both islands, Public servants and Dingy owners/operators are at very high risk.

access to land and in some cases **laziness and unwillingness to work.**

Objectives Analysis of HIV/AIDS in PNG.

Making positive the negative factors that are promoting HIV/AIDS gives the objectives or results (Figure 2). **Low HIV/AIDS infection rate** will result from increased **protection of and by individuals. Increased protection** results from; **Increased knowledge about causes of HIV/AIDS and its prevention, Women not shy to negotiate for safer sex,** there is **less unprotected sex for fun, increase condom use, less forced unsafe sex and less sex for money.** These could be boosted through the following means as explained below;

Cultural taboos are relaxed and therefore **support sex education** and this leads in most cases **to increased awareness about HIV/AIDS and its prevention**, and these result in **increased knowledge about causes and dangers of HIV/AIDS** by many individuals.

Adequate laws to protect sexual partners, night clubs promoting safe sex and **less crowded settlements** would promote **restriction on sexual activities in the society** and would lead to less proliferation of **multiple sexual partners**. These in combination with **less drugs and alcohol abuse** would lead in most cases to **less unprotected sex for fun.**

Less drugs and alcohol abuse would lead to decreased **rape cases**, which in addition to **less forced marriages** would lead to **less forced and unsafe sex** in many circumstances.

Lower number of individuals indulging in **sex for money** would result, if people have **adequate food** or **income** to support the family and self. These in turn would result from **increased employment** due to **increased employment avenues** and **improved education levels, improved access to land, less laziness and willingness to work.**

Fig. 1. Preliminary Constraints Analysis of HIV/AIDS in Papua New Guinea

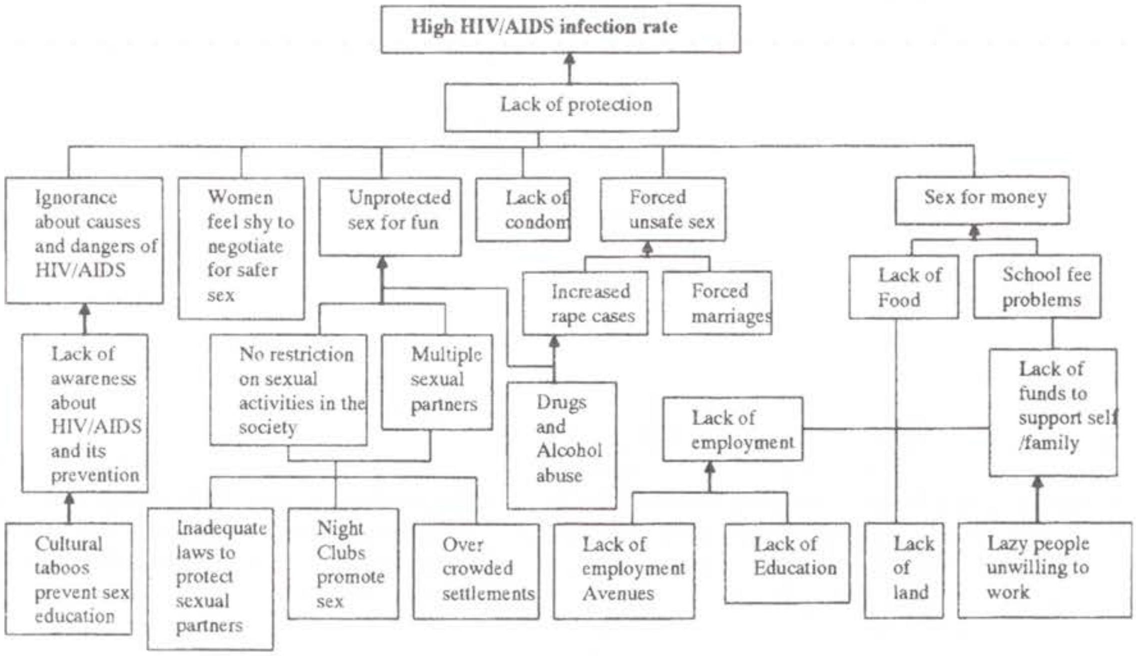
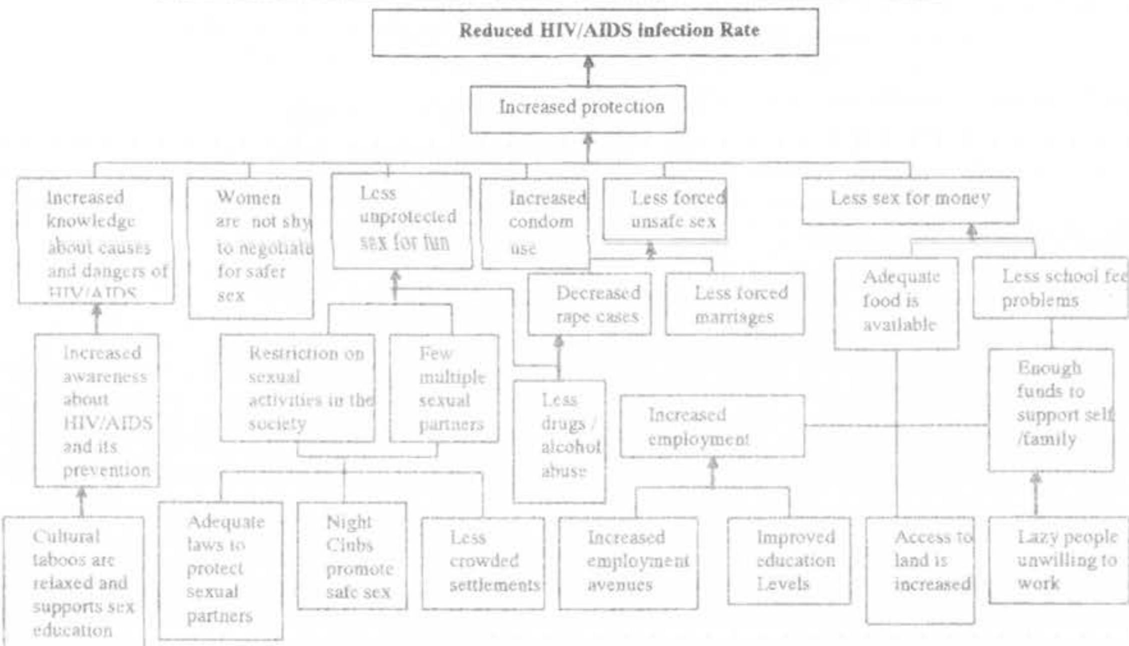


Fig. 2. Preliminary Objective Analysis of HIV/AIDS in Papua New Guinea



DISCUSSIONS

This study assumes that using Medical Assistants with reasonable knowledge of people and their rural lifestyles in the two communities may give us some understanding of the possible contributing factors to HIV/AIDS in these areas.

The study also assumes that this study may not be exhaustive as in all program planning and constraints analysis exercises, because the information presented is limited to the knowledge base of the participants. Thus other unknown or emerging issues may come to light in future as the sample base is expanded or more information becomes available. Nevertheless this study gives us some understanding of possible factors that may contribute to increasing spread of HIV/AIDS in these sites.

First is the acknowledgement that illegal sexual activities take place in both islands, and are predominant in some places; market places, plantations and gardens, shops, video and disco places, sport avenues, guest houses and private sector workers compounds and schools.

Second is the reasoning that certain traditional practices may promote the spread of HIV/AIDS; such as traditional circumcision /initiations, traditional marriage ceremonies, funeral gatherings and traditional sing–sing

Thirdly, is that, depending on the area, certain groups of people are more risk taking and therefore more at risk at getting HIV/ AIDS than the other groups based on pair wise analysis. The rankings from the two Islands are not identical but similar in some cases, indicating that group behavioral patterns may vary in different localities in some cases, but at the same time, similarities may exist in some instances. For example; youths are very high at risk in Trobriads, but of medium risk only in Kakar. While, Dingy owners/operators and Public Servants are at very high risk in both islands. Husbands are in high risk (Trobriands) to very high risk (Kakar). Wives are in Medium risk (Trobriands) to high risk (Karkar). Widowers are in medium risk in Trobriands but very high risk in Kakar, while Widows are in Low risk in Trobriands and medium risk in Kakar.

All said and done, topping the risk group in Trobriand are Youths and Sailors, and in Kakar, Two Kina Workers and Private Sector Workers. The low risk group in Trobriands are Widows and Church workers, and in Karkar is women groups.

CONCLUSIONS

This exercise to our knowledge is the first attempt of using the PRRA analysis in HIV/AIDS study in PNG, and we believe that it would provide some insight in understanding the issues of HIV/AIDS in PNG.

The identification of places of illegal sexual activities, traditional practices that may contribute, groups more at risk for HIV/AIDS and the issues that contribute to the lack of protection, as well as the possible solutions may be useful in the planning for HIV/AIDS prevention.

The constraints analysis indicated that, the issue of AIDS/HIV needs to be addressed holistically. It is a cross sectoral issue and needs to be addressed so. It is not only a medical issue, for example, education, jobs, employment and income, land, traditional practices, cultural taboos, inadequate laws, drugs and alcohol abuse etc needs to be addressed by the respective authorities. Addressing the issues collectively, and not in isolation [as is the case now], may be the best way to speed up the campaign and programs to reduce HIV/AIDS in PNG.

We agree with Piot et al. 2001 that certain ingredients are needed to effectively control the epidemic, and the four main lessons to be learnt from countries that have managed to contain the AIDS epidemic are;

1. There needs to be **unified national planning**.

2. **Proven strategies for reducing HIV infections need to be put into practice on a scale that matches the extent of the epidemic, and** for strategies to be effective, they need to be adapted to local community circumstances.

3. People need to have **ready access to essential drugs and equipment (e.g. condoms) for prevention of HIV infection and for care of those infected with HIV**. Prevention and care need to operate in synergy.

4. There needs to be a **positive attitude by the public to those people infected with HIV and those most at risk**. HIV-infected people are vital in the process of educating those not infected.

We hope that this study would be useful, in a small way to planners and HIV/AIDS workers, in planning strategies to compact and limit HIV/AIDS in PNG.

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EATING QUALITY OF PROMISING RICE VARIETIES EVALUATED AT SEVERAL LOCATIONS IN PAPUA NEW GUINEA

Joel G. Waramboi, Mohammad S. Sajjad, Anton Beko and Roy Masamdu

ABSTRACT

Consumer acceptability assessment of rice varieties in different locations in PNG showed significant differences in the taste preferences for eight rice varieties (1-5 scale; 1-worst score, 5-best score). Commercially available 'Trukai' rice was the most preferred in almost all locations, with a mean score of 4.23. NR 1 (3.97) had good eating quality comparable with Trukai. Varieties NR 16 (3.75), FB-91 (3.67) and N6-94 (3.47) were moderately preferred while preference for NR 2, NR 4 and NR 15 was significantly lower. Significant differences were also observed between sites and in the variety x site interaction. Mean scores showed that consumers at Ramu (3.83) liked rice more than the other site tested, while those at Bogia (3.26) and Balama (3.28) gave the lowest mean scores. The variety x site interaction shows that the order of preference of rice varieties differed significantly between test sites, indicating that there are site-specific differences in consumer preference for rice varieties.

Keywords: *Consumes acceptability, rice varieties, eating quality, Oryza sativa (L.).*

INTRODUCTION

Rice *(Oryza sativa L.)* has become an accepted food staple and a preferred component of the diet of many people in Papua New Guinea (PNG). Rice consumption rose from very low levels to 30.4kg per person per year in 2000 (Gibson 2001a). On a per capita basis, consumption is either relatively stable or declining but has been maintained by introduction of a new and cheaper brand sold as 'Roots Rice' (Gibson 2001b). The yield of some of the varieties presently cultivated appears to be low. Their quality is also said to be inferior compared to 'Trukai', which is the preferred imported blend of several varieties (Amoa *et al.* 1996).

The National Agricultural Research Institute (NARI) has been screening several promising rice varieties at several locations to identify and recommend superior, ecosystems-oriented and high-yielding varieties possessing good eating quality traits. New rice varieties need evaluation for consumer acceptability, sensory characteristics, specific end uses and preferred physico-chemical traits. Past research and development efforts placed little attention on incorporating these factors in the rice breeding and selection work.

Acquired tastes for certain types of rice may differ from one area to another due to differences in social structure, economic status and cultural traditions. Therefore, site-specific taste panels composed of judges from the seven areas listed in (Table 1) were conducted. Details of these sites can be obtained from (Hanson *et al.* 2001). The work of (Amoa *et al.* 1995) on three modern rice varieties, Wantok, Niupela and Taichung Sen 10 (TCS 10), was the first reported eating quality assessment of rice varieties in PNG.

Table 1. Details of multi-location consumer preference tasting trials

Site No.	Name of site	Local Level Government	District	Province	Date of trial	Number of tasters
1	Wareo	Kote	Finschhafen	Morobe	30/05/02	42
2	Usino	Igoi Sop	Usino Bundi	Madang	20/08/02	66
3	Balama	South Ambenob	Madang	Madang	23/08/02	70
4	Bogia	Bogia Coastal	Bogia	Madang	30/08/02	64
5	Ramu	Ramu	Upper Ramu	Madang	13/09/02	60
6	Intoap	Umi Atzera	Kaiapit	Morobe	18/09/02	29
7	Garaina	Garaina	Bulolo	Morobe	01/12/02	48

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The objectives of the current study were to identify locally adapted rice varieties with good eating quality, as well as to see if there were differences from one location to another in consumer preferences.

MATERIALS AND METHODS

Sample preparation

Milled samples of pure rice varieties from the NARI farm at Bubia were used in the tests. The varieties studied were NR 1 (IR-19661-23-3-2-2), NR 2 (Ayung), NR 4 (BG 379-2), NR 15 (Salumpikit), NR 16 (Azucena), N6-94 (Niupela 1994, line 6) and FB-91 (Finschhafen Brown 91). Trukai blend was purchased from shops and used as the standard. Unless specified, all experimental procedures for sample preparation and sensory evaluation were standardized at each location. Samples were pre-soaked for 10 minutes in excess water, drained and cooked in electric rice cookers following the method used by (Myklestad *et al.* 1968). In Garaina and Wareo, where electricity was unavailable, ordinary cooking pots were used. In all sites, the ratio of rice to water was the same (ie 1 cup rice: 2 cups water). Cooking was done with no added salt or other ingredients. Cooked samples were left to "steam off" for 15 minutes before being placed into bowls covered with aluminum foil. Each sample was labeled using unidentifiable code names.

Sensory evaluation

Sensory evaluations were conducted in open air spaces, resembling typical village settings in PNG. Both males and females ranging from 25-40 years old were selected as tasters. Each taster received a dessertspoonful of the samples, served warm on paper plates. Each plate was divided and labelled accordingly to accommodate four samples at any one time.

The order in which the varieties were evaluated was the same for each panelist (Durbin 1951). Scoring was done only once using a Hedonic scale (5=like extremely, best score; 1=dislike extremely, worst score) following the methods used by (Myklestad *et al.* 1968, Lamond 1977 and Amoa *et al. 1995*).

Data analysis

Acceptability scores at each site were analysed using panelists as replicates to compare varieties within sites. An analysis of the variety means from each site was also carried out, using sites as replicates to provide an overall perspective. Where varieties were missing at some sites, estimated values were calculated. Site by variety interactions were tested following the method of "Restricted Maximum Likelihood" (REML), a modelling-based procedure in GenStat.

RESULTS

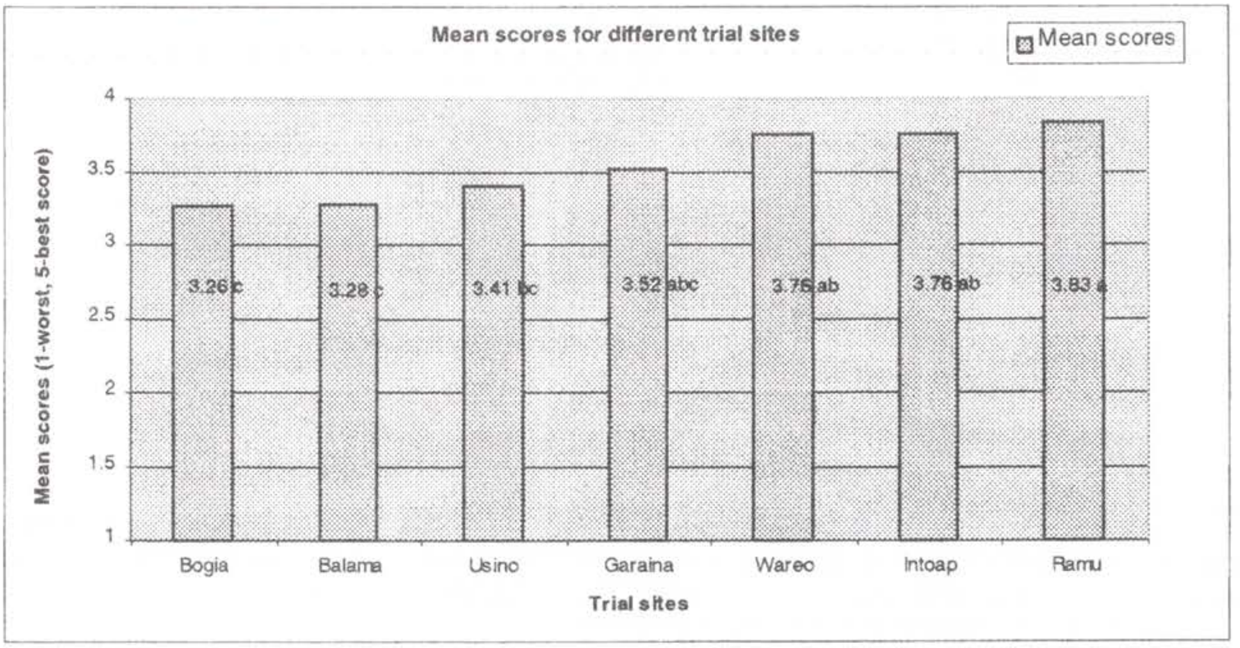
Site-specific consumer preference trials conducted in these sites showed significant differences in taste preferences for the rice varieties (Table 2). Overall, Trukai came out as the most preferred variety with a mean score of 4.23, but NR 1 was close behind with a score of 3.97, not significantly different to Trukai. At three sites, Usino, Bogia and Garaina, Trukai was significantly better than NR 1. In all other sites, no significant differences were observed between NR 1 and Trukai. NR 16 was the next most preferred, scoring highly at Ramu and Intoap. FB-91 was the most preferred variety at Ramu and also scored well at Wareo, where it is the variety grown traditionally by the farmers. Varieties NR 2, NR 4 and NR 15 gave consistently low scores at all sites.

Table 2. Mean scores for taste preference of different rice varieties

Rice variety	Mean scores for taste preferences at different sites							
	Garaina	Wareo	Usino	Balama	Bogia	Ramu	Intoap	Variety Mean
NR 1	3.66 b⁺	4.10 a⁺	3.98 b⁺	3.89 a⁺	3.89 b⁺	4.10 ab⁺	4.14 ab⁺	3.97 ab⁺
NR 2	2.87 d	2.98 c	2.97 de	2.79 e	3.09 de	3.68 bcd	3.17 cd	3.08 d
NR 4	3.68 b	3.58 ab	2.78 e	2.89 de	2.25 f	3.42 cde	3.35 cd	3.14 d
NR 15	3.02 cd	3.79 ab	2.76 e	2.94 de	2.86 e	3.17 e	2.93 d	3.07 d
NR 16	3.53 bc	na	3.32 cd	3.31 cd	3.42 cd	4.27 a	4.41 a	3.75 bc
N6-94	2.70 d	na	3.41 c	3.40 bc	3.16 de	na	4.17 ab	3.47 cd
FB-91	3.98 b	3.98 ab	3.14 cde	3.26 cd	3.67 bc	4.40 a	3.72 bc	3.67 bc
Trukai	4.68 a	4.02 ab	4.89 a	3.77 ab	4.56 a	3.83 bc	4.66 a	4.23 a

⁺*Mean scores in a column followed by the same letter are not significantly different ($p \leq 0.05$)*
na = not assessed

Figure 1. **Graph showing mean scores for different experimental sites**



Average scores for acceptability for rice varieties differed from one location to another (Figure 1). Consumers at Bogia and Balama in the Madang Province gave rice lower mean scores than consumers at the other sites. The mean score for Ramu was higher than at any other site tested, though similar to Wareo and Intoap.

Based on the REML analysis, significant interactions between sites and varieties were observed. Trukai rice scored highest at four sites, NR 1 at two sites and FB-91 at one site. The lowest score was given to NR 15 (3 sites), NR 2 (2 sites), NR 4 (1 site) and N6-94 (1 site).

DISCUSSION

The results of eating quality assessment of rice varieties confirm that taste preference for different rice varieties exist and does vary from one site to another. These differences could be due to cultural differences, social structure, economic levels and distinct geographic environments in these communities. Not all varieties were tested at each site, giving an 'unbalanced' design for evaluating site x variety interactions. This was approximated by employing the chi-square distribution for Wald's test using the REML method. Differences in scores at different sites could also be due to use of different samples at different sites.

Lower mean preference scores at Bogia, Balama and Usino could be attributed to the fact that rice is a new food crop in these areas. At Wareo in the Finschhafen district, rice has been grown for well over a century so the taste has been acquired, giving a higher mean score. Consumers at Ramu liked rice more than at any other site, maybe because they consume rice more often due to their close proximity to commercial outlets.

In these rural settings, ideal laboratory conditions could not be employed and this may have affected the results. Logistical constraints meant that the order in which the rice varieties were tasted had to be the same for each panelist. This could have led to a certain amount of bias in the results. Scoring for a particular sample could have been influenced, depending on whether the previous sample was liked or disliked. The use of cooking pots rather than rice cookers at Garaina and Wareo could also have affected the results.

Results also show that traditional landrace varieties and newly introduced, modern lines in PNG generally have less preferred eating quality compared to Trukai (Amoa *et al.* 1996). Trukai has been widely accepted in the PNG market since 1970. Since Trukai is a blend of several varieties, people have become habituated to it. It is used as a yardstick to measure other varieties and pure varieties may be at a disadvantage in assessment of eating quality compared with Trukai. The results also indicate that consumers at Wareo in the Finschhafen district have acquired a taste for FB-91. This rice is a traditional landrace variety that has been cultivated for more than a century. This suggests that consumers can acquire a taste preference for certain types of rice over time.

Taste preference scores for NR 1, NR 16, FB-91 and N6-94 (an improved line of Niupela) were promising (3.5 and above) and indicate high consumer acceptability. These findings support the work of previous researchers including Sajjad (1995) and (Amoa *et al.* 1995). NR 1 has been commercialised in the last few years by Trukai Industries Limited and is widely consumed by the local population as a component of a blend called 'Roots Rice'. On the other hand, N6-94 is an agronomically promising variety for upland cultivation (Wohuinangu and Sajjad 1992) and has acceptable eating quality. NR 16 has good eating quality, although scoring lower than NR 1 in most locations. Low preference scores for NR 2, 4 and 15 indicate that consumers may not accept these varieties. It should also be noted, however, that these varieties were not strongly disliked. Some adaptation of cooking methods to meet the needs of specific varieties may increase their acceptability. Future research may need to evaluate grain quality characteristics with a view to improving the eating quality of these varieties.

Variety selection and recommendation for PNG should incorporate eating quality results alongside other parameters such as yield, suitability for mechanization, adaptability to different soils, and pest and disease resistance. In future, similar work should cover other areas of the country to generate site-specific data on preferences for new rice varieties.

CONCLUSION

Trukai rice scored consistently well in all locations, while significant differences were observed among pure lines. Variety NR 1 had good eating quality for consumer acceptability comparable with Trukai, scoring well in almost all sites. Other varieties that scored well were NR 16, FB-91 and N6-94 while taste preference scores for NR 2, 4 and 15 were significantly lower. Maybe adaptation of cooking methods may improve their acceptability scores in taste tests. Acceptability of rice differed from one location to another with consumers at Ramu, Intoap, Wareo and Garaina scoring rice more highly than at all other sites.

ACKNOWLEDGEMENT

The authors acknowledge the help received from Messrs Maia Wamala, Sami Haenere, Peter Gendua, Clifton Gwabu and staff of the NARI Rice and Grain Research Programme. Help received from our collaborators at the test sites is also greatly acknowledged. We are also grateful to Messrs R. Mayer (Queensland DPI), A. Quartermain, G. Wiles and A. Simin (NARI) for comments on the draft and advice on data analysis.

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SHORT COMMUNICATION

SHEATH BLOTCH OF RICE - A NEW REPORT IN PAPUA NEW GUINEA

S.I. Akanda[1], M.E. Wagih, Y. Tomda and M.K. Maino

ABSTRACT

Sheath blotch of rice, caused by *Pyrenochaeta oryzae* was reported for the first time in Papua New Guinea (PNG). The pathogenicity was confirmed through artifical inoculation. Seasonal carryover, pre-disposing factors and management stategy of the disease are also discussed.

Keywords: *Rice, Sheath blotch.*

INTRODUCTION

Sheath blotch, a minor disease of rice, caused by *Pyrenochaeta oryzae* was first described in Japan by Miyake (1910). The disease has also been reported to occur in Bangladesh, Burma, China, India, Malaysia, Sierra Leone, Philippines and Thailand (Shahjahan *et al.* 1983).

The disease normally attacks the lower leaf sheath near the lower part of the stem, but occasionally found on the leaf blade and glumes at the later stages of plant growth. The initial symptoms are dark brown, oblong blotching on the leaf sheath. As the symptoms mature, the center gradually becomes grey or greyish - brown but the margins remain dark brown. The center of the spots becomes a bit sunken and associated with black pycnidia, protruding ostioles and setae merged from the sheath tissue. The blotches ultimately girdle the entire sheath and the leaves die. This in turn reduces the photosynthetic area, making the plants weaker and vulnerable to lodging, and ultimately affects grain filling.

MATERIALS AND METHODS

In August 2001, symptoms typical to the sheath blotch was observed on the rice var. IR 19661 at the Agricultural farm of the PNG University of Technology, Lae, Morobe Province of PNG, situated at 6°45' S and 147° E at an altitude of 65 m.a.s.l. Infected sheaths were collected from the field and brought to the laboratory. In preparation for the isolation of the causal organism, inocula were prepared by cutting small pieces of about 9 mm^2 from the lesion margins, and surface sterilized by dipping into one percent sodium-hypochlorite solution for two minutes. The sterilizing solution was decanted and the inocula were washed thoroughly with distilled water. Four inocula were then placed on the potato dextrose agar (PDA) plates. The plates were incubated at room temperature of about 25° C. In 2-3 days time, the fungus started to grow onto the culture medium. The fungus was transferred to one peercent water agar plates and subsequently purified through hyphal tip culture. On PDA medium, the fungus produced pycnidia and singled celled, hyaline pycnidiospores in 15-20 day-old cultures. The fungus was idendified as *Pyrenochaeta* sp. as described by Barnett & Hunter 1998.

To complete Koch's postulates, IR 19661 plants were inoculated at booting stage with the fungus in the screen house. Agar blocks with the 5-day-old fungus were placed on slightly wounded leaf sheaths with sticky tape.

RESULTS AND DISCUSSION

Water soaked lesions and brownish blotching similar to those found in the field were produced in 5-7 days after artificial inoculation (see photograph) of the IR 19661 rice plants in the screen house. *Pyrenochaeta* sp. was re-isolated from the artificially inoculated plants confirming the pathogenic cause of the disease. This is the first report of the occurrence of rice sheath blotch in Papua New Guinea. The disease with low to moderate level of infection was also observed in several rice varieties in Clean Water Trukai farm in Markham Valley, Lae. The primary infection takes place from the fungus in the infected straw and/or from the soil. The disease is aggravated with insect damage that makes the plant weaker and planting of susceptible rice varieties

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Figure 1. **Showing the typical sheath blotch symptoms on IR 19661 on artificial inoculation with *Pyrenochaeta* sp. in the screen house.**

(Miah & Shahjahan 1987). High temperature accompanied by high humidity further aggravates the disease. As a preventive measure, it is advisable to protect the crop from insect damage and to destroy/burn the infected straws in order to reduce the inoculum level in the soil that might otherwise initiate new infections (Miah & Shahjahan 1987). Despite the disease is currently of minor concern, it could become a major threat when when the rice cultivation in PNG extends in the future. This warrants a nationwide survey to determine the epidemiology, distribution and the possible impact of the sheath blotch on the rice industry in Papua New Guinea.

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M	- metre
a.s.l.	- above sea level
yr	- year
wk	- week
h	- hour

min - minute
s - second
k - kina
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n.r. - not recorded
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s.d. - standard deviation
s.e.m.- standard error of difference
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