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

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ABSTRACT

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

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

INTRODUCTION

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

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

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

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

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MATERIALS AND METHODS

Site Description

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

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

Rice Varieties (Treatments)

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

Experimental Design

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

Field Establishment and Maintenance

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

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

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

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

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

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

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

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

Disease Recording

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

Data Analyses

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

RESULTS

Unitech site

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

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

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

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

Clean Water site

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

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

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

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

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

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

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

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

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

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

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

DISCUSION

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

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

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

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

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

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

All the numbers are the means of four replications. Means followed by the same letter in a row are not significantly different at $p < 0.05$ (LSD) of 5.50 (about 15-25% leaf area infected) was observed at Clean Water during the second trial. Among other factors, the drought period during flowering period could have contributed to the increase in brown spot severity, particularly, if the plants suffer from water stress during the flowering and/or grain filling periods.

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

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

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

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

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

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

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

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