Annals of Tropical Research 36[1]:63-74(2014)

Effects of N Application on the Development of Blast Disease and Yield of Rice Under Sawah System in Nigeria

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ABSTRACT

Rice blast, caused by the fungus *Pyricularia grisea,* is one of the limiting factors in rice production causing severe crop losses under favourable environmental conditions.The effects of nitrogen applications on leaf blast development and yield of rice were studied under sawah system of production. WITA-4 and Jasmine rice varieties were planted and four levels (0, 30, 60 and 90 kg ha^{-1}) of urea fertilizer were imposed. Nitrogen and rice varieties treatments were arranged in a split plot design with N levels as main plots and varieties as subplots, with three replications. The results obtained indicate that Jasmine variety was not infected by the blast pathogen whereas WITA-4 variety was susceptible to the disease. Disease incidence was generally high on 0 and 90 kg ha^{-1} but there was no significant difference among treatments. However, there was a significant difference ($P=0.0001$) between the N treatments for final disease severity score and the total lesion area, with 90 kg ha^{-1} having the highest severity score and total lesion area. Significant differences between nitrogen treatment ($P = 0.001$), varieties ($P = 0.01$) and the nitrogen treatment x cultivar interactions ($P = 0.05$) with respect to grain yield were observed. In terms of yield, Jasmine variety had 5.4 tons/ha on 90 kg ha^{-1} N treatment but the effect of the blast was pronounced on WITA-4 variety with 4.7 tons/ha. Rice cultivation under sawah system does not preclude rice from blast infection; hence, an appropriate management system must be incorporated to ensure bumper harvest.

Keywords: Rice, Leaf Blast, Nitrogen, Sawah, Yield, Nigeria

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INTRODUCTION

Nitrogen (N) is essential for rice, and usually it is the most yield-limiting nutrient in irrigated rice production around the world (Samonte *et al.*, 2006). Balanced nutrition has an important role in determining plant resistance or susceptibility to diseases. Imbalanced fertilizer application, especially in wet season, create more severe diseases, lodging and resulting in low efficiency of nitrogen fertilizer application. Plants grown under excess nitrogen also tend to experience severe pathogenic damage (Huber and Watson, 1974; Richard-Molard *et al*., 1999; Long *et al*., 2000). Pham sy Tan *et al.* (2000) also concluded that adjusting the amount of nitrogen application and indigenous nitrogen is a key factor to get higher yield of rice and sustainability; however, excessive N fertilization increases susceptibility of plants to obligate pathogens and resistance to facultative parasites (Kiraly, 1976; Huber, 1980; Fageria *et al*., 1991).

Sawah is a levelled rice field surrounded by banks with inlet and outlet for irrigation and drainage. The basic elements of sawah system include improved irrigated rice basins, seedbed preparation, transplanting and spacing of seedlings, fertilizer application and most importantly, appropriate water management. Fashola *et al.* (2006) reported that the sawah system offers the best option for overcoming the constraints of rice production in Nigeria, namely, poor soil fertility, poor water management and poor varieties. Sawah rice production system was introduced to the inland valley of Nigeria because it can overcome soil fertility problems through enhancing the geological fertilization process, conserving water resources, and the high performance multi-functionality of the sawah type wetlands (Oladele and Wakatsuki, 2008). The sawah system offers excellent techniques for water control and soil fertility management.

The demand for rice in Nigeria has been soaring which was partly due to increase in population growth, increased income levels, rapid urbanization and associated changes in family occupational structures (Kolawole *et al*., 2010). Though rice contributes a significant proportion of the food requirements of the population, production capacity is far below national requirements. Every effort in Nigeria is geared towards improving and increasing the potentiality of rice yield. Increasing rice yield and production requires not only genetic improvements for higher yield potential but also better management technologies and systems including institutions (Oladele and Sakagami, 2004).

Rice blast, caused by the fungus *Pyricularia grisea* (Cooke) Sacc. (teleomorph, *Magnaporthe ogrisea* (T.T. Herbert) Yaegashi & Udagawa), has been one of the limiting factors to rice production causing severe crop losses under favourable environmental conditions. The fungus is capable of infecting rice plants at any growth stage from seedling to grain formation, causing collar rot, leaf blast, nodal blast, neck blast, or panicle blast (Webster and Gunnel, 1992). Severe blast has also been attributed to susceptible cultivar, loss of flood water, high nitrogen fertilization, sandy light soils, and fields surrounded by trees (Greer and Webster 2001; Groth *et al*., 1991; Lee, 1994; Long *et al*., 2000). Long periods of leaf wetness, high relative humidity, and temperatures of 17 to 28°C also favour rice blast development (Webster and Gunnel, 1992). The disease has been reported to cause substantial reductions in yield (Kingsolver *et al*., 1984, Rossman *et al.,* 1990; Webster and Gunnel, 1992).

Kurschner *et al.* (1992) reported that while nitrogen was essential for productivity, the severity of blast also increased with the rate of application. Several studies have shown that excessive nitrogen increases the susceptibility of the rice plant to rice blast (Correa and Zeigler 1991; Kingslover *et al.,* 1984; Kurschner *et al.*, 1992). The time of application and amount of N fertilizer has pronounced effect on blast (Huber, 1980). In Brazil, investigations under upland conditions showed that increased doses of N favoured both leaf and panicle blast (Faria *et al.,* 1982; Santos *et al.,* 1986). Long *et al*. (2000) reported that lack of effective management strategies, particularly N fertilization, water management, and the use of susceptible cultivars, has profound effects on rice blast development. Although rice blast disease has been reported in many rice fields in Nigeria, its occurrence and development has not been adequately studied on sawah system of rice production. This study aimed to investigate the effect of N application on rice blast development and yield under sawah system of production.

MATERIALS AND METHODS

This study was conducted at the inland valley site of Federal University of Agriculture, Abeokuta, Nigeria (003.43507°E, 07.2354°N, and 150m ASL) where soils are typically alfisols. Two rice varieties were used for the experiment, WITA-4 and Jasmine and four levels (0, 30, 60 and 90 kg ha^{-1}) of urea fertilizer were imposed. Nitrogen and rice varieties treatments were arranged in a split plot design with N levels as main plots and varieties as subplots with three replications under sawah system of rice production. Individual plot size was 5 m x 4 m and plants were spaced 20 cm between rows and 20 cm between hills. The two rice varieties were raised in the nursery and then transplanted 30 days after sowing. The plots were then flushed with water under sawah system. Weather variables were obtained from the Department of Water Resources and Agrometrology, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria.

Disease Measurement

Leaf blast incidence was measured at 8 weeks after transplanting (WAT) as the percentage of plants had one or more rice blast lesion; however, incidence of disease was monitored right from the nursery stage. Leaf blast severity (LBS) was assessed on four or five fully expanded leaves of 20 main tillers of randomly selected plants in the four central rows in each subplot weekly for 3 weeks after 8 WAT. Disease assessment was terminated when lesions started coalescing on the upper leaves. A 10-grade (0; 0.50; 1.0; 2.0; 4.0; 8.0, 16.0; 32.0; 64.0; 82.0% of leaf area affected) according to Notteghem (1981) was employed for evaluating leaf blast severity.

Yield Data

Yield (ton ha^{-1}) was estimated by harvesting the central rows of individual plots, excluding two border rows at each side and one end hills in each row. After harvest, grains were air-dried to 14% moisture level before weighing.

Data Analysis

The effect of N treatments on rice leaf blast was determined over the three week assessment period by calculating the area under the disease progress curves (AUDPC). Statistical analyses of AUDPCs were subjected to analysis of variance with the GLM and differences between N treatments were determined using Fisher's protected least significant difference (LSD) test procedure using SAS (version 9.1, SAS Institute, Cary, NC).

RESULTS

Environmental Conditions

Amounts of rainfall during the growing period followed the expected unimodal rainfall pattern typical of dry season period. Low levels of total rainfall (< 70 mm) from the vegetative stage to the last date of disease assessment were recorded between March 2012 and April 2012. Little or no rainfall was observed during the nursery and transplanting stage (Fig. 1). The mean temperature from nursery to harvesting period ranged from 27°C to 29°C with higher temperatures prevailing during the vegetative stage. Relative humidity with a mean of 80% did not vary much during the study period (Fig. 1).

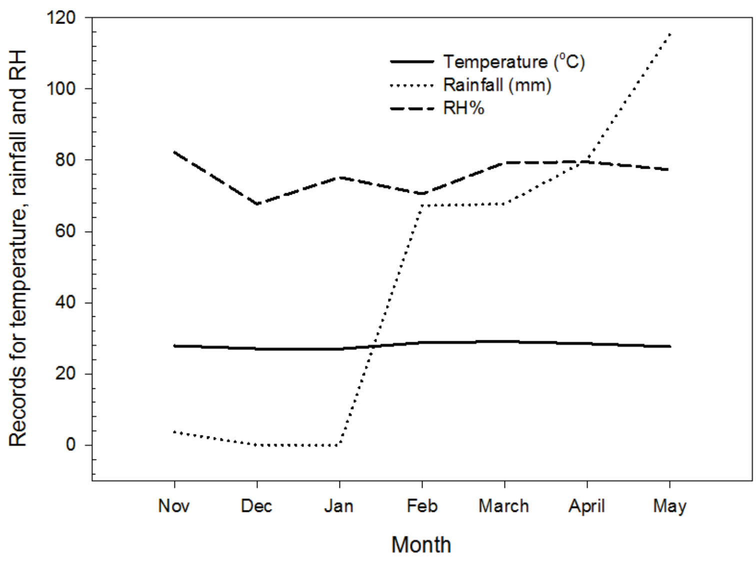

Figure 1. Temperature (°C), rainfall (mm) and RH (%) during the study period

Effect of nitrogen fertilization on the incidence of rice blast disease

Significant difference ($p=0.05$) was observed between varieties in terms of disease incidence. Rice blast symptoms were observed on WITA-4 cultivar on all the N treatments, but no disease incidence was observed on the Jasmine cultivar. Based on non-observant of rice blast incidence on Jasmine cultivar, this cultivar was omitted from further consideration. The disease incidence was considerably high in all the N treatments for WITA-4 variety; however, there was no significant (*P=0.05*) difference among the treatments (Fig. 2).

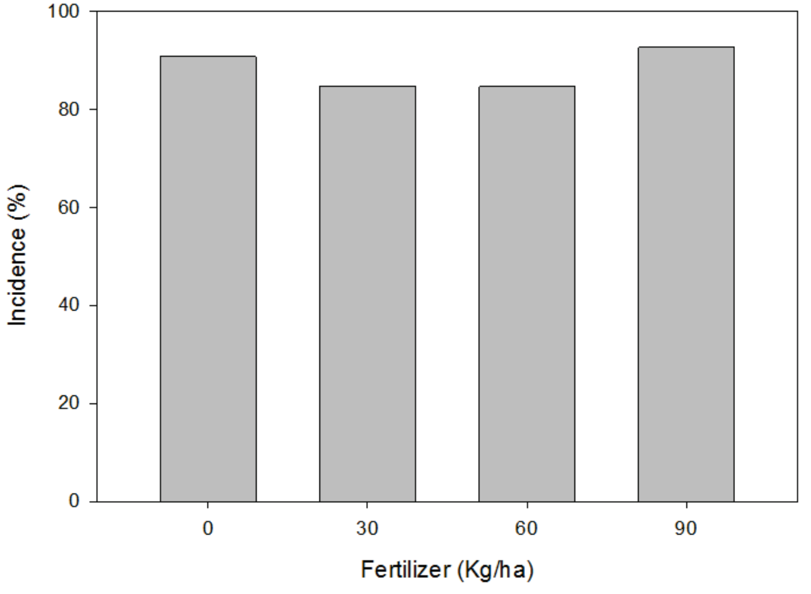

Figure 2. Percentage leaf blast incidence on WITA-4 at different N applications

Leaf blast disease severity and disease progress

Nitrogen treatments significantly (*P=0.0001*) affected the disease severity of the rice blast (Table 1). The 90 kg ha^{-1} N had levels of disease severity consistently higher than other fertilizer treatments. The leaf blast disease severity for both 0 kg ha^{-1} and 60 kg ha^{-1} N were comparably similar while the 30 kg ha^{-1} N treatment had the least disease severity. However, disease severity was generally high on the control (no nitrogen treatment) and high nitrogen treatment.

The analysis of the AUDPC data indicated that there were significant (*P = 0.0001*) differences among the N treatments for total lesion area per plant for WITA-4 (Table 1). The 90 kg ha^{-1} N treatment significantly increased disease severity and total lesion area per plant compared to the other N levels. The effect of nitrogen on total lesion area per plant was relatively lower on 30 kg ha^{-1} N.

Table 1. Leaf blast severity on WITA-4 variety under sawah system of production

Fertilizer (N/kg)	FDS (%)[a]	AUDPC[b]
0	44.3	640.5
30	32.7	518.0
60	45.0	596.2
90	67.3	892.5
LSD	12.4	114.4

[a] Final disease severity, [b] Area under disease progress curve, **Significant at P < 0.05

Effect of N treatment on grain yield of rice

There were significant differences between nitrogen treatment (*P = 0.001*), varieties (*P = 0.01*) and the nitrogen treatment x cultivar interactions (*P = 0.05*) with respect to grain yield. Yield (tons ha^{-1}) was generally higher on the Jasmine variety in all N treatments than the WITA-4 variety. Also, the 90 kg ha^{-1} N treatment for both rice varieties had the highest yield when compared with the other N treatments (Table 2).

Table 2. Effect of nitrogen (N) fertilization levels on yield (tons/ha) of WITA-4 and Jasmine varieties

N level	Varieties	Yield (tons/ha)
0	WITA-4	4.1
	Jasmine	3.6
30	WITA-4	3.8
	Jasmine	4.6
60	WITA-4	3.2
	Jasmine	4.5
90	WITA-4	4.7
	Jasmine	5.4
	Significance levels	
N		***
Varieties		**
N x Varieties		*

*, **, *** Significant at P < 0.05, P < 0.01, P < 0.001 respectively

DISCUSSION

Incidence of rice plant disease was not observed at any stage of growth on Jasmine variety; hence, it was considered immune/resistant to the disease. On the other hand, WITA-4 was susceptible. It was presumed at the start of the crop establishment the environment was disease-free at least to the minimum; however, research findings were contrary to the assumption as present investigations indicate that there were abundance of inoculum from previous rice stubbles, crop debris, soil surface and weeds around the area of cultivation due to the incidence and severity of the disease observed on WITA-4. This is in agreement with the report of Van der Plank (1963) that primary inoculum sources contribute to the early onset of the disease, thus greatly influences the intensity of an epidemic and subsequent yield loss. The rate of initial disease development at the nursery stage contributed substantially to the overall development of the disease as the crop matured.

The study findings also revealed that increasing N supply to rice aggravated the incidence and severity of the disease on WITA-4 variety. This is in agreement with previous studies (Kurschner *et al.* 1992; Long et al, 2000; Greer and Webster, 2001) that increasing N application leads to increased rate of infection. Furthermore, the application of single dose of fertilizer at the early vegetative stage might have been responsible for the increased rate of infection as previous findings (Amin and Venkatorao, 1979; Kurschner *et al*. 1992) indicate that split application of N fertilizer reduces excessive vegetative growth early in the season and reduced the severity of the blast. A unimodal pattern of disease development on the variety with disease incidence was observed, starting early at the nursery stage and increasing till it reached the panicle development stage. Then it started to decline towards the period when the grain was harvested. This disease progress could be attributed to the prevailing weather conditions of higher temperature and less rainfall during the vegetative stages. An increase in grain yield was observed on Jasmine variety from low N to high N application. This variety was not infected with the blast disease from the nursery until the physiological maturity stage, suggesting that this variety was immune to the disease.

The increase in yield across N levels could be attributed to the effect of N on the leaf area development, and consequently crop radiation interception as reported by Lemcoff and Loomis (1986). During reproductive development, N was mobilized from the leaves and stem to the panicle for the grain development (Ta and Weiland, 1992). Jasmine variety was able to utilize the available N efficiently for grain filling without any hindrance because of the non-necrotic lesion on the leaves leading to the increased yield.

On the other hand, WITA-4 had a decreasing yield from 0 kg ha^{-1} N to 60 kg ha^{-1} N followed with an increase in yield at 90 kg ha^{-1} N application. The ability of the WITA-4 to produce 4.9 tons/ha at 0 kg ha^{-1} can be attributed to its N-use efficiency even with the damage caused by the disease. The necrotic lesion on the leaves as a result of the blast significantly reduced the inflow of N through the affected part to the panicle for grain filling. This probably contributed to yield reduction in WITA-4 variety, although previous studies attributed yield losses more to neck blast than leaf blast (Cloud and Lee, 1993; Torres and Teng, 1993).

The two varieties responded differently to applied N but WITA-4 variety was at a higher-risk for leaf blast epidemics than the Jasmine under sawah system of rice production. An increase in yield for WITA-4 can be obtained if appropriate disease management measures are employed starting from the nursery stage until physiological maturity stage. Rice cultivation under sawah production system does not preclude rice from blast infection; therefore, an appropriate management system must be incorporated to avoid rice blast disease infection and yield loss.

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