REACTION OF RICE VARIETIES TO RICE BLAST - AN INSIGHT INTO UNDERSTANDING OF RICE RESILIENCE TO CLIMATE INDUCED RICE DISEASES

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ABSTRACT

This study is aimed at identifying the reaction in rice (Oryza sativa L.) varieties to loss in yield due to blast which is a climate induced rice disease. The experiment was carried out at hydromorphic fields of National Cereals Research Institute Badeggi, Southern Guinea Savanna of Nigeria in 2016. The treatments comprised of Ten rice varieties arranged in a randomized complete block design with three replicates. Data were collected on morpho-agronomic traits, 100 grain weight, harvested stool count, number of lesions, and diseases progression. Data collected were subjected to analysis of variance using general linear model procedure of SAS 2008. Results of disease progression showed that FARO 19 and ART16-16-11-25-1-B-1-B-11 had lowest disease progression rate. The results showed no significant differences in grain yield. However, the grain yield showed a range of 4242kgha^{-1} – 1212kgha^{-1}. FARO 19 and ART16-16-11-25-1-B-1-B-11 reactions to blast infestation showed that, they could be used to manage blast in endemic areas. It was concluded that all the varieties of rice can be cultivated with substantial level of yield production based on different levels of control measures. The study showed that differences in climatic environment, morpho-agronomic traits and plant nutrients content particularly silicon, phosphorus and nitrogen confer mechanism of resistance in rice varieties to blast disease infection.

Keywords: Reaction, Rice Blast, Resilience, Diseases, Climate

INTRODUCTION

Rice is the world's most important food cereal crop and a main food source for more than a third of the world's population (Gana *et al*., 2013). It is grown on 11 % of the world's cultivated land (Dogara *et al*., 2014). There is hardly any country in the world where rice is not utilized in one form or the other. It is one of the few food items whose consumption has no cultural, religious, ethnic or geographical boundary (Isa *et al.,* 2013).

Rice pests are any organisms or microbes with the potential to reduce the yield or value of rice crop. Rice pests include weeds, pathogens, insects, rodents and birds. A variety of factors can contribute to pest outbreaks, including the over use of pesticides and high rate of nitrogen fertilizer application (Jahn *et al*., 2005). Climatic condition also contributes to pests outbreaks. Rice gall midge and army worm outbreak tend to follow high rainfall in the wet season, while thrips outbreak is associated with drought (Douanghoupha *et al*., 2006). Rice diseases include rice ragged stunt, sheath blight, tungro and blast.

Developing disease resistant varieties is the best approach to crop management of rice. The two major diseases that affect rice production are rice blast and sheath blight (Otto, 2015). Outbreaks of these diseases have always proven to be disastrous (NCRI, 2002). Disease control by materials with low environmental effects is most desired (El-Kazzaz *et al*., 2015).

The use of chemical fungicides to control disease has longed been viewed as a last resort for disease management (Hajime, 2001). The use of seed treatment to prevent infection of seedlings after germination and use of fungicide to prevent infection of leaves and panicles during the growing season only attempt to reduce the incidence of blast disease on rice (Gohel and Chauhan, 2015). The objectives of the study was to evaluate the reaction of rice to blast disease and identify rice cultivars with slow blast disease progression rate in relation to the climate.

MATERIALS AND METHODS

This research work was carried out on the hydromorphic rice fields of National Cereals Research Institute (NCRI) Badeggi, Nigeria. Surface soil (0-15 cm) sample was collected from the hydromorphic field of NCRI Badeggi, using a hand trowel. The sample was air dried, gently crushed, passed through a 2 mm sieve and thoroughly mixed together to analyze for the physical and chemical properties.A sample of the soil was further passed through a 0.5 mm sieve to determine the total nitrogen using the micro kjehdal method.

Treatments and Experimental design

The Ten varieties (FARO 52, NERICA 7, FARO 16, FARO 19, ART16-16-11-25-1-B-1-B-11, FARO 49, ART16-9-29-12-1-1-B-1, NERICA 4, ART16-9-6-21-1-2-2-B-B-1 and FARO 38)of rice used for the experiment were collected from NCRI Badeggi due to their reactions to blast. . The treatments are the ten rice varieties which are arranged in a randomized complete block design with three replications.

Procedure

The pathogens collected were isolated from lesions on infected rice leaves in the central laboratory of NCRI, Badeggi using conidial isolation technique (Singh *et al*., 2000). The infected leaves were washed in sterile distilled water before cutting into pieces of 3 cm long. The cuttings were then surface-sterilised in 1 % mercury chloride for 15 seconds, then washed three times with sterile distilled water. They were then plated on moist sterilized filter papers placed in 9 cm petri dishes and treated with 3-5 mls of antibacterial (tetracycline) to avoid bacterial contamination and incubated at 29^{0}C for 24 hours.

Blast scoring was determined using WARDA, (1999) visual disease evaluation scale of 0, 1, 3, 5, 7, and 9, to determine the degree of infection on each variety. This was done at 1, 2, 3, 4, 5, and 6 weeks after inoculation (WAI) for leaf blast, and at 3 weeks after heading for panicle blast.

Disease incidence was determined based on the number of plants leaves infected, lesions and sizes of lesion on the leaves, neck and panicle infected based on WARDA, 2009protocols. This was used to calculate disease progression, (Vander Plank, 1963).

$$r = \frac{1}{t_2} - \; t_1 Log \frac{X_2(1-X_1)}{X_1(1-X_2)}$$

Where: r= rate of disease incidence

t_1= period of first assessment in days

t_2= period of second assessment in days

X_1= initial amount of disease

X_2= amount of disease at second assessment

The results were expressed as percentages increase of the initial values$(\frac{X}{A} x100)$.

Where A is the initial value and X is the difference between the initial and second value.

Other Data taken includes:

Morpho-Agronomic Traits: The data taken are; emergence percentage, days to 50% flowering, leaf area, plant height, tiller count, days to maturity, panicle number and panicle length.

Grain Yield: Data taken are; biomass weight, weight of panicle, harvested stool count, weight before winnowing, grain weight.

Plant Sampling: Rice leaves were sampled on each plot. The plant samples were oven dried at 60^{o}C for three days and milled. The total nitrogen, total phosphorus and silicon concentrations were determined using standard methods as outlined by (Agbenin, 1995).

Data Analysis

Data collected were subjected to Analysis of Variance (ANOVA) using General Linear Model (GLM) procedure of SAS (SAS, 2008). Means were separated using Duncan Multiple Range Test at 5 % level of probability where treatment means shows significant difference. Pearson correlation was used to determine the relationships between the mineral nutrients in the leaves of the rice varieties and level of blast disease infestation on the rice varieties.

RESULTS

Table 1 revealed that there was no significant difference between the varieties nutrient composition. Result of tiller count revealed that FARO 19 had the highest tiller count with significant difference to ART 16-16-11-25-1-B-1-B-11 but was not significantly different from other varieties. Number of days to maturity varied from 123 days (NERICA 4) to 128 days (ART16-16-11-25-1-B-1-B-11, FARO 38 and FARO 52).

Table 1: Mineral nutrients of the leaves

VARIETY	NC (gkg^{-1})	PC ($mgkg^{-1}$)	ABSC (gkg^{-1})	SC (gkg^{-1})
FARO 52	0.9^{a}	23.0^{a}	0.03^{ab}	10.3^{ab}
NERICA 7	1.0^{a}	22.2^{a}	0.03^{ab}	7.9^{ab}
FARO 16	0.94^{a}	23.2^{a}	0.03^{ab}	9.6^{ab}
FARO 19	0.9^{a}	24.5^{a}	0.017^{b}	5.6^{ab}
ART 16-16-11-25-1-B-1-B-11	0.92^{a}	23.1^{a}	0.03^{ab}	11.7^{ab}
FARO 49	0.9^{a}	23.3^{a}	0.03^{ab}	7.0^{ab}
ART16-9-29-12-1-1-1-B-1	0.94^{a}	23.3^{a}	0.04^{a}	13.2^{a}
NERICA 4	1.0^{a}	23.0^{a}	0.03^{ab}	8.73^{ab}
ART 16-9-6-21-1-2-2-B-B-1	0.93^{a}	23.1^{a}	0.04^{a}	8.9^{ab}
FARO 38	0.9^{a}	23.8^{a}	0.023^{ab}	11.2^{ab}
Mean	0.93	23.25	0.03	9.413
±SE	0.038	0.591	0.007	2.284
p-value	0.9284	0.6158	0.5439	0.5933

Values are presented in mean of four replicates. Values with the same superscript alphabets within the column are not significantly different at (p = 0.05) by Duncan Multiple Range Test. KEY: NC: Nitrogen content, PC: Phosphorus content, ABSC: Absorbed silicon, SC: Silicon content.

For days to maturity in Table 2, ART 16-16-11-25-1-B-1-B-11, was significantly different from all other varieties. FARO 52 gave the highest panicle number (16) while NERICA 4 had the lowest Panicle number (6.2). FARO 52 was significantly different (p = 0.05) from all varieties except

ART 16-9-6-21-1-2-2-B-B-1. For panicle blast, FARO 19 had the highest panicle length of 22.9cm while FARO16 had the lowest panicle length of 16.8cm. FARO 19 was significantly different from FARO 16 and ART 16-9-29-12-1-1-1-B-1.

Table 2: Morpho-agronomic traits of rice varieties

VARIETY	EP (%)	D50%F(days)	LA(cm^2)	PH(cm)	TC	DTM(days)	PN	PL(cm)
FARO 52	71.5^{ab}	70.3^{cde}	33.6^{cd}	51.9^{def}	14.7^{abc}	125.0^{bc}	16.0^{a}	19.5^{ab}
NERICA 7	49.1^{ab}	72.7^{bcd}	47.2^{bdc}	80.6^{ab}	14.3^{abc}	125.0^{bc}	9.2^{bc}	22.8^{a}
FARO 16	38.8^{ab}	77.3^{ab}	33.7^{cd}	55.2^{cdef}	15.9^{abc}	124.0^{bc}	10.3^{bc}	16.8^{b}
FARO 19	49.7^{ab}	77.0^{abc}	38.7^{cd}	84.7^{a}	14.0^{abc}	124^{bc}	9.6^{bc}	22.9^{a}
ART 16-16-11-25-1-B-1-B-11	86.1^{a}	66.0^{ef}	54.8^{abc}	63.2^{bcde}	15.8^{abc}	128.0^{a}	8.7^{bc}	19.5^{ab}
FARO 49	74.6^{ab}	77.7^{ab}	28.2^{d}	60cd^{ef}	15.4^{abc}	124.7^{bc}	8.7^{bc}	18.2^{ab}
ART 16-9-29-12-1-1-1-B-1	68.9^{ab}	75.0^{abc}	42.1^{bcd}	42.3ef	14.9^{abc}	125.3^{bc}	9.2^{bc}	17.3^{b}
NERICA 4	42.4^{b}	82.0^{a}	52.3^{abc}	69.4^{abcd}	10.3^{c}	123.0^{c}	6.2^{bc}	19.5^{ab}
ART 16-9-6-21-1-2-2-B-B-1	75.2^{ab}	77.0^{abc}	54.6^{abc}	52.7^{dcef}	16.8^{ab}	124.3^{bc}	11.7^{ab}	18.8^{ab}
FARO 38	77.0^{ab}	75.7^{abc}	33.3^{cd}	42.7^{ef}	13.9^{abc}	125.0^{bc}	6.3^{bc}	19.5^{ab}

Mean	63.330	75.070	41.850	60.270	14.600	124.830	9.590	19.480
±SE	16.664	4.452	9.843	14.479	1.768	1.307	2.794	2.021
p-value	0.2629	0.0001	0.0019	0.3957	0.1702	0.0018	0.0724	0.3647

Values are presented in mean of three replicates. Values with the same superscript alphabets within the column are not significantly different at (p = 0.05) by Duncan Multiple Range Test. KEY: EP: Emergence percentage, D50%F: Days to 50 % flowering, LA: Leaf area, PH: Plant height, TC: Tiller count, DTM: Days to maturity, PN: Panicle number, PL: Panicle length.

Result of yield parameters are presented in Table 3. Harvested stool count ranged from 47.3 (ART 16-16-11-25-1-B-1-B-11) to 23.7 (NERICA 7) There was no significant difference among the varieties apart from NERICA 7 which was significantly different from ART 16-16-11-25-1-B-1-B-11. The result of the biomass weight revealed that FARO 49 had the highest biomass weight (379g) while FARO 16 (122g) had the lowest biomass weight. In respect to weight of rice before winnowing, NERICA 7 recorded highest (169g) while FARO 16 was the least (70g). NERICA 7 recorded the highest (11.7g) panicle weight while NERICA 4 recorded the least panicle weight of (5g).

Table 3: Grain yield and its components traits for the ten rice varieties

VARIETY	HSC	BW(g)	WRBW(g)	W5P(g)	100GW(g)	GYH(kgha^{-1})
FARO 52	39.3^{ab}	326.3^{abc}	114.3^{ab}	9.7^{abc}	6.7^{a}	1212.0^{a}
NERICA 7	23.7^{b}	294.0^{abc}	169.0^{ab}	11.7^{a}	13.3^{a}	2424.0^{a}
FARO 16	29.0^{ab}	122.7^{c}	70.0^{b}	8.7^{abcde}	20.0^{a}	2424.0^{a}
FARO 19	38.7^{ab}	303.0^{abc}	72.0^{b}	8.3^{abcde}	16.7^{a}	3030.0^{a}
ART 16-16-11-25-1-B-1-B-11	47.3^{a}	315.0^{abc}	131.7^{ab}	8.7^{abcde}	20.0^{a}	3636.0^{a}

FARO 49	45.7^{ab}	379.3^{abc}	117.0^{ab}	7.3^{cde}	13.3^{a}	2424.0^{a}

ART16-9-29-12-1-1-1-B-1	39.0^{ab}	283.3^{abcs}	102.0^{ab}	9.7^{abcd}	23.4^{a}	4242.0^{a}
NERICA 4	26.7^{ab}	150.7^{bc}	153.7^{ab}	5.0^{e}	16.7^{a}	4242.0^{a}
ART 16-9-6-21-1-2-2-B-B-1	41.3^{ab}	325.7^{abc}	114.0^{b}	8.3^{abcde}	16.7^{a}	3030.0^{a}
FARO 38	42.3^{ab}	261.7^{abc}	83.0^{ab}	8.7^{abcde}	26.7^{a}	3030.0^{a}
Mean	37.300	275.378	112.670	8.610	17.350	2969.400
±SE	8.073	84.887	32.848	1.728	5.633	923.474
p-value	0.1794	0.0971	0.4603	0.0395	0.6635	0.66

Values are presented in mean of three replicates. Values with the same superscript alphabets within the column are not significantly different at (p = 0.05) by Duncan Multiple Range Test. KEY: HSC: Harvested stool count, BW: Biomass weight, WRBW: Weight of rice before winnowing, W5P: Weight of five panicles, 100GW: 100gram weight, GYH: Grain yield per hectare.

NERICA 7 was not significantly different from most varieties but was significantly different from NERICA 4 and FARO 52. 100 seed weight ranged from 6.7g to 26.7g. FARO 52 had the lowest 100 seed weight while FARO 38 recorded the highest 100 seed weight. There was no significant difference among the varieties. The seed yield per hectare had no significant difference among the varieties. The result in Table 4 shows that there was a significant difference among the varieties with respect to number of lesions. FARO 52 (9.1) had the highest while FARO 16 (3.9) gave the lowest. FARO 52 was significantly different from FARO 16 but showed no significant difference from other varieties. The disease progression varied significantly from 60.3 (NERICA 7) to 6.5 (ART 16-16-11-25-1-B-1-B-11). NERICA 7 was significantly different from most varieties but was not significantly different from FARO 16 and NERICA 4. Leaf blast ranged from 3.0 - 4.3. There was no significant difference (p = 0.05) among the rice varieties to leaf blast. Result of panicle blast showed that ART 16-9-29-12-1-1-B-1 was most affected (8.3). It was only significantly different from FARO 52.

Table 4: Reaction of rice varieties to blast disease

VARIETY	NL	DPGN	LB	PB

FARO 52	9.1^{a}	15.7^{fgh}	3.0^{a}	4.3^{b}
NERICA 7	7.2^{ab}	60.3^{a}	3.0^{a}	6.3^{ab}
FARO 16	3.9^{bc}	49.1^{abc}	3.7^{a}	7.7^{a}
FARO 19	4.8^{abc}	9.1^{gh}	3.7^{a}	7.7^{a}
ART 16-16-11-25-1-B-1-B-11	5.9^{abc}	6.5^{h}	3.0^{a}	7.0^{ab}
FARO 49	7.6^{ab}	18.7^{efgh}	3.7^{a}	7.7^{a}
ART16-9-29-12-1-1-1-B-1	8.0^{ab}	26.9^{defgh}	3.0^{a}	8.3^{a}
NERICA 4	5.2^{abc}	52.0^{ab}	3.0^{a}	7.0^{ab}
ART 16-9-6-21-1-2-2-B-B-1	7.2^{abc}	33.2^{bcdef}	3.0^{a}	7.7^{a}
FARO 38	8.0^{ab}	26.9^{defgh}	4.3^{a}	7.7^{a}
Mean	6.43	32.66	3.43	7.13
±SE	1.46	6.39	1.38	0.92
p-value	0.2838	0.0001	0.9999	0.4512

Values are presented in mean of three replicates. Values with the same superscript alphabets within the column are not significantly different at (p = 0.05) by Duncan Multiple Range Test. KEY: NL: Number of lesions, DPGN: Disease progression, LB: Leaf blast, PB: Panicle blast but was not significantly different from other varieties.

Correlation Analysis

Result of correlation coefficient in Table 5 showed that all parameters were not significantly correlated with blast infestation except for number of lesions and nitrogen content (r = 0.4*). Similarly, there was no significant correlation among the plant nutrients except for silicon and phosphorus content with negative but significant correlation and phosphorus and nitrogen content which showed the strongest relationship (r = 0.8**).

Table 5: Correlation analysis

	NL	DP	LB	PB	NC	PC	ABS	SC
NL	1	-0.309^{ns}	0.029^{ns}	-0.26^{ns}	0.384*	0.289^{ns}	0.269^{ns}	-0.23^{ns}
DP		1	-0.003^{ns}	-0.05^{ns}	0.042^{ns}	0.210^{ns}	-0.14^{ns}	-0.38^{ns}
LB			1	0.365^{ns}	-0.01^{ns}	-0.125^{ns}	-0.08^{ns}	0.132^{ns}
PB				1	-0.20^{ns}	-0.199^{ns}	0.167^{ns}	0.138^{ns}
NC					1	0.768**	0.312^{ns}	-0.27^{ns}

PC	1	0.189^{ns}	-0.511*
ABS		1	0.066^{ns}
SC			1

KEY: ^{ns}: Not significant, *: Significant, **: Very significant, NL: Number of lesions, DP: Disease progression, LB: Leaf blast, PB: Panicle blast, NC: Nitrogen content, PC: Phosphorus content, ABS: Absorbed silicon content, SC: Silicon content.

Discussion

This paper showed that blast disease greatly affects the agronomic traits of the rice varieties, which leads to variations in plant height, leaf area, tiller number, panicle length, panicle number, biomass weight, and grain yield. The results however, showed that leaf and panicle blast had no effect on the grain yield. This agrees with the findings of Koutroubas *et al.*, (2015), Who reported that inoculation of rice varieties with blast isolates affected immensely the overall agronomic traits of rice but had negative correlation to grain yield. At low humidity, varieties with high above average grain yield were characterized with average height, late flowering, wider leaves, fewer tillers, higher above ground biomass, late maturity and there was higher silicon and phosphorus content in their leaves. This corroborates with the report of Vange and Obi (2006), who reported that agronomic traits and cultural practice affects blast disease effects on seed yield. Similarly, varieties with low yield under the effect of high rainfall had; tiny leaves flowered earlier, more tillers, average height, reached maturity earlier and high rate of disease progression, which supports the works of Ishihara *et al.* (2014) who states that there is no significant difference between panicle and leaf blast under high humidity. Tiller count had significant variation which could be as a result of phosphorus level in the varieties. This supports the report of Alan *et al.* (2009) statement that tiller productions were highly responsive to phosphorus levels.

Experimental result showed that, some varieties (FARO 38, ART 16-9-6-21-1-2-2-B-B-1 and ART 16-9-29-12-1-1-1-B-1) had average rate of disease progression, high level of leaf silicon and nitrogen content and above average nitrogen content. This could be a reflection of late maturing, wide leaves, fewer tillers, average height and delayed maturing qualities they possessed, which is in line with the report of Huang *et al.* (2010), who reported that phenotypic variance is an evidence of resistance to rice climatic induced blast disease. From the experimental results all the varieties did not show any significant difference in respect to leaf and panicle blast, they however varied in terms of disease progression and seed yield with relations to the climate of the environment and silicon, phosphorus and nitrogen contents in the plant. This is similar with the works of Ashraf *et al.* (2017), which states that mechanism of resistance to blast is influenced by the climate of the environment and mineral nutrients of the plant. The result of the nutrient correlation of this research suggests that phosphorus uptake by rice plant tissue is a major determinant in the ability of its ability to resist blast infestations in relation to its individual early crop maturity aided by nitrogen uptake. Similarly, silicon positively aids rice resistance to blast at lower concentration of nitrogen (Mayamulla *et al.,* 2017), in line with this, the research also suggests that higher levels of silicon aids the regulation of nitrogen uptake in plant tissues which help to reduce the number of lesions, hence prevents blast infestation.

The experiment showed that grain yield showed no variation among the varieties with relations to the climatic condition. This could be as a result of the varietal yield potential differences and nutrient content level of the varieties in consent to the reports of Smith *et al.* (2012) who reported that grain yield showed no significant differences with respect to good management practices under high humid conditions. Similarly, effect of climate change on nutrients of the rice varieties is suggested to be a measure of the resistance mechanism in the rice varieties (Ashraf, *et al.,* 2017).

Conclusion

It was concluded that two varieties; NERICA 4 and ART16-9-29-12-1-1-1-B-1, gave the best reaction to blast infection under the Badeggi Hydromorphic climate conditions. Also, two varieties expressed slow disease progression rate effectively; FARO 19 and ART16-16-11-25-1-B-1-B-11. With the result of this study all the varieties of rice can be cultivated with substantial level of yield production based on different levels of control measures. The study showed that differences in climatic environment, morpho-agronomic traits and plant nutrients content particularly silicon, phosphorus and nitrogen confer mechanism of resistance in rice varieties to blast disease infection.

REFERENCES

Agbenin, J. O. (1995). Laboratory Manual for Soil and Plant Analysis. (Selected Method and Data Analysis). Published by the author. 140pp

Alan, M. M., Hasanuzzaman, M. & Nahar K. (2009). The dynamics of three irrigated rice varieties under varying phosphorus level. *American-Eurasian Journal of Agronomy*. 2(2), 88-94.

Ashraf M. A., Mohammed M. M., Ahammad A. J. S., & Mohammad N, M. (2017). Computational study of silicon transporter protein in rice and wheat. *International Journal of Computational Bioinformatics and In Silico Modeling*, 2(4), 199-205.

Dogara, A. M., & Jumare, A. I. (2014). Origin, distribution and heading date in cultivatedrice. *International Journal of Plant Biology and Research,* 2, 1008-1014.

Douangboupha, B. K., Khamphoukeo, K., Inthavang, S., Schiller J., & Jahn G. (2006). *Pest and Diseases of the Rice Production Systems of Laos,* 265-281.

El-kazzaz, M. K., Salem, E. A., Ghoneim, K. E., Elsharkawy, M. M., El-Kot, G. A. N., Kalboush, Z. A. E. (2015). Integrated control of rice kernel smut disease using plant extracts and salicylic acid. *Archives of Phytopathology and Plant Protection*. DOI: 10.1080/03235408.2015.1092202.

Gana, A. S., Shaba, S. Z., & Tsado, E. K. (2013). Principal component analysis of Morphological traits in thirty-nine accessions of rice *Oryza sativa* L. grown in a rainfed lowland ecology of Nigeria. *Journal of Plant Breeding and Crop Science*, 5(x), 120-126

Gohel, N. M., & Chauhan, H. L. (2015) Integrated management of leaf and neck blast disease of rice caused by *Pyricularia oryzae*. *African Journal of Agricultural Research*, 10(19), 2038-2040.

Hajime, K. (2001) *Pesticide outlook*. Japan Crop Protection Association-Chome Muromachi, Nihonbashi, Chuo-Ku, Tokyo 103, Japan, 1, 5- 8

Huang X., Xinghua W., Tao S., Qiang Z., Qi F., Yan Z., Canyang L., Chuanrang Z., Tingting L., Zhiwu Z., Meng L., Danlin F., Yunli G., Ahong W., Lu W., Liuwei D., Wenjun L., Yiqi L., Qijun W., Kunyan L., Tao H., Taoying Z., Yufeng J., Wei L. & Zhang L. (2010). Genome-wide association studies of 14 agronomic traits in rice landraces. *Journal of nature Genetics*, 4(2), 961-967

Isa, J. O., Cyprian, C. A., & Sam, O. O. (2013). Resource use efficiency and rice production in Guma Local Government Area of Benue State: An application of stochastic frontier production function. *International Review of Social Sciences and Humanities*, 3(1), 108-116

Ishihara T., Yuriko H, Shinichi O, Kaworu E, Nghia T, Keiko H, Taketo A, Fumihiko S & Shinzo K. (2014). Quantitative trait locus analysis of resistance to panicle blast in the rice cultivar Miyazakimochi. Journal of biomedical science 7(2) DOI: 10.1186/s12284-014-0002-9

Jahn, G. C., Almazan, L. P., & Pacia, J. (2005). Effects of nitrogen fertilizer on the intrinsic rate of increase of the rusty plum aphid, *Hysteroneura setariae* (Thomas) (Homoptera: Aohididae) on rice (*Oryza sativa L*). *Environmental Entomology*, .34(4), 938-943

Khush, G. S. (1997). Origin, dispersal, cultivation and variation of rice. *Plant Molecular Biology*, 35, 25–34

Koutroubas, S. D., Katsantonis, D., Ntanos, D. A., & Elisabetta, L. (2015). The effect of Blast disease on rice growth, yield and quality in the field. *Turkish Journal of Agriculture and Forestry*. 33 (5), 487-494.

Mayamulla, S., Weerarathne, L. V. Y., Maramba, B., Sirisena, D. N., & Suriyagoda, L. D. B. (2017). Variation in seed nutrient content, seedlings growth, and yield varieties of rice varieties grown in paddy field without application of fertilizers for forty years. *Journal of Crop and Pasture Science*. 68 (4), 337-348.

Otto M. (2015). Integrated pest management for rice production in Nigeria report on a consultancy for the *Competitive Africa Rice Initiative Program*me Abuja, Nigeria. Retrieved from https://www.growafrica.com/competitive/

Smith, J., Fukai, S., & Mitchell, J., (2012). Rice grain yield-a comparison between direct seeding and transplanting in Lao People Democratic Republic. *The Regional Institute online publishing.* Retrieved from http://www.dpi.nsw.gov.au

Vange T. & Obi I. U. (2006). Effect of planting date on some agronomic traits and grain Yield of upland rice varieties at Makurdi, Benue state, Nigeria· *Journal of Sustaianable Development in Agriculture and Environment 2, 86 – 92.*