# Inheritance of Silicon Uptake ability in Rice blast resistant Varieties

Rice blast disease is the most destructive disease to rice plants and can cause a lost in a yield ranging from 50 to 100. %. To develop resistant genotypes, it is necessary to determine the source of resistance, the nature of resistance and the mode of gene action that gives resistance to the disease. It is known that Silicon enhances durable resistance to rice blast disease. The rice silicon uptake inheritance can be studied through crossing the high silicon uptake with low silicon uptake genotypes. Seven genotypes were crossed in a full-dialel design, two genotypes having very high silicon uptake ability, two having moderate silicon ability, two having low silicon uptake ability and the last one was having very low silicon ability. The F1 plants were selfed and F2 plants were tested for silicon uptake ability. Then genetic traits of the segregating F2 populations and their parents were analyzed in order to determine the heritability. A high narrow sense coefficient of genetic determination suggested that there was a considerable heritability of resistance for rice blast. The analysis of gene action revealed that additive gene effects contributed more than the non-additive effects for the inheritance of silicon uptake ability as indicated by high Baker's ratio (above 0.8 and 0.3) for both silicon uptake and water lose respectively. Genotypes, GIZA182 and E20 were found to have the most desirable GCA among the genotypes used in the study.

*Key words: durable resistance, gene action, Silicon Uptake, Rice blast, resistant Varieties*

## Introduction

Rice is the principal food grain consumed by half of the world's population [1]. The crop has been cultivated for over 10,000 years [2] with Asia and Africa being the leading consumers [3]. Globally, the area under rice production is estimated at 150 million hectares with an annual output of 500 million metric tons [4]. India, Indonesia and Bangladesh are among the leading producers of rice [5]. In Africa, the crop is cultivated in over 75% of the countries and is an important food security crop in several countries including Benin, Angola, Ghana, Burkina Faso and Uganda [3].

In Uganda rice production from year 2010 to 2014 increased from 93 to 95 thousand hectares, with a production increase from 214 to 237 thousand tones [6]. Several constraints were responsible for the lack of attaining the potential yield including pests and disease, changing weather patterns and unfavorable soil conditions [7]. Among these constraints, diseases like rice yellow mottle virus, bacterial blight and blast presented the most formidable challenge to the farmers [7]. Rice blast, caused by *Magnaporthegrisea,* is one of the most devastating diseases, causing yield losses of 50 to 90% [8]. Identifying sources of resistance to the disease has been a major objective for many researchers involved in rice breeding programs [3].

Improving of genotypes with excellent properties such as resistance to both biotic and abiotic barriers, is necessary. To develop resistant varieties, it is necessary to determine the source of resistance, the nature of resistance and the mode of gene action that gives resistance to the disease. The inheritance can be identified by crossing the genotypes having high silicon uptake ability varieties with those that have low silicon uptake ability. The objective of the study was to determine the mode of gene action governing resistance to rice blast.

## Materials and methods

### Parental genotypes selected

All experiments were conducted at National Crop Resources Research Institute (NaCRRI) Namulonge in Uganda. Seven rice varieties from two sources were selected as parents for

F2 populations development in this experiment (Table 1). Three genotypes were selected based on an earlier screening of introduced lines under screen house conditions. The three genotypes were classified as having very high silicon uptake ability, and two had high silicon uptake. Four additional genotypes were selected, two had moderate silicon uptake abilities and two additional were had low and very low silicon uptake ability (Table 1).

Table 1: Genotypes used in the study

| *Genotypes* | *Silicon Uptake Rating* | *Source* |
|---|---|---|
| *METP48* | Very High Si Uptake | African Rice |
| *METP49* | High Si Uptake | African Rice |
| *GIZA 182* | High Si Uptake | Egypt |
| *MET P68* | Moderate Si Uptake | African Rice |
| *KOMBOKA* | Moderate Si Uptake | IRRI |
| *E 20* | Low Si uptake | IRRI |
| *METP20* | Very low Si Uptake | African Rice |

IRRI = International Rice Research Institute.

**Populations development**

The parental genotypes were planted in buckets filled with soil. Four seeds were planted in each bucket staggered at four week interval to synchronize flowering,planting was staggered at four weekly intervals and afull-diallel mating design was used to generate populations.

Crossing was done with the aid of a vacuum emasculator in the late morning (10:00am12:00pm) and late afternoon (3:00pm-5:00pm) on panicles that had already started flowering [9]. Immature spikelets and any that had already undergone anthesis were cut off at the bottom of the panicle, leaving only the emasculated spikelets in the panicle. After emasculation, panicles were covered with a pollinating bag secured with paper clips to keep out any external pollen [9]. A flowering panicle of the male parent was cut and dusted onto the emasculated panicle, gently tapped onto the receptive stigma and then covered with the pollinating bag [9 ]. Mature seeds from successful crosses were harvested and bagged according to the cross number.

The harvested $F_1$ seeds were placed in an air-dry oven for 7 days at 50 $^oC$ in order to break dormancy [10]. The $F_1$ seeds were later surface sterilized by 0.1 % Tween 20, followed by 70 % ethanol and washed twice with distilled water. Sterilized seeds were placed in sterile petridishes on moistened tissue papers and incubated for 48 hours at 30$^oC$. Pregerminated $F_1$ seeds were transferred to small cups where they germinated until they became strong enough for transplanting. Seedlings were transplanted into buckets filled with soil, and kept in the screen house. Morphological markers including plant height, tillering, days-to-flowering and days-tomaturity were used to differentiate successful crosses from selfed plants [9 ] .

**Experimental design**

The $F_2$ segregating population and parents were evaluated at National Centre for Rice Research Institute (NaCRRI) in the pots in Complete Random Design (CRD), replicated three times. All agronomic practices including fertilizer applications were done.

**Data collection and analysis**

Data for silicon uptake ability were collected according to IRRI's standard evaluation system for rice [11]. Three weeks after planting the data were analyzed by Analysis of Variance (ANOVA) Method [12 at a confidence level of $P < 0.05$ .

In order to select a good combination of parents, heritability, general combining ability and specific combining ability were calculated using recommend method Analysis of Variance (ANOVA) [13] at a confidence level of $P < 0.05$. The statistical model used was:

$$Y_{ijkl} = \bar{Y}... + g_i + g_j + s_{ij} + R_k + e_{ijk}$$

$\bar{Y}...$ is the grand mean, $g_i$ and $g_j$ are GCA effects of the $i^{th}$ and $j^{th}$ parents respectively, $s_{ij}$ is the SCA effect for the crosses between the $i^{th}$ and $j^{th}$ parents, $R_k$is replication means effects, and $e_{ijk}$is experimental error.

**RESULTS**

**Gene action determining rice blast resistance**

Analysis of variance of F2 segregating populations grown in screen house in season (2018

A) is presented in Table 3. ANOVA revealed significant ($P \leq 0.001$) differences among genotypes for silicon uptake abilities suggested wide genetic variability of genotypes resistance to rice blast.

The narrow sense coefficient of genetic determination was 0.56 for silicon uptake. The broad sense coefficient of genetic determination was 0.73 for silicon uptake and 0.99 for water loss effect. The relative importance of additive to non-additive gene action for silicon uptake was 0.77.

Table 2: Analysis of variance of F2 segregating rice genotypes with eight missing crosses for Silicon uptake and water loss under screen house condition at NaCRRI in (2018 A) season

| *SOV* | *d.f.* | *MS Uptake* | *MS Water lose* |
|---|---|---|---|
| *Replications* | 2 | 13917 ns | 0.000305*** |
| *Entries* | 40 | 21246** | 0.014675** |
| *GCA* | 6 | 16392** | 0.002354*** |
| *SCA* | 27 | 74964* | 0.004663** |
| *Crosses* | 33 | 91138ns | 0.004243ns |
| *Error (Residual)* | 80 | 46390 | 0.000010 |
| *Additive component ($\sigma^2$ GCA)* | 48396ns | Additive component ($\sigma^2$ GCA) | 0.000965*** |
| *Dominance component ($\sigma^2$ SCA)* | 28574ns | Dominance component ($\sigma^2$ SCA) | 0.004653** |
| *Bakers ratio* | 0.7721 | Bakers ratio | 0.293216564 |
| *CGD – BS* | 0.7299 | CGD – BS | 0.99848079 |
| *CGD – NS* | 0.5635 | CGD – NS | 0.292771106 |

Significant at ***P*** < 0.05 = *, P < 0.01 = **, P < 0.001= ***, p = probability, ns= non-significant, SOV= source of variation, CGD= coefficient of genetic determination, BS = Broad sense, NS= Narrow sense, GCA = general combining ability, and SCA = specific combining ability.

Estimates of the effects of general combining ability for individual parental lines for rice blast are presented in Table 3. For silicon uptake and water loss effect the desirable GCA effect for parents should be negative. Significant effects (P ≤ 0.001) of GCA and SCA variation among genotypes were observed. The results showed that three genotypes used in this experiment, H1,H4 and L6 had highly significant negative effect (-103.1765), (89.1765),(-118.176 ) respectively for silicon uptake suggesting that these genotypes had good levels of silicon uptake and hence had resistance to rise blast and as good general combiners would transfer resistance to rice blast. On the other hand, highly positive significant (P ≤ 0.001) GCA effects were obtained on the locally adapted genotypes H2 and L5 suggesting that these genotypes could not be a source of resistance to rice blast.

Generally, GCA effects were much higher than SCA effects, as illustrated by Baker's ratio

(Table 4), suggesting that gene action was predominantly additive for silicon uptake ability.

Table 3: Summary of GCA effects of rice genotypes to water lose and silicon uptake

| Parents | Wl P means | Si upk P means | Wl GCA effects | Si upk GCA effects |
|---|---|---|---|---|
| METP48 | 0.091 | 5318 | 0.0018 ns | -103.1765 ns |
| METP49 | 0.286 | 0598 | -0.0091*** | 273.8235** |
| GIZA182 | 0.143 | 0197 | -0.0132*** | -25.1765 ns |
| METP68 | 0.262 | 1701 | 0.0187*** | -89.1765ns |
| KOMBOKA | 0.091 | 0194 | 0.0216*** | 161.8235ns |
| E20 | 0.237 | 0302 | -0.0252*** | -118.1765ns |
| METP20 | 0.156 | 0052 | 0.0026 ns | -34.1765ns |

Significant at ***P*** < 0.05 = *, P < 0.01 = **, P < 0.001= ***, p = probability, ns= non-significant, Si = silicon, Wl = Water lose, upt = uptake and p = parent. And GCA = general combining ability, and SCA = specific combining ability

The specific combining ability of crosses are shown in Table 4. For silicon uptake ability, the most desirable SCA effects were obtained in cross METP49× MET P68 ((997.036 ***) and water loss effect had significant SCA effects for crosses (METP48× METP49), ( METP48× METP68), (METP48×KOMBOKA), (METP48×METP20), (METP49×GIZA182),( METP49×METP68), (METP49×E20),( GIZA182×METP68), (GIZA182× KOMBOKA), (GIZA182× METP20), (MET P68× KOMBOKA),( MET P68× E 20), (MET P68× METP20), and (E 20× METP20).

Table 4: SCA effects for water loss and silicon uptake in F2 segregating populations

| Cross | Water loss SCA Effect | Si uptake SCA Effect |
|---|---|---|
| METP48× METP49 | -0.048*** | 79.233 ns |
| METP48× GIZA182 | 0.000 ns | -126.21 ns |
| METP48× METP68 | -0.031*** | 333.55 ns |
| METP48×KOMBOKA | -0.138*** | -108.484 ns |
| METP48× E20 | -0.016 ns | 424.863 ns |
| METP48× METP20 | 0.048*** | -39.54 ns |
| METP49×METP48 | 0.006 ns | -55.667 ns |
| METP49× GIZA182 | 0.081*** | -115.83 ns |
| METP49× METP68 | 0.086*** | 997.036*** |
| METP49×KOMBOKA | 0.012 ns | -233.317 ns |
| METP49× E20 | -0.041*** | -116.119 ns |
| METP49× METP20 | 0.006 ns | -61.11 ns |
| GIZA182× METP68 | -0.029*** | 22.211 ns |
| GIZA182×KOMBOKA | 0.038*** | 73.828 ns |
| GIZA182× E20 | -0.01 ns | -278.706 ns |
| GIZA182× METP20 | 0.114*** | -11.959 ns |
| METP68× KOMBOKA | -0.068*** | 46.838 ns |
| METP68× E20 | 0.067*** | -101.55 ns |
| METP68× METP20 | -0.03*** | -197.23 ns |
| KOMBOKA× E20 | -0.005 ns | 177.628 ns |
| KOMBOKA× METP20 | 0.014 ns | -9.646 ns |
| E20× METP20 | 0.032*** | -211.2 ns |

Significant at ***P*** < 0.05 = *, P < 0.01 = **, P < 0.001= ***, p = probability, ns= non-significant, and GCA = general combining ability, and SCA = specific combining ability

## DISCUSSION

### Combining ability for resistance to rice blast

Understanding the mode of inheritance of resistance to rice blast is essential to facilitate the resistance breeding. Since the inheritance of resistance to rice blast or rice high silicon uptake ability in the genotypes depends on the genotype involved in the crossing, the pathogen race and environmental condition, it is important to assess the pattern of inheritance in every new resistance sources before the start of the breeding work [14]. The analysis of data from this study showed significant differences among the progenies tested with their parents. The results indicated that both additive and non-additive gene actions were involved in the inheritance of Silicon uptake ability. However, the additive portion was greater than the non-additive, suggesting that additive gene effects contribute more to silicon uptake ability and resistance to rice blast. Similar results were reported [14]. The low GCA values obtained in the genotypes used (GIZA 182 and E20) indicated their importance in contributing resistance to rice blast in crosses involving them. However, other genotypes showed positive GCA effects, suggesting their poor contribution for resistance to rice blast when crossed with other parents. Parent E20 with high negative GCA effects was potentially superior and may be included in breeding programs to introduce resistance to susceptible cultivars which otherwise have acceptable traits [14].

The proportion of additive to non-additive gene effects for rice silicon uptake was high, as estimated by Baker's ratio of 0.8 and 0.3 for both Silicon uptake and water loss effect respectively (obtained at 21 days), implying that additive genes effects were more important than non-additive [15]. The high Baker's ratio also implies that selection in early generations can be effective and therefore, methods such as pedigree selection, modified pedigree, or mass selection can be used.

A high narrow sense coefficient of genetic determination was obtained, suggesting that 56 % of the inheritance to silicon uptake ability was governed by additive genes and transmissible to the progeny. High broad sense coefficient of genetic determination (73%) for inheritance to

silicon uptake and (99 %) for water loss were observed in this study that showed the proportion of genotypic to environmental factors is very high suggesting that heritability of resistance to rice blast was high.

## CONCLUSION

The analysis of gene action revealed that additive gene effects contributed more than the non-additive effects for the inheritance of silicon uptake ability. Genotypes, GIZA 182 and E20 were found to be the most desirable source of resistance to rice blast GCA among the genotypes used in this study. The number of genotypes involved in the study for the silicon uptake ability showed variation in inheritance of resistance depending on the genotypes involved in the cross.

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