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INNSPUB

International Journal of Agronomy and Agricultural Research (IJAAR)
ISSN: 2223-7054 (Print) 2225-3610 (Online)
http://www.innspub.net
Vol. 9, No. 2, p. 9-21, 2016

RESEARCH PAPER | OPEN ACCESS

Evaluation of rice genotypes for resistance to the stalk-eyed fly (*Diopsis longicornis*) in rice in Uganda

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Article published on August 14, 2016

Key words: Improved rice genotypes, Stem borers, Infestations, Deadhearts.

Abstract

Globally, rice production is limited by abiotic and biotic factors. Of the insect pests attacking rice, the stalk-eyed fly is the most abundant. Major rice growing districts in Uganda are affected, and varieties grown by farmers are susceptible. The objective of this study was to identify sources of resistance to stalk-eyed flies among improved rice genotypes in Uganda. Fifty genotypes from the Africa Rice Centre, IRRI, South Korea and the National Crops Resources Research Institute (NaCRRI) in Uganda were screened under cage and field conditions at NaCRRI. Trials were laid out in an alpha lattice design, with 3 replications, for both experiments. Natural infestation (*D. longicornis* or *D. apicalis)* was used in the field while cage trials utilized artificial infestation with *D. longicornis*. Data on deadhearts were collected from seedling to tillering stages, at 7, 14, 21 and 28 days. Analyses of variance were performed using restricted maximum likelihood. Infestation levels for 31 (62%) rice genotypes were the same under both field and cage conditions, 4 (8%) genotypes showed higher susceptibility in the cage than in the field and 15 (30%) were more resistant in the cage than in the field. Genotypes NERICA 4, TXD306, NM7-22-11-B-P-1-1 and K85 were identified as the most resistant varieties. F_3 genotypes (GSR IR1- 5-S14-S2-Y1 x K85, Gigante x NERICA4, NERICA4 x Gigante, NERICA1x NERICA4, NERICA4 x NERICA6, and NERICA4 x SUPA) were also found resistant. These genotypes were recommended for release and further advancement, respectively.

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Introduction

Rice is an important staple food for more than half of the world's population (Javed *et al.,* 2015). Global production for 2014 was estimated at 740.2 million tons (Mt) with China, India, Indonesia, Vietnam, Thailand and Bangladesh being the major producers (FAO, 2015). In East Africa, rice is the second most important staple food, after maize. By 2014, annual consumption had reached 1.8 million metric tons. Production, however, stood at 1.25 million metric tons (FAO, 2014). In Uganda, rice was introduced by Indian traders as early as 1904 but did not spread widely nor gain popularity until the late 1940s (Odogola, unpublished). However, the production of rice remained low until 1974, when rice farmers appealed to the Government of Uganda for assistance. Today, rice is grown by smallholder farmers throughout the country, with a few large scale farmers in some areas (Ugen, unpublished). The area under rice cultivation was estimated at 80,000 hectares in 2002, almost doubling to 150,000 hectares by 2011. Production followed a similar trend, increasing from 120,000 Mt in 2002 to 164,000 Mt in 2009 and 220,000 Mt in 2013 (MAAIF, 2012). Consumption was estimated at 299,800 Mt in 2012, with a 19% production deficit forecasted (Ahmed, 2012; MAAIF, 2012).

As is the case of many developing countries, rice yield per unit area in Uganda is still very low, averaging 1.8t/ha for both lowland and upland rice, compared to a yield potential of 8 t/ha and 5 t/ha for lowland and upland rice, respectively, in developed nations (Karugia *et al.*, unpublished). Production is constrained by several factors: technological, bio-physical, socioeconomic, institutional and financial. Of these constraints, biotic and abiotic factors are the most important (Hadush, 2015). Abiotic stresses include: variable rainfall, with drought and flooding occurring in the same season; poorly-drained soils of the coastal lowlands, and alkalinity in dry areas. Biotic stresses include: weeds, insect pests (stem borers such as stalk eyed flies, African rice gall midge and rice bugs), diseases (blast, brown spot, and viral diseases), rats and birds (Hadush, 2015).

Among the biotic stresses, stem borers are considered as major insect pests of rice in Sub-Sahara Africa (Nacro *et al.*, 1996, Nwilene *et al.*, 2008a). Estimates of yield losses due to insects in Africa range from 10% to 15% (Nwilene *et al.*, 2013). Stalk-eyed flies (*Diopsis longicornis and Diopsis apicalis*) are among the stem borers which are widely-distributed and devastating pests of rice (Heinrichs and Barrion, 2004).

In Uganda, between 2010 and 2013, stalk-eyed flies were among the major pests reported on rice (Fujiie *et al.*, unpublished). Of the two species of stalk-eyed flies observed, *Diopsis longicornis* has been reported as the most abundant and most important on rice in Uganda (Fujiie *et al.*, unpublished). Damage from stalk-eyed fly larvae usually affects the central meristem of the plant, which is bored, resulting in a condition known as deadheart (Togola *et al.,* 2011). Stalk-eyed fly damage significantly reduces the following: tiller density, number of panicles, grain weight and numbers of mature panicles (Togola *et al.*, 2011). In West Africa, farmers use pesticides, biological and cultural control strategies to manage stalk-eyed flies. These control methods are, however, not effective due to the high level of reproduction of the stalk-eyed flies. Host plant resistance is, therefore, the most reliable and cost-effective means of controlling rice stalk-eyed flies (Nwilene *et al.*, 2008b; Togola *et al.*, 2011). The objective of this study was to contribute towards improved understanding of the response of rice genotypes to the stalk-eyed fly damage and identify sources of resistance to stalk-eyed flies among improved rice genotypes.

Materials and methods

Planting materials and field experiment

Fifty (50) rice genotypes from four sources: (i) Interspecific crosses with NERICA varieties and others breeding lines from Africa Rice Center, (ii) Released and advanced breeding lines from NaCRRI, (iii) Breeding lines from IRRI and (iv) South Korean lines were screened for resistance to stalk-eyed flies (Table1). The genotypes WITA-9 and NERICA-6 were used as checks since their adaptability and response to rice diseases are known.

The genotypes were screened under cage and field conditions at the National Crops Resources Research Institute in Central Uganda. The field was laid out in an alpha lattice design, with three replications. Seedlings were raised in the nursery using plastic cups filled with top soil. Seedlings were transplanted at 15 days after emergence and established in the field in 10 x 5 rows. Each row contained 5 plots with the dimension of $1m^2$, with plants spaced at 20cm x 20cm. One plant was established per hill, generating six hills per row and five rows per plot. The inter-plot and -block measurements were 40cm and 60 cm, respectively. The field experiment was conducted under flooded conditions with a 2.5cm level of water maintained for larval survival. Natural infestation of the stalk-eyed fly was used.

Caged experiment

A caged experiment was established in order to restrict species infestation of the stalk eyed fly to *Diopsis longicornis*, which is the most abundant and most important species that feeds only on rice. Although *Diopsis apicalis* occurred in the field, it was less abundant and considered a polyphagous species (Heinrichs and Barron, 2004). The caged experiment was set up using an alpha lattice design, with three replications. Each replicate comprised of a wooden box of dimensions 4m x 2.23m, filled with top soil and covered with a nylon mesh of 0.5mm gauge. The 50 genotypes were planted in 10 x 5 rows in each cage, as in the field. Genotypes were directly planted in each plot, which contained 5 rows. Three seeds were planted per hill using the dibbling method within a plant spacing of 10cm x 5cm. After germination, seedlings were thinned leaving one plant per hill and four hills per row. Interblock and interplot spacings of 30cm and 20cm were used, respectively. Adult stalk-eyed flies of the *Diopsis longicornis* species were collected from paddy rice fields at NaCRRI using a sweep net (Fujiie *et al.*, unpublished). The collected insects were sorted within a cage in a closed room in order to avoid the introduction of unwanted insects. Infestation was done in accordance with the method of Togola *et al.* (2011), where 25 individuals were released in the center of each screening cage to give a critical density of 50 individuals per square meter.

Data collection and analyses

Data collection followed guidelines in the international standard for evaluation of rice resistance to biotic and abiotic factors (Visalakshmi *et al* 2014). The data collected included: pest infestation or damage, plant agronomic and yield traits. Pest infestation and damage for stem borers in rice were evaluated on the basis of the proportion of deadhearts (Sarwar, 2012; Visalakshmi *et al.*, 2014). In this study, deadheart data were collected at seedling and tillering stages, which are considered critical periods for damage by the stalk-eyed fly in rice (Togola *et al.*, 2011). Stalk-eyed fly damage was collected at 7, 14, 21 and 28 days after transplanting, under field and cage conditions. Ten hills were selected randomly from the middle of each plot for scoring. The number of affected plants from each hill was counted out of the total number of tillers observed per hill and the average was taken for computing the percentage of deadhearts.

$$\% \text{ deadhearts} = \frac{\text{Number of deadhearts observed}}{\text{Total number of tillers observed per ten hills}} \times 100$$

Days to flowering were recorded at maximum flowering stage (70 to 75 days after sowing, at 50% heading), where ten hills were sampled randomly from the middle of each plot. Panicle length was recorded as the distance (cm) from the last node of the rachis to tip of the main panicle for each hill sampled. Number of effective panicles (tillers with panicles) was counted for ten (hills) per plot selected and sampled. Plant height was recorded at the ripening stage where ten hills per plot were randomly selected from the middle of the each plot and sampled. In order to determine the 1000-grain weight, a thousand clean sun-dried grains were counted from the total grain weight of ten hills per plot, after which the grains were weighed (g) and the average was taken at 14% seed moisture content. The 1000 grains were then floated for about 3 to 4 minutes and the filled grain was separated from the empty grain and weights were then taken.

The rice genotypes were placed into different resistance categories based on the pest damage rating scale (Elanchezhyan and Arumugachamy, 2015) (Table.2).

The analyses of variance (ANOVA) were performed using Restricted maximum likelihood (ReML). Where incomplete block within replication effects were found not effective, the traits were re-analyzed as a randomized complete block design (RCBD).

To determine the relationship between infestation and agronomic traits, correlation analysis was performed using the Genstat computer program (Payne *et al.*, 2009).

Results and discussion

Summary of rice genotype reaction under field and cage conditions

The reaction of different rice genotypes under field and cage condition is presented in Table 3.

Table 1. Origin, status and type of rice genotypes screened for resistance to the stalk-eyed fly (*Diopsis longicornis*).

No.	Genotypes	Origin	Status	Type
1	1027SUPALINE		Land race	Lowland
2	1052SUPALINE		Land race	Lowland
3	GSR IR1- 5-S14-S2-Y1 x K85 (F_3)		Not released	Lowland
4	GSR IR1- 3-S13-Y1-S1 x SR33686-HB3326-8 (F_3)		Not released	Lowland
5	GSR IR1- 4-D3-Y1-Y1 x NERICA4 (F_3)		Not released	Lowland
6	GIGANTE x NERICA4 (F_3)		Not released	Lowland
7	NAMCHE1		Released	Upland
8	NAMCHE1 x 1052SUPALINE (F_3)		Not released	Lowland
9	NAMCHE2		Released	Upland
10	NAMCHE3		Released	Upland
11	NERICA 6 x IRO9A-136(F_3)		Not released	Lowland
12	NERICA 6 x Pakistan(F_3)		Not released	Lowland
13	NERICA 6 x WAC-117(F_3)		Not released	Lowland
14	NERICA-L-20 x NERICA-13(F_3)	NaCRRI	Not released	Lowland
15	NERICA 4 x NAMCHE-1(F_3)		Not released	Lowland
16	NERICA 4 x NERICA-6(F_3)		Not released	Lowland
17	NERICA 4 x SUPA(F_3)		Not released	Lowland
18	NERICA1 x Gigante(F_3)		Not released	Lowland
19	NERICA1 x NERICA-4(F_3)		Not released	Lowland
20	NERICA4 x Gigante(F_3)		Not released	Lowland
21	NAMCHE4		Released	Upland
22	NAMCHE5		Released	Upland
23	NAMCHE6		Released	Upland
24	GSR -I-0057	Africa Rice	Released	Upland
25	IRO9A-136	Center	Released	Lowland
26	Jaribu		Released	Lowland
27	IR77454-22-B-20-2-2-B-TGR1		Released	Lowland
28	IR77454-22-B-20-2-2-B-TGR2		Released	Lowland
29	IR77454-22-B-20-2-2-B-TGR3		Released	Lowland
30	Gigante		Released	Lowland
31	KYABUKOOLI		Released	Lowland
32	Moroberekan		Released	Lowland
33	Sindano		Released	Lowland
34	SUPARICA		Released	Lowland
35	TXD 306		Released	Lowland
36	WITA12		Released	Lowland
37	WITA4		Released	Lowland
38	WITA 9 (check)		Released	Lowland
39	NM7-22-11-B-P-1-1		Released	Lowland
40	NERICA 6 (check)		Released	Lowland
41	NERICA13		Released	Lowland
42	NERICA4		Released	Lowland
43	NERICA1		Released	Lowland
44	K85	IRRI	Released	Lowland
45	Pakistan		Released	Lowland
46	SR34462-HB3370-61	Korea	Released	Lowland
47	SR34461-HB3369-65		Released	Lowland
48	SR33686-HB3326-30		Released	Lowland
49	SR33701-HB3330-71		Released	Lowland
50	SR33686-HB3326-2		Released	Lowland

The results obtained from field and cage experiments revealed similar response of the rice genotypes to stalk-eyed fly infestation for 31 genotypes (62%). Four genotypes (8%) were more susceptibility in the cage than in the field and 15 genotypes (30%) appeared more resistant in the cage than in the field Table 3. Seventeen genotypes were moderately resistant, ten resistant and four susceptible under both conditions.

Table 2. Standard Evaluation System for screening resistance to rice stems borer.

Scale code	% Dead hearts	Level of resistance
0	No visible damage	Highly Resistant
1	1-10%	Resistant
3	11-20%	Moderate resistant
5	21-30%	Moderate susceptible
7	31-60%	Susceptible
9	>60%	Highly susceptible

Source: (IRRI, 1996, Marwat *et. al.* 1985).

Table 3. Summary of rice genotype resistance levels under field and cage conditions.

Genotypes	Field		Cage		Comparison of cage with field reactions
	Average %DH	Status	Average %DH	Status	
Gigante	12.57	MR	12.01	MR	Same reaction
SR34461-HB3369-65	19.12	MR	11.62	MR	Same reaction
SR33686-HB3326-30	16.71	MR	10.7	MR	Same reaction
SR33701-HB3330-71	19.41	MR	14.36	MR	Same reaction
Kyabukooli	13.56	MR	12.72	MR	Same reaction
NAMCHE1	17.33	MR	10.98	MR	Same reaction
NAMCHE4	20.26	MR	11.02	MR	Same reaction
NAMCHE5	13.03	MR	10.97	MR	Same reaction
NERICA1 X Gigante F_3	14.02	MR	11.89	MR	Same reaction
NERICA13	16.01	MR	11.27	MR	Same reaction
NERICA4 x NAMCHE1F_3	11.61	MR	11.77	MR	Same reaction
NERICA6 x IRO9A-136F_3	18.92	MR	13.15	MR	Same reaction
NERICA6 x PakistanF_3	15.52	MR	11.26	MR	Same reaction
Sindano	19.38	MR	16.68	MR	Same reaction
SUPARICA	16.45	MR	15.00	MR	Same reaction
WITA12	14.6	MR	17.94	MR	Same reaction
WITA4	12.46	MR	18.31	MR	Same reaction
GSR IR1- 5-S14-S2-Y1 x K85 F_3	8.40	R	6.71	R	Same reaction
Gigante X NERICA4 F_3	8.33	R	6.95	R	Same reaction
K-85	5.50	R	5.48	R	Same reaction
NERICA 4 x Gigante F_3	8.03	R	6.76	R	Same reaction
NERICA1 x NERICA4 F_3	8.26	R	8.52	R	Same reaction
NERICA4	6.04	R	4.44	R	Same reaction
NERICA4 X NERICA6F_3	8.88	R	5.87	R	Same reaction
NERICA4 X SUPA F_3	8.76	R	5.99	R	Same reaction
NM7-22-11-B-P-1-1	5.44	R	5.31	R	Same reaction
TXD306	5.57	R	5.79	R	Same reaction
NAMCHE2	34.38	S	34.88	S	Same reaction
NERICA1	38.16	S	34.46	S	Same reaction
NERICA6	35.11	S	38.25	S	Same reaction
Pakistan	34.39	S	35.4	S	Same reaction
WITA9	19.23	MR	23.47	MS	Lower
GSR IR1- 4-D3-Y1-Y1 x NERICA4 F_3	8.66	R	11.12	MR	Lower
IRO9A-136	9.44	R	10.63	MR	Lower
Jaribu	10.24	R	11.58	MR	Lower
GSR -I-0057	10.46	MR	9.25	R	Higher
Moroberekan	15.02	MR	9.38	R	Higher
NAMCHE1 x 1052SUPALINEF_3	11.97	MR	9.48	R	Higher
NAMCHE3	14.89	MR	9.55	R	Higher
NERICA6 x WAC117 F_3	13.34	MR	9.53	R	Higher
IR77454-22-B-20-2-2-B-TGR1	25.71	MS	16.34	MR	Higher
IR77454-22-B-20-2-2-B-TGR2	21.55	MS	14.45	MR	Higher
IR77454-22-B-20-2-2-B-TGR3	23.75	MS	16.15	MR	Higher
1027SUPALINE	20.55	MS	14.77	MR	Higher
1052SUPALINE	28.98	MS	17.07	MR	Higher
GSR IR1- 3-S13-Y1-S1 x SR33686-HB3326-8F_3	23.43	MS	12.54	MR	Higher
SR34462-HB3370-61	22.93	MS	12.93	MR	Higher
SR33686-HB3326-2	24.03	MS	15.97	MR	Higher
NAMCHE6	23.73	MS	12.98	MR	Higher
NERICA-L-20 X NERICA13F_3	21.07	MS	11.86	MR	Higher

R= resistant, MR = moderately resistant& S = susceptible and %DH= percent deadheart.

One genotype reacted as moderately resistant in the field and susceptible under cage conditions and other three were resistant in the field and moderately resistant in the cage Table 3. The reverse was also observed in the cage, where five genotypes were resistant in the cage and moderately resistant in the field and another 10 genotypes displayed moderate resistance in the cage and were moderately susceptible in the field (Table 3). The differential response of rice genotypes to biotic stress, such as stem borers, is often related to materials having different genetic backgrounds and environmental factors (Nwilene *et al.*, 2002; Togola *et al.,* 2011; Sarwar, 2012).

Table 4. Analysis of variance for percentage deadheart of fifty rice genotypes screened under field and cage conditions.

		Mean squares under field				Mean squares under cage			
Source of variation	Df	7DAT	14DAT	21DAT	28DAT	7DAI	14DAI	21DAI	28DAI
Replication	2	16.461	4.23	26.083	1.114	3.786	21.32	16.02	0.02
Rep.Block	26	-	17.38	-	0.627	-	14.46	6.61	-
Genotype	49	128.89***	436.10***	556.65***	97.747***	105.17***	311.54***	236.28***	198.81***
Residual	72	8.541	11.86	5.31	0.626	4.418	10.32	5.53	1.877
LEE (Lattice effective error)	80	-	12.921	-	0.619	-	11.14	5.77	-

DF = Degree of freedom, DAT= Days after transplanting, DAI= days after infestation, ns= not significant, * Significant, *** highly significant.

Table 5. Resistance categories of rice genotypes on different dates after planting under field and cage conditions.

Categories	Number of genotypes under cage conditions				Number of genotypes under cage conditions			
	7DAT	14DAT	21DAT	28DAT	7DAI	14DAI	21DAI	28DAI
Resistant	6	8	13	45	33	6	13	42
Moderate resistant	26	12	17	1	12	22	27	3
Moderate susceptible	15	20	2	4	5	18	6	4
Susceptible	3	10	18	none	none	4	4	1

DAT= Days after transplanting, DAI = Days after infestation.

In support of this, variations in the levels of infestation with stem borers in rice have been observed to differ with the environment (Ogah, 2013). Screening under both field and cage conditions is, however, the recommended approach for evaluation of reaction of rice genotypes to stem borers as it is more realistic for fast screening (Togola *et al.,* 2011).

Table 6. Analysis of variance for tiller number of the fifty rice genotypes screened under field and cage conditions.

Mean square	Tiller number under field					Mean square Tiller number under cage			
Source of variance	DF	7DAT	14DAT	21 DAT	28 DAT	7DAI	14 DAI	21 DAI	28 DAI
Replications	2	0.35^{ns}	2.32*	65.33***	154.82***	0.10*	0.06^{ns}	0.04^{ns}	2.56*
Rep.Block	26	0.20^{ns}	0.85^{ns}	4.60_{ns}	6.88*	-	0.32^{ns}	0.25*	0.95*
Genotype	49	2.66***	9.34***	54.40***	58.76***	0.04*	0.53**	0.67***	3.38***
Residual	72	0.19	0.7	4.58	4.34	0.03	0.24	0.16	0.56
LEE (Lattice effective error)	79	0.19	0.73	4.58	4.8	-	0.26	0.18	0.63

DF= degree of freedom, DAT = days after transplanting DAI= days after infestation tiller number, ns = not significant, * = significant, ** = highly significant, *** highly significant.

In general, there were no differences in symptom type or expression between the two species of stalk eyed flies that occurred in the field. In addition, the rice genotypes exhibited higher resistance levels under cage conditions. While enhanced response under cage conditions could be attributed to lower levels of infestation due to the presence of only one species (*D. longicornis*), available data could not be used to support this argument.

Table 7. The mean number of tillers for the fifty rice genotypes under field and cage conditions.

Genotypes	Mean under field	Genotypes	Mean under cage
Moroberekan	5.55	NAMCHE2	2.30
NERICA4 x NERICA6 F_3	5.79	NERICA4 x SUPA	2.51
NERICA1 x NERICA4 F_3	5.87	SUPARICA	2.55
NAMCHE6	6.09	SR33701-HB3330-71	2.56
NERICA13	6.26	Gigante	2.63
NAMCHE1	6.41	NERICA4 x NERICA6 F_3	2.64
Pakistan	6.82	NERICA1 x NERICA4 F_3	2.66
NAMCHE4	6.88	NERICA1	2.72
NAMCHE1 x 1052SUPALINE F_3	6.91	SR34462-HB3370-61	2.72
NAMCHE2	7.21	NAMCHE5	2.73
GINGANTE x NERICA4F_3	7.38	NERICA6 x IRO9A-136 F_3	2.74
NAMCHE5	7.52	Moroberekan	2.75
NERICA4 x NAMCHE1F_3	7.53	SR33686-HB3326-2	2.76
NERICA-6 x Pakistan F_3	7.63	1052SUPALINE	2.77
NM7-22-11-B-P-1-1	7.65	NAMCHE6	2.78
NERICA1 x Gigante3	7.75	SR34461-HB3369-65	2.78
Sindano	7.80	NAMCHE1	2.83
NERICA4	7.91	NERICA4	2.83
NAMCHE3	7.99	NM7-22-11-B-P-1-1	2.83
NERICA-L20 x NERICA13F_3	7.99	NERICA1 x Gigante3	2.84
NERICA6	8.02	NERICA13	2.85
NERICA1	8.22	1027SUPALINE	2.89
SR34462-HB3370-61	8.25	NERICA6	2.89
SUPARICA	8.26	NAMCHE3	2.91
1052SUPALINE	9.01	GINGANTE x NERICA4F_3	2.92
1027SUPALINE	9.05	NERICA 4 x Gigante3	2.92
NERICA4 x SUPA	9.18	NAMCHE4	2.95
SR33686-HB3326-2	9.25	NERICA-L20 x NERICA13F_3	3.04
Gigante	9.81	NERICA4 x NAMCHE1F_3	3.06
SR33686-HB3326-30	9.88	SR33686-HB3326-30	3.07
GSR IR1- 5-S14-S2-Y1 x K85 F_3	10.63	Sindano	3.08
GSR IR1- 3-S13-Y1-S1 x SR33686-HB3326-8F_3	10.79	NAMCHE1 x 1052SUPALINE F_3	3.14
GSR IR1- 4-D3-Y1-Y1 x NERICA4F_3	10.79	GSR IR1- 3-S13-Y1-S1 x SR33686-HB3326-8F_3	3.18
SR33701-HB3330-71	11.45	Pakistan	3.18
NERICA6 x IRO9A-136 F_3	11.57	GSR IR1- 4-D3-Y1-Y1 x NERICA4F_3	3.20
NERICA 4 x Gigante3	11.74	WITA9	3.24
SR34461-HB3369-65	11.76	TXD-306	3.26
WITA12	11.90	GSR IR1- 5-S14-S2-Y1 x K85 F_3	3.27
NERICA6 x WAC-117 F_3	12.31	IR77454-22-B-20-2-2-B-TGR1	3.27
IRO9A-136	12.59	NERICA-6 x Pakistan F_3	3.27
JARIBU	12.59	IRO9A-136	3.37
K85	12.60	IR77454-22-B-20-2-2-B-TGR2	3.45
IR77454-22-B-20-2-2-B-TGR3	13.15	GSR -I-0057	3.50
TXD-306	13.21	Kyabukooli	3.62
GSR -I-0057	13.30	IR77454-22-B-20-2-2-B-TGR3	3.63
Kyabukooli	13.43	NERICA6 x WAC-117 F_3	3.69
IR77454-22-B-20-2-2-B-TGR1	13.69	K85	3.84
WITA4	13.69	JARIBU	3.97
WITA9	14.18	WITA12	4.14
IR77454-22-B-20-2-2-B-TGR2	14.53	WITA4	4.43

Unfortunately, studies done on rice reaction to stem borers in Benin and Nigeria used either under field or cage conditions making it difficult to compare the results from both situations (Nwilene *et al.*, 2002; Togola *et al.,* 2011; Ogah *et al.,* 2012). The percentage of deadhearts differed significantly (P<0.001) between rice genotypes under both field and cage conditions on all sampling dates (i.e. at 7, 14, 21 and 28 days) Table 4.

The summary of rice genotypes resistance categories in respect to time of data collections are presented in Table 5. The overall genotypic response under cage and field conditions in resistant (at 28 DAT) and moderately susceptible (from 7 to 28 DAT) categories seemed to be similar by numbers. Levels of susceptibility were also higher under field conditions at 14 and 21 DAT. This period corresponds to the 10-20 day period within which the stalk eyed fly is reported to have its most devastating effects (Togola *et al.,* 2011).

Table 8. Analysis of variance for agronomic and yield traits of the fifty rice genotypes under field and cage conditions.

	Mean squares for Agronomic traits under field								Mean squares for Agronomic traits under cage						
Source of variance	DF	PH(cm)	DF	P.NO	PL (cm)	1000 GW(g)	FGW (g)	EGW (g)	PH (cm)	DF	P.NO	PL (cm)	1000 GW(g)	FGW (g)	EGW (g)
Replications	2	1783.15**	329.42^{ns}	1.68^{ns}	40.34*	1.89^{ns}	1.85^{ns}	0.00^{ns}	438.96*	7.33^{ns}	1.18^{ns}	56.27*	0.42^{ns}	1.53^{ns}	0.45^{ns}
Rep.Block	26	203.22**	337.98^{ns}	1.71^{ns}	15.38^{ns}	1.72*	1.29^{ns}	0.16^{ns}	96.62*	-	1.17^{ns}	11.51^{ns}	2.24^{ns}	2.44^{ns}	-
Genotype	49	136.59^{ns}	34.65^{ns}	2.32*	19.60*	2.87***	2.23***	0.66***	507.12***	323.05***	5.56***	42.63***	1.94^{ns}	1.88^{ns}	0.61^{ns}
Residual	72	86.24	37.4	1.3	11.34	1.03	0.95	0.1	62	11.6	1.1	8.9	1.57	2.05	0.49
LEE (Lattice effective error)	79	101.2	48.1	1.4	12.18	1.15	1.02	0.1	68	-	1.1	9.5	1.7	2.13	-

DF= Degree of freedom, PH (cm) =Plant height, DF= Day to flowering, P.NO = panicle number, PL (cm) =panicle length, 1000 GW (g) = A thousand grain weight, FGW (g) = Filled grain weight, EGW (g) = Empty grain weight, ns=not significant,*significant, and *** highly significant.

Table 9. Mean performance of the fifty rice genotypes in agronomic and yield traits, under field conditions.

	Agronomic traits			Yield traits			
Genotype	PH (cm)	DF	P.NO	PL (cm)	1000 GW(g)	FGW (g)	EGW (g)
IR77454-22-B-20-2-2-B-TGR1	89.92	86.18	5.09	23.84	21.08	18.65	2.41
IR77454-22-B-20-2-2-B-TGR2	92.74	83.42	5.64	22.93	21.06	17.09	3.12
IR77454-22-B-20-2-2-B-TGR3	90.44	88.84	5.98	24.37	20.72	17.07	3.02
1027SUPALINE	93.61	94.34	6.17	23.58	21.32	18.07	2.63
1052SUPALINE	105.23	88.05	6.05	24.43	18.28	15.95	2.21
GSR IR1- 5-S14-S2-Y1 x K85(F_3)	98.63	92.45	5.66	24.58	20.07	18.09	2.59
GSR IR1- 3-S13-Y1-S1 x SR33686-HB3326-8 F_3	83.49	87.06	5.07	19.04	21.01	18.52	2.46
GSR IR1- 4-D3-Y1-Y1 x NERICA4 F_3	89.96	85.32	5.16	30.28	21.82	17.75	4.01
Gigante	79.63	85.81	5.02	19.43	20.24	17.91	2.39
Gigante x NERICA4 F_3	89.99	88.81	6.01	20.49	20.32	18.03	2.02
GSR -I-0057	92.67	84.89	5.69	22.06	21.25	18.53	2.76
IRO9A-136	85.81	87.82	5.68	22.23	18.73	15.90	2.82
Jaribu	83.41	91.86	4.64	21.92	20.08	17.73	2.31
K85	87.34	79.57	6.02	21.38	21.02	18.74	2.26
SR34462-HB3370-61	94.75	86.07	6.69	23.59	20.58	18.33	2.03
SR34461-HB3369-65	85.65	87.65	7.07	23.43	20.04	17.72	2.65
SR33686-HB3326-30	85.41	84.95	5.58	21.23	20.97	18.86	2.13
SR33701-HB3330-71	92.19	90.87	6.62	23.51	20.07	17.69	2.34
SR33686-HB3326-2	91.83	84.45	5.97	21.43	18.13	16.64	1.58
KYABUKOOLI	98.11	88.66	6.94	24.99	20.89	18.3	2.65
Moroberekan	81.55	86.9	6.99	17.05	20.04	17.44	2.58
NAMCHE1	94.55	87.69	5.64	23.05	19.99	17.67	2.33
NAMCHE1 x 1052SUPALINE F_3	96.87	92.54	5.15	22.37	19.79	17.84	1.89
NAMCHE2	94.21	88.27	6.28	23.04	18.37	16.88	1.49
NAMCHE3	82.82	92.04	6.88	19.36	19.26	17.14	2.13
NAMCHE4	101.45	85.89	6.05	23.83	20.88	19.07	1.71
NAMCHE5	90.17	83.94	7.33	22.06	19.82	17.67	2.05
NAMCHE6	89.06	84.97	5.71	23.23	21.25	19.21	2.01
NERICA 4 x Gigante F_3	93.99	86.27	7.31	22.21	20.09	17.67	2.52
NERICA1	85.65	90.59	5.48	21.56	20.15	18.02	1.91
NERICA1 x Gigante F_3	104.88	90.97	6.18	24.87	20.27	17.88	2.29

NERICA1 x NERICA4 F_3	75.57	90.13	6.33	19.15	20.01	17.75	2.42
NERICA13	99.41	88.58	6.33	23.26	21.04	18.87	2.14
NERICA4	95.06	86.85	4.61	25.35	20.38	17.85	2.52
NERICA4 x NAMCHE1F_3	103.38	82.09	6.38	22.26	20.01	18.01	2.19
NERICA4 x NERICA6 F_3	89.66	87.58	7.31	19.09	18.11	15.83	2.37
NERICA4 x SUPA F3	94.71	93.88	7.04	25.95	20.23	18.06	2.21
NERICA6	85.82	88.06	8.14	19.47	20.55	18.05	2.54
NERICA6 x IRO9A-136 F_3	80.64	90.01	5.96	18.07	20.09	17.97	2.24
NERICA6 x PARKISTAN F_3	95.54	88.42	5.06	23.05	22.22	19.25	2.89
NERICA6 x WAC117 F3	89.22	88.79	6.34	22.68	19.43	17.71	1.82
NERICA-L-20 X NERICA13 F_3	88.53	81.29	5.96	22.26	21.05	18.65	2.38
NM7-22-11-B-P-1-1	92.01	87.06	4.65	22.38	21.23	19.46	1.83
Pakistan	98.79	91.52	4.35	21.03	18.87	15.88	3.04
Sindano	95.09	86.23	6.45	21.81	18.39	16.68	1.82
SUPARICA	98.22	90.32	6.45	21.96	21.23	18.58	2.54
TXD306	94.52	84.28	8.05	22.62	20.31	18.33	2.00
WITA12	99.08	85.27	7.57	25.26	19.41	17.9	1.48
WITA4	79.48	88.78	6.03	31.06	18.15	16.59	1.52
WITA9	88.45	78.09	5.32	23.77	20.24	17.33	2.82
Mean	91.4	87.5	6.14	22.69	20.19	17.87	2.33
P.V	0.117	0.886	<0.025	<0.029	0.001	<0.001	<0.001
LSD(0.05)	16.35	11.29	1.93	5.67	1.74	1.64	0.62
CV (%)	11.01	7.93	19.41	15.38	5.31	5.65	16.06

PH (cm) = Plant height, DF= Day to flowering, P.NO= panicle number, PL (cm) = panicle length, 1000 GW (g) = A 1000 grain weight, FGW (g) = Filled grain weight, EGW= Empty grain weight (g), PV= probability values, LSD= Least significant different.

Growth and yield parameters

The results for agronomic and yield traits at different levels of significance for the fifty rice genotypes screened under both field and cage conditions are presented in Tables 6-10. The number of tiller counts differed significantly among the 50 genotypes screened for resistance to the stalk-eyed fly under field and cage conditions at all dates assessed (7, 14, 21 and 28 days) as presented in Table 6, while the mean summary is presented in Table 7. Of the 50 genotypes screened for resistance to the stalk-eyed fly, the overall mean number of tillers per genotype under field ranged from 5.55 to 14.53 while tillers counts general mean per genotype under cage ranged from 2.3 to 4.4 (Table 7).

Table 10. Mean performance of the fifty rice genotypes in agronomic and yield traits, under cage conditions.

	Agronomic traits			*Yield Traits*			
Genotype	PH (cm)	DF	P.NO	PL (g)	1000 GW(g)	FGW (g)	EGW (g)
IR77454-22-B-20-2-2-B-TGR1	95.09	110.67	10.15	20.80	17.96	14.79	3.17
IR77454-22-B-20-2-2-B-TGR2	93.80	114.00	10.15	22.53	18.16	15.48	2.80
IR77454-22-B-20-2-2-B-TGR3	92.53	112.00	9.62	22.61	19.00	16.18	2.77
1027SUPALINE	110.70	87.67	4.21	21.92	17.92	14.62	3.37
1052SUPALINE	97.31	86.67	5.26	26.08	18.40	15.21	3.17
GSR IR1- 5-S14-S2-Y1 x K85 F_3	89.99	86.33	4.38	24.19	18.10	14.43	3.57
GSR IR1- 3-S13-Y1-S1 x SR33686-HB3326-8 F_3	69.36	85.33	4.42	20.64	17.94	14.73	3.23
GSR IR1- 4-D3-Y1-Y1 x NERICA4 F_3	93.61	83.33	4.73	21.87	16.59	13.29	3.33
Gigante	57.69	95.00	4.43	16.61	18.13	15.23	2.80
Gigante x NERICA4 F^3	97.86	81.00	5.61	24.56	18.95	15.35	3.67
GSR -I-0057	98.66	91.67	4.32	25.40	18.06	14.60	3.60
IRO9A-136	78.46	87.33	4.27	22.17	17.98	14.39	3.57
Jaribu	78.07	94.33	4.94	21.72	17.92	14.09	3.87
K85	89.20	86.33	4.92	22.95	19.70	15.95	3.73
SR34462-HB3370-61	85.62	72.33	5.40	20.69	17.60	14.60	2.97
SR34461-HB3369-65	81.56	72.33	4.36	12.04	19.22	16.15	3.13
SR33686-HB3326-30	70.53	76.00	4.38	14.19	17.58	13.63	4.00
SR33701-HB3330-71	62.01	75.00	4.52	20.79	17.21	13.54	3.70
SR33686-HB3326-2	67.67	74.67	6.10	18.34	19.66	16.24	3.40
Kyabukooli	106.35	91.33	4.98	22.63	17.57	13.62	4.00
Moroberekan	109.36	113.00	4.24	25.99	18.61	14.99	3.60
NAMCHE1	97.53	90.00	5.72	15.96	17.72	14.31	3.37
NAMCHE1 x 1052SUPALINE (F_3)	70.87	88.33	4.89	22.46	17.42	14.26	3.13
NAMCHE2	96.23	87.00	4.33	26.24	17.05	13.57	3.43
NAMCHE3	91.11	88.33	5.12	23.11	17.50	13.67	3.73
NAMCHE4	84.14	87.33	5.21	25.34	19.12	15.35	3.70
NAMCHE5	94.73	90.33	5.16	26.68	18.99	15.68	3.33

NAMCHE6	83.79	90.00	4.27	25.48	18.31	14.03	4.30
NERICA 4 x Gigante (F_3)	70.19	75.00	3.58	17.00	16.95	13.99	3.00
NERICA1	86.51	80.33	4.44	26.10	19.04	14.84	4.23
NERICA1 x Gigante F_3	97.01	87.33	4.90	26.34	18.73	15.63	3.13
NERICA1 x NERICA4 F3	89.20	79.33	4.63	25.04	17.72	14.62	3.03
NERICA13	96.90	80.00	5.07	34.57	17.90	14.63	3.33
NERICA4	93.13	80.67	4.68	25.25	18.70	14.92	3.90
NERICA4 x NAMCHE1F_3	70.55	79.67	4.17	24.27	18.57	15.59	3.03
NERICA4 x NERICA6 F_3	66.89	77.33	4.35	23.73	17.42	14.10	3.23
NERICA4 x SUPA (F3)	77.45	82.00	4.41	18.02	18.39	14.31	4.03
NERICA6	90.29	81.33	4.99	23.20	17.36	14.35	3.07
NERICA6 x IRO9A-136 F_3	91.14	81.67	4.67	26.62	19.12	15.34	3.90
NERICA6 x Pakistan F^3	98.87	84.67	5.04	26.26	18.66	15.48	3.20
NERICA6 x WAC-117 F_3	94.71	89.00	4.73	21.18	19.51	15.28	4.17
NERICA-L-20 X NERICA13F_3	96.56	81.00	4.82	25.04	19.54	15.73	3.70
NM7-22-11-B-P-1-1	84.50	86.33	4.85	26.31	18.55	15.29	3.33
Pakistan	96.05	90.33	5.39	22.21	18.86	15.86	2.90
Sindano	108.91	117.67	4.59	22.60	17.19	14.81	2.47
SUPARICA	88.41	84.33	5.24	21.00	18.13	15.81	2.30
TXD306	60.90	88.33	6.87	25.16	19.36	15.70	3.67
WITA12	84.19	89.33	5.70	21.31	17.48	13.90	3.53
WITA4	82.73	86.33	5.17	20.86	18.72	14.63	4.07
WITA9	79.78	91.67	3.95	24.19	19.75	15.70	3.93
Mean	86.97	87.43	5.13	22.81	18.28	14.85	3.43
P.V	<0.001	<0.001	<0.001	<0.001	<0.302	<0.686	<0.183
LSD(0.05)	13.42	5.52	1.69	5	2.12	2.38	1.14
CV (%)	9.49	3.9	20.26	13.49	7.13	9.83	20.48

PH (cm) =Plant height, DF= Day to flowering, P.NO= panicle number, PL (cm) =panicle length, 1000 GW (g) = A 1000 grain weight, FGW (g) = Filled grain weight, EGW= Empty grain weight (g), PV= probability values, LSD= Least significant different, CV%= coefficient of variance.

In the field, panicle length differed significantly (P<0.05) among the rice genotypes screened for resistance to the stalk-eyed fly (Table 8) with an average of 22.69 (Table: 9) while panicle length differed significantly (P <0.001) among rice genotypes in the cage, averaging 22.81cm (Table 10). Panicle number was significant in both locations with an average under field ranged from 4.35 to 8.14 and under cage ranged from 3.58 to 10.15 (Table 9 and 10). Plant height was significant in the cage with the average between 57.69 and 109.36 (Table 10). In general, plant height averaged at 86.97cm under cage conditions (Table 10). Days to flowering did not differ in the field but significantly differed in the cage with the average ranged from 72.3 to 117.7 days with an overall mean of 87.43 days (Table 10). These significant variations observed among the 50 genotypes with respect to agronomic traits could be attributed to differences in genetic background (Javed *et al.,* 2015) and response to environmental conditions (Ogah *et al*., 2013). Agronomic traits like tillering have been reported to be influenced by plant spacing and water availability (Rubia, 1994).

Tillering ability has also been related to resistance to stalk eyed flies, with plants that exhibit high tillering ability compensating with growth of new tillers (Togola *et al.,* 2011).

The analysis of variance showed that 1000 grain weight (g) was highly significant (P<0.001) among the 50 genotypes of rice screened under field conditions, with an overall mean of 20.19 g (Table 9). On the other hand, 1000 grain weight was not significant (P>0.05) among the 50 genotypes under cage conditions (Table 8). However, the general mean recorded was 18.28g while the mean range was between 18.11 - 22.22g (Table 10). Filled grain weight was highly significant at (P<0.001) under field conditions (Table 8), with an overall mean of 17.87g (Table 9). On the other hand, filled grain weight was not significantly different (P>0.05) among the 50 genotypes of rice screened for resistance to the stalk-eyed fly under cage conditions (Table 8). Analysis of variance revealed significant differences (P<0.001) in empty grain weight among the rice genotypes screened under field conditions, with general mean of 2.33 g (Table 8 and 9) while empty grain weight was not significantly different (P>0.05) among genotypes under cage condition (Table 8).

These differences in the levels of significant could have been attributed to differences in genetic potential of the materials evaluated as has been observed for similar studies on rice (Javed *et al.*, 2015).

The effect of stalk eyed flies on yield attributes cannot, however, be refuted since Alghali and Osisanya (1984) reported such negative effects on unfilled spikelet and grain weights. Similarly, Feijen (1979) and Rao *et al.* (1987) reported lower tiller numbers with higher infestation levels.

Table 11. Correlation for growth parameters, yield traits, and stalk-eyed fly damage under field conditions.

1000 GW	-													
14DH	-0.21	-												
14DTNO	0.11	-0.73***	-											
21DH	-0.19	0.70***	-0.71***	-										
21DTNO	0.24	-0.87***	0.73***	-0.81***	-									
28DH	-0.08	0.65***	-0.38*	0.45***	-0.48***	-								
28DTNO	0.24	-0.86***	0.71***	-0.82***	0.98***	-0.48***	-							
7DH	-0.15	0.78***	-0.61***	0.48***	-0.78***	0.59***	-0.78***	-						
7DTNO	-0.01	-0.53***	0.59	-0.50***	0.52***	-0.28*	0.54***	-0.58***	-					
DF	-0.13	-0.15	0.01	-0.08	0.06	-0.29*	0.08	-0.11	0.07	-				
FGW	0.83***	0.02	-0.02	-0.05	-0.02	0.01	-0.04	0.06	-0.05	-0.14	-			
PH	0.03	0.04	-0.02	0.11	-0.10	-0.01	-0.10	0.01	0.04	0.04	0.05	-0.01	-	
PL	0.07	0.12	-0.05	-0.01	0.05	0.36*	0.04	0.11	-0.13	0.01	0.00	0.44**	0.37*	-
PNO	-0.21	0.35 *	-0.29*	0.09	-0.29*	0.17	-0.27	0.23	0.09	-0.03	-0.09	-0.14	0.06	-0.10
	1000g	14DDH	14DTNO	21DDH	21DTNO	28DDH	28DTNO	7DDH	7DTNO	DF	FGW	LR	PH	PL

*= significant (P<0.05), ** = significant (P<0.01), and *** highly significant (P<0.001), those values without star are not significant,1000 GW(g) = A thousand grain weight(g), 14DTNO = 14 days tiller number; 14DH = 14days % deadhearts, 21DTNO = 21days tiller number, 21DH= 21days % deadhearts, 28DH = 28days % deadhearts , 28DTNO= 28 days tiller number,7DTNO=7 days tiller number, 7 DH=7 days % deadhearts, DF= Day to flowering days, FGW= filled grain weight(g), PH= plant height P.NO= panicle number; PL (cm) =panicle length, PL = panicle length and PNO = panicle number

Table 12. Correlation for growth parameters, yield traits, and stalk-eyed fly damage under cage conditions.

1000GW	-													
14DH	0.28	-												
14DTNO	-0.21	-0.71***	-											
21DH	0.23	0.86***	-0.67***	-										
21DTNO	-0.17	-0.63***	0.63***	-0.59***	-									
28DH	0.22	0.79***	-0.56***	0.81***	-0.51***	-								
28DTNO	-0.12	-0.71***	0.75***	-0.67***	0.59***	-0.51***	-							
7DH	0.18	0.76***	-0.68***	0.72***	-0.50***	0.83***	-0.62***	-						
7DTNO	-0.08	-0.01	0.06	-0.18	0.13	0.01	-0.04	0.05	-					
DF	-0.00	-0.16	0.23	-0.16	0.36*	0.09	0.31*	0.00	0.17	-				
FGW	0.83***	0.10	-0.06	0.07	0.02	0.19	-0.05	0.14	0.05	0.13	-			
PH	0.01	-0.24	0.04	-0.19	0.04	-0.07	0.15	-0.08	0.09	0.41**	0.05	0.08	-	
PL	0.15	0.07	-0.28**	0.17	-0.15	-0.01	-0.13	0.08	-0.17	0.11	0.10	-0.09	0.39***	-
PNO	0.12	-0.24	0.41*	-0.09	0.49***	-0.00	0.52***	-0.14	-0.06	0.54***	0.29*	0.11	0.12	-0.02
	1000GW	14D%DH	14DTNO	21D%DH	21DTNO	28D%DH	28DTNO	7D%DH	7DTNO	DF	FGW	LR	PH	PL

*= significant (P<0.05), ** = significant (P<0.01), and *** highly significant (P<0.001), those values without star are not significant,1000 GW(g) = A thousand grain weight(g), 14DTNO = 14 days tiller number; 14DH = 14days deadhearts, 21DTNO = 21days tiller number, 21DH= 21days deadhearts, 28DH = 28days % deadhearts , 28DTNO= 28 days tiller number, 7DTNO=7 days tiller number, 7DH=7 days % deadhearts, DF= Day to flowering days, FGW= filled grain weight(g), PH= plant height P.NO= panicle number; PL (cm) =panicle length, PL = panicle.

Relationship between damage and agronomic variables

Correlation between field collected data is presented in Table 11. The results demonstrated positive and significant correlations under field conditions between 1000g weight and filled grain weight, deadhearts on different dates, panicle length and percentage deadhearts at 28 DAT, leaf ratio and panicle length; panicle length and plant height, and panicle number and percentage deadhearts at 14 DAT (Table11).

On the other hand, negative correlations were observed between tiller number and the percentage of deadhearts on all dates, percentage of deadhearts at 28 DAT and days to flowering; and panicle number with tiller number. Under cage conditions, positive correlations were observed between 1000 g weight and filled grain weight, dead hearts on different dates, panicle number and percentage deadheart at 14, 21 and 28 DAI, panicle length and plant height, panicle number and days to flowering and days to flowering with tiller number at 21 and 28 DAI (Table 12). Negative correlations were observed between panicle length and tiller number at 14 DAT, tiller number and percentage 7, 14 and 28 DAI (Table12). Positive correlations were recorded among yield attributes, such as 1000 grain weight and filled grain weight as well as agronomic traits such as panicle length, leaf ratio, and plant height and panicle number when compared with dead heart occurrence at different days. These relationships implied that pest damage increased early in the vegetative stage and genotypes with good yield and growth traits may have had the opportunity to compensate in later stages of growth (Ogah, 2013). Nevertheless, the level and time of attack, as well as general growing conditions such as soil quality, hills spacing, and variety influenced recovery (Feijen, 1979). Under normal conditions, the influence of feeding larvae was positive or neutral and only became negative when poor growing conditions were combined with a late and heavy attack (Heinrichs and Barrion, 2004).

Conclusion

In conclusion, the performance of the 50 genotypes differed due to their diverse genetic background. The present study has provided evidence of the existence of stalk-eyed fly resistant rice genotypes. Based on the agronomic traits, yield performance and the reaction to the stalk-eyed fly damage, NERICA 4, TXD306, NM7-22-11-B-P-1-1 and K85 were identified as the best performance varieties. Therefore, these varieties can be adopted and grown by farmer in stalk-eyed fly prone area in Uganda. Furthermore, six F_3 genotypes developed at NaCRRI (GSR IR1- 5-S14-S2-Y1 x K85, Gigante x NERICA4, NERICA4 x Gigante, NERICA1x NERICA4, NERICA4 x NERICA6, and NERICA4 x SUPA) were found resistant to stalk eyed fly infestation and are recommended for advancement.

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