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Effect of African rice gall midge on yield and its components on inter-specific rice progenies, using correlation and principal components as analysis tools

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Inter-specific rice progeny lines (*Oryza glaberrima* × *Oryza sativa*) were evaluated for African rice gall midge resistance at two locations in 2010 cropping season. The experiment was made of 16 rice progeny lines including the two parents; FARO52 and Tog 7442 and a known susceptible check FARO 37. The experiment was conducted in the lowland experimental fields of National Cereals Research Institute at Badeggi and Edozhigi. The fields were laid out in a randomized complete block design in three replications. Gall midge was scored at 42 and 63 days after transplanting, other parameters collected include plant height, days to 50% flowering and grain yield. Principal component analysis indicates that the first three principal components accounted for 64.5% of the total variation in the population across the two locations. Correlation analysis showed a negative correlation (P=0.05) between percentage midge infestations at 63 DAT with number of panicle squared meter. Grain yield did not correlate significantly (P=0.05) with percentage gall midge infestation at 42 and 63 DAT, but there was a significant positive correlation (P=0.05) between percentage gall midge infestation at 42 and 63 DAT. Result revealed that FAROX 521-E-900-1, FAROX 521-H-559-1 and FAROX 521-H-686-1 are found to be resistance to African rice gall midge (AfRGM), while FAROX 521-E-430-1 and FAROX 521-H-433-1 gave a better yield potential under midge infestation and could be used for further genetics studies.

Key words: African rice gall midge (AfRGM), inter-specific, correlation, principal component, grain yield.

INTRODUCTION

Rice is one of the most important food crops in the world and feeds over half of the global population (FAO, 2004). It consists of the two cultivated species, namely the Asian rice (*Oryza sativa*) and the African rice (*Oryza glaberrima*). *O. glaberrima* is traditionally found in diverse West African agro ecosystems but it is largely abandoned in favor of high yielding *O. sativa* cultivars due to its poor agronomic performance (Linares, 2002). However, *O. sativa* cultivars with their high yield potential are often not sufficiently adapted to harsh biotic and abiotic conditions of Africa. Rice is cultivated in virtually all the agro-ecological zones of Nigeria. Despite this, the area cultivated to rice still appears small. In 2000, out of about 25 million hectares of land cultivated to various food crops, only about 6.37% was cultivated to rice. During this period, the average national yield was 1.47 tons per hectare. Significant improvement in rice production in Nigeria started in 1980 when output increased to 1 million tons while area cultivated and yield rose to 550 thousand hectares and 1.98 tons per hectare respectively, (WARDA, 1996). But in the 1990s, while rice output increased, the yield of rice declined, suggesting extension

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by production to marginal areas with poor yield and more production constraints.

Pests and diseases are important natural factors limiting the production of rice and, in severe cases, they account for 100% of crop losses. Singh et al. (1997) gave a detailed account of these biotic stresses; such as striga in upland rice, leaf scald, neck blast and African rice gall midge (AfRGM) in rain fed lowland. Recent efforts by rice breeders have resulted in the evolution of blast- and AfRGM-resistant rice varieties (Anonymous, 1997). African rice gall midge, *Orseolia oryzivora* Harris and Gagne is an insect pest indigenous to Africa (Williams et al., 2002). It is widely distributed south of Sahara, particularly in West Africa but has not been found outside the continent (Williams et al., 2002). Serious losses were reported from southern Burkina Faso in the late 1970s and extensive outbreaks occurred in South-eastern Nigeria in 1988 which causes about 80% yield losses from farmer's fields (Ukwungwu et al., 1989; Williams et al., 2002). The AfRGM is a pest of lowland rice but upland rice fields are occasionally attacked (Singh et al., 1997; Williams et al., 2002). Average yield of rain fed rice is low at 1.5 to 2.0 t/ha, and productivity is generally constrained by uncertain water supply, low soil fertility, insect pests, pathogens, weeds infestation, and poverty (Wade et al., 1999). This study will allow management interventions aimed at increasing productivity in AfRGM endemic areas.

MATERIALS AND METHODS

The experiment was established in 2010 cropping season at National Cereals Research Institute experimental field at two locations namely; Badeggi (Latitude 9°45'N, Longitude 6°07'E and altitude 70.5 m above sea level (msl) and Edozhigi Latitude 9°45'N and Longitude 6°17'E altitude 50.57 meters above sea level (msl) all in Guinea Savannah agro-ecological zone of Nigeria. Nursery is raised three weeks prior to the transplanting. The 16 rice progenies with the parents, local checks (FARO52 and Tog, 7442) and a known susceptible check, FARO 37 used in this experiment were collected from Rice Breeding Unit of National Cereals Research Institute, Badeggi.

The trials were laid out in a randomized complete block design with three replications in 5 × 2 m plots. The seedlings at 21 days old were transplanted at 3 seedlings per stand at a spacing of 20 × 20 cm within and between rows. The equivalent of 40 kg each of N, P_2O_5 and K_2O per ha were applied at transplanting using NPK 15-15-15, 40 kg N/ha was applied at 21 and 42 days after transplanting, at equal splits using urea. Manual hand weeding was carried out at 21 and 42 days after transplanting. Galls were counted on twenty five plants at random in each plot at 42 and 63 days after transplanting. The total number of tillers from each of the twenty five randomly selected plants was also counted. Percentage hill and tiller infestation was computed using the following formula.

$$\text{Infested hill percentage} = \frac{\text{No of infested hills}}{\text{Total number of hill}} \times 100$$

$$\text{Infested tiller percentage} = \frac{\text{No of infested tillers}}{\text{Total number of tillers}} \times 100$$

Tiller damage levels were expressed as scores between the values of 0 and 9, according to standard evaluation system for rice (IRRI, 1986) as shown in the Table 1.

Data collected

Rice tiller count (42 and 63 DAT). Number of panicle per m^2, plant height, leaf area, days to 50% flowering, phenotypic acceptability, grain yield and 1000 grain weight.

Statistical analysis

The data collected were subjected to principal component and correlation analysis using MSTAT package 1.3 versions.

RESULTS

Principal component analysis of morpho-physiological traits

The principal component analysis results are presented in Tables 1 and 2. The first principal component accounted for 31.2% of the total variation in the population; this was contributed by gall midge score at 42 DAT. Gall midge score at 63 DAT gave 19. 85% gall midge score at 42 DAT (0.393) and grain yield (0.264). Of less importance to this component are days to 50% flowering (0.256), plant height (0.251), numbers of tiller per meter square at 42 and 63 DAT (0.083). Panicle per m^{-2} and 1000 grain weight contributed negatively to the first component. The second principal component accounted for 19.85% of total variation. Major characters that contributed to this component include plant height (0.408), numbers of days to 50% flowering (0.402) leaf area (0.441), gall midge at 42 and 63, 1000 grain weight. Tiller count at 42 DAT contributed negatively to the principal component. The third principal component accounted for 13.4% of the total variation. Tiller count at 42 and 63 DAT, panicle count and grain yield are major contributors to the component. The three principal components accounts for 64.5% of the total variation in the population (Table 3).

Variability amongst the morphological characters

Table 4 shows characteristics of morphological cluster groups. Group 1 record high gall midge score of 21.27 and 19.4% at 42 and 63DAT respectively, with mean grain yield of 1.21 t/ha as compared to the yield of 3.50 and 4.36 t/ha obtained from genotypes in Groups 6 and 7, irrespective of high gall midge score of 20.36 and 22.23% at 42DAT respectively. Flowering occurred at the range of 58 and 81 days with genotype in Group 1 given 58, as compared to the genotypes in Groups 2, 3 and 4 with flowering days ranging from 65 and 68 days. While the genotypes in Groups 5, 6 and 7 gave the highest

Table 1. Standard evaluation system for rice.

Scores	% Tiller damage	Rating (reaction)
0	No damage	Highly resistance or immune
1	Less than 1%	Resistance
3	1-5%	Moderately resistance
5	6-10%	Moderately susceptible
7	11-25%	Susceptible
9	Above 25%	Highly susceptible

Table 2. Characteristic roots and percent of total variation of the first four principal components.

Principles	Latent roots	Percentage variance	Cumulative variance
Gall Midge count at 42 DAT	4.057	31.205	31.205
Gall Midge count at 63 DAT	2.581	19.85	51.055
Grain yield (kg/ha)	1.751	13.472	64.528
Days to 50% flowering	1.468	11.293	75.821

Table 3. Components (Eigen vectors), total variation accounting for 64% of character combination to the first three principal components.

Name of variables	Principal 1	Principal 2	Principal 3
Gall Midge count at 42 DAT	0.397	-0.111	-0.274
Gall Midge count at 63 DAT	0.393	-0.393	-0.103
Grain yield (kg/ha)	0.264	0.323	0.269
Days to 50% Flowering	0.256	0.402	0.101
Plant height at maturity(cm)	0.251	0.408	-0.101
Tiller count at 63 DAT	0.083	0.159	0.473
Tiller count at 42 DAT	0.029	-0.002	0.500
Panicle count/m2	-0.203	0.106	0.304
Phenotypic acceptability	-0.267	-0.171	-0.126
Leaf area	-0.296	0.441	-0.127
1000 grain weight	-0.338	-0.015	-0.085

flowering days, ranging from 76 to 81 days, respectively.

Correlation analysis

The result of correlation analysis (Table 5) shows that grain yield did not correlate significantly (P=0.05) with percentage gall midge infestation at either 42DAT or 63 DAT, but there was a significant positive correlation (P=0.5) between percentage gall midge infestation at 42DAT and 63DAT. Also, negative correlations were observed between percentage gall midge infestation at 42DAT and phenotypic acceptability score and leaf area. Negative correlation also exists between percentage midge infestations at 63DAT with number of panicle m^{-2}. Panicles m^{-2} and number of tillers m^{-2} at 42DAT and 63DAT did not correlate significantly with any other character. However, number of days to 50% positively correlates with plant height and correlate negatively (P=0.05) with 1000 grain weight. Similarly, there was a positive correlation between plant height and 1000 grains weight. Grains yield significantly (P=0.05) has positive correlation with 1000 grain weight and leaf area.

Scatter diagram analysis

This illustrates the genetic relationship among the genotypes using principal component 1 and 2 as shown in Figure 1. The result shows that clusters of FAROX 521-H-493-1, FAROX 521-H-698-1, FAROX 521-H-547-1and FAROX 521-H-686-1 are moderately susceptible. Also cluster of Tog 7442, FAROX 521-H-559-1, FAROX 521-H-521-1 and FAROX 521-E-612-1 recorded low yield

Table 4. Cluster groups with group character means.

Group / P_1P_2	Gm42 (%)	Gm63 (%)	Gyld (t/ha)	50%Fl	Pl ht	$T/m^2 42$	$T/m^2 63$	Pnc/m^2	PA	1000 gwt	L/A
1	21.27	19.4	1.20	58	86.06	406	466	51	2	27	16
2	14.36	16.99	1.52	68	79.9	478	532	54	3	24	21
3	10.41	11.6	1.88	68	88.5	478	585	66	4	26	25
4	9.9	13.4	2.41	65	89.6	558	501	62	3	24	21
6	20.36	19.1	3.50	81	113	469	582	55	1	24	28
7	22.23	18.27	4.36	78	98.93	546	605	55	1	21	16
P_1 and P_2	Group member										
Group 1	**1**, FAROX 521-H-297-1										
Group 2	**5**, FAROX 521-H-493-1: **14**, FAROX 521-H-698-1**:** **7**, FAROX 521-H-547-1:**12**, FAROX 521-H-686-1										
Group 3	**18**, Tog 7442: **10**, FAROX 521-H-559-1: **11**, FAROX 521-E-612-1: **6**, FAROX 521-H-521-1										
Group 4	**8**, FAROX 521-H-558-1: **15**, FAROX 521-H-878-1: **16**, FAROX 521-E-900-1: **13**, FAROX 521-H-688-1 : **4**, FAROX 521-H-462-1										
Group 5	**9**, FAROX 521-E-559-1										
Group 6	**3**, FAROX 521-H-433-1: **2**, FAROX 521-E-430-1: **17**, FARO 37										
Group 7	**19**, FARO 52										

Table 5. Correlation coefficient between gall midge infestation, yield component, yield and morphological characters of rice.

Correlation	GLMG42	GLMG63	TLCNT42	TLCNT63	50%FL	PA	PNCL	PLHT	1000GWT	GRNYLD	LLT	LWT	LAI
GLMG42	1												
GLMG63	0.68**	1.00											
TLCNT42	0.03	-0.10	1.00										
TLCNT63	0.00	-0.01	0.20	1.00									
50%FL	0.15	0.26	0.04	0.36	1.00								
PA	-0.36*	-0.21	-0.03	-0.16	-0.21	1.00							
PNCL	-0.42	-0.50**	-0.06	0.05	0.03	-0.03	1.00						
PLHT	0.17	0.21	-0.01	0.08	0.64**	-0.31	-0.03	1.00					
1000GWT	-0.22	-0.37	-0.01	-0.14	-0.44*	0.14	-0.06	-0.29	1.00				
GRNYLD	0.29	0.19	0.27	0.28	0.41	-0.54*	0.03	0.49*	-0.26	1.00			
LLT	-0.12	0.06	-0.27	-0.20	0.34	-0.14	-0.03	0.45*	-0.03	0.12	1.00		
LWT	-0.50*	-0.56**	0.08	0.00	-0.22	0.19	0.26	-0.27	0.54**	-0.15	0.29	1.00	
LAI	-0.46*	-0.39	-0.02	0.03	0.08	0.1 4	0.14	0.09	0.39*	0.02	0.63**	0.85**	1

**= Highly Significant, * = Significant at 5% probability levels.

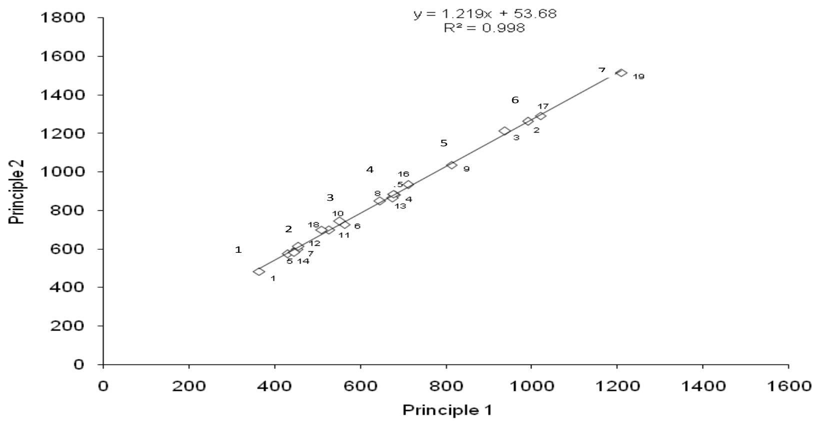

Figure 1. Scatter diagram, showing the position of individual variety. **1**; FAROX 521-H-297-1**, 2**: FAROX 521-E-430-1, **3**; FAROX 521-H-433-1, **4**; FAROX 521-H-462-1, **5**; FAROX 521-H-493-1**, 6**; FAROX 521-H-521-1**, 7**; FAROX 521-H-547-1, **8**; FAROX 521-H-558-1, **9**; FAROX 521-E-559-1, **10**; FAROX 521-H-559-1,**11**; FAROX 521-E-612-1,**12**; FAROX 521-H-686-1,**13**; FAROX 521-H-688-1, **14**; FAROX 521-H-698-1, **15**; FAROX 521-H-878-1, **16**; FAROX 521-E-900-1,**17**; FARO 37,**18**; Tog 7442, **19**; FARO 52.

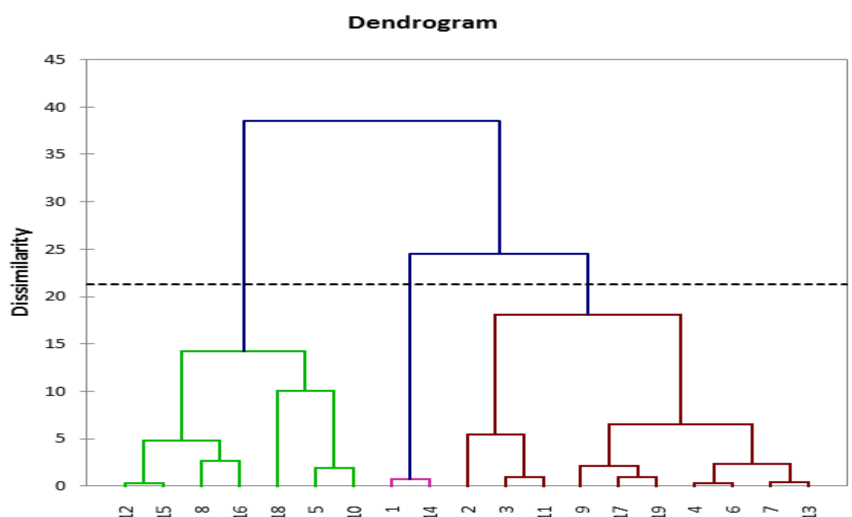

Figure 2. Dendogram showing the minimum distance between cluster groups.

and resistance to gall midge, while FAROX 521-H-558-1, FAROX 521-H-878-1, FAROX 521-E-900-1, FAROX 521-H-688-1 and FAROX 521-H-462-1 recorded minimum yield and resistant to gall midge. Furthermore, FARO 37, FAROX 521-E-430-1 and FAROX 521-H-433-1 cluster together and combine high yield with high susceptibility to gall midge. Lastly FARO 52 which is highly susceptible and recorded the highest yield

Cluster analysis

Figure 2 present the morphological dendogram showing the minimum distance between cluster groups and genotypes were divided into three groups. Thus genotypes in Group 1 have good grain yield and moderately resistance to rice gall midge. The genotypes in Group 2 are highly susceptible and gave lowest grain yield, while genotypes in Group 3 produced the highest grain yield with genotype 19 given 4.36 t/ha.

DISCUSSION

Principal components analysis and hierarchical clustering generated from similarity or genetic distance matrix has provided an overall pattern of variation as well as the degree of relatedness among the progenies. The factor score of the characters; gall midge score at 42 and 63 DAT, grain yield, days to 50% flowering, plant height and panicle/m^2 were mostly correlated with the first principal components of the principal components axes.

This observation in addition to the character means value of the seven similarity cluster grouping of the genotypes confirmed the contribution of the three traits to grain yield among the 19 genotypes. The implication is that if selection is to be made between cluster groups for a future breeding exercise, days to 50% flowering, plant height and panicle/m^2 should be given high priorities. According to Aliyu et al. (2000) cluster analysis has the singular efficacy and ability to identify genotypes with highest level of similarity using the dendrogram.

The insignificant correlation that exists in grain yield and percentage gall midge infestation might be due to the low gall midge infestation observed in 2010 cropping season. This result agrees with the previous findings of Ogunbayo et al. (2010) who reported that AfRGM was negatively correlated to rice grain yield. The study has also shown that percentage tiller damage by AfRGM at 63DAT is negatively correlated with number of panicles; this might be due to inability of damage tiller to produce panicle which will contribute to higher grain yield production. This result is contrary to the findings of Ogunbayo et al. (2010) who indicated that AfRGM is highly significantly associated with panicle/m^2.

However, the insignificant correlation between panicle/m^2 and number of tiller/m^2 might be attributed to low panicle production from the tiller. On the other hand, flowering date correlate positively with plant height and also negatively correlated with 1000 grain weight. Aris et al. (2009) suggested that, plant height character which had negative effect on grain yield and 1000 grain weight should be considered in the selection process by selecting rice plant type with semi-dwarf or intermediate plant height. The direct positive correlation of 1000 grain weight on grain yield indicates that, a direct selection through trait would be much effective for the improvement of grain yield per plant. Yoshida (1981) stated that the components of rice grain yield consisted of number of spikelet, percentage of filled spikelet and 1000 grain weight and among others.

Conclusion

There is Agro-morphological variation among the 19 genotypes evaluated, gall midge score at 42 and 63 DAT, days to 50% flowering, grain yield, plant height and panicle/m^2 contributed a greater proportion of variation in the principal component analysis. FAROX 521- H-433-1 and FAROX 521 –E-430-1 gave the highest grain yield similar to the sativa check FARO 52 and FARO 37, while FAROX 521-E-900-1 recorded higher resistance percentage to AfRGM, and therefore recommended for a future rice breeding programs in Nigeria.

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