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Heritability of resistance to rice yellow mottle virus disease and of yield related attributes in segregating generations of rice

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Abstract

Heritability is the important genetic component in determining the effectiveness of selection in crop breeding program such as rice. A study was carried out at National Crops Resources Research Institute (NaCRRI) in Uganda to estimate heritability of resistance to Rice yellow mottle virus disease (RYMV) and of yield related traits. The parents and their F3, F4 and F5 segregating progenies were evaluated under field conditions. Recorded traits included yield, tiller number, days to flowering, days to maturity and yield per hill. It was found that heritability estimates computed through both variance components and parent offspring-regression methods were high for resistance to RYMV (Heritability= 68.7 to 98.1%) in F3, F4 and F5. These results indicated that the resistance to RYMV trait is heritable and under genetic control. Selection for resistance to RYMV in early generations could be effective. Furthermore, our results indicated that the studied yield related attributes are important and could be used for selection in rice breeding. Parental lines Nerica 11 and Nerica 12 were identified most suitable in breeding for resistance to RYMV while Nerica 8 and Nerica 13 could be used effectively in breeding for yield.

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Introduction

Rice (*Oryza sativa* L.) is the most widely grown cereal in the world for human consumption, with cultivated area of almost 150 million ha and a total production of almost 600 million mega grams annually (Khush, 2005). The world population is growing and likely to reach 8 billion by 2030 and rice production must increase by 50% to meet the future demand (Khush and Brar, 2002).The development of high yielding and disease resistant cultivars with wide adaptability is the ultimate aim of plant breeders. Thus, effective genetic components of breeding to increase grain yield could be achieved (Ullah *et al.*, 2011). The heritability of a character has a major impact on the methods chosen for population improvement (Fehr, 1987). An important function of heritability parameter is the expression of the degree of correspondence between the phenotypic and genotypic values (Bruce, 2010). It also provides information about the extent to which a particular character can be transmitted to the successive generations (Falconer, 1981; Falconer and Mackay, 1996). Thus, the knowledge of heritability of a trait guides a plant breeder to predict behavior of succeeding generations and helps to predict the response to selection (Waquar-UL-Haq *et al.*, 2008). The higher the heritability estimates, the simpler are the selection procedures (Khan and Naqvi., 2011).

The estimates of heritability for yield and yield related components have been widely studied in rice genotypes. The broad sense heritability is the relative importance of genotype and environment in the determination of phenotypic value. Karthikeyan *et al.* 2010 recorded broad sense heritability estimates of 99.8% for days to flowering, 99.2 5 for days to maturity and 73.2% for grain yield plant. Padmaja *et al.* 2008 also reported 98.5% for days to flowering, 78.7% for total tillers per plant and 87.2% for 100 grain weight. Khalid *et al.* 2012 recorded high heritability estimates (>85%) for plant height, number of tillers and 1000 grain weight in upland rice. Ogunbayo *et al.* 2014 obtained high heritability of yield and reported that the number of tillers, panicle length,1000 grain-weight are important yield related traits and could be used for selection in rice breeding programmes. However, the information on heritability estimates in advanced generations of crosses is scanty. Also, estimates of heritability for resistance to rice yellow mottle virus disease in advanced generations would raise the information on selection criteria in rice breeding .

The present study aimed at ascertaining heritability of resistance to RYMV and yield related attributes in advanced generations of selected crosses. The information so obtained would be used in formulating a rice breeding programme with convenient strategies regarding selection for resistance to RYMV and yield related traits

Material and methods

Study site

The study was conducted in the field at the NaCRRI located at 00 32'' N of the Equator and 32 37'' E. The area has a bimodal rainfall pattern and an average annual rainfall of 1200mm. It is at an elevation of 1150 meters above sea level and has a tropical wet and mild dry climate with slightly humid conditions.

Plant materials

Eleven F3 populations, previously generated at NaCRRI- Namulonge from seven parents that differed in their levels of resistance to RYMV, were advanced to F5 generations by selfing. The seven parents and their F3, F4, and F5 populations constituted the genetic materials used in this study (Table 1).

Advancement of populations

During the first season of 2011 (2011A), F3 progenies including eleven crosses previously generated at Namulonge were advanced to F4. F4 generations were advanced to F5 during the second season of 2011 (2011B). The harvesting strategy for the F3 generated three representatives of each of the eleven populations, one bulk and two individual plant selections, and the F4 were harvested similarly. This strategy produced nine F5 representatives for each F3 population.

Evaluation of generations of selfed progeny

Forty entries including thirty three crosses i.e. eleven crosses for each F3, F4 and F5 generations, and their seven parents were sown in April 2012 in a 10 x 4 alpha lattice design with three replications. Bulked seeds were used. Twenty one days old nursery was transplanted in the field with a spacing of 20 cm within rows and 20 cm between rows. The plot size was 1.2 m x 1.5 m with a total of 49 plants per plot. The experiment was hand weeded, prior to fertilizer application, at 15 days and 35 days after transplanting. Basal fertilizer of urea and 17-17-17 NPK was applied at a rate of 50kg ha-1.

Data collection

Data on 10 random plants per entry from each replication were recorded for RYMV disease severity and other four quantitative traits including heading date (date when 50% of the shoots had flowered), maturity date (date when plants reached physiological maturity = at harvesting), tiller number per plant, and seed yield in grams per hill. RYMV disease severity was scored using the 1- 9 IRRI standard scale (IRRI, 2002).

Data analysis

Analyses of variance for all traits were conducted on mean disease score of 10 individual plant data. The analysis was done on an individual plot basis using GenStat software 14th Ed.

The heritability was estimated using both components of variance and parent-offspring regression. Based on estimated components of variance, heritability was determined as:

Narrow sense heritability (h^2) = Vg/Vp

Where, Vg= (MSG-MSE)/r; Vp= MSG/r, Vg and Vp are genetic and phenotypic variances, respectively; MSG and MSE are genotypic and error mean squares, respectively, from analysis of variance and r = number of replication.

Using parent-offspring regression method, the slope of regression of offspring on parent informed us about resemblance between relatives

$$b_{op} = \frac{V_a}{2V_p} = \frac{1}{2}h^2$$

Where b_{op} is the slope of one parent- offspring regression, Va is variance due to additive gene effects, Vp is the phenotypic variance of the parent and h^2 the narrow sense heritability.

Results

Analysis of variance for resistance to RYMV and yield related traits

Mean squares for analysis of variance in table 2 revealed that genotypes differed significantly ($P \leq 0.001$) for all the traits. Compared to the parent used, the progeny means displayed a significant difference ($P \leq 0.001$) for resistance to RYMV and other traits, except the period to mature was not significant. Generations and interaction between generations and crosses were not significantly different ($P \leq 0.05$) for resistance to RYMV and number of tillers per plant.

Performance of parents, F3, F4 and F5 generations

In comparing the general performance of parents and F3, F4 and F5 generations for resistance to RYMV, the parents showed lower levels of resistance (averaged mean = 3.7) compared to F3, F4 and F5 generations which had almost the same level of resistance with averaged means of 3.3, 3.4 and 3.4, respectively. For other traits, the parents had higher tillering ability than all the three generations but flowered later. The seed yield/hill was lower in parents compared to the three generations and was higher in F3 among generations.

In comparing the overall performance in three generations, the results revealed that all F3, F4 and F5 crosses were consistently resistant to RYMV disease and F3 generation showed a high yield $hill^{-1}$ than F4 and F5 generations. Crosses involving parent Nerica 12 as female consistently showed higher resistance, followed by parent Nerica 11 in F3. In this generation, the highest yield was recorded in crosses involved parent Nerica 8 followed by Nerica 13 (Table 3). In F4, RYMV score was lowest when Nerica 11 followed by Nerica 13 was used as female parents

(Table 4). In the case of yield, crosses involving parent Nerica 11 had more yield followed by Nerica 13. Highest resistance was found in crosses involving female parents Nerica 11 followed by Nerica 12 in F5. Results for yield performance revealed that crosses involving female parent Nerica 12 was consistently highest followed by Nerica 10 (Table 5). Generally flowering date and maturity time was later in F3 generations than in the F4 and F5 generations.

Table 1. Parental lines and crosses used in the study and their pedigrees.

Genetic material	Pedigree
Parents	
NER 8 upland	WAB 450-1-BL1-136-HB
NER 10 lowland	WAS 122-IDSA-10-WAS-7-2-FKR1-TGR89
NER 11 upland	WAB 450-16-2-BL2-DV1
NER 12 upland	WAB 880-1-38-20-17-P1-HB
NER 13 upland	WAB 880-1-38-20-28-P1-HB
IR 64 lowland	IR 18348-36-3-3
Gigante lowland	Local accession from Mozambique
Crosses	
Ner 8x Ner 12	
Ner 10x Ner13	
Ner 11x Ner 8	
Ner 11x Ner 13	
Ner 12x Ner 11	
Ner 12x Ner 13	
Ner 13x Ner 10	
Ner 13x Ner 12	
Ner 13x IR64	
Ner 13xGig	
IR 64x Ner 12	

Heritability estimates in F3, F4 and F5 generations

Heritability estimates of resistance to RYMV and yield related traits are presented in Table 6. The heritability estimates were computed using variance components with and without inclusion of parents, and the parent- offspring regression methods. The results of all methods showed high values of estimated narrow sense heritability, with the range of 81.9 - 97.8%; 68.7 - 97.8% and 68.1 - 98.1% in the F3, F4 and F5, respectively, for most of the characters evaluated.

Other studied traits (number of tillers per plant, days to flowering, days to maturity and seed yield hill^{-1}) also showed high heritability by all methods, ranging between 54.3-91.5% for days to 50% flowering in F3; 57.0-95.7 % in F4 and 32.0-95.3% in F5. The estimates of heritability for days to mature ranged between 51.0-90.0% in F3; 71.0-86.5% in F4 and 46.0-89.8% in F5.

The estimates of heritability for tillering ability ranged widely according to method, with values between 11.0-79.7% in F3; 34.8-82.8% in F4 and 11.0-83.2% in F5, For yield/hill, these values were between 22.0-84.2% in F3; 79.0-92.1% in F4 and 28.0-93.8 in F5.

Table 2. Mean squares from analysis of variance of RYMV score severity and yield related traits for seven parents and eleven crosses in the F3, F4 and F5 generations (Individual plot basis).

SOV	df	RYMV at flowering	Number of tillers	Days to 50% flowering	Days to maturity	Yield per hill
Genotypes	39	1.9***	26.54***	106.86***	31.16***	120.93***
P vs C	1	2.49***	136.73***	114.42***	1.35 ns	277.71***
Within P	6	9.22***	90.51***	373.64***	68.49***	218.54***
Within C	32	0.56***	11.10 ns	56.60***	25.09***	97.73***
Gen	2	0.09ns	17.83 ns	224.07***	75.17***	4.27 ns
Crosses	10	1.67***	14.12*	97.42***	47.88***	159.29***
Gen x crosses	20	0.06 ns	8.92 ns	19.45*	8.69**	76.29***
Error	78	0.09	7.30	10.84	4.13	17.44

*, **, *** significant at 0.05, 0.01, 0.001 probability levels respectively; ns not significant at 0.05 probability
P= Parents, C= crosses, Gen= Generation.

Discussion

The results from analysis of variance revealed that the genotypes were significantly different for all the traits, indicating the presence of considerable genetic variability among parents, F3, F4 and F5 progenies for resistance to RYMV and yield related traits evaluated. This has resulted into difference in performance among parents and their progenies. Comparing the performance of parents, F3, F4 and F5 generations for resistance to RYMV, the overall F3, F4 and F5 mean showed that the crosses in all generations were more resistant, earlier flowering and had higher yield hill^{-1} than parents. The increased overall score parental mean and reduced parental yield were probably due to the contribution of parent IR 64 which was highly susceptible and had lower yield hill^{-1}.

Table 3. Mean performance and mean squares of seven parents and eleven crosses of rice for rice yellow mottle virus resistance and yield related traits in the F3 generation.

		Traits				
Parent and crosses		RYMV	Days to 50% Flow	Days to maturity	Number tillers	yield/hill
Parents						
NER 8		2.1a	68ab	119a	12.0a	19.9b
NER 10		2.9c	65a	118a	18.1bcd	8.5a
NER 11		2.5ab	64a	118a	14.8abc	22.2bc
NER 12		2.5ab	78fgh	125de	14.8abc	28.5cd
NER 13		2.4ab	68ab	119a	10.9a	27.8cd
Gigante		2.6bc	81h	128f	21.5de	19.3b
IR 64		7.1d	95i	128f	26.4e	6.9a
Avg mean (Parents)		3.2	74	122	17	19
F3 generation						
NER 8 x Ner 12		2.4ab	71bcde	123cd	14.0abc	32.9d
NER 10 x Ner13		2.9cd	75defgh	123bcd	18.7cd	23.8bc
NER 11 x Ner 8		2.3ab	73bcdef	126def	13.2ab	18.6b
NER 11 x Ner 13		2.6bcd	69abc	120abc	14.7abc	18.4b
NER 12 x Ner 11		2.2ab	74bcdef	124d	13.9abc	18.3b
NER 12 x Ner 13		2.5abc	69abcd	121abc	12.3a	28.2cd
NER 13 x Ner 10		2.9d	76efgh	126def	14.8abc	25.5bcd
NER 13 x Ner 12		2.3ab	80gh	128ef	12.5a	21.9bc
NER 13 xGigante		2.4ab	77efgh	126def	18.8cd	28.8cd
NER 13 x IR64		2.9cd	69abc	120ab	13.5ab	18.2b
IR 64 x Ner 12		2.9cd	75cdefg	125de	15.6abc	23.8bc
Avg Mean (F3)		2.6	74	124	14.7	23.4
Source of variation	df			Mean Squares		
Rep	2	0.41	11.7	61.6	68.9	24.2
Genotypes	17	3.70***	156.2***	37.7***	44.2***	134.8***
Error	34	0.07	13.3	3.9	8.9	21.3

Means in the same column followed by same letters do not differ significantly at P≤ 0.05; *** significant at 0.001 probability level.

Table 4. Mean performance and mean squares of seven parents and eleven crosses of rice for rice yellow mottle virus resistance and yield related traits in the F4 generation.

		Traits				
Parent and crosses		RYMV scores	Days to 50% Flow	Days to maturity	Number tillers	yield/hill
Parents						
NER 8		2.1a	68bcd	119bcd	12.0a	19.9bcd
NER 10		2.9c	65bc	118b	18.1de	8.5a
NER 11		2.5ab	64b	118bc	14.8abcd	22.2cdef
NER 12		2.5ab	77e	125fg	14.8abcd	28.5gh
NER 13		2.4ab	68bcd	119bc	10.9a	27.8fgh
Gigante		2.6bc	81e	128g	21.5e	19.3bcd
IR 64		7.1d	95f	128g	26.4f	6.9a
F4 generation						
NER 8 x Ner 12		2.4ab	67bcd	120bcde	14.1abcd	20.0bcd
NER 10 x Ner13		2.9bcd	72d	123ef	13.8abcd	26.3efgh
NER 11 x Ner 8		2.4ab	71d	123ef	12.7ab	24.4defg
NER 11 x Ner 13		2.2a	72d	123def	13.1abc	34.2i
NER 12 x Ner 11		2.8bcd	69cd	121bcde	17.1bcde	17.4bc
NER 12 x Ner 13		2.4ab	69cd	121bcdef	12.9abc	21.8cde
NER 13 x Ner 10		2.9bcd	68bcd	120bcde	13.8abcd	20.1bcd
NER 13 x Ner 12		2.3a	720d	122cdef	12.9abc	30.77hi
NER 13 xGigante		2.5abc	70d	122cdef	15.3abcd	21.5cde
NER 13 x IR64		3.1d	55a	112a	17.2cde	15.2b
IR 64x Ner 12		3.1d	69cd	121bcdef	14.4abcd	18.5bc
Avg mean (F4)		2.6	69	121	14.3	23
Source of Variation	df			Mean squares		
Rep	2	0.29	6.2	62.4	29.4	42.9
Genotypes	17	3.70***	194.7***	42.3***	41.7***	145.8***
Error	34	0.08	8.4	5.7	7.2	11.5

Means in the same column followed by same letters do not differ significantly at P≤ 0.05; *** significant at 0.001 probability level.

Comparing the performance of crosses, we can discuss that the parents Nerica 8, Nerica11, Nerica 12 and Nerica 13 contributed to the performance for resistance to RYMV and yield which suggest that they were good combiners for those traits. Therefore, they could be used effectively and extensively in breeding for both resistance to RYMV and yield. It was further noted that F3 generation exceeded the F4 and F5 generations and F4 exceeded F5 for yield hill^{-1} which may be due to deterioration of heterosis in advanced generations. These results are in agreement with the findings of Soomro *et al.* (2010) who also reported that the F2 generation exceeded F3 generation in upland cotton for all quantitative traits he evaluated including yield hill^{-1}.

High heritability estimates were observed for resistance to RYMV for all methods of estimation (68.1 to 98.1 %). This means that resistance to RYMV is highly heritable and it was reported that the high heritable characters are least affected by environmental fluctuations (Soomro *et al.,* 2010). The above observations suggest that the additive gene effect was more important in all generations and that the selection for resistance to RYMV in early generations would be effective. Results of further comparison of parental performance revealed that crosses involving parents Nerica 11 consistently showed high RYMV resistance followed by Nerica 12 implies that the two parents could be most suitable for breeding for resistance to RYMV.

Table 5. Mean performance and mean squares of seven parents and eleven crosses of rice for rice yellow mottle virus resistance and yield related traits in the F5 generation.

Parent and crosses		RYMV scores	Days to 50% Flow	Days to maturity	Number tillers	yield/hill
Parents						
NER 8		2.1a	68ab	119ab	12.0ab	19.9bc
NER 10		2.9c	65a	118a	18.1cd	8.5a
NER 11		2.5ab	64a	118a	14.8abc	22.2bcd
NER 12		2.5ab	78de	125c	14.8abc	28.5fg
NER 13		2.4ab	68ab	119ab	10.9a	27.8efg
Gigante		2.6bc	81e	128d	21.5d	19.3bc
IR 64		7.1d	94f	128d	26.4e	6.9a
F5 generation						
NER 8 x Ner 12		2.5ab	71bc	122bc	15.3abc	23.0cde
NER 10 x Ner13		2.9c	73c	123c	11.1a	32.2g
NER 11 x Ner 8		2.4ab	75cd	1245c	11.6ab	18.2bc
NER 11 x Ner 13		2.3ab	74cd	124c	12.3ab	31.2g
NER 12 x Ner 11		2.6bc	72bc	124c	14.1abc	20.4bc
NER 12 x Ner 13		2.4ab	73cd	124c	12.2ab	32.5g
NER 13 x Ner 10		2.9c	75cd	125c	15.9bc	17.0b
NER 13 x Ner 12		2.5ab	73cd	123c	11.9ab	25.8def
NER 13 x Gigante		2.4ab	72c	125c	13.6abc	19.4bc
NER 13 x IR64		2.9c	64a	116a	16.0bc	11.6a
IR 64 x Ner 12		2.9c	72bc	123c	12.2ab	20.9bcd
Avg mean (F5)		2.6	73	123	13.3	22.9
Source of Variation	df			Mean squares		
Rep	2	0.30	6.5	58.7	19.8	6.9
Genotypes	17	3.63***	150.1***	34.6***	47.5***	170.8***
Error	34	0.07	6.9	3.6	7.9	10.6

Means in the same column followed by same letters do not differ significantly at P≤ 0.05; *** significant at 0.001 probability level.

Among other traits studied, the heritability was found to be also high through both methods (over 50%). High heritability values related to days to 50% flowering, days to maturity and to yield hill^{-1} indicated reasonable variation for these traits. This suggests that selection can be practiced by using these traits to improve paddy yield in rice and simple selection methods would be effective for these traits, at least in F3 and later generations. Further observation that there was higher yield for crosses involved parents Nerica 8 followed by Nerica 13 indicates that these parental lines could be used effectively in breeding for yield. The heritability estimates obtained in the present study are relatively similar to the heritability estimates previously observed. Similarly, Akhtar *et al.* (2011) reported high heritability estimates for days to maturity and paddy yield and low heritability for number of tillers plant^{-1} when estimating heritability in fine grain rice in Pakistan.

Table 61. Estimation of heritability for resistance to RYMV and yield contributing traits in F3, F4 and F5 generations by parent-offspring regression and through variances components with and without inclusion of parents.

	Parents + Crosses			Crosses only			Parent-offspring
Characters	Genotypic variance	Phenotypic variance	Heritability (H)%	Genotypic variance	Phenotypic variance	Heritability (H)%	Regression b-value (x100)
F3 generation							F4 vs F3
RYMV resistance	1.2	1.2	97.8	0.1	0.1	86.3	81.9
Tiller number	11.8	14.7	79.7	2.2	4.9	43.9	11.0
Days to 50% flowering	47.6	52.1	91.5	7.4	13.7	54.3	64.0
Days to maturity	11.3	12.6	90.0	5.6	6.7	83.6	51.0
Yield/hill	37.8	44.9	84.2	13.9	24.4	57.0	22.0
F4 generation							F5 vs F4
RYMV resistance	1.2	1.2	97.8	0.1	0.1	83.9	68.7
Tiller number	11.5	13.9	82.8	0.9	2.6	34.8	66.0
Days to 50% flowering	62.1	64.9	95.7	19.0	22.6	84.1	57.0
Days to maturity	12.2	14.1	86.5	7.2	9.4	76.5	71.0
Yield/hill	44.8	48.6	92.1	28.3	33.0	85.7	79.0
F5 generation							F5 vs F3
RYMV resistance	1.2	1.2	98.1	0.1	0.1	80.0	68.1
Tiller number	13.2	15.8	83.2	1.1	3.2	34.6	11.0
Days to 50% flowering	47.7	50.0	95.3	6.4	9.2	69.6	32.0
Days to maturity	10.3	11.5	89.8	4.7	5.7	82.5	46.0
Yield/hill	53.4	56.9	93.8	41.9	46.6	90.1	28.0

The results are also consistent with the findings of Zahid *et al.* (2006) who reported variation and high heritability for the yield contributing traits. Reza *et al.* (2010) reported high heritability in plant height. High heritability (87.0-91.0%) was also reported for plant height, heading date and tiller number and low heritability (37.0%) in grain yield (Asadollah, 2010). Sabu *et al.* (2009) reported high heritability for tillers per plant, when he was studying the heritability of agronomically important traits in *O. sativa* x *O. rufipogon* cross.

Conclusion

The study to estimate heritability of resistance to RYMV and of yield related traits within advanced generations in selected crosses revealed high heritability values for resistance to RYMV character and yield contributing traits. The results suggest that selection for resistance to RYMV is easy and should be done in early and subsequent generations. Furthermore, the simple selection methods can be practiced by using the yield contributing traits to improve paddy yield in rice.

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