Identification of transgressive segregation for yield and resistance to yellow stem borer (*Scirpophaga incertulas* Walker) in F_2 segregating generation of six rice crosses (*Oryza sativa* L.)

Abstract

The research investigation on the occurrence of transgressive segregation in F_2 populations derived from six rice crosses namely: ADT 43 X TKM 6, ADT 43 X ASD 12, ADT 45 X TKM 6, ADT 45 X ASD 12, ASD 16 X TKM 6 and ASD 16 X ASD 12 with the aim of identifying superior genotypes for yield and resistance to the yellow stem borer (*Scirpophaga incertulas*). This research was conducted through series of field observations for transgressive segregants at Plant Breeding Farm, Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University during *Kharif* season of 2022. The crosses involved high-yielding but susceptible female parents (ADT 43, ADT 45, ASD 16) and YSB resistant but low yielding male parents (TKM 6, ASD 12). In the F_2 generation, a wide range of phenotypes was observed for yield-related traits and YSB resistance. Twelve superior transgressive segregants were identified in each cross, exhibiting increased grain yield per plant, number of productive tillers, and number of grains per panicle, coupled with high levels of resistance to YSB. The results suggest that the parents carried different alleles and genes governing yield and its component traits, allowing the accumulation of favorable alleles in the F_2 progeny through recombination. The identification of these high-performing transgressive segregants provides opportunities for further evaluation and potential use in rice breeding programs to develop improved cultivars with enhanced yield and biotic stress resistance.

Keywords: Rice, Transgressive segregation, Yellow stem borer and F_2 generation.

Introduction

Rice is an Asian crop with a chromosome number of 2n = 2x = 24 and belongs to the family of Poaceae, as most of the rice is produced and consumed in Asia. Global rice (paddy) production increased more than threefold between 1961 and 2019, from 215 million tonnes to 755 million tonnes; most of the production was from Asia. In 2020, over 756 million tons of rice were produced in 143 countries, however, it was 598 million tons in 2000. This depicting that production was increasing and the cultivating area was decreased (FAO, 2022). In 2019, the global agricultural land area was 4.8 billion hectares (ha), down 3 percent or 0.13 billion hectares compared with 2000 (FAO, 2022). The transgressive segregation in plants refers to the phenomenon where the offspring of a cross between two parent plants exhibit traits that fall outside the range of variation observed in the parental lines. This can result in the emergence of novel and sometimes improved phenotypes in the progeny. Transgressive segregation has important implications in plant breeding and genetics. It allows breeders to access a wider range of phenotypic diversity, which can be valuable for the selection and development of improved crop varieties. Transgressive segregation can lead to the identification of superior individuals with desirable traits, such as increased yield, disease resistance, or abiotic stress tolerance. Additionally, understanding the genetic basis of transgressive segregation can provide insights into the complex interactions between genes and the potential for generating novel and beneficial phenotypes. This knowledge can inform strategies for plant breeding, genetic engineering, and the conservation of genetic diversity in plant populations. The process of transgressive segregation involves the following key steps:

1. **Genetic Diversity:** Transgressive segregation is more likely to occur when the parental lines used in the cross are genetically diverse. This diversity can arise from different genetic backgrounds, geographic origins, or breeding histories.
2. **Complementary Alleles:** During the cross, the parental lines may contribute different alleles (variant forms of a gene) for the same trait. These complementary alleles can interact in the offspring, leading to the expression of a phenotype that exceeds the range observed in the parents.
3. **Epistasis:** Epistasis refers to the interaction between different genes, where the expression of one gene is influenced by the presence or absence of another gene. In the context of transgressive segregation, epistatic interactions between genes can produce novel phenotypes that are not present in the parental lines.
4. **Quantitative Trait Loci (QTLs):** Transgressive segregation is often associated with quantitative traits, which are controlled by multiple genes (QTLs) with small individual effects. The combination of these QTLs in the offspring can result in the expression of extreme phenotypes.

The main objective of the present investigation is to identify the transgressive segregants for yield and resistant sources of rice yellow stem borer from the six crosses under field conditions.

Materials and Methods

The field experiments were conducted at Plant Breeding Farm, Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University during *Kharif* season of 2022 with F_2 segregating generation of six crosses of rice *viz*., ADT 43 X TKM 6, ADT 43 X ASD 12, ADT 45 X TKM 6, ADT 45 X ASD 12, ASD 16 X TKM 6 and ASD 16 X ASD 12. The main objective if the present investigation is to identify the transgressive segregants for yield and resistant sources of rice yellow stem borer from the six crosses under field conditions. The F_2 generation along with parents was grown and all the required data was recorded from 350 F_2 plants of each cross. The phenotypic data of yield and yield related traits was recorded along with resistance to YSB.

In F_2 segregating generation of six cross the mean performance of the individual progenies in the population was compared with the parental mean and the superior progenies were identified. Yield characters considered for identification of transgressive segregants are,

i. Number of productive tillers per plant
ii. Number of grains per panicle and
iii. Grain yield per plant and
iv. Resistance status to yellow stem borer

Results and Discussion

Transgressive segregation produced hybrid progeny phenotypes that were superior to the parental phenotypes. Such plants were produced by accumulation of favourable genes (positive alleles) from both the parents as a consequence of recombination followed by segregation and additive gene action are also the main reasons for the occurrence of transgressive segregants. Unlike heterosis, extreme phenotypes caused by transgressive segregation were heritably stable. Kshirsagar *et al*. (2013) suggested that transgressive segregation could be exploited for development of genotypes in tomato (*Solanum lycopersicon* L.) with positive characters from both the parents.

Performance of parents

The female parents ADT 43 and ASD 16 had high grain yield per plant, number of productive tillers per plant and number of grains per panicle but has a susceptible status (scale 7) to yellow stem borer and ADT 45 had even higher grain yield per plant, number of productive tillers per plant and number of grains per panicle but was highly susceptible (scale 9) to yellow stem borer. Incase of male parents, both TKM 6 and ASD 12 has shown highly resistant status (scale 0) to yellow stem borer. TKM 6 and ASD 12 had the lowest grain yield but TKM 6 had grain yield higher than ASD 12 but lower than all other female parents.

Performance of six rice crosses

In the present investigation 12 superior transgressive segregants for high grain yield per plant, number of panicles per plant and number of grains per panicle were identified in each of the F_2 segregating generations of all the six crosses *viz*., ADT 43 X TKM 6, ADT 43 X ASD 12, ADT 45 X TKM 6, ADT 45 X ASD 12, ASD 16 X TKM 6 and ASD 16 X ASD 12 of rice. In all the six crosses wide range of phenotypes were observed for most the characters in the F_2 generation. This clearly suggested that all traits were governed by many genes (polygenes) and alleles governing these traits seemed to act in additive manner showing polygenic inheritance. High variability for number of tillers per plant and grain yield per plant in F_2 populations of rice was reported by Balat *et al*. (2018), Kiran *et al*. (2012), Shet *et al*. (2012) and Reddyyamini *et al*. (2019) and Bollineni *et al*. (2021).The F_2 plants that surpassed the parental limits were observed in all the six crosses for all the traits *viz*., plant height, number of productive tillers, total number of tillers, panicle length, number of grains per panicle, grain yield per plant, and thousand grain weight. Reddy (2008) reported transgressive segregants over both the parents for panicle length, filled grains, spikelet number, spikelet fertility and single plant yield in Basmati 370 x Jaya derived F_2 population. This clearly indicated that the parents had different alleles and genes governing yield and its component traits. Hence, there was a lot of scope to bring in beneficial alleles into a single genotype through rigorous selection in later generations for yield and yield attributes. The Plate 1 shows the white ear head symptoms observed in six rice crosses in F_2 generation.

The significant superior performance of segregants due to the contribution of component characters. The plant number 320 (ADT 43 X TKM 6), plant number 100 (ADT 43 X ASD 12), plant number 289 (ADT 45 X TKM 6), plant number 138 (ADT 45 X ASD 12), plant number 48 (ASD 16 X TKM 6), and Plant number 228 (ASD 16 X ASD 12) exhibited highest grain yield per plant which was due to contribution of component characters like number of tillers per plant, productive tillers per plant and number of grains per panicle. While superior performance was also due to the highly resistance and resistance status observed during screening for yellow stem borer (YSB) of the segregants in all the six crosses. The crossing between high yielding parents (ADT 43, ADT 45, ASD 16) with yellow stem borer resistant parents (TKM 6, ASD 12) brought together beneficial alleles from both parents in transgressive segregants. High yielding transgressive segregants also showed resistance to rice yellow stem borer. Superior transgressive segregants were identified in all six crosses for grain yield and contributing traits along with YSB insect resistance. It would be worthwhile to evaluate the performance of progenies derived from desirable transgressive segregants in future generations for their further use in breeding programmes of rice. The list of desirable transgressive segregants for yield along with YSB resistance in F_2 population of the six rice crosses were tabulated from Table 1 to Table 6. The similar studies on identification of transgressive segregation in rice were done by Mahalingam *et al*. (2012), Varma *et al*. (2012), Kumari *et al*. (2013), Manjappa *et al*. (2014), Uday *et al*. (2014), Reddyyamini *et al*. (2019) and Swarajyalakshmi *et al*. (2021).

Conclusion

It is possible to introduce a number of beneficial alleles into a single genotype through careful selection in subsequent generations, as evidenced by polygenic inheritance and high frequencies of favourable transgressive segregants for yield and resistant traits. The F_2 population which confers the maximum genotypic variation provides the opportunity for individual plants selection, which may help in the development and release of a new variety that combines high yielding capacity with yellow stem borer resistance. The single plants with a greater number of favourable characters can be selected in F_2 generations of rice crosses, which significantly boosts the rice crop production. The identification of yellow stem borer resistant rice transgressive segregants has been a significant advancement in following areas,

1. **Reduced pesticide and insecticide use:** Farmers can significantly reduce or eliminate the need for chemical insecticides, resulting in lower production costs and a reduced environmental impact.
2. **Improved crop yields:** YSB-resistant varieties experience less damage from insect pests, leading to higher and more stable yields.
3. **Environmental sustainability:** Reduced pesticide use helps protect beneficial insects, such as pollinators and natural predators of pests, promoting biodiversity and ecosystem health.
4. **Improved human health:** Lower exposure to chemical insecticides reduces the risks associated with their use, such as acute poisoning and long-term health issues for farmers and consumers.

Table 1. List of desirable transgressive segregants in F_2 population of the cross ADT 43 X TKM 6 along with their parents

S. No	F_2 plant number	Number of productive tillers per plant	Number of grains per panicle	Grain yield per plant	Scoring for YSB
1	Plant 104	29.00	159.00	71.00	Highly Resistant

2	Plant 320	29.00	164.00	73.71	Highly Resistant
3	Plant 103	28.00	167.00	72.47	Highly Resistant
4	Plant 132	28.00	164.00	71.63	Highly Resistant
5	Plant 326	28.00	160.00	70.78	Highly Resistant
6	Plant 348	28.00	165.00	72.07	Highly Resistant
7	Plant 22	27.00	163.00	67.77	Highly Resistant
8	Plant 131	27.00	164.00	69.07	Highly Resistant
9	Plant 258	27.00	165.00	67.71	Highly Resistant
10	Plant 287	27.00	160.00	68.25	Resistant
11	Plant 106	26.00	167.00	69.03	Resistant
12	Plant 109	26.00	168.00	69.45	Resistant
S. No	**Parents**	**Number of productive tillers per plant**	**Number of grains per panicle**	**Grain yield per plant**	**Scoring for YSB**
1	ADT 43	18.00	156.00	47.36	Susceptible
2	TKM 6	12.00	137.00	22.07	Highly Resistant

Table 2. List of desirable transgressive segregants in F_2 population of the cross ADT 43 X ASD 12 along with their parents

S. No	F_2 plant number	Number of productive tillers per plant	Number of grains per panicle	Grain yield per plant	Scoring for YSB
1	Plant 211	31.00	158.00	73.99	Highly Resistant
2	Plant 100	30.00	181.00	89.59	Highly Resistant
3	Plant 89	28.00	180.00	81.64	Highly Resistant
4	Plant 207	30.00	166.00	77.68	Highly Resistant
5	Plant 67	29.00	162.00	72.83	Highly Resistant
6	Plant 116	29.00	167.00	78.45	Highly Resistant
7	Plant 186	28.00	181.00	82.64	Highly Resistant
8	Plant 267	28.00	173.00	77.98	Highly Resistant
9	Plant 95	27.00	175.00	74.18	Highly Resistant
10	Plant 318	27.00	173.00	77.07	Highly Resistant
11	Plant 340	26.00	180.00	82.83	Highly Resistant
12	Plant 319	25.00	182.00	80.99	Resistant
S. No	**Parents**	**Number of productive tillers per plant**	**Number of grains per panicle**	**Grain yield per plant**	**Scoring for YSB**
1	ADT 43	18.00	156.00	47.36	Susceptible
2	ASD 12	14.00	110.00	20.98	Highly Resistant

Table 3. List of desirable transgressive segregants in F_2 population of the cross ADT 45 X TKM 6 along with their parents

S. No	F_2 plant number	Number of productive tillers per plant	Number of grains per panicle	Grain yield per plant	Scoring for YSB

1	Plant 93	25.00	192.00	94.56	Highly Resistant
2	Plant 289	25.00	220.00	102.30	Highly Resistant
3	Plant 26	24.00	217.00	99.47	Highly Resistant
4	Plant 272	24.00	196.00	89.84	Highly Resistant
5	Plant 342	23.00	201.00	87.83	Highly Resistant
6	Plant 281	23.00	200.00	88.78	Highly Resistant
7	Plant 286	23.00	200.00	88.32	Highly Resistant
8	Plant 308	23.00	207.00	81.41	Highly Resistant
9	Plant 323	23.00	199.00	88.11	Resistant
10	Plant 297	23.00	212.00	91.66	Resistant
11	Plant 127	23.00	211.00	81.53	Resistant
12	Plant 120	23.00	196.00	81.59	Resistant
S. No	**Parents**	**Number of productive tillers per plant**	**Number of grains per panicle**	**Grain yield per plant**	**Scoring for YSB**
1	ADT 45	19.00	186.00	69.35	Highly Susceptible
2	TKM 6	12.00	137.00	22.07	Highly Resistant

Table 4. List of desirable transgressive segregants in F_2 population of the cross ADT 45 X ASD 12 along with their parents

S. No	F_2 plant number	Number of productive tillers per plant	Number of grains per panicle	Grain yield per plant	Scoring for YSB
1	Plant 59	25.00	199.00	89.35	Highly Resistant
2	Plant 70	25.00	212.00	94.65	Highly Resistant
3	Plant 339	25.00	197.00	92.24	Highly Resistant
4	Plant 263	25.00	220.00	90.97	Highly Resistant
5	Plant 276	25.00	203.00	86.07	Highly Resistant
6	Plant 331	25.00	219.00	91.15	Highly Resistant
7	Plant 343	25.00	203.00	90.99	Highly Resistant
8	Plant 208	25.00	218.00	89.97	Highly Resistant
9	Plant 138	24.00	222.00	94.67	Highly Resistant
10	Plant 305	24.00	209.00	88.48	Resistant
11	Plant 313	24.00	219.00	86.88	Resistant
12	Plant 300	23.00	228.00	89.88	Resistant
S. No	**Parents**	**Number of productive tillers per plant**	**Number of grains per panicle**	**Grain yield per plant**	**Scoring for YSB**
1	ADT 45	19.00	186.00	69.35	Susceptible
2	ASD 12	14.00	110.00	20.98	Highly Resistant

Table 5. List of desirable transgressive segregants in F_2 population of the cross ASD 16 X TKM 6 along with their parents

S. No	F_2 plant number	Number of productive tillers per plant	Number of grains per panicle	Grain yield per plant	Scoring for YSB

1	Plant 13	25.00	204.00	112.79	Highly Resistant
2	Plant 317	25.00	210.00	114.21	Highly Resistant
3	Plant 181	25.00	186.00	111.06	Highly Resistant
4	Plant 215	24.00	210.00	114.18	Highly Resistant
5	Plant 235	24.00	208.00	119.45	Highly Resistant
6	Plant 340	24.00	199.00	107.03	Highly Resistant
7	Plant 45	24.00	208.00	121.69	Highly Resistant
8	Plant 190	24.00	193.00	107.43	Highly Resistant
9	Plant 179	23.00	198.00	110.17	Highly Resistant
10	Plant 267	23.00	212.00	117.49	Highly Resistant
11	Plant 82	23.00	210.00	117.46	Highly Resistant
12	Plant 129	23.00	209.00	117.33	Highly Resistant
S. No	**Parents**	**Number of productive tillers per plant**	**Number of grains per panicle**	**Grain yield per plant**	**Scoring for YSB**
1	ASD 16	18.00	182.00	87.82	Susceptible
2	TKM 6	12.00	137.00	22.07	Highly Resistant

Table 6. List of desirable transgressive segregants in F_2 population of the cross ASD 16 X ASD 12 along with their parents

S. No	**F_2 plant number**	**Number of productive tillers per plant**	**Number of grains per panicle**	**Grain yield per plant**	**Scoring for YSB**
1	Plant 239	27.00	188.00	112.82	Highly Resistant
2	Plant 268	26.00	204.00	118.69	Highly Resistant
3	Plant 310	26.00	192.00	123.60	Highly Resistant
4	Plant 228	26.00	205.00	126.16	Highly Resistant
5	Plant 217	25.00	202.00	122.60	Highly Resistant
6	Plant 334	25.00	199.00	119.45	Highly Resistant
7	Plant 240	25.00	200.00	111.62	Highly Resistant
8	Plant 247	24.00	199.00	113.27	Highly Resistant
9	Plant 211	24.00	217.00	125.04	Highly Resistant
10	Plant 329	24.00	212.00	121.82	Highly Resistant
11	Plant 95	23.00	214.00	114.51	Highly Resistant
12	Plant 348	23.00	201.00	112.23	Highly Resistant
S. No	**Parents**	**Number of productive tillers per plant**	**Number of grains per panicle**	**Grain yield per plant**	**Scoring for YSB**
1	ASD 16	18.00	182.00	87.82	Susceptible
2	ASD 12	14.00	110.00	20.98	Highly Resistant

Plate 1. White ear head damage symptoms observed in F_2 generation of rice six crosses

ADT 43 X TKM 6 | ADT 43 X ASD 12 | ADT 45 X TKM 6 | ADT 45 X ASD 12 | ASD 16 X TKM 6 | ASD 16 X ASD 12

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