Transgressive Segregation for Yield and its Component Traits in Rice (*Oryza sativa* L.)

B. Reddyamini1*, K. Hariprasad Reddy1, V. Lakshmi Narayana Reddy1, P. Ramesh Babu1 and P. Sudhakar2

1Department of Genetics and Plant Breeding, S.V. Agricultural College, Tirupati, ANGRAU, AP, India
2Department of Crop Physiology, S.V. Agricultural College, Tirupati, ANGRAU, AP, India

*Corresponding author

**ABSTRACT**

Transgressive segregation produces hybrid progeny phenotypes that exceed the parental phenotypes. Unlike heterosis, extreme phenotypes caused by transgressive segregation are heritably stable. Maximum genetic variation in F2 generation provides the first opportunity for selection of individual plants, any one of which may end up into a new cultivar. F2 plants that surpassed the parental limits were observed in both the crosses for all the traits viz., plant height, number of panicles per plant, panicle length, number of grains per panicle, spikelet fertility, biomass per plant, grain yield per plant, harvest index and 1000 grain weight. High frequency of favourable transgressive segregants were observed for plant height and number of grains per panicle in the cross between BPT5204 and NLR33892, whereas BPT5204 x NLR33892 cross recorded higher number of desirable transgressive segregants spikelet fertility. Polygenic inheritance and high frequencies of favourable transgressive segregants for yield and its component traits indicates there is a lot of scope to bring in beneficial alleles into a single genotype through careful selection in later generations.

**Keywords**

Rice (*Oryza sativa* L.), Transgressive segregants

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**Introduction**

Rice (*Oryza sativa* L.) is the primary staple food in many countries and is one of the most important cereal crops grown all over the world. Globally, rice was occupying an area of an area of 162.97 million hectares with a production of 495.03 million tonnes and productivity of 4530 kg ha−1 in 2017-18 (World Agricultural Production, USDA, May 2019). During 2017-18, in India rice cultivation was done in an area of 42.95 million hectares with a production and productivity of 112.91 million tonnes and 2585 kg ha−1, respectively. In Andhra Pradesh, it is grown in an area of 2.15 million hectares with a production of 8.05 million tonnes and productivity of 3741 kg ha−1 (https://www.indiaagristat.com/). Current global yield increase rates (1.0% per year) of rice are insufficient to meet food demand for the estimated nine billion people in 2050.
Major constraints for productivity and sustainability of rice in the country are the inefficient use of inputs such as fertilizer, water and labour coupled with new emerging challenges from climate change, rising fuel prices, increasing cost of cultivation, and socioeconomic changes such as migration of labour, urbanization, least affected towards agricultural work by youth, and concern from environmental pollution. The only way to sustain rice production for meeting the increasing population demand is to increase the productivity per unit of area of rice with enhanced resource use efficiency.

The rice yield is a complex trait and is mainly determined by three key component traits viz., grain number per panicle, number of panicles per plant (productive tillers) and grain weight or grain size. Number of panicles is in turn dependent on the tillering ability including primary, secondary, and tertiary tillers per plant. Likewise, number of grains per panicle can also be relying on two subcomponents: number of spikelets per panicle and seed setting rate of the spikelets. Grain weight is largely determined by grain size, which is specified by its three grain dimensions (grain length, grain width, and grain thickness), and the degree of grain filling. These yield and its component traits are quantitatively inherited (Allard, 1960; Hallauer and Miranda, 1988) and controlled by many genes (Thoday, 1961) with small effects often regarded as Quantitative Trait Locus (QTL) (Geldermann, 1975).

Transgressive segregation is often observed for quantitative traits in the offspring of both intraspecific and interspecific hybrids. Transgressive segregation produces hybrid progeny phenotypes that are better than the parental phenotypes with respect to one or more characters. Transgressive segregation is often associated with recombinations, chromosome rearrangements, transposable element mobilization, DNA methylation and changes to gene expression. Success in obtaining the desired transgressive segregants depends on obtaining genetic recombination between both linked and unliked alleles (Briggs and Allard, 1953). F2 generation represents maximum genetic variation and provides the first opportunity for selection of individual plants, any one of which may end up into a new cultivar. Unlike F1 hybrid rice cultivation where farmers buy new seeds every cropping season, transgressive lines would be an inbred. The selection of these phenotypes in segregating hybrid populations may be a major source of novel adaptations in hybrids. Careful selection and identification of these phenotypes are of great contributions to increasing rice production.

Keeping in view of the importance of transgressive segregants, the present investigation was made to identify transgressive segregants for yield and yield attributes in F2 population of two crosses derived by crossing a popular semi-dwarf, high-yielding and fine grain variety with good cooking quality variety, Samba Mashuri (BPT5204) with Prabhat (MTU3626) having high grain weight and Pardhiva (NLR33892) with long panicle and high grain number per panicle.

Materials and Methods

The base material for the present investigation includes three high yielding varieties of rice viz., Samba Mashuri (BPT5204), Prabhat (MTU3626) and Pardhiva (NLR33892) which were used as parents to develop F2 populations. Varietal characteristics of parents were presented in Table 1 and Figure 1. During kharif, 2016 Samba Mashuri (BPT5204) was crossed with two male parents Prabhat (High grain weight) and Pardhiva (Large Panicle length and high grain
number) to develop F₁ seeds. F₁ plants of two crosses were selfed to produce F₂ seed in rabi, 2016-17. F₂ population of two crosses was evaluated phenotypically for yield and its components traits along with parents during kharif, 2017 at wetland farm, S. V. Agricultural College, Tirupati. Mature plants were harvested individually. Data was recorded on yield and yield attributed viz., plant height, number of panicles per plant, panicle length, number of grains per panicle, spikelet fertility, biomass per plant, grain yield per plant, harvest index and 1000 grain weight in 280 randomly selected F₂ plants in each cross and 30 plants in each parent.

In the present study, transgressive segregants were identified by finding the number of plants exceeding mean value of the higher parent or lagging behind the mean value of the lower parent by critical difference at 5 percent level.

Results and Discussion

Transgressive segregation produces hybrid progeny phenotypes that are superior to the parental phenotypes. Such plants are produced by accumulation of favourable genes from both the parents as a consequence of segregation and recombination. Unlike heterosis, extreme phenotypes caused by transgressive segregation are heritably stable. Kshirsagar et al., 2013 suggested that transgressive segregation can be exploited for development of genotypes with positive characters from both the parents. Transgressive segregants for yield and its component traits in F₂ population of the crosses BPT5204 x MTU3626 and BPT5204 x NLR33892 were presented in Table 2 and 3, respectively. The F₂ mean value was in-between the parents for all the characters except for harvest index in BPT5204 x MTU3626 and for all the traits in BPT5204 x NLR33892 cross. In both the crosses wide range of phenotypes were observed for all the characters in the F₂. This clearly suggests that all traits were governed by many genes and alleles governing these traits seem to act in additive manner showing polygenic inheritance. High variability for number of tillers, biological yield and grain yield in F₂ populations of rice was reported by Balat et al., 2018, Kiran et al., 2012 and Ratnakar et al., 2012.

F₂ plants that surpassed the parental limits were observed in both the crosses for all the traits viz., plant height, number of panicles per plant, panicle length, number of grains per panicle, spikelet fertility, biomass per plant, grain yield per plant, harvest index and 1000 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 Basmati370 x Jaya F₂ population. This clearly indicates that the parents had different alleles and genes governing yield and its component traits. Hence, there is a lot of scope to bring in beneficial alleles into a single genotype through rigorous selection in later generations for yield and yield attributes. High frequency of favourable transgressive segregants were observed for plant height and number of grains per panicle in the cross between BPT5204 and NLR33892, whereas BPT5204 x NLR33892 cross recorded higher number of desirable transgressive segregants spikelet fertility. Transgressive segregants with lower value than lowest parent were high in number of panicles per plant, panicle length, spikelet fertility, biomass per plant, grain yield per plant and harvest index for the cross between BPT5204 and MTU3626. In BPT5204 x NLR33892 cross, number of panicles per plant, biomass per plant, grain yield per plant and harvest index recorded higher number of lowest value transgressive segregants.
### Table 1: Salient Features of Parents used in developing F$_2$ populations

| S. No. | Variety                  | Pedigree                  | Duration | Thousand Grain Weight (g) | Year of release | Characters                                                                                                                                 |
|--------|--------------------------|---------------------------|----------|---------------------------|-----------------|------------------------------------------------------------------------------------------------------------------------------------------|
| 1      | SambaMashuri (BPT5204)   | (GEB24xTN-1) x Mahsuri    | 140-145 days | 13                        | 1986, Bapatla, A.P., India | Medium slender grains, non-lodging open type canopy with dark green erect short leaves. Fine grain variety with excellent cooking quality. Susceptible to blast and bacterial leaf blight. |
| 2      | Prabhat (MTU3626)        | IRB x MTU 3               | 130-135 days | 28                        | 1976, RARS, Maruteru   | Bold seeded high yielding variety. Non lodging, suitable for direct seeding and suitable for parboiled rice.                                |
| 3      | Pardhiva (NLR33892)      | Tikkana x MTU 4870        | 155-160 days | 17                        | 2007 ARS, Nellore  | Long duration, highly Photosensitive variety with 28cm panicle length and around 350-400 grains per panicle. Resistant to blast.           |

### Table 2: Transgressive segregants for yield and its component traits in F$_2$ population of the cross between BPT 5204 and MTU 3626

| Trait                        | F$_2$ Generation of BPT 5204 X MTU 3626 cross | Parents | No. of Transgressive Segregants |
|------------------------------|----------------------------------------------|---------|---------------------------------|
|                              | Total No. of Plants Scored | Mean | Highest Plant Value | Lowest Plant Value | BPT5204 | MTU3626 | Higher than Highest Parent | Lower Than Lowest Parent |
| Plant height (cm)            | 280                          | 95   | 119                          | 71                | 95.17   | 88.17   | 103                         | 73                         |
| Number of panicles per plant| 280                          | 7.05 | 23                           | 2                 | 9.53    | 7.17    | 25                          | 203                        |
| Panicle length (cm)          | 280                          | 24.11 | 30                           | 17                | 24.52   | 26.53   | 19                          | 188                        |
| Number of grains per panicle | 280                          | 243.30 | 420                          | 93                | 234.19  | 194.3   | 102                         | 86                         |
| Spikelet fertility (%)       | 280                          | 68.48 | 96.15                        | 4.55              | 87.99   | 85.13   | 9                           | 253                        |
| Biomass per plant (g/plant)  | 280                          | 43.72 | 130.9                        | 12.3              | 48.02   | 35.1    | 50                          | 142                        |
| Seed yield per plant (g/plant)| 280                        | 16.48 | 90.6                         | 1.51              | 22.4    | 15.6    | 18                          | 234                        |
| Harvest index (%)            | 280                          | 39.19 | 75.97                        | 5.67              | 46.72   | 44.51   | 35                          | 237                        |
| 1000 grain weight (g)        | 280                          | 25.89 | 33                           | 12                | 13.23   | 29.2    | 2                           | 3                          |
Table 3: Transgressive segregants for yield and its component traits in F2 population of the cross between BPT 5204 and NLR33892

| Trait                              | F2 Generation of BPT 5204 X MTU 3626 cross | Parents                      | No. of Transgressive Segregants |
|------------------------------------|--------------------------------------------|-------------------------------|---------------------------------|
|                                    | Total No. of Plants Scored                  | Mean                          | Highest Plant Value | Lowest Plant Value | BPT5204 | NLR33892 | Higher than Highest Parent | Lower Than Lowest Parent |
| Plant height (cm)                  | 280                                         | 110.48                        | 140               | 70                 | 95.17    | 137.85    | 2                              | 32                         |
| Number of panicles per plant       | 280                                         | 6.17                          | 20                | 2                  | 9.53     | 7.53      | 33                             | 220                        |
| Panicle length (cm)                | 280                                         | 25.82                         | 32                | 18                 | 24.52    | 29.23     | 20                             | 75                         |
| Number of grains per panicle       | 280                                         | 310.10                        | 582               | 125                | 234.19   | 389.37    | 27                             | 46                         |
| Spikelet fertility (%)             | 280                                         | 85.23                         | 92.44             | 63.87              | 87.99    | 83.79     | 87                             | 85                         |
| Biomass per plant (g/plant)        | 280                                         | 41.84                         | 103.4             | 17.6               | 48.02    | 64.24     | 24                             | 196                        |
| Seed yield per plant (g/plant)     | 280                                         | 15.44                         | 40                | 4.9                | 22.4     | 24.9      | 20                             | 252                        |
| Harvest index (%)                  | 280                                         | 36.45                         | 62.01             | 18.37              | 46.72    | 38.65     | 17                             | 163                        |
| 1000 grain weight (g)              | 280                                         | 14.77                         | 18                | 12                 | 13.23    | 17.23     | 38                             | 71                         |

Fig. 1: Variation in panicle characters of parents and their F1s of BPT5204 x MTU3626 and BPT5204 x NLR33892 crosses
Occurrence of such transgressions is possibly due to accumulation of complementary alleles from both the parents at multiple loci in certain F2 population (Tanksley, 1993) and unmasking of recessive deleterious alleles due to inbreeding (Rick and Smith 1953).

Polygenic inheritance and high frequencies of favourable transgressive segregants for yield and its component traits indicates there is a lot of scope to bring in beneficial alleles into a single genotype through careful selection in later generations and identification of plants with many desirable traits are of great contributions to increasing rice production.

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