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Evaluation of back cross inbred lines for grain shattering and yield related traits in Rice (*Oryza sativa* L.)

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Abstract
Rice is the staple food in the majority of Asian countries in general and India in particular. Current rice acreage faces a lot of difficulties rising from urbanization and climate change. In India rice is an important food crop cultivated majorly in kharif season. Biotic and abiotic stresses are major constraints in rice production. Apart from these stresses, physiological traits like high grain shattering is also a contributor to the problems faced by farmers. Grain shattering causes significant yield loss in the mega variety MTU1010. Hence, introgression of low grain shattering QTLs/genes into mega variety MTU 1010 is highly necessary. JGL17004, a high yielding low grain shattering variety was selected as donor parent. Eight four backcross inbred lines in BC_2F_8 generation were developed from the cross MTU1010/JGL17004. Phenotyping of BILs for low grain shattering and yield traits was undertaken in the present study. Out of 84 BILs, 54 lines showed low grain shattering, 20 lines showed moderate shattering and 10 lines showed high grain shattering. Recurrent parent showed more shattering percentage than JGL17004. The mean of BILs was in between the parent for most of the traits *viz.*, Sh, DFF, PL, SF, GYPP and TW. ANOVA for augmented RBD showed that phenotyping data was significant for all the traits. The BILs 55 and 53 recorded a low shattering of 1.52% and 0.34% respectively with a high grain yield per plant (35.7 g and 33.8 g respectively).

Keywords: Rice, grain shattering, yield, backcross inbred lines (BILs)

Introduction
Rice (*Oryza sativa* L.) is the most important food crops cultivated alround the globe and is the staple food for more than half of the world's population. India ranks second in area among the rice-producing countries in the world, but the productivity is low compared to other countries like China, Thailand etc. The major reason for low productivity in the country is due to abiotic and biotic stresses. Andhra Pradesh is one of the major rice producing states of the country with a total area of 23 lakh ha and production of 86.58 lakh tonnes. Total productivity of the state was 3765 kg/ha (Indiastat 2020) [6].

While biotic stresses are major obstacles for crop production, abiotic stresses are equally damaging. Apart from biotic/abiotic stresses, high shattering in certain varieties can cause heavy losses. So, varieties with high shattering percentage are not preferred by most of the farmers. Mega variety CottondoraSannalu (MTU-1010) was released from RARS, Maruteru in 1999 with the parentage MTU2067/IR 64. It has a duration of 120 days, with an average yield of 6.0-6.5 t/ha. It has long slender grain type. It also has special features like semi dwarf stature, resistant to blast and tolerant to BPH. It has wide adaptability and cultivated in many states of the country. But the yield losses with grain shattering makes it less favorable. So, there is a lot of promise for introgression of low grain shattering genes to MTU1010. So in this present investigation we have undertaken phenotyping BIL population (MTU 1010 / JGL17004) in BC_2F_8 generation for low grain shattering and yield traits.

Material and Methods
The BIL population derived from MTU1010 and JGL17004 was evaluated in *kharif* 2020 at RARS Maruteru, Andhra Pradesh, India. The field experiment was conducted in augmented design. Each BIL was transplanted in 4 rows with 4.5 m length and a spacing of 20 x 15 cm. All the standard package of practices were followed. Observations on 10 traits *viz.*, score for grain shattering (Sh), plant height (PHt), days to fifty percent flowering (DFF), number of ear bearing tillers per plant(EBT), panicle length (PL), number of filled grains per panicle (FG), number of unfilled grains per panicle (UFG), spikelet fertility (SF), grain yield per plant (GYPP) and test weight (TW) were recorded.

For measuring grain shattering five mother panicles were collected at physiological maturity. The initial weight was recorded. These panicles were dropped from uniform height and some of the grains shattered. Again the weight of panicles was measured after shattering. Then the shattering % was computed. The percentage was estimated with the following formula.

$$\text{\% of Grain shattering} = \frac{\text{Wt. before shattering} - \text{Wt. after shattering}}{\text{Wt. before shattering}} \times 100$$

The shattering types are categorized as low, medium and high (Low - <5%, Medium- 5 to 10%, and High- >10%).
For all the traits, data on five plants was recorded except DFF which was recorded on plot basis. The height of plant from the ground to the tip of the tallest panicle (awn excluded) was recorded as plant height in cm. Days to 50 per cent flowering was calculated as the number of days, at which 50 percent of the plants in the plot flowered. For ear bearing tillers per plant, the panicle bearing tillers per plant were counted at maturity. Length of the primary panicle from the panicle base to tip was measured to record panicle length in cm. The number of filled grains in a single panicle was counted and was recorded as total number of filled grains per panicle. Meanwhile, the number of unfilled grains in a single panicle was counted and was recorded as total number of unfilled grains per panicle.
Spikelet fertility was obtained from the ratio of filled grains to the total number of grains and expressed as percentage. Spikelet fertility was computed by using the formula as given below.

$$\text{Spikelet fertility} = \frac{\text{Total number of filled grains}}{\text{Total number of grains}} \text{X100}$$

When the plants are at physiological maturity all the plants were harvested in the plot and the grain yield per plant was recorded. Weight of 1000 well developed grains (test weight) at 12-14 percent moisture content was weighed using an electronic balance and recorded in g as test weight.
The data recorded in the present study was subjected to Analysis of variance for investigating genetic differences within the BIL population. The collected data on the above-mentioned characters were subjected to Analysis of Variance (ANOVA) using augmented RBD analysis.

Results and Discussion

The mean phenotypic performance of the BILs was presented in Table 1. The summary of Augmented RBD ANOVA was presented in Table 2.

Score for grain shattering (Sh)

Based on the shattering score, out of 84 BILs fifty four lines showed low grain shattering (<5%). Twenty lines showed moderate shattering between 5 to 10%. Ten lines showed high shattering (>10%). The line BIL30 showed the lowest shattering of 0.11% while the line BIL124 showed the highest shattering of 27.69%. The BIL mean was 4.58%. Recurrent parent MTU1010 recorded 14.05% shattering while, the donor parent JGL 17004 exhibited 1.61%. The results were in conformity with Cai and Morishima (2000) [3] whose findings reported that the parent W 19444 has high shattering when compared with the other parent Pei-kuh. The results were in conformity with Tsujimura *et al.* (2019) [8] who reported significant differences were observed for shattering data in the F_2 population obtained from a cross between Nipponbare and *O. rufipogon*W630.

Plant height (PHt)

The mean plant height of MTU 1010 was 104.4 cm and JGL 17004 was 95.5 cm. The mean plant height in BIL was 110.5 cm. The plant height varied from 135.8 cm (BIL90) to 85.4 cm (BIL9) in the lines. Most BILs recorded a higher value than the parents. The donor parent recorded less height than the recurrent parent. Bres-patry *et al.* (2001) [1] reported plant height was significant in DH population generated from anther culture of F_1 derived from a cross between temperate *japonica* variety Miara and C6, a variety with high shedding.

Days to 50 per cent flowering (DFF)

Most BILs recorded days to 50 per cent flowering lesser than the donor parent while a few BILs have recorded higher than the recurrent parent. The mean value for days to 50 per cent flowering was 91.77 days in BILs. MTU1010 was late with 94 days to reach 50 per cent flowering whereas JGL 17004 was early with 88 days. BIL 53 and BIL 73 took 112 days for 50% flowering which was the highest whereas BIL 8, BIL 45 and BIL 49 recorded 76 days which was much lower than the parents.

Table 1: Mean phenotypic performance of BILs along their parents

Trait name	MTU1010	JGL17004	BIL mean	BIL range	SD
Sh	14.05	1.61	4.58	0.11-27.69	4.82
Pht	104.4	95.5	110.5	85.4-135.8	10.25
DFF	94	88	91.77	76-112	10.16
EBT	7.4	6.7	8.55	6.20-12.40	1.08
PL	25.8	20.5	23.08	19.00-28.94	1.87
FG	172	125	92.20	44-204	30.48
UFG	18	17	20.96	4-52	11.21
SF	90.53	88.03	81.19	47.83-96.23	9.38
GYPP	16.9	12.2	16.23	6.24-35.71	5.59
TW	23.6	21.4	22.88	15.95-27.34	1.94

Sh, Score for grain shattering; PHt, Plant height; DFF, Days to 50 per cent flowering; EBT, Number of ear bearing tillers per plant; PL, Panicle length; FG, Number of filled grains per panicle; UFG, Number of unfilled grains per panicle; SF, Spikelet fertility; GYPP, Grain yield per plant; TW, Test weight.

Number of Ear bearing tillers per plant (EBT)

MTU 1010 recorded 7.4 ear bearing tillers per plant while JGL 17004 recorded 6.7 ear bearing tillers per plant. BIL159 showed the highest number (12.4) of ear bearing tillers per plant while, BIL2 showed the lowest (6.2) ear bearing tillers per plant. The mean value for BILs was 8.55. A majority of the BILs seem to have recorded more ear bearing tillers than the recurrent parent. The results were in agreement with Rani *et al.* (2013) [5] who reported a mean value of 8.7 ear bearing tillers per plantin the advanced backcross lines of BPT5204.

Panicle length (PL)

The lowest panicle length was recorded in the line BIL170 (19.0 cm) while the highest panicle length (28.9 cm)was recorded in BIL90. The mean value of panicle length was 23.08 cm in BILs. MTU1010 had the long panicle (25.8 cm) which was more than that of the JGL17004 (20.5 cm). Most of the BILs along with donor parent have showed lesser panicle length than the recurrent parent. Rani *et al.* (2013) [5] also reported similar findings with a mean value of 23.7 cm panicle length in the advanced backcross lines of BPT 5204.

Number of filled grains per panicle (FG)

The number of filled grains/panicle in MTU1010 was 172 whereas JGL17004 had 125 grains per panicle. BILs showed lesser number of filled grains compared to both the parents. BIL55 recorded 204 filled grains per panicle which was the highest among the BILs while, BIL119 showed only 44 filled grains per panicle which was the least in the population. Mean value of filled grains was 92.20. The results were in conformity with Kulkarni *et al.* (2020) [4] who reported that KMR-3R had more filled grains per panicle (320) in comparision with the other parent IR58025B (251).

Number of unfilled grains per panicle (UFG)

Number of unfilled grains/panicle in BILs ranged from 4 in BIL62 to 52 in BIL1 with a mean of 20.96. The number of unfilled grains in MTU 1010 was 18 and was 17 in JGL 17004. The number of unfilled grains in both the parents was almost the same. The results were in agreement with Sahu *et al.* (2017) [6]who reported unfilled grains per panicle ranged from 4 to 131 in 45 F_3 lines generated from a cross of Swarna x IR 86931-B-6. Buu *et al.* (2014) [2] reported that ANOVA for number of unfilled grains was significant in BC_2F_2 lines derived from the cross of OM5930/N22.

Spikelet fertility (SF)

Spikelet fertility of 90.53% was recorded in MTU 1010 while it was 88.03% in JGL 17004. Even though the number of filled grains/panicle varied between parents but the spikelet fertility was very close to each other. The highest percentage of spikelet fertility among the BILs was observed in BIL 55 (96.23%). The lowest spikelet fertility was shown by BIL119 with 47.83 percentage. Mean value of spikelet fertility in BILs was 81.19 per cent. The results were in conformity with Rani *et al.* (2013) [5] whose findings showed that the spikelet fertility ranged between 42 to 90.7% in the advanced backross lines.

Grain yield per plant (GYPP)

Grain yield per plant in BILs varied from 6.24 g in BIL159 to 35.7g in BIL55 while the mean value of BILs was 16.23 g. The recurrent parent MTU 1010 had a grain yield of 16.9 g while it was 12.2 g in JGL 17004.

Test weight (TW)

MTU 1010 recorded a test weight of 23.6 g while JGL 17004 recorded 21.4 g. Test weight of BIL6 was 27.3 g which was the highest while, BIL73 showed the test weight of 16.0 g which was the lowest. Mean value for BILs was 22.88 g. Most BILs recorded lower test weight than recurrent parent. These results were in conformity with Kulkarni *et al.* (2020) [4] who reported a mean test weight of 21.41g in RILs generated from IR58025B/KMR-3R.

Table 2: Analysis of Variance for Augmented R.B.D in BIL population

	DF	**Shattering (%)**	**Plant height (cm)**	**Days to 50% flowering**	**Ear bearing tillers per plant**	**Panicle length (cm)**	**Number of filled grains per panicle**	**Number of unfilled grains per panicle**	**Spikelet fertility (%)**	**Grain yield per plant (g)**	**Test weight (g)**
Block (ignoring Treatments)	3.00	12.49	859.19**	694.42**	1.73***	3.67	6487.11***	335.75**	692.39***	114.51***	10.45***
Treatment (eliminating Blocks)	85.00	27.11*	85.45*	78.77*	1.31***	4.026*	1019.01**	113.43*	68.89**	27.71**	3.43**
Checks	1.00	309.51**	158.42 *	84.50*	0.98**	57.78**	4512.50 ***	3.13	10.77	46.08 **	9.03**
Checks + Varvs. Var.	84.00	23.75*	84.58*	78.70*	1.31***	3.39	977.44**	114.74 *	69.58**	27.49 **	3.36**
Error	3.00	2.57	8.03	7.50	0.01	0.42	21.50	10.46	2.37	0.37	0.06
Block (eliminating Check + Var.)	3.00	2.07	10.47	7.67	0.07*	0.17	7.00	1.46	0.45	0.13	0.00
Entries (ignoring Blocks)	85.00	27.47*	115.41*	103.01*	1.36 ***	4.150*	1247.74**	125.21*	93.32**	31.75**	3.81**
Checks	1.00	309.51**	158.42*	84.50 *	0.98 **	57.78**	4512.50***	3.13	10.77	46.08**	9.03**
Varieties	83.00	23.48*	106.41*	104.42*	1.17 ***	3.55	939.89**	126.92*	89.28**	31.71**	3.77**
Checks vs. Varieties	1.00	77.19*	819.61**	4.37	17.44***	0.02	23533.98***	107.00 *	510.01***	20.84**	1.01*
Error	3.00	2.57	8.03	7.50	0.01	0.42	21.50	10.46	2.37	0.37	0.06
Ci - Cj	1.00	3.61	6.38	6.16	0.18	1.46	10.43	7.28	3.47	1.38	0.57
BiVi - BiVj	1.00	7.21	12.75	12.33	0.37	2.92	20.87	14.56	6.93	2.75	1.14
BiVi - BjVj	1.00	8.84	15.62	15.10	0.45	3.58	25.56	17.83	8.49	3.37	1.40
Ci - VI	1.00	6.99	12.35	11.93	0.36	2.83	20.20	14.09	6.71	2.66	1.10

*-significant at $P < 0.05$; **- significant at $P < 0.01$; ***-significant at $P < 0.001$

The analysis of variance (ANOVA) of the BIL population evaluated in Augumented RBD (Table 2) and the summary showed that the values were significant for most of the traits at $P < 0.05$ and $P < 0.01$ which indicated considerable variation among the BILs.

Conclusion

In the recurrent parent MTU1010 high grain shattering is the major constraint and there is a dire need to develop varieties with MTU 1010 grain type coupled with low grain shattering. So, the present study was taken to introgress low grain shattering QTLs/genes into meag variety MTU 1010. JGL17004 which has very low grain shattering was taken as donor parent. Eighty four BILs were generated from the cross of MTU1010/JGL17004 showed considerable variation for grain shattering and yield traits. The BILs with low grain shattering can be further evaluated and can be promoted to yield trials. The BILs can be useful for further studies in fine mapping of the low grain shattering trait.

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