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TRANSGRESSIVE SEGREGANTS IN BARLEY (*HORDEUM VULGARE L.*)

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ABSTRACT

The present research work was carried out to estimate transgressive segregants in barley (*Hordeum vulgare* L.) among 29 genotypes (20 crosses along with 9 parents) of barley for ten agronomical characters. These genotypes were sown in randomized block design with three replications during rabi, 2022. Transgressive segregants in desirable directions were reported for all the characters in the F₂ generation of four crosses (RD 2508 x BCLA 11-6, RD 2552 x BCLA 11-6, RD 2660 x RD 3005, RD 2715 x BH 1025). In general, the highest proportion of transgressive segregants was recorded for grains per spike followed by grain yield per plant, plant height, tillers per plant, harvest index, chlorophyll content, and 1000-grain weight. Based on the performance of transgressive segregants, it was concluded that when the desired intensity of a character is not available in the parents, transgressive breeding can be successfully used to extend the limit of expression of character. This could be possible by accumulating favourable plus genes in hybrid derivatives from both the parents involved in hybridization. In most of the transgressive segregants, in each of the four crosses, better parent yield was transgressed simultaneously with the transgression of one or several other characters. Simultaneous transgression of the grain yield per plant in association with the grains per spike, tillers per plant, spike length, 1000-grain weight and chlorophyll content were observed more frequently and it was concluded that grain yield per plant was dependent on these characters. The most promising transgressive segregants viz. plant number 88 of RD 2508 x BCLA 11-6, plant number 65 and 88 of RD 2660 x RD 3005, plant number 52, 54 and 55 of RD 2715 x BH 1025 and plant number 68 of RD 2552 x BCLA 11-6 transgressed for grain yield per plant in addition to the higher expression of other five characters than the better parent. These transgressants need to be evaluated further for maintaining consistency in their performance. If they are superior in further generations, they may be identified as improved varieties after adequate evaluation or used in future breeding programmes for amalgamation of desired genetic constellations.

Keywords : Transgressive segregants, Barley, Genotypes, Grain yield per plant.

Introduction

Barley (*Hordeum vulgare* L., $2n = 2x = 14$) is the world's fourth most important cereal crop after wheat, maize and rice belongs to the Poaceae family. Barley, also known as "Jau" in Hindi, is one of India's most indispensable cereal grain crop. In India, it is grown mostly as a rabi season crop, with sowing taking place from October to December and harvesting taking place from March to May. Barley is most paramount cereal crop and considered as the first cereal domesticated for use by man as food and feed (Potla *et al.*, 2013). At the time of growing stage, it demands temperatures of 12°C to 16°C and at the time of maturity, temperatures of 30°C to 32°C. It is extremely sensitive to frost at

any stage of development and has a high-capacity tolerance for dryness. Barley is usually grown on marginal to sub-marginal terrain and in rainy conditions. It is a crucial crop of Northern region of India and among three major groups of barley viz., two-row barley, four-row barley, six-row barley and husk and husk-less barley are available. In India, barley research has initiated with the development of new cultivars for various uses in different industries. It is an economically important crop plant, the fourth cereal worldwide in terms of the planting area, utilized almost 60 per cent as animal feed, around 30 per cent for malt production, 7 per cent for seed production and only 3 per cent for human food (Baik *et al.*, 2008).

Transgressive segregants are produced in F₂ population by accumulation of favourable genes from the parents involved in hybridization. The studies on transgressive segregants also help to find out their proportions for various yield contributing characters and these characters having high variability and heritability, will be highly useful in population development and other breeding programs. The main objective of present investigation was made to identify transgressive segregants for yield and yield attributes in F₂ population of 20 crosses derived by crossing a different 9 genotypes of barley.

Materials and Methods

The present study was conducted during Rabi, 2022 at Instructional Farm, S.K.N College of Agriculture, Jobner, India. The experimental plot is situated at 26.9706°N latitude, 75.3791°E longitude and at an elevation of 400 meters above mean sea level in agro climatic zone III A (semi-arid eastern plain zone) in Rajasthan. The climate of the zone is typically semi-arid which is characterized by extreme of the temperature in both summer and winter with aridity of atmosphere and salinity of rhizosphere. The temperature shoots to as high as 48°C during summer while it cascades below freezing point during winter. The average rainfall of the locality is about 400 mm, which is mostly received during July to September. Weather parameters play an important role in affecting plant growth and development of the crop.

The experimental material consisting of 29 entries involving 9 parents and their 20 F₂s was sown in a randomized block design (RBD) consisting of three replications during rabi, 2022 and only 4 best crosses is analyzing for transgressive segregants. Each cross was sown in 2 rows and row length was 3 meters. The inter and intra row spacing's was followed 20 cm and 10 cm, respectively. Table 1 presents the genotype information which is available in the Department of Plant Breeding and Genetics, S.K.N. College of Agriculture.

Table 1: List of Genotype/ variety of Barley (*Hordeum vulgare* L.)

S. No.	Details of the parents
1	RD 2508
2	RD 2552
3	RD 2592
4	RD 2660
5	RD 2715
6	BH 1025
7	BCLA 11-6
8	RD 3005
9	RD 3002

	Details of the F ₂ s
10	RD 2508 X BH 1025
11	RD 2508 X BCLA 11-6
12	RD 2508 X RD 3005
13	RD 2508 X RD 3002
14	RD 2552 X BH 1025
15	RD 2552 X BCLA 11-6
16	RD 2552 X RD 3005
17	RD 2552 X RD 3002
18	RD 2592 X BH 1025
19	RD 2592 X BCLA 11-6
20	RD 2592 X RD 3005
21	RD 2592 X RD 3002
22	RD 2660 X BH 1025
23	RD 2660 X BCLA 11-6
24	RD 2660 X RD 3005
25	RD 2660 X RD 3002
26	RD 2715 X BH 1025
27	RD 2715 X BCLA 11-6
28	RD 2715 X RD 3005
29	RD 2715 X RD 3002
19	RD 2592 X BCLA 11-6
20	RD 2592 X RD 3005
21	RD 2592 X RD 3002
22	RD 2660 X BH 1025
23	RD 2660 X BCLA 11-6
24	RD 2660 X RD 3005
25	RD 2660 X RD 3002
26	RD 2715 X BH 1025
27	RD 2715 X BCLA 11-6
28	RD 2715 X RD 3005
29	RD 2715 X RD 3002

Using mean data, the analysis of variance for different traits was performed to evaluate the variability among genotypes as reported by Panse and Sukhatme (1985). Burton's formula (1952) was used to calculate the amount of phenotypic co-efficient of variation (PCV) and genotypic co-efficient of variation (GCV) present in a trait. The Johnson *et al.* (1955) approach is used to calculate the genotypic and phenotypic variances. Broad sense heritability is calculated using the method established by Hanson *et al.* (1956) and Johnson *et al.* (1955). Limiting value: The limiting normal deviation (N. D) value was calculated as given below (Panse and Sukhatme, 1985).

Results and Discussion

Transgressive segregation analysis

Out of 20 F₂'s, only 4 F₂'s *i.e.* RD 2508 x BCLA 11-6, RD 2552 x BCLA 11-6, RD 2660 x RD 3005 and RD 2715 x BH 1025 were selected on the basis of high number of transgressive segregants found in the present study and high GCA effect for most of the parents in previous study (Line × Tester analysis for yield and yield attributes in Barley, *Hordeum vulgare*

(L.) Anurag Badoliya 2022). Frequency distribution and percentage of desirable transgressive segregants described for all the characters, individually and for combination of contributing characters along with yield, have been disclosed separately for F₂'s of each of the four crosses viz., RD 2508 x BCLA 11-6, RD 2552 x BCLA 11-6, RD 2660 x RD 3005 and RD 2715 x BH 1025. The results of each cross were revealed separately.

The occurrence of transgressive segregants in segregating generation due to accumulation of favourable alleles by means of segregation and recombination, from the parent involved in the parents. Now transgressive breeding can be used as a positive tool in plant breeding. Transgressive segregant is the progeny from a hybrid, which exceeds either of the two parents of the hybrid with respect to one or more characters. Success in obtaining the desired transgressive segregants depends on genetic recombination between linked and unlinked alleles (Briggs and Allard, 1953). Gardner (1968) also suggested that parents do not represent the extremes in terms of intensities of desired characters. Smith (1966) suggested that to have a reasonable chance of getting transgressive segregants, parents should have favourable expressions of the desirable characters and be somewhat distantly related so that different sets of genes may control the desired character in two parents. These crosses were selected based on a high number of transgressive segregants among 20 crosses and high GCA effect for most of the parents in previous study (Anurag Badoliya, 2022).

Transgressive segregants of RD 2508 X BCLA 11-6 for different characters in barley

In terms of plant height, the parent RD 2508 (71.2 cm) was dwarf, but the parent BCLA 11-6 (85.64 cm) was tall. The average plant height in the F₂ segregating generation was 84.25 cm (Table 2). In the F₂ generation, the transgressive segregants for plant height were 27.78 per cent with a range of 87.10 to 93.60 cm. The threshold value for plant height was 86.97 (Table 3). Data presented in Table 2, the superior parent, BCLA 11-6 (11.2cm) had higher tillers per plant and 10.31 mean value in the F₂ generation. The percentage transgressant for this trait in the F₂ generation was 25.56 per cent with a range of 13 to 14. The threshold value for tillers per plant was 12.71 (Table 3).

Out of the two parental lines, RD 2508 and BCLA 11-6 recorded 48.87 and 67.99 grains per spike, respectively. In the F₂ progeny, the average number of grains per spike was 66.9. The transgressive segregations in F₂ generation for grains per spike were 35.56 per cent (Table 2). The threshold value for this trait was 69.44 (Table 3). The average spike length in the parent RD 2508 and BCLA 11-6 was 8.67 and 8.62 cm, respectively, as shown in Table 2. The average spike length was 8.59 cm in the F₂ generation. The transgressive segregants in F₂ were found 22.22 per cent with a range of 9.50 to 10.20 cm. The threshold value for spike length was 9.41 (Table 3).

Table 2: Means, Standard deviations, frequency distribution and percentage of desirable transgressive segregants (T.S.) in F₂ generations of the cross RD 2508 X BCLA11-6

S. No.	Generations	Mean ± S.E	S.D.	Frequency distribution in standard deviation units											Total Plants	N.D. value	Desirable T.G. %
				-5	-4	-3	-2	-1	0	1	2	3	4	5			
1. Plant height (cm)																	
	RD 2508 (-)	71.20±0.1	0.54	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BCLA 11-6 (+)	85.64±0.12	0.68	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	84.25±0.34	3.23	0	1	0	0	30	34	23	1	1	0	0	90	60.89	27.78
2. Tillers per plant																	
	RD 2508 (-)	10.77±0.18	0.99	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BCLA 11-6 (+)	11.20±0.13	0.70	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	10.31±0.07	0.70	1	0	3	15	0	38	0	0	0	20	3	90	-2.02	25.5
3 Grains per spike																	
	RD 2508 (-)	48.87±0.15	0.82	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BCLA 11-6 (+)	67.99±0.14	0.74	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	66.90±0.59	5.63	0	0	0	6	27	25	29	3	0	0	0	90	57.56	35.56
4. Spike length (cm)																	
	RD 2508 (+)	8.67±0.07	0.38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BCLA 11-6 (-)	8.62±0.1	0.53	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	8.59±0.06	0.53	0	1	0	6	25	38	0	18	2	0	0	90	-6.79	22.22
5. 1000-grain weight (g)																	
	RD 2508 (-)	32.95±0.16	0.85	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BCLA 11-6 (+)	40.02±0.14	0.79	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	39.16±0.08	0.79	0	0	4	8	27	33	0	0	7	10	1	90	-14.95	20.00
6. Chlorophyll content (SPAD)																	
	RD 2508 (+)	54.35±0.1	0.53	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BCLA 11-6 (-)	50.21±0.15	0.82	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	52.93±0.09	0.82	0	1	10	17	26	14	0	0	2	11	9	90	-9.16	24.44
7. Harvest index (%)																	
	RD 2508 (+)	39.00±0.06	0.32	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BCLA 11-6 (-)	34.74±0.12	0.68	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	38.57±0.07	0.68	0	0	5	11	29	21	0	13	6	4	1	90	-17.09	26.67
8. Grain yield per plant (g)																	
	RD 2508 (+)	27.26±0.06	0.35	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BCLA 11-6 (-)	20.98±0.16	0.85	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	27.17±0.09	0.85	0	2	4	15	23	14	11	13	6	0	2	90	-4.02	35.56

Table 2 showed that the average 1000-grain weight in RD 2508 and BCLA 11-6 was 32.95 and 40.02 g, respectively. In the segregating generation, the mean of 1000-grain weight was 39.16 g. The transgressive segregants in F₂ ranged from 41.70 to 43 g. The desirable transgressive segregants was 20 per cent. The 1000-grain weight threshold value was 41.57 (Table 3). Data presented in table 2 reveals that the average chlorophyll content of RD 2508 and BCLA 11-6 were 54.35 and 50.21, respectively. In F₂ segregating population the average chlorophyll content was 52.93. The transgressive segregants in F₂ in terms of more chlorophyll content than superior parent were 24.44 per cent with a range of 56.60 to 57. Threshold value for chlorophyll content was 55.39 (Table 3).

Data presented in table 2, reveals that the harvest index of RD 2508 and BCLA 11-6 were 39.00 and 34.74, respectively. In F₂ segregating generation the harvest index was 38.57. The transgressive segregants in F₂ in terms of more harvest index than exceeding parent were 26.67 per cent with a range of 39.70 to 42.00. Threshold value for harvest index was 39.63

Data represented in Table 2, evoked that the mean value for grain yield per plant in the RD 2508 greater parent was 27.26 g, and in the F₂ generation, it was 27.17 g. The percentage of transgressants for grain yield per plant was 35.56 per cent. The threshold value for seed yield.

Table 3: Threshold value, frequency and range in values of transgressive segregants (T.S.) for eight characters in F₂ generation of the cross **RD 2508 X BCLA 11-6** and **RD 2552 x BCLA 11-6** in barley

Character	RD 2508 X BCLA 11-6				RD 2552 x BCLA 11-6			
	Threshold value	Desirable T. S.		Range of F ₂	Threshold value	Desirable T. S.		Range of F ₂
		Frequency	Range of segregants			Frequency	Range of segregants	
Plant height (cm)	86.97	25.00	87.10 to 93.60	86.97	86.97	30.00	87.10 to 90.80	78.50 to 93.60
Tillers per plant	12.71	23.00	13.00 to 14.00	12.60	12.60	23.00	13.00 to 14.00	8.00 to 14.00
Grains per spike	69.44	32.00	70.00 to 77.00	69.44	69.44	33.00	70.00 to 78.00	52.00 to 78.00
Spike length (cm)	9.41	20.00	9.50 to 10.20	9.66	9.66	18.00	9.70 to 11.00	5.90 to 11.00
1000-grain weight (g)	41.57	18.00	41.70 to 43.00	57.67	57.67	18.00	58.00 to 60.60	50.50 to 60.60
Chlorophyll content (SPAD)	55.39	22.00	56.60 to 57.00	53.16	53.16	23.00	53.30 to 57.70	45.10 to 57.70
Harvest index (%)	39.63	24.00	39.70 to 42.00	38.83	38.83	20.00	38.90 to 40.40	33.60 to 40.40
Grain yield per plant (g)	27.95	32.00	28.00 to 31.60	36.53	36.53	30.00	35.00 to 37.60	29.10 to 37.60

per plant was 27.95 g and between transgressants, ranged from 28 to 31.6 g. Summary of the data on the frequency and percentage of transgressive segregants for the character combination yield and other character combinations presented in Table 4. Barley yield in conjugation with one or more characters transgressed significantly with the corresponding character in six different character combinations with any other characters. Grain yield per plant was transgressed simultaneously with, grain per spike, tillers per plant, spike length, 1000-grains weight, chlorophyll content with 0.83 per cent transgressants. In the second case, grain yield per plant along with four other characters, *i.e.*, grain per spike, tillers per plant, spike length and

1000-grain weight were transgressions of 0.83 per cent. In the third case, grain yield per plant was transgressed together with grain per spike, tillers per plant and spike length with transgressants 1.67 per cent. The transgressants of grain yield per plant with grain per spike took place in a single combination and were transgressed by 5 per cent. In the F₂ generation, the highest proportion of transgressive segregants (12.50%) was observed for grain yield per plant with a frequency of 15. For grain yield per plant and combination of characters, the per cent of transgressants in the F₂ segregating generation produced a total of 26.66 per cent transgressive segregants.

Table 4: Frequency and percentage of simultaneous transgressive segregation (T.S.) for grain yield per plant in combination with other characters in the cross **RD 2508 X BCLA 11-6**, **RD 2552 x BCLA 11-6**, **RD 2660 x RD 3005** and **RD 2715 x BH 1025** in barley

Sr. No.	Character combinations	RD 2508 X BCLA 11-6		RD 2552 x BCLA 11-6		RD 2660 x RD 3005		RD 2715 x BH 1025	
		F ₂		F ₂		F ₂		F ₂	
		Frequency	% of T.S	Frequency	% of T.S	Frequency	% of T.S	Frequency	% of T.S
1	Grain yield per plant + grains per spike + tillers per plant + spike length + 1000-grain weight + chlorophyll content	1	0.83	1	0.83	2	1.67	3	2.50
2	Grain yield per plant + grain per spike + tillers per plant + spike length + 1000-grain weight	1	0.83	2	1.66	1	0.83	0	0.01
3	Grain yield per plant + grain per spike + tillers per plant + spike length	2	1.67	2	1.66	5	4.16	0	0.01
4	Grain yield per plant + grain per spike + tillers per plant	7	5.83	0	0.01	0	0.0	0	0.01
5	Grain yield per plant + grain per spike	6	5.00	11	9.16	4	3.33	9	7.50
6	Grain yield per plant alone	15	12.50	14	11.66	19	15.83	18	15.00
	Total	32	26.66	30	24.97	31	25.83	30	25.00

Transgressive segregants of RD 2552 X BCLA 11-6 for different characters in barley

In terms of plant height, the parent RD 2552 (69.81 cm) was short, but the parent BCLA 11-6 (85.64 cm) was tall. The average plant height in the F₂ segregating generation was 85.20 cm (Table 5). In the F₂ generation, the Transgressive segregants for plant height were 33.33 per cent with a range of 87.10 to 90.80 cm. The threshold value for plant height was 86.97 (Table 3). Data in Table 5, the increasing parent, RD 2552 (11.33) had higher tillers per plant and 10.98 in the F₂ generation. The percentage transgressant for this trait in the F₂ progeny was 25.56 per cent with a range of 13 to 14. The threshold value for tillers per plant was 12.60.

Out of the two parental lines, RD 2552 and BCLA 11-6 recorded average 57.63 and 67.99 grains per spike, respectively. In the F₂ segregating generation, the average number of grains per spike was 65.68. The transgressive segregations in F₂ generation for grains per spike were 36.67 per cent showed in Table 5. The threshold value for this trait was 69.44, presented in Table 6.

The spike length in the parent RD 2552 and BCLA 11-6 was 8.35 and 8.62 cm, respectively, as shown in Table 5. The average spike length was 8.25 cm in the F₂ generation. In terms of spike length, the transgressive segregants in F₂ were 20 per cent with a range of 9.70 to 11 cm. The threshold value for spike length was 9.66 (Table 3).

Table 5: Means, Standard deviations, frequency distribution and percentage of desirable transgressive segregants (T.S.) in F₂ generations of the cross **RD 2552 x BCLA 11-6**

S. No.	Generations	Mean ± S.E	S.D.	Frequency distribution in standard deviation units											Total Plants	N.D. value	Desirable T.G.%
				-5	-4	-3	-2	-1	0	1	2	3	4	5			
1. Plant height (cm)																	
	RD 2552 (+)	69.80±0.11	0.58	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BCLA 11-6 (-)	85.64±0.12	0.68	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	85.20±0.35	3.29	0	0	0	9	18	33	27	3	0	0	0	90	61.08	33.33
2. Tillers per plant																	
	RD 2552 (+)	11.33±0.12	0.65	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BCLA 11-6 (-)	11.20±0.13	0.70	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	10.98±0.18	1.67	0	0	0	5	32	30	13	10	0	0	0	90	6.03	25.56
3. Grains per spike																	
	RD 2552 (+)	57.63±0.15	0.82	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BCLA 11-6 (-)	67.99±0.14	0.74	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	65.68±0.7	6.62	0	0	0	5	27	25	29	4	0	0	0	90	59.52	36.67
4. Spike length (cm)																	
	RD 2552 (-)	8.35±0.08	0.45	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BCLA 11-6 (+)	8.62±0.1	0.53	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	8.25±0.11	1.05	0	0	0	3	25	44	4	13	1	0	0	90	1.37	20.00
5. 1000-grain weight (g)																	
	RD 2552 (+)	56.32±0.13	0.69	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BCLA 11-6 (-)	40.02±0.14	0.79	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	54.49±0.25	2.40	0	0	0	3	31	37	9	9	1	0	0	90	34.97	21.11
6. Chlorophyll content (SPAD)																	
	RD 2552 (+)	51.65±0.14	0.77	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BCLA 11-6 (-)	50.21±0.15	0.82	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	51.06±0.3	2.89	0	0	0	5	20	42	15	8	0	0	0	90	35.49	25.56
7. Harvest index (%)																	
	RD 2552 (+)	37.46±0.13	0.70	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BCLA 11-6 (-)	34.74±0.12	0.68	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	37.03±0.16	1.53	0	0	0	4	23	43	14	6	0	0	0	90	14.63	22.22
8. Grain yield per plant (g)																	
	RD 2552 (+)	33.59±0.27	1.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BCLA 11-6 (-)	20.98±0.16	0.85	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	33.30±0.2	1.92	0	0	0	6	25	29	24	6	0	0	0	90	19.19	33.33

Data represented in Table 5 reveal that the average 1000-grain weight in RD 2552 and BCLA 11-6 were 56.32 and 40.02 g, respectively. In the segregating generation, the mean of 1000-seed weight was 54.49 g. The transgressive segregants in F₂ ranged from 58.00 to 60.60 g and 21.11 per cent of desirable transgressive segregants was recorded. The threshold value was 57.67 (Table 3).

Data presented in table 5 revealed that the average chlorophyll content of RD 2552 and BCLA 11-6 were 51.65 and 50.21 respectively. In F₂ segregating population the average chlorophyll content was 51.06. The transgressive segregants in F₂ in terms of higher chlorophyll content than increasing parent were 25.56 per cent with a range of 53.30 to 57.60. Threshold value 53.16 for chlorophyll content was recorded and presented in Table 3.

Data presented in Table 5 reported that the harvest index of RD 2552 and BCLA 11-6 were 37.46 and 34.74, respectively. In F₂ progeny the harvest index was 37.03. The transgressive segregants in F₂ in terms of more harvest index than better parent were 22.22 per cent with a range of 38.9 to 40.4. Threshold value for harvest index was 38.83 presented in Table 3. Data (Table 5) shows that the average grain yield per plant in the RD 2552 was 33.59 g and in the F₂ generation the yield was 33.3 g. The recorded of transgressants for grain yield per plant was 33.33 per cent. The threshold

value for seed yield per plant was 36.53 g and between transgressants, ranged from 35 to 37.6 g represented in Table 3. Summary of the data presented in Table 4 on the frequency and percentage of desirable transgressive segregants for the character combination yield and other character combinations. Barley yield in conjugation with one or more characters transgressed significantly with the corresponding character in six different character combinations with any other characters. Grain yield per plant was transgressed simultaneously with, grain per spike, tillers per plant, spike length, 1000-grain weight, chlorophyll content with 0.83 per cent transgressants. In the second case, Grain yield per plant along with four other characters, *i.e.*, grain per spike, tillers per plant, spike length and 1000-grain weight were transgressions of 1.66 per cent. In the third case, Grain yield per plant was transgressed together with grain per spike, tillers per plant and spike length with transgressants 1.66 per cent. The transgressants of grain yield per plant with grain per spike took place in a single combination and were transgressed by 9.16 per cent. In the F₂ segregation generation, the highest proportion of transgressive segregants (11.16%) was observed for grain yield per plant with a frequency of 14. For grain yield per plant and combination of characters, the per cent of transgressants in the F₂ segregating generation produced a total of 24.97 per cent transgressive segregants.

Table 6: Threshold value, frequency and range in values of transgressive segregants for eight characters in F₂ generation of the cross RD 2660 x RD 3005 and RD 2715 x BH 1025 in barley

Character	Threshold value	Desirable T. S.		Range of F ₂	Threshold value	Desirable T. S.		Range of F ₂
		Frequency	Range of segregants			Frequency	Range of segregants	
Plant height (cm)	74.75	20.00	75.40 to 79.60	65.10 to 79.60	90.15	23.00	90.40 to 99.70	80.80 to 99.7
Tillers per plant	13.17	25.00	14.00 to 16.00	11.00 to 16.00	13.35	22.00	14.00 to 15.00	7.00 to 15.00
Grains per spike	59.29	37.00	60.00 to 66.00	44.00 to 66.00	76.23	31.00	77.00 to 83.00	60.00 to 83.00
Spike length (cm)	9.14	22.00	9.30 to 10.10	6.20 to 10.10	11.85	28.00	11.90 to 13.00	8.40 to 13.00
1000-grain weight (g)	50.68	14.00	50.80 to 52.10	46.30 to 52.10	47.69	17.00	47.70 to 50.20	41.10 to 50.20
Chlorophyll content (SPAD)	54.46	16.00	54.00 to 58.00	48.20 to 58.00	55.66	15.00	55.80 to 59.00	48.70 to 59.00
Harvest index (%)	42.08	19.00	42.20 to 43.40	38.80 to 43.40	41.32	12.00	41.50 to 43.40	36.80 to 42.70
Grain yield per plant (g)	8.62	31.00	28.80 to 30.90	24.00 to 30.90	29.67	30.00	29.70 to 31.80	24.50 to 31.80

Transgressive segregants of RD 2660 X RD3005 for different characters in barley

In terms of plant height, the parent RD 2660 (70.94 cm) was dwarf, but the parent RD 3005 (72.16 cm) was tall. The average plant height in the F₂ segregating generation was 71.33 cm (Table 8). In the F₂ generation, the Transgressive segregants for plant height were 22.22 per cent with a range of 75.40 to 79.60 cm. The threshold value for plant height was 74.75 (Table 6). Data in Table 4, revealed that the increasing parent, RD 3005 (11.6) had higher tillers per plant and 12.8 in the F₂ generation. The percentage desirable transgressant for this trait in the F₂ generation was 27.78 per cent with a range of 14 to 16. The threshold value for tillers per plant was 13.17 and presented in table 6.

Parents, RD 3005 and RD 2660 recorded average 49.92 and 57.58 grains per spike, respectively. In the F₂ progeny, the average number of grains per spike was 55.59. The transgressive segregations in F₂ generation for grains per spike were 41.11 per cent (Table 8). The threshold value for this trait was 59.29 (Table 6). The average spike length in the parent RD 2660 and RD 3005 was 8.14 and 7.65 cm, respectively, as shown in Table 8. The average spike length was observed 8.11 cm in the F₂ generation. In terms of spike length, the transgressive segregants in F₂ were found 24.44 per cent with a range of 9.30 to 10.10 cm. The threshold value for spike length was 9.14 (Table 6).

Data presented in Table 7 the mean of 1000-grain weight in RD 2660 and RD 3005 were 34 and 49.09 g, respectively. In the segregating generation, the average 1000-grain weight was 48.19 g. The transgressive segregants in F₂ ranged from 50.80 to 52.10 g, and desirable transgressive segregants was recorded 24.44. The 1000-grain weight have threshold value was 50.68 (Table 6).

Data presented in table 7 disclosed that the average chlorophyll content of RD 2660 and RD 3005 were 48.4 and 52.62 respectively. In F₂ segregating generation the average chlorophyll content was 52.12. The transgressive segregants in F₂ in terms of higher

chlorophyll content than increasing parent were 17.78 per cent with a range of 54.00 to 58.00. Threshold value for chlorophyll content was 54.46.

Data presented in table 7 disclosed that the harvest index of RD 3005 and RD 2660 were 40.9 and 37.87 respectively. In F₂ segregating population the harvest index was 40.75. The transgressive segregants in F₂ in terms of higher harvest index than increasing parent were 21.11 per cent with a range of 42.2 to 43.4. Threshold value for harvest index was 42.08.

Data showed in Table 7, displaced that the average grain yield per plant in the RD 2660 better parent was 27.6 g, and in the F₂ generation, it was 27.31 g. The percentage of transgressants for grain yield per plant was 34.44 per cent. The threshold value for grain yield per plant was 8.56 g and between transgressants, ranged from 28.8 to 33.9 g and presented in table 6. Summary of the data showed in Table 4 on the frequency and percentage of transgressive segregants for the character combination with yield and other yield component character combinations. Barley yield in conjugation with one or more characters transgressed significantly with the corresponding character in six different character combinations with any other characters. Grain yield per plant was transgressed simultaneously with, grain per spike, tillers per plant, spike length, 1000-grain weight, chlorophyll content with 1.67 per cent transgressants. In the second case, Grain yield per plant along with four other characters, *i.e.*, grain per spike, tillers per plant, spike length and 1000-grain weight were transgressions of 0.83 per cent. In the third case, Grain yield per plant was transgressed together with grain per spike, tillers per plant and spike length with transgressants 4.16 per cent. The transgressants of grain yield per plant with grain per spike took place in a single combination and were transgressed by 3.33 per cent. In the F₂ generation, the highest proportion of transgressive segregants (15.83%) was observed for grain yield per plant with a frequency of 19. For grain yield per plant and combination of characters, the per cent of transgressants in the F₂ segregating generation produced a total of 25.83 per cent transgressive segregants.

Table 7: Means, Standard deviations, frequency distribution and percentage of desirable transgressive segregants (T.S.) in F₂ generations of the cross **RD 2660 x RD 3005**

S. No.	Generations	Mean ± S.E	S.D.	Frequency distribution in standard deviation units											Total Plants	N.D. value	Desirable T.G.%
				-5	-4	-3	-2	-1	0	1	2	3	4	5			
1. Plant height (cm)																	
	RD 2660 (-)	70.94±0.11	0.62	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	RD 3005 (+)	72.16±0.24	1.32	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	71.33±0.38	3.59	0	0	0	5	25	40	13	7	0	0	0	90	54.88	22.22
2. Tillers per plant																	
	RD 2660 (-)	11.60±0.15	0.80	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	RD 3005 (+)	13.37±0.14	0.75	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	12.80±0.15	1.42	0	0	0	0	41	24	9	16	0	0	0	90	4.15	27.78
3. Grains per spike																	
	RD 2660 (+)	57.58±0.16	0.87	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	RD 3005 (-)	49.92±0.16	0.88	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	55.59±0.65	6.13	0	0	0	8	25	20	33	4	0	0	0	90	50.22	41.11
4. Spike length (cm)																	
	RD 2660 (+)	8.14±0.09	0.51	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	RD 3005 (-)	7.65±0.1	0.55	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	8.11±0.1	0.96	0	0	0	4	20	44	14	8	0	0	0	90	0.69	24.44
5. 1000-grain weight (g)																	
	RD 2660 (-)	34.00±0.15	0.81	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	RD 3005 (+)	49.09±0.14	0.76	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	48.19±0.15	1.45	0	0	0	0	33	43	0	13	1	0	0	90	2.35	15.56
6. Chlorophyll content (SPAD)																	
	RD 2660 (-)	48.40±0.17	0.94	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	RD 3005 (+)	52.62±0.13	0.73	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	52.12±0.22	2.05	0	0	0	5	20	49	8	6	2	0	0	90	24.82	17.78
7. Harvest index (%)																	
	RD 2660 (-)	37.87±0.11	0.60	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	RD 3005 (+)	40.90±0.13	0.71	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	40.75±0.12	1.16	0	0	0	7	20	44	11	8	0	0	0	90	3.92	21.11
8. Grain yield per plant (g)																	
	RD 2660 (+)	27.60±0.09	0.52	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	RD 3005 (-)	23.07±0.12	0.65	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	27.31±0.17	1.62	0	0	0	5	26	28	24	7	0	0	0	90	11.76	34.44

Transgressive segregants of RD 2715 X BH 1025 for different characters in barley

In terms of plant height, the genotype BH 1025 (82.84 cm) was dwarf, but the genotype RD 2715 (88.82 cm) was tall. The average plant height in the F₂ segregating population was 88.02 cm (Table 7). In the F₂ generation, the Transgressive segregants for plant height were 25.56 per cent with a range of 90.40 to 99.70 cm. The threshold value for plant height was 90.15 (Table 6).

According to the data in Table 8, the better parent, RD 2715 (11.8) had higher tillers per plant and 12.31 in the F₂ generation. The desirable percentage transgressant for this trait in the F₂ generation was 24.44 per cent with a range of 14 to 15. The threshold value for tillers per plant was 13.35. Out of the two parental lines, RD 2715 and BH 1025 recorded average 74.76 and 32.01 grains per spike, respectively. In the F₂ segregating generation, the average number of grains per spike was 72.02. The transgressive segregations in F₂ generation for grains per spike were 34.44 per cent (Table 8). The threshold value for this trait was 76.23 and showed in table 6.

The average spike length in the parent RD 2715 and BH 1025 was 11.11 and 8.13 cm, respectively, as shown in Table 8. The average spike length was 11.02 cm in the F₂ generation. In terms of spike length, the transgressive segregants in F₂ were 31.11 per cent with

a range of 11.90 to 13 cm. The threshold value for spike length was 11.85 (Table 6). Bharathi and Reddy (2019) suggested that the genetic analysis for transgressive segregation in F₂ helps determine the potency of different crosses achieving efficiency in early generation selection and reducing population size in later generations. The favourable genes impacting yield and yield-governing traits combine to create transgressive segregants. Apart from the frequency of transgressive segregants, the intensities of the characters' expressions were achieved by the transgressants in each of the crosses examined. This also provided an insight into the extended limits and intensities of desired character's expression achieved by transgressive breeding. These findings were supported by Al-Bakry *et al.* (2011), Dahat *et al.* (2017) and Kumar *et al.* (2017) in wheat.

Data showed in Table 8 the average 1000-grain weight in RD 2715 and BH 1025 were 42.62 and 45.97 g, respectively. In the segregating F₂ generation, the average 1000-grain weight was 44.53 g. The transgressive segregants in F₂ ranged from 47.70 to 50.20 g and desirable transgressive segregants was found 18.89. The 1000-grain weight threshold value was 47.69 (Table 6).

Data presented in table 8 reveals that the average chlorophyll content of RD 2715 and BH 1025 were 53.45 and 53.97, respectively. In F₂ segregating

generation the average chlorophyll content was 52.88. The transgressive segregants in F₂ in terms of more chlorophyll content than increasing parent were 16.67 per cent with a range of 55.80 to 59. Threshold value for chlorophyll content was 55.66 (table 6).

Data presented in table 8 reveals that the harvest index of RD 2715 and BH 1025 were 40.79 and 36.09, respectively. In F₂ segregating generation the harvest index was 39.43. The transgressive segregants in F₂ in terms of higher harvest index than better parent were 13.31 per cent with a range of 41.25 to 43.4. Threshold value for harvest index was 41.32 (table 6).

Data in Table 8 shows that the average grain yield per plant in the RD 2715 better parent was 28.59 g, and in the F₂ generation, it was 28 g. The percentage of desirable transgressants for grain yield per plant was 33.33 per cent. The threshold value for seed yield per plant was 29.67 g and between transgressants, ranged from 29.7 to 31.9 g (table 6).

Summary of the data in Table 4 on the frequency and percentage of transgressive segregants for the

character combination with yield and other yield contributing character combinations. Barley yield in conjugation with one or more characters transgressed significantly with the corresponding character in six different character combinations with any other characters. Grain yield per plant was transgressed simultaneously with, grain per spike, tillers per plant, spike length, 1000-grain weight, chlorophyll content with 2.50 per cent transgressants. In the second case, grain yield per plant along with four other characters, *i.e.*, grain per spike, tillers per plant, spike length and 1000-grain weight were transgressions of 0.01 per cent. In the third case, Grain yield per plant was transgressed together with grain per spike, tillers per plant and spike length with transgressants 0.01 per cent. The transgressants of grain yield per plant with grain per spike took place in a single combination and were transgressed by 7.50 per cent. In the F₂ generation, the highest proportion of transgressive segregants (15%) was observed for grain yield per plant with a frequency of 18. For grain yield

Table 8: Means, Standard deviations, frequency distribution and percentage of desirable transgressive segregants (T.S.) in F₂ generations of the cross **RD 2715 x BH 1025**

S. No.	Generations	Mean ± S.E	S.D.	Frequency distribution in standard deviation units											Total Plants	N.D. value	Desirable T.G.%
				-5	-4	-3	-2	-1	0	1	2	3	4	5			
1. Plant height (cm)																	
	RD 2715 (+)	88.82±0.12	0.68	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BH 1025 (-)	82.84±0.11	0.60	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	88.02±0.42	4.01	0	0	0	4	26	37	17	1	5	0	0	90	68.20	25.56
2. Tillers per plant																	
	RD 2715 (+)	11.80±0.14	0.79	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BH 1025 (-)	11.50±0.18	0.96	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	12.31±0.17	1.62	0	0	0	0	34	34	9	13	0	0	0	90	5.75	24.44
3. Grains per spike																	
	RD 2715 (+)	74.76±0.14	0.75	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BH 1025 (-)	32.01±0.15	0.83	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	72.02±0.7	6.68	0	0	0	6	25	28	30	1	0	0	0	90	65.45	34.44
4. Spike length (cm)																	
	RD 2715 (+)	11.11±0.07	0.38	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BH 1025 (-)	8.13±0.1	0.56	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	11.02±0.11	1.03	0	0	1	3	27	31	20	8	0	0	0	90	1.16	31.11
5. 1000-grain weight (g)																	
	RD 2715 (-)	42.62±0.14	0.74	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BH 1025 (+)	45.97±0.16	0.88	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	44.53±0.22	2.08	0	0	0	2	23	48	0	16	1	0	0	90	22.66	18.89
6. Chlorophyll content (SPAD)																	
	RD 2715 (-)	53.45±0.09	0.47	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BH 1025 (+)	53.97±0.16	0.86	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	52.88±0.2	1.90	0	0	0	6	15	54	0	14	1	0	0	90	26.54	16.67
7. Harvest index (%)																	
	RD 2715 (+)	40.79±0.05	0.27	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BH 1025 (-)	36.09±0.16	0.86	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	39.43±0.12	1.15	0	0	0	5	18	55	0	10	2	0	0	90	7.03	13.33
8. Grain yield per plant (g)																	
	RD 2715 (+)	28.59±0.1	0.55	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	BH 1025 (-)	18.27±0.16	0.89	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	F ₂	28.00±0.18	1.73	0	0	0	5	30	25	24	6	0	0	0	90	13.48	33.33

per plant and combination of characters, the per cent of transgressants in the F₂ segregating generation produced a total of 25 per cent transgressive segregants.

The ranking of four crosses based on the proportion of transgressive segregants in the F₂ generation depending on the involvement of better parents is presented in Table 9.

The first rank appeared for four characters in RD 2715 x BH 1025, and two characters in RD 2552 x BCLA 11-6 whereas it was for one character in each cross, RD 2508 x BCLA 11-6 and RD 2660 x RD 3005. This indicated that RD 2715 x BH 1025 was found to be promising among the four crosses for producing desirable transgressive segregants for yield and yield contributing characters. RD 2552 x BCLA

11-6 secured the second rank for most characters, indicating a relatively lesser number of transgressive segregants. RD 2508 x BCLA 11-6 and RD 2660 x RD 3005 had the third rank for the majority of the characters, which indicated a relatively lesser number of transgressive segregants.

Apart from the frequency of transgressive segregants, the intensities of the characters' expression achieved by the transgressants in each of the crosses examined. In the present investigation, the highest yielding transgressants produced 36.6, 37.6, 30.9 and 31.8 g grain yield per plant in RD 2508 x BCLA 11-6, RD 2552 x BCLA 11-6 and RD 2660 x RD 3005 and RD 2715 x BH 1025 respectively, as against 26.26, 33.59, 27.6 and 28.59 grain yield per plant produced by their respective better parents (Table 5.2). Cross 1 RD 2508 x BCLA 11-6), cross 2 (RD 2552 x BCLA 11-6), cross 3 (RD 2660 x RD 3005) and cross 4 (RD 2715 x

BH 1025) produced the average tillers per plant were 14, 14, 16 and 15 respectively as against 11.2, 11.3, 13.37 and 11.8 per plant, produced by their respective better parents. These intensities for the spike length were 10.2 (RD 2508 x BCLA 11-6), 11 (RD 2552 x BCLA 11-6), 10.1 (RD 2660 x RD 3005) and 13 (RD 2715 x BH 1025) higher than those of their respective better parents.

The data in Table 10, is evident that when the desired intensity of a character is not available in the parents, transgressive breeding can be employed to extend the limit of expression of character. It is, therefore, concluded that transgressive breeding is effective for extending the limit of character expression if the plant breeder is interested in isolating the rare genotypes. This method imposes more selection pressure, resulting in the highest character recovery than other breeding approaches.

Table 9: Ranking of four crosses based on proportion of the transgressive segregants for different characters in F₂ generation

Characters	Cross No.	Better parent	F ₂	Rank
Plant height (cm)	RD 2508 x BCLA 11-6	BCLA 11-6	84.25	3
	RD 2552 x BCLA 11-6	BCLA 11-6	85.20	2
	RD 2660 x RD 3005	RD 3005	71.33	4
	RD 2715 x BH 1025	RD 2715	88.02	1
Tillers per plant	RD 2508 x BCLA 11-6	BCLA 11-6	10.31	4
	RD 2552 x BCLA 11-6	RD 2552	10.98	3
	RD 2660 x RD 3005	RD 3005	12.80	1
	RD 2715 x BH 1025	RD 2715	12.31	2
Grains per spike	RD 2508 x BCLA 11-6	BCLA 11-6	66.90	2
	RD 2552 x BCLA 11-6	BCLA 11-6	65.68	3
	RD 2660 x RD 3005	RD 2660	55.59	4
	RD 2715 x BH 1025	RD 2715	72.02	1
Spike length (cm)	RD 2508 x BCLA 11-6	RD 2508	8.59	2
	RD 2552 x BCLA 11-6	BCLA 11-6	8.25	3
	RD 2660 x RD 3005	RD 2660	8.11	4
	RD 2715 x BH 1025	RD 2715	11.02	1
1000-grain weight (g)	RD 2508 x BCLA 11-6	BCLA 11-6	39.16	4
	RD 2552 x BCLA 11-6	RD 2552	54.49	1
	RD 2660 x RD 3005	RD 3005	48.19	2
	RD 2715 x BH 1025	BH 1025	44.53	3
Chlorophyll content (SPAD)	RD 2508 x BCLA 11-6	RD 2508	52.93	1
	RD 2552 x BCLA 11-6	RD 2552	51.06	4
	RD 2660 x RD 3005	RD 3005	52.12	3
	RD 2715 x BH 1025	BH 1025	52.88	2
Harvest index (%)	RD 2508 x BCLA 11-6	RD 2508	38.57	3
	RD 2552 x BCLA 11-6	RD 2552	37.03	4
	RD 2660 x RD 3005	RD3005	40.75	1
	RD 2715 x BH 1025	RD 2715	39.43	2
Grain yield per plant (g)	RD 2508 x BCLA 11-6	RD 2508	27.17	4
	RD 2552 x BCLA 11-6	RD 2552	33.30	1
	RD 2660 x RD 3005	RD 2660	27.31	3
	RD 2715 x BH 1025	RD 2715	28.00	2

Simultaneous transgressive segregation for two or more characters in each of the four crosses (RD 2508 x BCLA 11-6, RD 2552 x BCLA 11-6, RD 2660 x RD 3005, RD 2715 x BH 1025)

In each of the four crosses under study, the grain yield per plant of the better parent was transgressed simultaneously with one or several other characters. Five characters, *viz.*, grains per spike, tillers per plant, spike length, 1000-grain weight, and chlorophyll content in addition to grain yield per plant, were considered for this purpose. Interestingly, some

important and rare transgressive segregants, though low in frequency, were picked up in each of the four crosses. In addition, there were several such combinations of characters in which grain yield per plant was transgressed in conjunction with transgression with other agronomic characters. The details of these rare and critical transgressive segregants are as follows. Notably, observation on eight characters out of the ten characters including grain yield per plant, was recorded on 90 plants in respective four crosses presented in Table 11. A total

of 32, 30, 31 and 30 individuals in cross RD 2508 x BCLA 11-6, RD 2552 x BCLA 11-6 and RD 2660 x RD 3005 and RD 2715 x BH 1025, respectively, were transgressed for grain yield per plant and its combination with other five characters. Simultaneous transgressive segregants and similar finding reported by Shivakumar *et al.* (2013) in chickpea. If we examine the total number of transgressive segregants for grain yield per plant in these crosses, we find that 123 individuals transgressed beyond the better parent in the F₂ generation. It is clear from Table 12, that the majority of the individuals, whenever increasing parent grain yield per plant was transgressed; there was simultaneous transgression for one or more other yield contributing characters like grains per spike, tillers per

plant, spike length, 1000-grain weight, and chlorophyll content. The obvious reason for this could be that grain yield per plant has been dependent on the grains per spike, tillers per plant, spike length, 1000-grain weight, and chlorophyll content alternatively and similar findings were also reported by Chowdhary *et al.* (1980), Micalsova (1981) in barley. It can be concluded that the genes of these characters are linked to each other. Whether it is linkage drag or dependency of grain yield per plant on some of the grain yield components, it could be safely inferred that the selection of transgressive segregants for grains per spike, tillers per plant, spike length, 1000-grain weight, and chlorophyll content will automatically lead to increase in grain yield per plant in barley.

Table 10: The extended limits achieved by transgressive segregants in respect of various characters in F₂ generation of four crosses (RD 2508 x BCLA 11-6, RD 2552 x BCLA 11-6, RD 2660 x RD 3005, RD 2715 x BH 1025)

Characters	Highest intensity of character expression in four crosses			
	F ₂			
	RD 2508 x BCLA 11-6	RD 2552 x BCLA 11-6	RD 2660 x RD 3005	RD 2715 x BH 1025
Plant height (cm)	93.6 (85.64)	90.8 (85.64)	79.6 (72.16)	99.7 (88.82)
Tillers per plant	14 (11.2)	14.0 (11.33)	16 (13.37)	15 (11.8)
Grains per spike	77 (67.99)	78 (67.99)	69 (57.58)	83 (74.76)
Spike length (cm)	10.2 (8.67)	11 (8.62)	10.1 (8.14)	13 (11.11)
1000-grains weight (g)	43 (40.02)	60.6 (56.32)	52.1 (49.01)	50.2 (45.97)
Chlorophyll content (SPAD)	57 (54.35)	57.7 (51.65)	58 (52.62)	59 (53.97)
Harvest index (%)	42 (39)	40.47 (37.46)	43.4 (40.9)	42.7 (40.79)
Grain yield per plant (g)	31.6 (26.26)	37.6 (33.59)	30.9 (27.6)	31.8 (28.59)

Value in () is represent the mean value of better parent.

Table 11: Number of transgressive segregants in four crosses of barley (RD 2508 x BCLA 11-6, RD 2552 x BCLA 11-6, RD 2660 x RD 3005, RD 2715 x BH 1025)

S. No.	Characters	Name of crosses			
		RD 2508 x BCLA 11-6	RD 2552 x BCLA 11-6	RD 2660 x RD 3005	RD 2715 x BH 1025
1.	Plant height (cm)	25	30	20	23
2.	Tillers per plant	23	23	25	22
3.	Grains per spike	32	33	37	31
4.	Spike length (cm)	20	18	22	28
5.	1000-grain weight (g)	18	18	14	17
6.	Chlorophyll content (SPAD)	22	23	16	15
7.	Harvest index (%)	24	20	19	12
8.	Grain yield per plant (g)	32	30	31	30

Promising transgressive segregants having the combination of desirable attributes in the F₂ generation of four crosses

Among the promising transgressive segregants listed in table 13, the transgressive segregants plant number 52, 54 and 55 of cross 4 (RD 2715 x BH 1025) were the most profitable. They produced 30, 30 and 30 g grain yield per plant, respectively, which were 4.93, 4.93 and 4.93 per cent higher than their respective higher parent of grains per spike, tillers per plant, spike length, 1000-grain weight and chlorophyll content. In cross RD 2552 x BCLA 11-6, one transgressive segregant, *i.e.* plant number 68 were most promising,

which yielded the increasing parent by 4.19 per cent more grain yield per plant, respectively. In addition, they produced a higher expression of most of the characters, *i.e.* grains per spike, tillers per plant, spike length, 1000-grain weight and chlorophyll content. From this study, it can be suggested that the most promising transgressive segregants listed in table 5.5 need to be evaluated further. For example, suppose they confirm their superiority in further generations. In that case, they might be considered for multi-location evaluation for release as a variety or might be used as a parent in the future breeding programme in barley.

Table 12: Rare and important transgressants in four crosses (RD 2508 x BCLA 11-6, RD 2552 x BCLA 11-6, RD 2660 x RD 3005, RD 2715 x BH 1025)

Cross No.	Frequency of transgressants (%)	Characters for which transgression was simultaneous
RD 2508 x BCLA 11-6	0.83	Grain yield per plant + grains per spike + tillers per plant+ spike length + 1000-grain weight + chlorophyll content
RD 2552 x BCLA 11-6	0.83	
RD 2660 x RD 3005	1.67	
RD 2715 x BH 1025	2.50	
RD 2508 x BCLA 11-6	0.83	Grain yield per plant + grains per spike + tillers per plant + spike length + 1000-grain weight
RD 2552 x BCLA 11-6	1.66	
RD 2660 x RD 3005	0.83	
RD 2508 x BCLA 11-6	1.66	Grain yield per plant + grains per spike + tillers per plant + spike length
RD 2552 x BCLA 11-6	1.66	
RD 2660 x RD 3005	4.16	Grain yield per plant + grains per spike + tillers per plant
RD 2508 x BCLA 11-6	5.83	
RD 2508 x BCLA 11-6	5.00	Grain yield per plant + grains per spike
RD 2552 x BCLA 11-6	9.16	
RD 2660 x RD 3005	3.33	
RD 2715 x BH 1025	7.50	
RD 2508 x BCLA 11-6	12.50	Grain yield per plant
RD 2552 x BCLA 11-6	11.66	
RD 2660 x RD 3005	15.83	
RD 2715 x BH 1025	15.00	

Table 13: Promising transgressive segregants having combinations of desirable attributes

Characters	Plant no.	Plant height	Tillers per plant	Grains per spike	Spike length	1000-grain weight	Chlorophyll content	Harvest index	Grain yield per plant	% yield in creased over better parent
Cross-1 (RD 2508 x BCLA 11-6)										
F ₂	88	89.20	13.00	75.00	9.50	42.60	56.20	39.70	28.40	4.18
BCLA-11-6		85.64	11.20	67.99	8.62	40.02	50.21	34.74	20.98	
RD 2508		71.20	10.77	48.87	8.67	32.95	54.35	39.00	27.26	
Cross-2(RD 2552 x BCLA 11-6)										
F ₂	68	88.6	14.00	72.00	10.20	58.00	54.00	37.10	35.10	4.19
BCLA-11-6		85.64	11.20	67.99	8.62	40.02	50.21	34.74	20.98	
RD 2552		69.8	11.33	57.63	8.35	56.32	51.65	37.46	33.59	
Cross-3 (RD 2660 x RD 3005)										
F ₂	65	70.00	14.00	60.00	10.10	50.90	55.00	39.60	29.8	7.97
RD 3005		72.16	13.37	49.92	7.65	49.09	52.62	40.90	23.07	
RD 2660		70.94	11.60	57.58	8.14	34.00	48.40	37.87	27.60	

F ₂	88	71.70	15.00	64.00	9.40	51.80	56.00	42.50	29.00	5.07
RD 3005		72.16	13.37	49.92	7.65	49.09	52.62	40.90	23.07	
RD 2660		70.94	11.60	57.58	8.14	34.00	48.40	37.87	27.60	
Cross-4 (RD 2715 x BH 1025)										
F ₂	52	90.50	15.00	81.00	13.00	47.70	56.20	41.50	30.00	4.93
RD 2715		88.82	11.80	74.76	11.11	42.62	53.45	40.79	28.59	
BH 1025		82.84	11.50	32.01	8.13	45.97	53.97	36.09	18.27	
F ₂	54	88.00	14.00	77.00	12.90	48.20	56.00	39.90	30.00	4.93
RD 2715		88.82	11.8	74.76	11.11	42.62	53.45	40.79	28.59	
BH 1025		82.84	11.5	32.01	8.13	45.97	53.97	36.09	18.27	
F ₂	55	89.30	14.00	79.00	12.00	47.80	55.90	39.60	30.00	4.93
RD 2715		88.82	11.80	74.76	11.11	42.62	53.45	40.79	28.59	
BH 1025		82.84	11.50	32.01	8.13	45.97	53.97	36.09	18.27	

Conclusion

On the basis of the performance of transgressive segregants, it was concluded that transgressive breeding could be successfully used to extend the limit of expression of character. This could be possible by the pickup of favourable plus genes in hybrid derivatives from both parents involved in hybridization. In most of the transgressive segregants, in each of the four crosses, (RD 2508 x BCLA 11-6, RD 2552 x BCLA 11-6, RD 2660 x RD 3005, RD 2715 x BH 1025). Better parent yield was transgressed simultaneously with the transgression of one or several other characters. Simultaneous transgression of grain yield per plant in association with the grains per spike, tillers per plant, spike length, 1000-grain weight and chlorophyll content was observed more frequently. It was concluded that grain yield per plant is dependent on this character. The most promising transgressive segregants viz., plant Number 88 of RD 2508 x BCLA 11-6, plant No. 65 and 88 of RD 2660 x RD 3005, plant no.52, 54 and 55 of RD 2715 x BH 1025 and plant no. 68 of RD 2552 x BCLA 11-6 transgressed for grain yield per plant in addition to the higher expression of other characters than the higher parent. They produced 4.18 (RD 2508 x BCLA 11-6), 7.97 and 5.07 (RD 2660 x RD 3005), 4.30, 4.30 and 4.30 (RD 2715 x BH 1025) and 4.19 (RD 2552 x BCLA 11-6) per cent more grain yield per plant than their respective better parents than other segregants.

Conflict of interest

The authors declare that there is no conflict of interest.

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