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Crossability Between Two Forms of Newly Developed Barley (*Hordeum vulgare*) Genotype

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A B S T R A C T

Barley (*Hordeum vulgare* L.), the crop of present era being versatile in nature, is grown worldwide under various agro climatic situations. It flourishes well under limited resources of irrigation and fertilizer. Barley thrives better yield in problematic situation and climatic change, like rainfed, diaraland, marginal area of river & saline and alkaline soil. The nutritional and medicinal importance of this crop is of permanent value. The second most important use of barley is for malt, which is used mostly in beer, but also in hard liquors, malted milk and flavorings in a variety of foods. Barley malt can be added to many food stuffs such as biscuits, bread, cakes and desserts. Brewer's and distiller grains and sprouts from malting barley also have desirable protein content for animal diets (Akar *et al.*, 2004). The crossabilities of 18 genetically diverse varieties of hulled/hulless barley (*Hordeum vulgare* L.), namely NDB-943, NDB-1173, NDB-1057, NDB-1618, NDB-1445, NDB-3, NDB-1173, RD-2768, RD 2909, RD-2899, HUB-240, KB-1319, BH-999, DWRB-137, HUB-114, RD-2794, Karan 16, BHS 352 and Dolma collected from various coordinating unit, were selected for building up the experimental materials. A pair of 18 different barley varieties involved in three groups of Hulled x Hulled, Hulled x Hulless and Hulless x Hulless were crossed during winter 2015-16 and 2016-17 respectively, at Research Farm of NDUA&T, Kumarganj, Faizabad. The experimental materials used for the present investigation comprised of the parents (P_1 and P_2), the F_1's, and the back crosses (B_1 and B_2) seeds with both the parents of each of the fifteen crosses. The whole experiment was conducted in normal fertile soil (pH 8.4). The row to row and plant to plant distance was kept 50 cm and 15cm respectively. The total number of seeds set and total number of florets pollinated were counted. The seed setting in different crosses was thus influenced by genotype(s) of the parents themselves, and it is suggested that hulless barley may be used as female for better seed setting. Thus, it is suggested that (1) desirable genotype(s) expressing high number of seed setting may be further mated inter se in order to enlarge the genetic variability and (2) The genotypes showing high value of crossability may prove their worthy as best combiners with other genotypes.

Introduction

The eco-friendly barley plant has several cylindrical culms (tillers) with hollow internodes separated by solid nodes. Typically there are 5-7 internodes in a culm which increase in length and are progressively smaller in diameter towards the tip. The number of tillers per plant is influenced by plant density of crop stand, genetic and environmental factors. Though the height of culms is affected by genetic and environmental factors, the height of individual culms in the same plant may vary. Barley's flower (inflorescence), commonly called 'ear' (spike), is distinguishable into two morphological types six-rowed and two-rowed. In the six rowed spike, a triplet of spikelets is placed on alternating sides, in a zigzag manner, at each node of the flat rachis, while in the two-rowed spike, the lateral spikelets of the triplet are either sterile or are more or less rudimentary). Analysis of carbonized grain samples have suggested that the six-rowed barley is of later origin than the two-rowed forms (Zohary, 1973). The florets consist of a lemma, which terminates in a long or short awn, and a palea. The awns may vary in length from 0.5cm (awnless or awnleted) to 25cm in different species. The awns in some varieties, called 'hooded barley', get modified to develop hoods which may be of different shapes and sizes. The sexual parts of the plant are enclosed by the lemma and palea. The anthers are three in number, while the ovary's stigma is bifurcated and hairy. Pollination is mainly by self-pollination. The fertilized ovary grows to form the grain which may be hulled (lemma and palea remain attached to the seed at maturity) or hulless (naked barley, threshing free of the lemma and palea). Except in cultivated species of barley, the rachis is fragile at maturity causing shattering of grains. The grain color of hulless varieties may be pale yellow, amber, blue, red-purple or various shades of grey to black. On the other hand, hulled grains may be pale yellow or may show a greenish tinge due to blue aleurone color and yellow husks. The husk may have shades of yellow, orange, brown or even grey or black. During 2016-17, India had about 6.93 lakh ha area with production of 17.81 lakh tonnes and productivity of 25.8 q/h (DES). In Uttar Pradesh, Barley occupies an area of 1.24 lakh ha with total production of 4.47 lakh tonnes and productivity of 24.5q/ha (DES).

Materials and Methods

The crossabilities of 18 genetically diverse varieties of hulled and hulless barley (*Hordeum vulgare* L.), NDB-943, NDB-1173, NDB-1057, NDB-1618, NDB-1445, NDB-3, NDB-1173, RD-2768, RD2909, RD-2899, HUB-240, KB-1319, BH-999, DWRB-137, HUB-114, RD-2794, Karan 16, BHS 352 and Dolma collected from various coordinating unit, were selected for building up the experimental material. The experimental materials used for the present investigation comprised of the parents (P_1 and P_2), the F_1's, and the back crosses (B_1 and B_2) seeds with both the parents of each of the fifteen set of crosses viz. RD-2768 X NDB-3, RD-2768 X NDB-1173, RD-2768 X NDB-943, RD-2909 X NDB-3, RD-2909X NDB-1173, RD-2768 X NDB-943, NDB-1057 X NDB-3, NDB-1057 X NDB-1173, NDB-1057 X NDB-943, RD-2899 X NDB-3, RD-2899 X NDB-1173, RD-2899 X NDB-943, NDB-1618 X NDB-3, NDB-1618 X NDB-1173, NDB-1618 X NDB-943, HUB-240 X NDB-3, HUB-240 X NDB-1173, HUB-240 X NDB-943, NDB-1445 X NDB-3, NDB-1445 X NDB-1173, NDB-1445 X NDB-943, KB-1319 X NDB-3, KB-1319 X NDB-1173, KB-1319 X NDB-943, BH-999 X NDB-3, BH-999 X NDB-1173, BH-999 X NDB-943, DWRB-137X NDB-3, DWRB-137X NDB-1173, DWRB-137X NDB-943, HUB-114 X NDB-3, HUB-114 X NDB-1173, HUB-114 X NDB-943, RD-2794 X NDB-3,

RD-2794 X NDB-1173, RD-2794 X NDB-943. Karan 16 xNDB 943, BHS 352 x NDB 943 and Dolma x NDB 943.

A pair of 18 different barley varieties involved in three groups of Hulled x Hulled, Hulled x Hulless and Hulless x Hulless were crossed during winter 2015-16 and 2016-17.respectively, at Research Farm of NDUA&T Kumarganj, Faizabad.

The whole experiment was conducted in normal fertile soil (pH 8.4). The row to row and plant to plant distance was kept 50 cm. and 15cm. respectively. The total numbers of seed set and total number of florests pollinated were counted. The extent of crossability was calculated as follows:

$$\text{Crossability (\%)} = \frac{\text{No. of seeds set}}{\text{No. of florets pollinated}} \times 100$$

Results and Discussion

The crossability between hulled and hulless barley varied from 9% with an average crossability of 50.58%. Crossability in hulled x hulled form of barley ranged from 9 to 87 %, hulled x hulless 9 to 74 %, while in case of hulless x hulless barley its range was 40 to 56 %, such variation represented inter varietal difference and opening of floral parts which may be used during population improvement. It has been observed that hulled barley must be used as maternal parent because its agronomic superiority is better than hulless barley. The cross between NDB-1618 X NDB-1173 exhibited the highest crossability of 87% while the lowest crossability of 9 % was recorded in the cross of NDB-1445X NDB-3. The seed setting in different crosses was thus influenced by genotype of the parents and flower's opening thus, it is suggested that hulled barley may be used as female for better seed setting.

Crossability in back crossing by parent (P_1) in hulled x hulled form of barley ranged from 12 to 69 %, hulled x hulless, 27 to 66%, while in case of hulless x hulless barley it was reached up to 41 to 61%, this showed inter varietal difference which may be used in population improvement through crossing programme.

The crossing between hulled and hulled barley varieties NDB-1445 X NDB-3, the resultant F_1 after back crossing by parent (P_1) exhibited the highest crossability of 69% while the lowest crossability of 12 % was recorded in the cross of RD-2909 X NDB-3, the resultant F_1 after back crossing by parent (P_1). The seed setting in different crosses was thus influenced by genotype of the parents and opening of florets thus, it is suggested that hulled barley may be used as female for better seed setting.

The crossing between hulled and hulless barley varieties NDB-1618 X NDB-943, the resultant F_1 after back crossing by parent (P_1) exhibited the highest cross ability of 66%.

While the lowest crossability of 27% was recorded in the cross of RD-2768 X NDB-943, the resultant F_1 after back crossing by parent (P_1). The seed setting in different crosses was thus influenced by genotype of the parents, and opening of florets thus, it is suggested that hulless barley may be used as male for better seed setting.

The crossing between hulless and hulless barley varieties Karan-16 X NDB-943, the resultant F_1 after back crossing by parent (P_1) exhibited the highest cross ability of 53% while the lowest crossability of 41% was recorded in the cross of BHS 352 X NDB-943, the resultant F_1 after back crossing by parent (P_1). The seed setting in different crosses was thus influenced by genotype of the parents, and opening of florets thus, it is suggested that hulless barley may be used as male for better seed setting (Table 1–9).

Table.1 Crossability between hulled and hulled barley varieties

S. No	Female parent (P_1) (All Hulled)	Male parent(P_2) (All Hulled)	No. of spikes attempted	No. of florets pollinated	No. of seed set	Crossability (%)
1.	RD-2768	NDB-3	5	20X5=100	17	17
2.	RD-2768	NDB-1173	5	20X5=100	36	36
3.	RD-2909	NDB-3	5	20X5=100	70	70
4.	RD-2909	NDB-1173	5	20X5=100	78	78
5.	NDB-1057	NDB-3	5	20X5=100	43	43
6.	NDB-1057	NDB-1173	5	20X5=100	73	73
7.	RD-2899	NDB-3	5	20X5=100	26	26
8.	RD-2899	NDB-1173	5	20X5=100	61	61
9.	NDB-1618	NDB-3	5	20X5=100	64	64
10.	NDB-1618	NDB-1173	5	20X5=100	87	87
11.	HUB-240	NDB-3	5	20X5=100	47	47
12.	HUB-240	NDB-1173	5	20X5=100	47	47
13.	NDB-1445	NDB-3	5	20X5=100	9	9
14.	NDB-1445	NDB-1173	5	20X5=100	43	43
15.	KB-1319	NDB-3	5	20X5=100	28	28
16.	KB-1319	NDB-1173	5	20X5=100	28	28
17.	BH-999	NDB-3	5	20X5=100	20	20
18.	BH-999	NDB-1173	5	20X5=100	16	16
19.	DWRB-137	NDB-3	5	20X5=100	29	29
20.	DWRB-137	NDB-1173	5	20X5=100	17	17
21.	HUB-114	NDB-3	5	20X5=100	58	58
22.	HUB-114	NDB-1173	5	20X5=100	64	64
23.	RD-2794	NDB-3	5	20X5=100	42	42
24.	RD-2794	NDB-1173	5	20X5=100	39	39
Average					43.41	43.41

Table.2 Crossability between hulled and hulless barley varieties

S. No	Female parent(P_1)) (All Hulled)	Male Parent(P_2) (All Hulless)	No. of Spike attempted	No. of florets pollinated	No. of seed set	Crossability (%)
1.	RD-2768	NDB-943	5	20X5=100	44	44
2.	RD-2909	NDB-943	5	20X5=100	74	74
3.	NDB-1057	NDB-943	5	20X5=100	49	49
4.	RD-2899	NDB-943	5	20X5=100	35	35
5.	NDB-1618	NDB-943	5	20X5=100	54	54
6.	HUB-240	NDB-943	5	20X5=100	58	58
7.	NDB-1445	NDB-943	5	20X5=100	9	9
8.	KB-1319	NDB-943	5	20X5=100	33	33
9.	BH-999	NDB-943	5	20X5=100	63	63
10.	DWRB-137	NDB-943	5	20X5=100	16	16
11.	HUB-114	NDB-943	5	20X5=100	65	65
12.	RD-2794	NDB-943	5	20X5=100	43	43
Average					45.25	45.25

Table.3 Crossability between hulless and hulless barley varieties

S. No	Female parent(P_1)) (All Hulless)	Male Parent(P_2) (All Hulless)	No. of Spike attempted	No. of florets pollinated	No. of seed set	Crossability (%)
1.	Karan-16	NDB-943	5	20X5=100	56	56
2.	Dolma	NDB-943	5	20X5=100	40	40
3.	BHS 352	NDB-943	5	20X5=100	51	51
Average					49	49

Table.4 Back crossing between hulled and hulled barley varieties by parent (P_1) x Parent (P_2)

S. No	Parent (P_1) x Parent (P_2) (Hulled)	F_1 X P_1(B_1) (Hulled)	No. of Spike attempted	No. of florets pollinated	No. of seed set	Crossability (%)
1.	RD-2768 X NDB-3	RD-2768	5	20X5=100	62	62
2.	RD-2768 X NDB-1173	RD-2768	5	20X5=100	68	68
3.	RD-2909 X NDB-3	RD-2909	5	20X5=100	12	12
4.	RD-2909X NDB-1173	RD-2909	5	20X5=100	59	59
5.	NDB-1057 X NDB-3	RD-1057	5	20X5=100	16	16
6.	NDB-1057 X NDB-1173	RD-1057	5	20X5=100	52	52
7.	RD-2899 X NDB-3	RD-2899	5	20X5=100	63	63
8.	RD-2899 X NDB-1173	RD-2899	5	20X5=100	64	64
9.	NDB-1618 X NDB-3	NDB-1618	5	20X5=100	57	57
10.	NDB-1618 X NDB-1173	NDB-1618	5	20X5=100	67	67
11.	HUB-240 X NDB-3	HUB-240	5	20X5=100	61	61
12.	HUB-240 X NDB-1173		5	20X5=100	47	47
13.	NDB-1445 X NDB-3	NDB-1445	5	20X5=100	69	69
14.	NDB-1445X NDB-1173	NDB-1445	5	20X5=100	66	66
15.	KB-1319 X NDB-3	KB-1319	5	20X5=100	14	14
16.	KB-1319 X NDB-1173	KB-1319	5	20X5=100	57	57
17.	BH-999 X NDB-3	BH-999	5	20X5=100	14	14
18.	BH-999 X NDB-1173	BH-999	5	20X5=100	60	60
19.	DWRB-137X NDB-3	DWRB-137	5	20X5=100	61	61
20.	DWRB-137 X NDB-1173	DWRB-137	5	20X5=100	62	62
21.	HUB-114 X NDB-3	HUB-114	5	20X5=100	55	55
22.	HUB-114 X NDB-1173	HUB-114	5	20X5=100	64	64
23.	RD-2794 X NDB-3	RD-2794	5	20X5=100	50	50
24.	RD-2794 X NDB-1173	RD-2794	5	20X5=100	45	45
Average					51.87	51.87

Table.5 Back crossing between hulled and hulled barley varieties by parent (P_1) x Parent (P_2)

S. No	Parent (P_1) x Parent (P_2) (Hulled)	F_1 X P_2(B_2) (Hulled)	No. of Spike attempted	No. of florets pollinated	No. of seed set	Crossability (%)
1.	RD-2768 X NDB-3	NDB-3	5	20X5=100	56	56
2.	RD-2768 X NDB-1173	NDB-1173	5	20X5=100	51	51
3.	RD-2909 X NDB-3	NDB-3	5	20X5=100	40	40
4.	RD-2909 X NDB-1173	NDB-1173	5	20X5=100	69	69
5.	NDB-1057 X NDB-3	NDB-3	5	20X5=100	68	68
6.	NDB-1057 X NDB-1173	NDB-1173	5	20X5=100	66	66
7.	RD-2899 X NDB-3	NDB-3	5	20X5=100	60	60
8.	RD-2899 X NDB-1173	NDB-1173	5	20X5=100	68	68
9.	NDB-1618 X NDB-3	NDB-3	5	20X5=100	64	64
10.	NDB-1618 X NDB-1173	NDB-1173	5	20X5=100	50	50
11.	HUB-240 X NDB-3	NDB-3	5	20X5=100	69	69
12.	HUB-240 X NDB-1173	NDB-1173	5	20X5=100	63	63
13.	NDB-1445 X NDB-3	NDB-3	5	20X5=100	53	53
14.	NDB-1445X NDB-1173	NDB-1173	5	20X5=100	50	50
15.	KB-1319 X NDB-3	NDB-3	5	20X5=100	42	42
16.	KB-1319 X NDB-1173	NDB-1173	5	20X5=100	67	67
17.	BH-999 X NDB-3	NDB-3	5	20X5=100	65	65
18.	BH-999 X NDB-1173	NDB-1173	5	20X5=100	64	64
19.	DWRB-137X NDB-3	NDB-3	5	20X5=100	66	66
20.	DWRB-137 X NDB-1173	NDB-1173	5	20X5=100	56	56
21.	HUB-114 X NDB-3	NDB-3	5	20X5=100	63	63
22.	HUB-114 X NDB-1173	NDB-1173	5	20X5=100	48	48
23.	RD-2794 X NDB-3	NDB-3	5	20X5=100	66	66
24.	RD-2794 X NDB-1173	NDB-1173	5	20X5=100	60	60
Average					59.33	59.33

Table.6 Back crossing between hulled and hulless barley varieties by parent (P_1) x Parent (P_2)

S. No	Parent (P_1) x Parent (P_2) (Hulled)	F_1 X P_2 (Hulless)	No. of Spike attempted	No. of florets pollinated	No. of seed set	Crossability (%)
1.	RD-2768 X NDB-943	F_1 X NDB-943	5	20X5=100	65	65
2.	RD-2909 X NDB-943	F_1 X NDB-943	5	20X5=100	67	67
3.	NDB-1057 X NDB-943	F_1 X NDB-943	5	20X5=100	62	62
4.	RD-2899 X NDB-943	F_1 X NDB-943	5	20X5=100	62	62
5.	NDB-1618 X NDB-943	F_1 X NDB-943	5	20X5=100	66	66
6.	HUB-240 X NDB-943	F_1 X NDB-943	5	20X5=100	37	37
7.	NDB-1445 X NDB-943	F_1 X NDB-943	5	20X5=100	64	64
8.	KB-1319 X NDB-943	F_1 X NDB-943	5	20X5=100	64	64
9.	BH-999 X NDB-943	F_1 X NDB-943	5	20X5=100	55	55
10.	DWRB-137X NDB-943	F_1 X F_1 X F_1 X NDB-943	5	20X5=100	60	60
11.	HUB-114 X NDB-943	F_1 X NDB-943	5	20X5=100	64	64
12.	RD-2794 X NDB-943	F_1 X NDB-943	5	20X5=100	35	35
Average					58.41	58.41

Table.7 Back crossing between hulled and hulless barley varieties by Parent (P_1) x Parent (P_2)

S. No	Parent (P_1) x Parent (P_2) (Hulled)	F_1 X P_1 (Hulled)	No. of Spike attempted	No. of florets pollinated	No. of seed set	Crossability (%)
1.	RD-2768 X NDB-943	F_1 X RD-2768	5	20X5=100	27	27
2.	RD-2909 X NDB-943	F_1 X RD-2909	5	20X5=100	63	63
3.	NDB-1057 X NDB-943	F_1 X RD-1057	5	20X5=100	54	54
4.	RD-2899 X NDB-943	F_1 X RD-2899	5	20X5=100	64	64
5.	NDB-1618 X NDB-943	F_1 X NDB-1618	5	20X5=100	66	66
6.	HUB-240 X NDB-943	F_1 X HUB-240	5	20X5=100	42	42
7.	NDB-1445 X NDB-943	F_1 X NDB-1445	5	20X5=100	25	25
8.	KB-1319 X NDB-943	F_1 X KB-1319	5	20X5=100	60	60
9.	BH-999 X NDB-943	F_1 X BH-999	5	20X5=100	51	51
10.	DWRB-137X NDB-943	F_1 X DWRB-137	5	20X5=100	61	61
11.	HUB-114 X NDB-943	F_1 X HUB-114	5	20X5=100	63	63
12.	RD-2794 X NDB-943	F_1 X RD-2794	5	20X5=100	40	40
Average					51.33	51.33

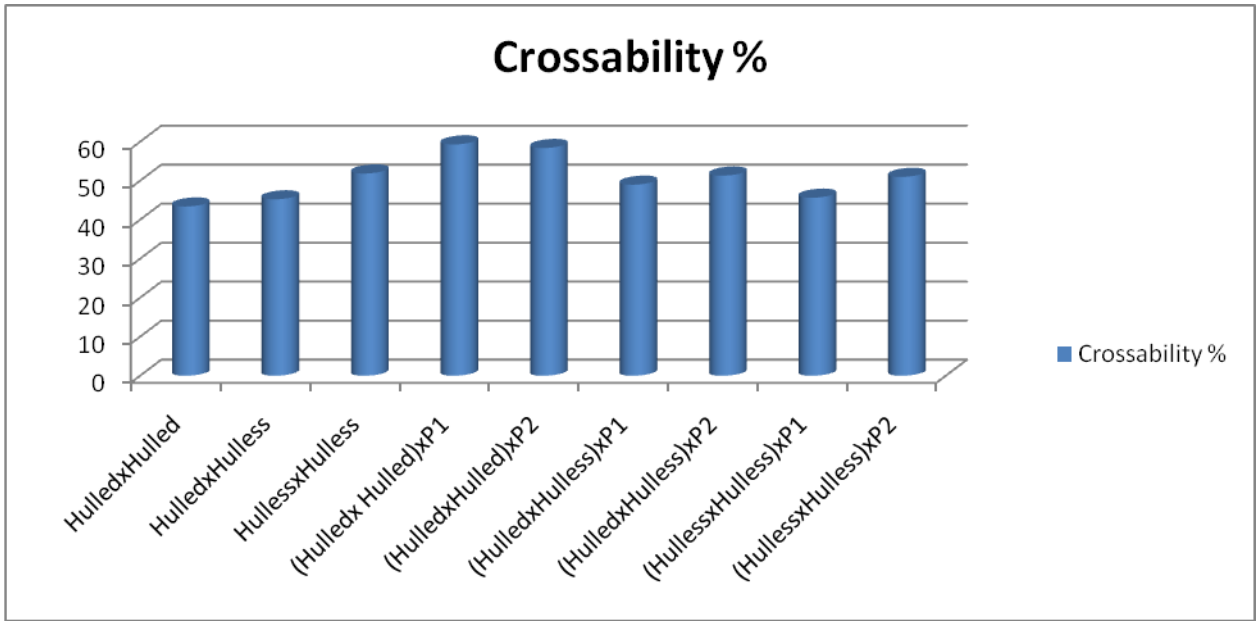
Table.8 Back crossing between hulless and hulless barley varieties by parent (P_1) x Parent (P_2)

S. No	Parent (P_1) x Parent (P_2) (hulless)	F_1 X P_1 (hulless)	No. of Spike attempted	No. of florets pollinated	No. of seed set	Crossability (%)
1.	Karan-16 X NDB-943	F_1 X Karan-16	5	20X5=100	53	53
2.	Dolma X NDB-943	F_1 X Dolma	5	20X5=100	43	43
3.	BHS 352 X NDB-943	F_1 X BHS 352	5	20X5=100	41	41
Average					45.66	45.66

Table.9 Back crossing between hulless and hulless barley varieties by parent (P_1) x Parent (P_2)

S. No	Parent (P_1) x Parent (P_2) (hulless)	F_1 X P_2 (hulless)	No. of Spike attempted	No. of florets pollinated	No. of seed set	Crossability (%)
1.	Karan-16 X NDB-943	F_1 X NDB-943	5	20X5=100	61	61
2.	Dolma X NDB-943	F_1 X NDB-943	5	20X5=100	49	49
3.	BHS 352 X NDB-943	F_1 X NDB-943	5	20X5=100	43	43
Average					51	51

$$\text{Average Crossability (\%) over three groups} = \frac{43.41 + 45.25 + 51.87 + 59.33 + 58.41 + 51.33 + 49 + 45.66 + 51}{9} = 50.58\%$$



Crossability in back crossing by parent (P_2) in hulled x hulled form of barley ranged from 40 to 69 % while in case of hulled x hulless barley it was reached up to 35 to 67%, this showed inter varietal difference which may be used in population improvement. The crossing between hulled and hulled barley varieties RD-2909 X NDB-1173, the resultant F_1 after back crossing by parent (P_2) exhibited the highest cross ability of 69% while the

lowest cross ability of 40 % was recorded in the cross of RD-2794 X NDB-943, the resultant F_1 after back crossing by parent (P_2).The seed setting in different crosses was thus influenced by genotype of the parents, and it is suggested that hulless barley may be used as male for better seed setting.

The crossing between hulled and hulless barley varieties RD-2909 X NDB-943, the resultant F_1 after back crossing by parent (P_2) exhibited the highest cross ability of 67% while the lowest cross ability of 35% was recorded in the cross of RD-2909 X NDB-3, the resultant F_1 after back crossing by parent (P_2). The seed setting in different crosses was thus influenced by genotype of the parents, and opening of florets thus, it is suggested that hulless barley may be used as male for better seed setting.

The crossing between hulless and hulless barley varieties Karan-16 X NDB-943, the resultant F_1 after back crossing by parent (P_2) exhibited the highest cross ability of 61% while the lowest cross ability of 53% was recorded in the cross of BHS 352 X NDB-943, the resultant F_1 after back crossing by parent (P_2). The seed setting in different crosses was thus influenced by genotype of the parents, and opening of florets thus, it is suggested that hulless barley may be used as male for better seed setting.

Thus it is suggested that (1) desirable genotype (s) expressing high number of seed setting may be further mated inter se in order to enlarge the genetic variability (2)

The genotype(s) showing high value of crossability may prove their worthy as best combiners with other. (3) Flower morphology may also affected the extent of crossability, thus open florets may enlarged the seed setting.

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