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EVALUATION OF DROUGHT TOLERANCE INDICES IN CROSSES OF BARLEY (*HORDEUM VULGARE* L.) UNDER IRRIGATED AND RAINFED CONDITIONS

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Abstract

In order to evaluate drought resistance criteria in four indigenous and ten exotic genotypes and their 40 crosses were tested under two different environment (rainfed and irrigated). Five drought tolerance indices, yield under drought (Y_d), yield potential (Y_p), drought susceptibility index (S), drought intensity index (DII) and geometric mean (GM) were used. There were significant differences for all criteria among the genotypes. The selection was based on yield under moisture stress (Y_d) in first instance, which was followed supported by drought susceptible index (S) and geometric mean (GM) to identify drought tolerant/resistant cross. Marriya x BH 902 was most desirable cross from which selection of the plants gave highest mean yield under rainfed (Y_d =28.19) along with the maximum geometric mean (29.90) having 2nd rank and S value <1 (0.61). Although the cross Athoulpa x BH 902 has higher Y_d (27.27), maximum GM (30.67), but it showed poor value for drought susceptibility index (S = 1.17). V Morles × K 603 ranked 3rd for Y_p and 4th for drought susceptibility index (S = 0.61). Considering drought susceptible index out of 40 crosses 20 showed value less than 1, while Pristage x Lakhan (S= 0.50) and Pristage x RD 2508 (S= 0.55) showed 1st and 2nd rand respectively. Among the parents Yardu showed highest drought susceptible index (S= 0.66) and also good rank for Y_d, Y_p and GM followed by Marriya and K 603.

Key words : Barley, drought, yield, intensity index, exotic, rank.

Introduction

Barley (*Hordeum vulgare* L.) was one of the first domesticated crops and has been used as a regular source of food, being part of several links in the food industry, mainly in the malting industry (Cattivell *et al*., 1994) and currently the fourth most important cereal crop of India. Barley originates from the Eastern Mediterranean region where plants experience many abiotic stresses in the field. It is grown in many areas where climatic conditions are unfavourable. Though, its commercial value is less than that of wheat but it replaces the later in the dry regions in areas of too low and erratic rainfall. Because of low input requirement and better adaptation, it survives easily under rainfed condition and known as poor men's crop (Verma *et al*., 2010). All barley species are with fourteen chromosomes (2n = 14). Based on the morphology, *Hordeum vulgare* L. is the only cultivated species which has two – distant phenotypic forms *viz*., six rowed (*Hordeum vulgare*, *H. hexasstichum*) and two rowed (*H. distichum*).

Drought is a major environmental stress reducing crop yield around the world (Bruce *et al*., 2002). The combined effects of drought and high temperature on the physiology, growth, water relations, and yield are significantly higher than the individual effects (Grigorova *et al*., 2011). Yet, compared to other cereals, barley is well adapted to the adverse conditions due to better water-use efficiency and mechanisms of drought escape, avoidance and tolerance. Induced osmotic adjustment may allow plants to extract water from the soil under drought and therefore may be an important component of drought resistance in barley (Blum, 1989). Ceccarelli *et al*. (1998) demonstrated that the most effective way to improve productivity of barley grown in drought conditions is to use locally adapted germplasm and select in the target environment(s). Although, breeding for drought resistance based on direct selection for grain yield in the target environment (empirical or pragmatic breeding) appears to be the most obvious solution. This approach faces two major problems; first one, the precision of the yield trials conducted under drought conditions, and secondly, the existence of several target environments, each characterized by its own specific type of drought and combination of stress (Ceccarelli and Grando, 2002).

Breeding for drought resistance based on putative traits (traits associated with drought resistance, but easier to select for than grain yield) has been very popular, but the progress is still slow. However, most of traits were controlled by multiple genes and environments play an important role in the expression of specific traits. In several studies, it has been shown that the developmental genes are key factors in the determination of yield potential under drought condition (Teulat *et al*., 2001; Forster *et al*., 2004). These genes are responsible for photoperiod response, basic vegetative period, earliness and vernalization.

Materials and methods

The experimental materials consisted of genetic materials, for the present investigation comprised of four testers (Indigenous) and ten lines (exotic) (table 1). Line × Tester fashion was followed for making 40 F_1s, using testers as female and lines as male parents during 2013-14. Investigation was conducted during the rabi season (2014-15) by growing all 40 F_1s with their parents at the Agriculture Research Farm of Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. Sowing of same material was done in both rainfed as well irrigated conditions with Randomized Block Design and three replications.

Single row 5.0 m in length at the distance between rows was 0.25 cm was followed for sowing of F_1s and parents. Distance between two plants is 10 cm apart. All recommended cultural practices were considered. Data were recorded on 10 individual guarded plants chosen at random from each row.

Yield under drought (Y_d), yield potential (Y_p), drought susceptibility index (S) and geometric mean (GM) was considered as the potential indicators for drought tolerance of a variety or cross. The selection method was followed according to Schneider *et al*. (1997), which was first on GM followed by selection based on yield under drought (Y_d).

$$GM = \sqrt{Y_p \times Y_d}$$

Where,

GM = Geometric mean of a cross/variety

Y_d = Mean yield of a cross/variety under moisture stress (rainfed)

Y_p = Mean yield of a cross/variety under moisture non-stress (irrigated)

Drought susceptibility Index (S)

$S = [1-(Y_d / Y_p)]/ DII$ (Fischer and Maurer, 1978).

Drought intensity index (DII)

$(DII) = [1-(X_d / X_p)]$

Where,

X_d = Mean yield averaged across crosses/varieties in the moisture stress (rainfed) condition

X_p = Mean yield averaged across crosses/varieties in moisture non-stress (irrigated) condition

Results and Discussion

A total of 54 breeding material (table 2), which included 40 segregation F_2 population along with their parents were grown under moisture stress (rainfed) and moisture non-stress (irrigated) conditions during *rabi* 2014-15 to calculate drought susceptibility index (S). Grain yield per plant under moisture stress (Y_d) and moisture non-stress (Y_p) environment were utilized to calculate S value. The selection was based on yield under moisture stress (Y_d) in first instance, which was followed supported by drought susceptible index (S) and geometric mean (GM) to identify drought tolerant/resistant cross.

Table 1 : Details of selected barley genotypes.

S. no.	Name of lines/ testers	Pedigree/Source	Origin
	Lines		
1.	Moroc 9-75	CIMMYT	Exotic
2.	Rihane	CIMMYT	Exotic
3.	Pristage	CIMMYT	Exotic
4.	Yardu	CIMMYT	Exotic
5.	Atahualpa	CIMMYT	Exotic
6.	Himani	CIMMYT	Exotic
7.	Marriya	CIMMYT	Exotic
8.	V Morles	CIMMYT	Exotic
9.	Kheel	CIMMYT	Exotic
10.	HBSH 126	CIMMYT	Exotic
	Testers		
1.	RD 2508	RD2035 / P409	Indigenous
2.	K 603	K257 / C138	Indigenous
3.	BH 902	BH495 / EB7576	Indigenous
4.	Lakhan	K12 / IB226	Indigenous

Table 2 : Drought susceptibility index for lines, tester and theircrosses during year *Rabi* 2014-15.

S. no.	Name of Line/Tester and crosses	Y_d	Rank	Y_p	Rank	GM	Rank	S	Rank
1	RD 2508	17.51	45	24.15	34	20.56	42	1.55	33
2	K 306	18.46	41	21.94	45	20.14	43	0.89	15
3	BH 902	19.87	33	25.58	26	22.55	30	1.33	29
4	Lakhan	15.72	48	19.89	49	15.49	50	0.94	17
5	MORAC-9-75	17.86	43	21.15	47	19.55	45	0.95	18
6	Rihane	8.26	53	12.69	54	10.54	53	2.5	35
7	Pristage	16.98	46	22.29	43	19.45	46	1.33	29
8	Yardu	19.65	36	24.72	31	22.04	31	0.66	5
9	Athoulpa	12.94	51	16.43	52	14.58	51	1.16	25
10	Himani	10.53	52	13.27	53	11.82	52	1.15	24
11	Marriya	20.84	29	24.91	28	22.78	27	0.91	16
12	V Morules	19.67	35	23.87	36	21.67	37	0.98	19
13	Kheel	14.77	50	19.54	50	16.99	48	1.35	30
14	HBSH 126	17.38	45	20.15	48	18.71	47	0.76	9
15	Moroc 9-75 × RD 2508	25.08	9	30.86	8	27.82	6	1.04	21
16	Moroc 9-75 × K 603	24.19	12	27.01	20	25.56	16	0.58	3
17	Moroc 9-75 × BH 902	25.40	7	30.26	9	27.72	7	0.89	15
18	Moroc 9-75 × Lakhan	24.89	10	28.29	15	26.53	13	0.68	6
19	Rihane × RD 2508	19.13	39	24.74	30	21.75	35	1.26	27
20	Rihane × K 603	23.02	17	28.47	13	25.60	15	1.05	22
21	Rihane × BH 902	25.51	6	31.45	6	28.32	5	1.07	23
22	Rihane × Lakhan	16.19	47	23.26	39	21.11	40	1.69	34
23	Pristage × RD 2508	20.73	30	22.96	42	21.81	33	0.55	2
24	Pristage × K 603	22.62	20	25.97	24	24.23	23	0.71	7
25	Pristage × BH 902	24.75	11	28.20	16	24.76	21	0.72	8
26	Pristage × Lakhan	20.94	28	22.98	41	21.93	32	0.50	1
27	Yardu × RD 2508	25.09	8	29.50	11	27.20	10	0.88	14
28	Yardu × K 603	19.20	38	23.48	38	21.23	39	1.05	22
29	Yardu × BH 902	23.55	15	26.98	21	25.20	18	0.72	8
30	Yardu × Lakhan	23.93	13	32.05	3	27.69	8	1.44	32
31	Athoulpa × RD 2508	19.84	34	23.52	37	21.60	38	0.89	15
32	Athoulpa × K 603	19.08	40	24.67	32	21.69	36	1.28	28
33	Athoulpa × BH 902	27.27	2	34.50	1	30.67	1	1.16	25
34	Athoulpa × Lakhan	21.76	24	26.51	23	24.01	24	1.00	20
35	Himani × RD 2508	18.46	41	21.16	46	19.76	44	0.72	8
36	Himani × K 603	20.97	27	24.79	29	22.80	26	0.89	15
37	Himani × BH 902	21.81	23	27.74	18	24.59	22	1.22	26
38	Himani × Lakhan	15.23	49	18.51	51	16.79	49	1	20
39	Marriya × RD 2508	25.72	5	27.83	17	26.75	12	0.83	13
40	Marriya × K 603	22.60	21	29.40	12	25.77	14	1.28	28
41	Marriya × BH 902	28.19	1	31.72	5	29.90	2	0.61	4
42	Marriya × Lakhan	26.58	4	32.50	2	29.39	3	1.00	20
43	V-Morles × RD 2508	23.88	14	31.89	4	27.59	9	1.39	31
44	V-Morles × K 603	26.82	3	30.10	10	28.41	4	0.61	4
45	V-Morles × BH 902	22.84	18	26.53	22	25.52	17	0.78	10

Table 2 continued...

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46	V-Morles × Lakhan	21.63	25	25.12	27	23.30	25	0.79	11
47	Kheel × RD 2508	19.90	32	25.86	25	22.68	29	1.28	28
48	Kheel × K 603	22.82	19	27.38	19	24.99	20	0.94	17
49	Kheel × BH 902	21.16	26	24.45	33	22.74	28	0.78	10
50	Kheel × Lakhan	23.32	16	31.11	7	26.93	11	1.39	31
51	HBSH 126 × RD 2508	19.91	31	23.89	35	21.80	34	0.80	12
52	HBSH 126 × K 603	18.30	42	23.11	40	20.56	42	1.16	25
53	HBSH 126 × BH 902	22.04	22	28.36	14	25.00	19	1.22	26
54	HBSH 126 × Lakhan	19.28	37	22.28	44	20.72	41	0.83	13

Y_p and Y_d mean yield of a family under nonstress and stress, respectively
GM = Geometric mean of a family under nonstress and stress
S = Drought susceptible index

Overall mean of Y_p = 25.36
Overall mean of Y_d = 20.81
Drought intensity index (DII) = 0.18

The observations showed that the cross Marriya × BH 902 was most desirable cross from which selection of the plants gave highest mean yield under rainfed (Y_d = 28.19) along with the maximum geometric mean (29.90) having 2nd rank and S value <1 (0.61). Although, the cross Athoulpa × BH 902 has higher Y_d (27.27), maximum GM (30.67), but it showed poor value for drought susceptibility index (S = 1.17). V Morles x K 603 ranked 3rd for Y_p and 4th for drought susceptibility index (S = 0.61). The variety or cross, which shows higher Y_d and GM with least S value (<1) is identified as drought resistant/tolerant and therefore, it might be concluded on the basis of Y_d, GM and S values that plant derived from the crosses Marriya × BH 902 and V Morles × K 603 are drought resistant/ tolerant. The selection in high yielding environment is expected to produce response or no response in low yielding conditions. Considering drought susceptible index out of 40 crosses 20 showed value less than 1, while Pristage x Lakhan (S= 0.50) and Pristage x RD 2508 (S= 0.55) showed 1st and 2nd rand, respectively. Among the parents Yardu showed highest drought susceptible index (S = 0.66) and also good rank for Y_d, Y_p and GM followed by Marriya and K 603. The results are in conformity with Lal *et al*. (2009), Samarah (2005), Akcura *et al*. (2011), Khokhar *et al*. (2012), Marouf *et al*. (2013) and Maisa'a (2015).

Conclusion

On the basis of Y_d, Y_p, GM and S values, it may be concluded that, plants derived from the crosses Marriya × BH 902 and V Morles × K 603 showed relatively higher drought tolerance, which are expected to give high yield along with drought tolerance in further segregating generation.

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