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Study of Drought Susceptibility Index for Grain Yield and Associated Traits in Barley (*Hordeum vulgare* L.) Genotypes under Limited Moisture condition of Rajasthan

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ABSTRACT: Drought is one of the most common abiotic stresses, posing a major challenge to sustainable food production, as it can reduce the potential yield by up to 70% in crop plants. In arid and semi-arid regions, either reduction in water supply in soil or high transpiration can cause drought experience in crops. It has been reported that drought stress could reduce grain yield by 49–87% in barley. Drought occurs in all climatic regions and 16.2-41.2% of arable land worldwide is considered as drought-prone area. Drought continues to be an important challenge to agricultural researchers and plant breeders. It is assumed that by the year 2025, around 1.8 billion people will face absolute water shortage and 65% of the world's population will live under water-stressed environments. It is one of the consequences of climate change that has a negative impact on crop growth and yield. It is extremely important to improve essential crops to meet the challenges of drought stress which limits crop productivity and production. The overall ranking indicated that parents DWRUB 64, BH 946, RD 103 and RD 2592, were found the most desirable parents as they possessed high drought tolerance for most of the studied characters. Among the F_1 crosses BH 946 × PL 426, BH 946 × RD 103, RD 2592 × PL 426, PL 426 × RD 2052, PL 426 × RD 103 and RD 2592 × RD 2035 and in F_2 crosses RD 2592 × PL 426, DWRUB 64 × DWRB 137, PL 426 × RD 103, PL 426 × RD 2508 and RD 103 × RD 2052 were found to be desirable for most of the studied characters. An overall evaluation in limited moisture environment revealed that the crosses RD 2592 × PL 426 and PL 426 × RD 103 were found more desirable as they possessed high drought tolerance for most of the studied traits across the generations.

Keywords: Barley, Drought, Tolerance, Stress, Rainfed.

INTRODUCTION

Barley (*Hordeum vulgare* L.) is a self-pollinated cereal crop having chromosome number 2n=2x=14 and a member of poaceae family. It is grown in tropical and temperate climate globally, over a wide range of environment because of its broad ecological adaptation, low input requirement and better adaptability to harsh conditions, i.e. drought, salinity, alkalinity and marginal lands. Barley can be utilized as animal feed (60%), for malt production (30%), seed production (7%) and for human food (3%) (Baik and Ullrich 2008).). In Rajasthan, it is an important *rabi* cereal crop after wheat in both area and production. It is grown over an area of 2.88 lakh hectares and a total production of 8.31 lakh tonns with an average grain productivity of 2884 kg per hectare (Anonymous 2019-20).

In ancient Sanskrit texts of Indo-Aryans, barley is termed as "Yava" and was probably most stable food during vedic period. Barley is grown as irrigated, rainfed crop and under residual soil moisture. It's yield have not significantly increased and vary mostly in response to fluctuation in climatic conditions. Drought occurs in all climatic regions and 16.2-41.2% of arable land worldwide is considered as drought-prone area (Wang *et al.*, 2014; Kebede *et al*., 2019). It has been forecasted that presently the drought severity and frequency will increase in dry regions due to climate change (IPCC, 2014). It has been reported that drought stress could reduce grain yield by 49-87% in barley (Samarah, 2005; Samarah *et al.*, 2009). Drought is one of the most common abiotic stresses, posing a major challenge to sustainable food production, as it can reduce the potential yield by up to 70% in crop plants (Gosal *et al.*, 2009). In arid and semi-arid regions, either reduction in water supply in soil or high transpiration can cause drought experience in crops (Reddy *et al.*, 2004). It has been reported that drought stress could reduce grain yield by 49–87% in barley

(Samarah, 2005; Samarah *et al.,* 2009). Thus, developing drought-tolerant cultivars is an extremely significant issue among breeders and agronomists. Nutrient uptake, metabolism of nutrients and translocation are reduced because of the adverse effects of drought on transpiration, size of the source and sink tissues, assimilate translocation, phloem loading, dry matter partitioning, pollination and seed set, though the level of effects differs with growth stage, plant species, and the intensity of drought.

Climate change is a major threat to most of the agricultural crops grown in tropical and sub-tropical areas globally. Drought stress is one of the consequences of climate change that has a negative impact on crop growth and yield. In the past, many simulation models were proposed to predict climate change and drought occurrences, and it is extremely important to improve essential crops to meet the challenges of drought stress which limits crop productivity and production. Wheat and barley are among the most common and widely used crops due to their economic and social values. Many parts of the world depend on these two crops for food and feed, and both crops are vulnerable to drought stress (Kapoor *et al.,* 2020). Drought tolerance is a function of integrated plant system at the tissue and whole plant level and is determined by different combination of genes which are critical for drought tolerance at different stages of the life cycle. Therefore, understanding the physiological responses of barley crop to drought stress is prerequisite in identifying the characters to be used in breeding for drought tolerance. The genetic studies will require utmost attention when breeding objective is high grain yield along with drought tolerance. Though a number of studies have been attempted to get reliable information concerning inheritance of these traits, but still it requires some more work. Thus, an effective breeding strategy can be developed for breeding high yielding drought tolerant barley genotypes. Hence, in the present investigation an effort has been made to understand the response of barley genotypes to drought tolerance, genetic makeup of grain yield under normal and limited moisture conditions and to suggest the suitable breeding methodology for further improvement.

There is a need for the development of abiotic and biotic stress tolerant new varieties of barley for the enhancement of crop productivity. Proper choice of parents on the basis of combining ability for putative drought tolerant attributes as well as productive traits and selection in typical target environment will help in combining complex traits, such as, productivity and drought tolerance. The presence of additive gene effect is particularly utilized in the development of pureline varieties. Drought is predominantly controlled by additive genes (Solmon *et al*., 2003). Likewise, the dominance and epistatic gene effects (non-additive components) is also valuable for development of hybrid varieties (Munir *et al*., 2007).

MATERIAL AND METHODS

The present investigation was carried out during *rabi* 2018-19 and 2019-20 at Research Farm, Rajasthan Agricultural Research Institute (Sri Karan Narendra Agriculture University, Jobner), Durgapura, Jaipur (Rajasthan). Ten diverse parents namely: BH 946, RD 2592, DWRUB 64, DWRB 137, PL 426, PL 419, RD 103, RD 2035, RD 2052 and RD 2508 were selected and crossed in diallel fashion (excluding reciprocals) in all possible combinations during *rabi* 2018-19. In *summer* 2019, half of the F1's seed was multiplied during off-season at IARI regional station, Wellington (Tamil Nadu) to advance the generation. In *rabi* 2019-20 ten varieties along with their 45 F1's and 45 F2's progenies were evaluated under the limited moisture condition created by giving only three irrigations at the crop stage of 30, 60 and 90 days with three replications in randomized block design. Each replication contained two parts. The parents and F_1s sown in two rows with 3 m row length and F_2s were sown in 4 rows of 3 m in each replication. Row to row and plant to plant distance was kept 30 cm and 10 cm, respectively. Non-experimental rows were planted all around the experiment to eliminate the border effects, if any. All recommended agronomical package of practices were adopted to raise good crop. Observations were recorded days to maturity, plant height, number of effective tillers per plant, flag leaf area, 1000-grain weight, grain yield per plant and harvest index.

Drought susceptibility index (DSI) was calculated for grain yield and other attributes over stress (Drought stress - water stress conditions) and non-stress environment (Normal - fully irrigated conditions) by using the formula as suggested by Fisher and Maurer (1978).

DSI = [l-YD/YP]/D

Where; YD = mean of the genotype in stress environment (drought).

YP = mean of the genotype under non-stress environment.

D = 1-[mean YD of all genotypes/mean YP of all genotypes].

The DSI value was used to characterize the relative tolerance of genotypes based on minimization of yield losses compared to normal environmental conditions.

RESULT AND DISCUSSION

All the characters studied showed a reduction in the mean performance of parents, F_1's and F_2's under limited moisture environment (E_2) in comparison to normal irrigated environment (E_1). The DSI was calculated for each parents, F_1's and F_2's separately for each character in drought stress environment i.e. E_2 (limited moisture) against E_1 (normal irrigated). Similar result also reported by Ajalli and Salehi (2012); Singh *et al.* (2017) in barley. On the basis of DSI, the parents, F_1's and F_2's were classified as highly tolerant, tolerant, moderately tolerant and susceptible to drought stress [(Table 1) E_1 vs E_2)]

Table 1: Drought susceptibility indices for yield and its contributing traits in E_2 (limited moisture) in comparison to E_1 (normal irrigated) environment.

Parents	Days to heading	Days to maturity	Plant height (cm)	Number of effective tillers per plant	Flag leaf area (cm^2)	Peduncle length (cm)	Number of grains per spike	Number of Spikelets per spike	Spike length (cm)	Biomass per plant (g)	1000-grain weight (g)	Grain yield per spike (g)	Grain yield Per plant (g)	Harvest index (%)
Parents														
BH 946	0.64	0.47	0.66	0.96	0.86	1.48	1.41	1.19	0.80	0.57	1.55	1.33	0.75	0.84
RD 2592	0.81	0.58	0.57	0.99	0.99	0.95	0.79	0.46	1.15	1.31	0.73	1.60	1.13	1.03
DWRUB 64	1.18	1.86	0.87	0.97	0.55	0.94	0.78	0.74	0.52	0.58	0.61	0.42	0.66	0.67
DWRB 137	1.48	1.43	1.09	0.51	0.95	0.95	0.96	0.92	1.03	1.17	1.06	0.87	1.42	1.71
PL 426	1.16	1.07	1.10	1.19	0.40	0.99	1.06	1.41	1.07	0.69	1.09	1.26	1.15	1.47
PL 419	0.90	1.20	1.12	1.01	1.04	1.44	0.77	0.46	1.08	1.36	0.94	0.86	0.97	0.65
RD 103	0.92	0.66	0.63	1.16	1.15	0.56	0.90	0.32	1.03	0.24	0.82	0.78	0.69	0.95
RD 2035	0.56	0.70	1.81	0.88	0.91	0.99	1.11	1.70	0.95	0.80	0.37	0.90	0.94	1.02
RD 2052	1.37	0.98	1.11	1.38	1.94	0.87	1.10	1.60	1.16	1.03	1.09	0.98	0.89	0.76
RD 2508	0.97	0.98	0.87	0.80	0.93	0.86	1.05	0.88	1.02	1.78	1.70	0.82	1.32	1.05
F_1 crosses														
BH 946 × RD 2592	0.50	1.07	0.83	0.87	0.95	0.98	1.02	0.75	1.01	0.76	1.23	1.11	0.80	0.80
BH 946 × DWRUB 64	1.19	1.58	0.48	1.03	1.51	1.02	0.67	0.86	0.75	1.02	0.80	1.09	0.80	0.54
BH 946 × DWRB 137	1.32	1.01	1.44	1.24	1.60	0.92	1.33	0.79	1.26	1.10	1.13	0.95	0.92	0.66
BH 946 × PL 426	0.72	1.56	1.58	0.74	0.92	1.36	0.92	1.36	1.09	0.08	0.11	1.68	0.25	0.39
BH 946 × PL 419	1.04	0.92	1.27	1.26	1.02	1.42	0.86	0.38	0.88	1.26	1.18	0.97	0.94	0.55
BH 946 × RD 103	0.83	1.00	0.51	0.92	0.61	0.93	1.46	1.21	0.96	0.75	0.90	0.36	0.58	0.35
BH 946 ×RD 2035	1.03	0.21	0.80	0.44	1.04	0.94	1.12	1.21	1.06	0.76	1.85	0.91	0.72	0.63
BH 946 × RD 2052	1.15	1.51	0.00	0.78	1.05	0.76	1.37	0.98	0.94	0.81	0.84	1.22	0.86	0.89
BH 946 × RD 2508	1.21	0.77	1.40	1.07	0.58	0.83	1.05	0.73	1.09	0.88	1.17	1.12	0.94	0.99
RD 2592 × DWRUB 64	0.84	2.21	0.76	0.99	1.34	0.10	0.75	1.10	1.18	0.29	1.41	1.29	1.44	2.53
RD 2592 × DWRB 137	0.88	1.48	1.55	1.38	0.82	1.59	0.63	0.89	0.69	0.85	1.39	1.70	1.43	2.11
RD 2592 × PL 426	0.93	1.69	1.02	0.86	1.43	1.29	0.60	0.26	1.12	0.31	0.65	0.90	0.29	0.18
RD 2592 × PL 419	0.50	1.58	1.07	0.99	1.11	0.89	0.77	0.60	0.64	1.30	1.47	1.00	1.15	1.02
RD 2592 × RD 103	1.06	0.40	0.72	1.08	0.70	1.12	0.74	0.60	1.02	0.83	0.60	1.11	1.20	1.63
RD 2592 ×RD 2035	0.65	0.26	0.43	1.15	0.82	0.64	0.60	1.12	0.93	1.51	0.06	1.17	1.38	1.38
RD 2592 × RD 2052	1.06	1.03	0.82	0.83	0.81	0.92	1.07	0.97	1.06	1.10	1.46	0.96	1.08	1.09
RD 2592 × RD 2508	1.04	1.09	0.91	0.89	0.61	1.58	0.95	0.99	0.95	1.69	1.70	1.02	1.44	1.33
DWRUB 64 × DWRB 137	1.04	0.63	0.71	0.74	1.18	0.73	1.59	0.78	0.97	0.60	0.78	1.40	0.59	0.52
DWRUB 64 × PL 426	0.84	1.09	0.57	1.26	0.47	1.30	0.36	0.47	1.33	0.61	0.92	1.21	0.81	0.96
DWRUB 64 × PL 419	0.87	1.44	0.89	1.29	0.27	1.77	0.13	0.52	1.11	1.23	0.79	0.83	1.03	0.81
DWRUB 64 × RD 103	1.08	1.27	1.32	1.12	1.09	0.46	0.98	1.27	0.24	0.95	0.93	0.82	1.23	1.57
DWRUB 64 ×RD 2035	0.96	0.39	0.22	0.96	1.20	0.96	0.87	1.40	1.53	1.28	0.60	0.51	1.31	1.44
DWRUB 64 × RD 2052	0.91	1.40	1.02	0.89	0.76	0.81	1.54	0.94	1.22	1.01	0.62	0.75	0.93	0.83
DWRUB 64 × RD 2508	1.04	1.35	1.23	0.75	0.63	0.82	1.31	0.99	1.29	1.55	0.43	0.94	1.19	0.84
DWRB 137 × PL 426	1.27	1.22	1.16	0.66	1.30	0.61	1.22	1.33	0.81	1.12	0.96	0.76	1.34	1.67
DWRB 137 × PL 419	1.01	0.21	0.85	1.06	1.44	1.74	1.28	0.53	1.23	0.66	1.91	0.82	1.17	1.70
DWRB 137 × RD 103	1.24	1.06	1.34	1.13	1.45	1.24	0.22	0.74	0.54	1.31	1.46	1.22	1.29	1.35
DWRB 137 × RD 2035	1.04	0.08	1.07	1.56	0.62	0.95	0.98	0.97	1.22	1.37	0.12	0.78	1.18	1.03
DWRB 137 × RD 2052	1.06	0.88	1.21	1.01	0.82	0.55	0.56	1.15	0.95	0.45	1.15	0.86	0.67	0.83
DWRB 137 × RD 2508	0.98	0.63	1.32	0.80	0.51	0.97	0.99	0.34	1.00	1.02	0.60	0.94	0.82	0.56
PL 426 × PL 419	0.84	0.77	1.18	1.21	1.07	1.73	1.82	1.20	0.94	0.77	0.22	0.77	0.75	0.70
PL 426 × RD 103	1.02	0.72	1.13	1.30	1.07	0.27	0.54	0.42	0.16	0.84	0.16	0.77	0.76	0.60
PL 426 × RD 2035	0.94	0.71	1.06	1.60	1.20	1.45	1.12	1.49	1.08	0.70	1.13	1.75	0.74	0.73
PL 426 × RD 2052	1.02	0.23	0.56	0.86	0.68	1.30	1.18	1.07	1.26	0.30	0.08	1.16	0.47	0.59
PL 426 × RD 2508	0.88	1.09	0.62	0.37	1.39	1.76	1.09	0.67	1.50	0.84	0.16	0.96	0.61	0.28
PL 419 × RD 103	1.21	1.04	1.31	0.97	0.67	0.61	0.93	1.14	0.75	1.17	1.66	1.05	0.92	0.62
PL 419 × RD 2035	0.65	0.99	1.67	0.82	0.87	0.21	0.93	0.98	0.82	0.44	1.63	1.36	0.56	0.63
PL 419 × RD 2052	1.23	1.20	1.05	0.95	1.16	0.98	0.95	1.59	1.24	1.10	0.94	0.74	0.97	0.82
PL 419 × RD 2508	1.38	1.02	1.26	1.04	1.12	1.05	1.67	1.48	0.93	1.20	1.20	0.66	1.21	1.28
RD 103 × RD 2035	1.14	0.82	0.84	1.11	1.13	1.03	1.04	1.34	1.60	1.21	1.06	1.03	1.26	1.40
RD 103 × RD 2052	0.92	0.72	0.89	0.77	0.70	1.07	1.06	1.00	0.74	0.19	1.60	0.60	0.35	0.46
RD 103 × RD 2508	1.16	0.99	0.71	1.02	0.94	0.59	1.10	1.18	0.70	1.58	0.95	1.07	1.37	1.25
RD 2035 × RD 2052	1.08	0.69	1.53	1.03	1.56	1.15	1.00	1.79	0.39	1.48	1.11	0.84	1.00	0.42
RD 2035 × RD 2508	1.15	1.81	1.11	0.81	0.92	0.07	0.88	1.24	0.90	1.71	1.09	0.99	1.20	0.63
RD 2052 × RD 2508	1.06	0.90	1.29	0.84	1.13	0.94	1.06	1.11	0.97	1.25	1.88	0.84	1.25	1.33
F_2 crosses														
BH 946 × RD 2592	0.06	1.57	0.86	0.82	0.98	0.84	1.10	1.00	1.15	0.77	0.73	1.01	0.84	0.88
BH 946 × DWRUB 64	0.99	1.90	0.81	0.79	1.53	1.15	0.95	0.71	0.74	0.66	0.24	0.90	0.75	0.79
BH 946 × DWRB 137	1.42	0.31	1.00	1.24	1.40	1.09	0.76	0.48	1.16	0.66	0.16	1.20	0.61	0.50
BH 946 × PL 426	1.53	1.65	1.06	0.66	1.19	1.29	1.15	1.13	0.85	0.57	1.32	1.28	0.60	0.57
BH 946 × PL 419	1.16	1.52	1.08	0.76	0.94	1.32	0.39	1.12	1.40	1.26	1.05	1.15	0.94	0.58
BH 946 × RD 103	0.78	0.91	0.64	1.09	0.57	1.27	1.33	0.90	1.15	1.16	0.24	0.91	0.83	0.42
BH 946 ×RD 2035	1.22	1.12	0.56	0.98	0.09	1.47	0.84	0.99	0.76	1.11	1.04	0.35	0.90	0.67
BH 946 × RD 2052	0.94	1.71	0.78	0.93	1.05	0.89	1.34	1.09	1.62	1.02	1.11	1.15	0.97	0.90
BH 946 × RD 2508	0.73	1.30	0.63	1.25	0.65	0.81	0.77	1.13	0.93	0.96	0.64	1.26	1.07	1.19
RD 2592 × DWRUB 64	1.02	1.43	0.59	0.86	0.84	0.42	1.07	1.24	1.40	0.69	1.82	0.86	1.48	2.29
RD 2592 × DWRB 137	0.99	0.76	1.18	1.19	0.93	1.59	1.03	0.35	0.91	0.86	0.65	1.50	1.35	1.92
RD 2592 × PL 426	1.45	0.36	1.01	0.23	1.27	1.12	0.90	0.77	0.53	0.74	0.88	0.86	0.52	0.24
RD 2592 × PL 419	0.72	1.37	1.11	1.30	1.40	1.29	0.86	0.87	0.64	1.42	0.82	1.13	1.11	0.77

RD 2592 × RD 103	1.18	0.45	0.77	1.29	0.54	1.68	0.63	1.41	1.11	0.62	0.25	0.69	1.25	1.86
RD 2592 ×RD 2035	0.81	0.28	0.95	1.07	0.73	1.04	1.00	0.88	1.03	1.21	0.96	1.00	1.21	1.26
RD 2592 × RD 2052	0.79	1.10	0.96	0.75	0.94	0.77	0.96	0.96	0.91	0.60	1.51	0.91	1.06	1.51
RD 2592 × RD 2508	1.13	1.16	0.68	1.05	0.59	1.39	0.43	1.18	0.94	1.33	2.00	1.03	1.46	1.73
DWRUB 64 × DWRB 137	0.62	1.54	0.91	1.30	0.73	0.71	1.89	1.39	1.12	0.26	1.33	1.34	0.21	0.15
DWRUB 64 × PL 426	0.77	1.32	1.28	1.29	0.93	0.59	0.32	0.28	1.55	0.34	0.76	1.32	0.60	0.80
DWRUB 64 × PL 419	1.03	0.91	1.44	1.11	0.78	2.06	0.47	0.77	0.88	1.06	0.74	0.79	1.05	1.04
DWRUB 64 × RD 103	1.28	0.74	0.98	1.17	1.38	0.42	0.79	1.21	0.20	1.06	0.61	0.84	1.18	1.33
DWRUB 64 ×RD 2035	0.71	1.18	1.14	0.80	1.50	1.46	1.04	1.28	1.44	0.88	0.54	0.39	1.16	1.46
DWRUB 64 × RD 2052	0.74	1.12	1.18	0.99	0.83	0.90	1.21	0.71	1.12	1.09	0.56	1.00	1.08	1.09
DWRUB 64 × RD 2508	1.19	1.16	1.29	0.78	0.49	1.21	1.62	1.05	1.10	1.53	0.45	0.79	1.27	1.06
DWRB 137 × PL 426	1.16	0.47	1.16	0.62	1.28	1.06	1.08	0.89	1.08	1.06	0.93	0.34	1.37	1.79
DWRB 137 × PL 419	1.37	1.02	0.96	1.32	1.38	1.43	0.17	0.92	0.99	0.39	2.22	1.19	1.23	2.00
DWRB 137 × RD 103	1.37	1.11	1.30	0.60	1.61	1.14	1.35	0.97	0.40	1.35	1.62	0.87	1.25	1.20
DWRB 137 × RD 2035	1.12	0.13	1.00	1.40	0.98	1.34	0.36	0.80	1.38	1.72	0.28	0.74	1.52	1.51
DWRB 137 × RD 2052	0.96	0.90	1.23	1.23	0.88	1.37	0.47	0.96	0.73	0.35	1.66	1.06	0.70	0.99
DWRB 137 × RD 2508	0.82	0.88	1.26	1.19	0.50	0.84	1.18	0.81	1.28	1.23	1.59	1.31	0.98	0.70
PL 426 × PL 419	1.16	0.64	0.99	1.02	1.14	1.41	1.62	1.26	0.58	0.42	0.72	0.77	0.65	0.84
PL 426 × RD 103	0.90	0.73	1.07	1.46	1.09	0.04	1.71	0.68	0.33	0.84	0.53	0.87	0.57	0.22
PL 426 × RD 2035	1.01	0.65	0.77	1.65	1.39	1.18	1.77	1.07	1.52	0.52	0.52	1.34	0.56	0.53
PL 426 × RD 2052	0.75	0.52	1.08	0.83	0.46	0.84	0.60	1.33	0.78	0.49	0.65	1.05	0.49	0.42
PL 426 × RD 2508	1.31	0.56	1.10	0.56	1.04	1.42	0.59	0.52	0.97	1.01	0.26	1.16	0.65	0.23
PL 419 × RD 103	1.13	0.08	1.08	0.93	0.62	0.45	1.22	1.07	0.66	1.29	1.57	0.80	1.04	0.76
PL 419 × RD 2035	1.10	0.93	1.08	0.76	1.07	0.61	1.32	0.72	1.26	0.81	1.47	0.94	0.87	0.90
PL 419 × RD 2052	0.26	1.54	0.85	0.96	1.02	0.18	0.73	1.31	0.59	1.19	0.66	0.85	0.93	0.62
PL 419 × RD 2508	0.96	1.79	0.89	1.02	1.13	0.67	0.75	0.81	0.47	1.18	1.34	1.07	1.05	0.93
RD 103 × RD 2035	1.08	0.70	0.59	1.22	1.06	0.92	1.23	0.87	1.60	1.72	1.08	1.61	1.35	1.04
RD 103 × RD 2052	0.85	0.64	0.94	0.41	0.59	1.05	0.79	1.11	0.78	0.02	1.16	0.89	0.04	0.04
RD 103 × RD 2508	0.97	0.79	1.03	1.13	1.14	0.66	1.60	0.95	0.97	1.25	1.35	0.97	1.26	1.34
RD 2035 × RD 2052	0.75	1.12	0.59	0.89	1.22	0.39	1.53	1.70	1.03	1.30	1.67	1.06	0.78	0.15
RD 2035 × RD 2508	1.58	1.47	0.91	0.60	0.74	0.65	0.46	1.55	1.05	2.20	1.43	1.00	1.33	0.28
RD 2052 × RD 2508	0.75	1.29	1.76	0.68	1.16	0.07	1.04	1.12	0.99	1.09	1.69	0.88	1.14	1.21

Resemblance across the generations indicated the superiority of the crosses i.e. RD 2592 × PL 426 and PL 426 × RD 103 found more tolerant for most of the studied traits across the F_1 and F_2 generations under limited moisture condition (E_2). Low drought stress intensity (D-value) i.e. 0.01 to 0.20 revealed that the parameters *viz.* days to heading (0.16), days to maturity (0.11), peduncle length (0.19), number of grains per spike (0.18), biomass per plant (0.18), 1000-grain weight (0.11) and harvest index (0.18) were less affected whereas plant height (0.23), number of effective tillers per plant (0.33), flag leaf area (0.30), number of spikelets per spike (0.28), spike length (0.34), grain yield per spike (0.23) and grain yield per plant (0.33) with high drought stress intensity (D-value) *i.e.* 0.21 to 0.50, suffered more under E_2 environment. These results are in accordance with earlier reports of Nazari and Pakniyat (2010); Ajalli and Salehi (2012); Zare (2012); Haddadin (2015); Moradi *et al.* (2015); Dorostkar *et al.* (2016); EL-Shawy *et al.* (2017); Sefatgol and Ganjali (2017); Singh *et al.* (2017); Hellal *et al.* (2019); Feizi *et al.* (2020).

In this study genotypes were classified arbitrarily into four different categories i.e. highly drought tolerant (DSI < 0.50), drought tolerant (DSI: 0.51-0.75), moderately drought tolerant (DSI: 0.76-1.00) and Drought susceptible (DSI > 1.00).

Perusal of Table 1 revealed that parents, F_1 and F_2 generations showed both high and moderate drought tolerance. In F_1 generation, the crosses BH 946 × PL 426, RD 2592 × PL 426, RD 103 × RD 2052 and PL 426 × RD 2052 and in F_2 generation, crosses RD 103 × RD 2052, DWRUB 64 × DWRB 137 and PL 426 × RD 2052 showed DSI value less than 0.50 hence, these crosses were least affected under limited moisture condition (E_2) for grain yield per plant while among the parents, DWRUB 64, RD 103 and BH 946 ; in F_1, the crosses BH 946 × RD 103, BH 946 × RD 2035, DWRUB 64 × DWRB 137, DWRB 137 × RD 2052, PL 426 × PL 419, PL 426 × RD 2035, PL 426 × RD 2508 and PL 419 × RD 2035 and in F_2, crosses BH 946 × DWRUB 64, BH 946 × DWRB 137, BH 946 × PL 426, RD 2592 × PL 426, DWRUB 64 × PL 426, DWRB 137 × RD 2052, PL 426 × PL 419, PL 426 × RD 103, PL 426 × RD 2035 and PL 426 × RD 2508 revealed DSI value 0.50-0.75, hence, these parents and crosses were considered as moderate drought tolerant.

The overall results indicated that parents DWRUB 64, BH 946, RD 103 and RD 2592, were found the most desirable as they possessed high drought tolerance for most of the studied characters. Among the F_1 crosses BH 946 × PL 426, BH 946 × RD 103, RD 2592 × PL 426, PL 426 × RD 2052, PL 426 × RD 103 and RD 2592 × RD 2035 and in F_2 crosses RD 2592 × PL 426, DWRUB 64 × DWRB 137, PL 426 × RD 103, PL 426 × RD 2508 and RD 103 × RD 2052 were found to be desirable for most of the studied characters on the basis of DSI.

An overall perusal of the Table 1 revealed that the crosses RD 2592 × PL 426 and PL 426 × RD 103 found more tolerant for most of the studied traits across the F_1 and F_2 generations under limited moisture condition (E_2).

CONCLUSION

Based on the drought susceptibility index, the parents DWRUB 64, BH 946, RD 103 and RD 2592 were most desirable parents in E_2 environment as they attained high DSI value for yield and its contributing traits. As a consequence, it is recommended that these parents may perform as potential donors for drought tolerance.

These parents should be further exploited for improvement of grain yield under rainfed conditions. DSI should be taken as an important criterion for breeding barley genotypes suitable for rainfed or drought stress environment. There is a need for the development of abiotic and biotic stress tolerant new varieties of barley for the enhancement of crop productivity. The most alternative is to increase the yield per unit area through better crop management practices and increasing the cultivation of high yielding varieties with adequate resistance to biotic and abiotic stresses. New wheat and barley genotypes having a high degree of drought tolerance are produced through breeding by making crosses from promising drought-tolerant genotypes and selecting among their progeny. Also, identifying genes contributing to drought tolerance is very important. Improving drought stress tolerance is a very challenging task for wheat and barley researchers and more research is needed to better understand this stress.

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Conflict of Interest. None.

REFERENCES

Ajalli, J. and Salehi, M. (2012). Evaluation of drought stress indices in barley (*Hordeum vulgare* L.). *Annals of Biological Research, 3*(12): 5515-5520.

Anonymous, (2019-20). Rajasthan Agricultural Statistics at a Glance, Rajasthan Government.

Baik, B. K. and Ullrich, S. E. (2008). Characteristics, improvement and renewed interest. *Journal of cereal science, 48*(2): 233-242.

Dorostkar, S., Paknyiat, H., Kordshooli, M. A., Ghorbani, R., Aliakbari, M., Sobhanian, N. and Valiloo, R. (2016). Evaluation of several drought tolerance criteria in cultivated varieties of barley (*Hordeum vulgare* L.) and their relationships with yield reduction. *Science Research, 4*(2): 26-32.

EL-Shawy, E. E., EL-Sabagh, A., Mansour, M. and Barutcular, C. (2017). A comparative study for drought tolerance and yield stability in different genotypes of barley (*Hordeum vulgare* L.). *Journal of Experimental Biology and Agricultural Sciences, 5*(2): 151-162.

Feizi, M., Solouki, M., Sadeghzadeh, B., Fakheri, B. and Mohammadi, S. A. (2020). Evaluation of drought tolerance indices for barley landraces under irrigated and dry conditions. *Bioscience Journal, 36*(5):1518-1527.

Fischer, R. A. and Maurer, R. (1978). Drought resistance in spring wheat varieties. *Australian Journal of Agricultural Research, 29*: 897- 912.

Gosal, S. S., Wani, S. H. and Kang, M. S. (2009). Biotechnology and drought tolerance. *Journal of Crop Improvement, 23*(1): 19–54.

Haddadin, M. F. (2015). Assessment of drought tolerant barley varieties under water stress. *International Journal of Agriculture and Forestry, 5*(2): 131-137.

Hellal F., Hady M. A., Khatab I., El-Sayed S. and Abdelly C. (2019). Yield characterization of Mediterranean barley under drought stress condition. *AIMS Agriculture and Food, 4*(3): 518–533.

Intergovernmental Panel on Climate Change 2014. Climate Change 2013 – The Physical Science Basis. Cambridge University Press.

Kapoor, D., Bhardwaj, S., Landi, M., Sharma A., Ramakrishnan M. and Sharma A. (2020). The impact of drought in plant metabolism: how to exploit tolerance mechanisms to increase crop production. *Applied Sciences, 5692*(10): 1-19.

Kebede, A., Kang, M. S. and Bekele, E. (2019). Chapter Five - Advances in mechanisms of drought tolerance in crops, with emphasis on barley. *Advances in Agronomy, 156*(1): 265–314.

Moradi, Z., Farshadfar, E. and Shirvani, H. (2015). Screening of drought tolerant genotypes in bread wheat (*Triticum aestivum*) using morpho-physiological traits and integrated selection index. *Biological Forum – An International Journal, 7*(1): 163-172.

Munir, M., Chowdhry, M. A. and Malik, T. A. (2007). Correlation studies among yield and its components in bread wheat under drought conditions. *International Journal of Agriculture and Biology, 9*(2): 287-290.

Nazari, L. and Pakniyat, H. (2010). Assessment of drought tolerance in barley genotypes. *Journal of Applied Sciences, 10*(2): 151-156.

Reddy, A. R., Chaitanya, K. V. and Vivekanandan, M. (2004). Drought-induced responses of photosynthesis and antioxidant metabolism in higher plants. *Journal of Plant Physiology, Munich, 161*: 1189-1202.

Samarah, N. H. (2005). Effects of drought stress on growth and yield of barley. *Agron Sustain Dev, 25*(1): 145-149.

Samarah, N. H., Alqudah, A. M., Amayreh, J. A. and McAndrews, G. M. (2009). The effect of late-terminal drought stress on yield components of four barley cultivars. *Journal of Agronomy and Crop Science, 195*(1): 427–441.

Sefatgol, F. and Ganjali, H. (2017). Evaluation of drought stress tolerance in advanced barley cultivars in Sistan region. *Bioscience Biotechnology Research Communication, 10*(2): 276-286.

Singh, B., Dhaka, A. K., Kumar, M., Kumar, S. and Pannu, R. K. (2017). Evaluation of drought tolerance indices for selection of barley (*Hordeum vulgare* L.) cultivars under different levels of irrigation. *International Journal of Current Microbiology and Applied Sciences, 6*(9): 624-632.

Solomon, K. F., Labuschagen, M. T. and Bennie, A. T. P. (2003). Responses of Ethiopian durum wheat genotypes to drought stress. *South African Journal of Plant and Soil, 20*: 55-58.

Wang, Q., Wu, J., Lei, T., He, B., Wu, Z. and Liu, M. (2014). Temporal-spatial characteristics of severe drought events and their impact on agriculture on a global scale. *Quaternary International, 349*(1): 10–21.

Zare, M. (2012). Evaluation of drought tolerance indices for the selection of Iranian barley (*Hordeum vulgare*) cultivars. *African Journal of Biotechnology, 11*: 15975–15981.

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