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Drought susceptibility index analysis in Indian mustard (*Brassica juncea* L.)

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Abstract

Climatic variation like drought is a catastrophe in the current era as it has a high level of impingement on the yield of rain-fed crops like *Brassica juncea*. Present investigation was aimed at investigating the effects of drought on seed yield and its allies in a set of 03 testers, 15 lines and 45 hybrids devised from them under two contrasting environments irrigated (E1) and rainfed (E2) in two seasons (2018-19 and 2019-20). Parents RH-761, RB-24, RH-749, RH-1209 and RB 66 and hybrids RH-1209 × RH761, RH-1209 × RB-24, RB-77 × RB-24, RL-1359 × RH749 and RH-1209 × RH749 reflected a good drought susceptibility index value for various yield allied and drought tolerance related traits under consideration. These cultivars could be utilized for the development of drought tolerant cultivars for further breeding programs.

Keywords: *Drought susceptibility index, Indian mustard, rainfed, yield*

Introduction

Indian mustard (*Brassica juncea* L, AABB 2n = 36), a major oilseed crop of Indian subcontinent is a natural amphidiploid combining the genomes of two species, *B. rapa* (AA, 2n = 20) and *B. nigra* (BB, 2n = 16). India produced 10.1 million tons of rapeseed and mustard in year 2020-21. The area under rapeseed and mustard in India is 6.7 million hectares, with a productivity of 1511 kg/ha during 2020-21. In the state of Jammu & Kashmir the area under rapeseed - mustard is 51870 ha with production of 59600 MT and 1149 kg per productivity during 2018-19.

Drought is defined as an extended span of months/years when a region witnesses scarcity in its water supply, (surface or underground water) because of feeble precipitation (below average) on regular basis. It has global occurrence because of being a global phenomenon which negatively affects and causes noteworthy damage due to its random occurring nature and extent. Climatic fluctuations like drought stress/water scarcity stress have high impact on the rain-fed crop yield (Kumar and Upadhyay, 2019). In agricultural prospects, drought is the state in which the water content available in root hair zone is relatively less than the optimum content required for sustaining maximum growth and productivity (Deikman *et al.,* 2012). It is a catastrophe in the eye of today's world as roughly on global basis, drought affects approximately 40 % of world's land area. Currently, around the globe 7 % of world's population resides in the water scarce areas and is predicted to increase up to 67 % by 2050. As much as 1.2 billion hectares of land among total rainfed agricultural areas of world is on verge of severe drought stress (Passioura *et al.,* 2007). On an average, approximately 70 % yield of every crop succumbs to drough (Kaur *et al.,* 2017). Drought stress brought up by no or feeble rainfall in dry or wet seasons, also results by deviation of rainfall patterns, affects all round growth and development of plants, retards numerous morphological traits by reducing cell division as well as expansion, retards leaf size as well as leaf area, reduces plant height, disturbs root to shoot ratio, number of nodes, number of branches, seeds per pod and ultimately less yield (Langadi *et al.,* 2021; Alghabari *et al.,* 2016). With the onset of water scarcity, numerous morpho-physiological, anatomical and molecular changes are marked in plants. The morphological impacts in the form of inhibited seed germination, feeble early seedling growth etc. prevail under drought stress (Harris *et al.,* 2007) along with other traits like plant biomass accumulation as well as partitioning, harvest index and crop productivity, all are negatively affected by drought stress. Drought affects plant growth and development by numerous morpho-physiological disorders which affect nutrient uptake and reduce actively movement of photosynthates (Yuncai and Schmidhalter, 2005), also affects relative water content, osmotic potential, leaf temperature etc. (Fanaei *et al.,* 2012). Long-term intense water deûcit spells, which rely on plant-genotype-speciûc features, also rests on stress intensity, stress length, pace and recovery eûectiveness to control plant performance (Hazrati *et al.,* 2017). Photosynthesis activity is declined primarily by stomatal closure, membrane injury and varied functioning of numerous enzymes, particularly ATP synthesizing enzymes (Sharma *et al.,* 2020). A drought is an extended period of months or years when region notes a deficiency in its water supply, whether surface or underground water because of consistent below average precipitation. Water stress causes heavy yield losses in Indian mustard (17-94 %) (Choudhary *et al.,* 2021). Low water availability during stem elongation, flowering and pod development causes reduction of pods per plant leading to, grain yield reduction (Gunasekara *et al.,* 2006). Analyzing the effects of drought on yield and yield attributes of Indian mustard is very crucial for identifying drought tolerant traits (Chauhan *et al.,* 2007). Drought susceptibility index (DSI) is a useful tool for comparison of cultivar performances under drought and irrigated conditions and identifying tolerant genotypes for drought (Fischer and Maurer, 1978). DSI characterizes the stability of yield between two environments (Singh *et al.* 2018). It expresses the separate effects of yield potential and drought susceptibility on yields under drought. In these terms, lower DSI is considered synonymous with higher drought resistance (Fischer and Maurer, 1978). In view of above facts, present study is aimed at investigating the effects of drought on yield attributing traits with, the objective of identifying Indian mustard genotypes and their hybrids which can withstand water stress with minimum loss in yield. We have made efforts in this direction by attempting crosses among reported high yielding tolerant genotypes for moisture stress tolerance, to identify and classify germplasms that includes parents and F_1 hybrids on the basis of DSI.

Materials and Methods

Plant material, experimental design and location

The research material in the form of various cultivars comprising of drought tolerant testers (03) and drought susceptible lines (15) and 45 F_1s which were produced by crossing these testers to lines via L× T fashion. The trials were sown at two different locations (E_1= Irrigated and E_2= Rainfed) at the research field of PBG SKUAST Jammu and ACRA Dhiansar respectively, by setting up the experiment using randomized complete block design (RCBD) with three replications. The trials for both the seasons (2018-19 and 2019-20) were sown with three replications in 2 lines of length 5m each. The spacing between row to row was 45 cm and plant to plant distance of 10 cm was maintained. It was followed by performing hybridization using L×T mating design.

Observations and evaluation

Observations were recorded on five randomly selected plants of each cultivar from each replication. The effect of drought was assessed as percentage reduction in mean performance of a trait under rainfed conditions in relation to its performance under irrigated conditions. Accordingly, DSI for yield and its allied traits was calculated using, the formula devised by Fischer and Maurer (1978);

$$DSI= (1-Ys/Yi) / (1-Xs/Xi)$$

Where,

Ys = mean seed yield of a genotype under a water stress environment (E_2), Yi = mean seed yield of same genotype under stress free environment (E_1), Xs = mean seed yield of all genotypes under water stress environment and Xi = mean seed yield of all genotypes under stress free environment (irrigated). In the present study, DSI values for different traits were calculated and genotypes were classified into four different categories: Drought tolerant (DSI < 0.70), moderately drought tolerant (DSI 0.71 to 1.20), moderately drought susceptible (DSI 1.21 to 1.50) and highly drought susceptible (DSI > 1.50 (statistical analysis, was performed by using Windostat (9.2) statistical software).

Results and Discussion

Performance of the cultivars

Significant differences among genotypes for all studied traits were revealed by statistical analysis. Performance of all the yield as well as drought related traits reduced under rainfed condition except proline, A substantial reduction in number of siliqua per plant under rainfed conditions 0.8% (Kranti × RH-749) to 32 % in Pusa Bold × RH749 except 1.71 %. The reduction in seed yield per plant ranged between 20 % in RH761 to 70.1 % in RSPR-01 × RH749. The reduction in grain yield can be ascribed to the relative more reduction in the growth parameters including stem, root and leaf growth, further decreasing number of siliqua per plant, siliqua length and 1000 seed weight. Quantitative aspects as well as the quality of the produce (as there were observed reductions in the oil content of the seeds as well) were adversely affected by moisture stress (Choudhary *et al.,* 2021; Singh *et al.,* 2019). The decrease in siliqua per plant and seed yield recorded in our study is alike the study of Mirzaei *et al.* (2013) who stated that drought stress significantly seed yield, number of seeds per siliqua, number of siliqua per plant, test weight, plant height and oil content of cultivars (Hyola-401, Hyola-308, Zarfam and PF) in Iran. In the present study, reductions in yield along with simultaneous reduction in test weight round 42 % in case of RSPR-01 × RH749, while 1 % increase in test weight was recorded in DRMR-51 × RH749 under drought conditions, the reduction in yield and its allies was reported by Akanksha *et al.* (2020). The possible reason behind this decline in whole round of traits under drought stress is reduced cell division especially at the critical stages like flowering causing both reduction in yield as well as test weight (Pandey *et al.,* 2001).

Drought susceptibility index

The DSI values of parents (1^{st} and 2^{nd} season) and their hybrids is presented in Tables 1-3. Larger DSI values indicate greater drought susceptibility. The DSI value of the parents the first season ranged from 0.43 to 1.50 for the parents RH-761 and JM-12-6 respectively. As is reflected in Table 1 among all the parents under consideration, RH-761, RB-24, RH-749, RH-1209 and RB66 with the respective DSI value of 0.43, 0.46, 0.5, 0.52 and 0.66 fall under drought tolerant category as there DSI value is under 0.7. Parents, DRMR-51, RB-77, RL-359, DRMR-4006, PM-25, PM28, PM-195, Pusa Bold and Kranti with the respective DSI values of 0.93, 0.93, 0.95, 0.96, 0.98, 0.99, 1.02, 1.1 and 1.17 rested in moderately drought tolerant category as there DSI value lied under the range of 0.71-1.19. Among all the parents, for some cultivar the DSI value surpassed 1.2 mark and were judged as drought susceptible, In this category Tawari, RSPR-01, DRMR-659-49 and JM-12-6 with the DSI values of 1.23, 1.25 1.43 and 1.5 respectively.

The DSI value of the second season ranged from 0.39 to 1.40 for the parents RH-749 and DRMR-51 respectively. As is reflected in the Table 2, among all the 18 parents in consideration RH-749, RH-761, RB-24, PM-195 and RB-77 with the respective DSI values of 0.39, 0.48, 0.49, 0.55 and 0.68 fall under drought tolerant category as there DSI value is under 0.7 mark. Parents like DRMR-51, RH-1209, JM-12-6, RSPR-01, Tawari, Kranti, DRMR-659-49, Pusa Bold, RB66 and PM28 with the respective DSI values of 0.76, 0.93, 0.93, 0.95, 0.99, 1.01, 1.07 and 1.19 rested in moderately drought tolerant category as there DSI value lied within the range of 0.71-1.19. Among all the parents, DSI value for some cultivar surpassed 1.2 mark and were judged as drought susceptible, this category PM28, RL-359, DRMR-4006, PM-25, DRMR-51 and Tawari with the DSI values of 1.22, 1.22, 1.22, 1.39 and 1.4 respectively.

The DSI values the 45 hybrids devised from crossing of 3 testers to 15 lines in the typical fashion of L×T matting design revealed that Table 3 among all the RH-1209 × RH-761, RH-1209 × RB-24, RB-77 × RB-24, RL-359 × RH749 and RH-1209 × RH749 with the respective DSI values of 0.5, 0.54, 0.58, 0.6 and 0.61 rested in the drought tolerant category as there DSI value was below 0.7 mark. Hybrids DRMR-51 × RH749 , JM-12-6 × RH-749, PM-195 × RB24, RL-359 × RB24, RB-77 × RH761, Kranti × RH-749, Pusa Bold × RH761, Tawari × RB-24, DRMR-4006 × RH749, DRMR-4006 × RB24, PM-25 × RH749, Kranti × RB24, RB66 × RH749, RB66 × RB24, DRMR-659-49 × RH761, Tawari × RH761, PM-28 × RH-761, DRMR-51 × RH761, RB66 × RH761, RB-77 × RH749, RSPR-01×RB-24, Tawari × RH749, RSPR-01 × RH761, DRMR-4006 × RH761, PM-25 × RB24, PM-195 × RB761, PM-28 × RB24, JM-12-6 ×

Table 1: Drought susceptibility index of *Brassica juncea* parents (1^{st} year)

S. No.	Cultivar	E_1 (mean seed yield)	E_2 (mean seed yield)	DSI	DSI range	Remarks
1	RH-761	18.5	14.9	0.43	<0.6	Tolerant
2	Rb-24	17.0	13.5	0.46		
3	RH-749	18.1	14.0	0.50		
4	RH-1209	14.8	11.3	0.52		
5	RB-66	16.0	11.2	0.66		
6	RB-77	15.4	8.9	0.93	0.7-1.1	Moderate tolerant
7	DRMR-51	12.7	7.3	0.93		
8	RL-359	11.8	6.7	0.95		
9	DRMR-4006	18.3	10.4	0.96		
10	PM-25	15.6	8.7	0.98		
11	PM-28	20.1	11.1	0.99		
12	PM-195	16.1	8.7	1.02		
13	Pusa Bold	17.8	9.0	1.10		
14	Kranti	16.4	7.7	1.17		
15	Tawari	14.7	6.5	1.23	>1.2	Susceptible
16	RSPR-01	19.8	8.6	1.25		
17	DRMR-541-46	15.6	5.5	1.43		
18	JM-12-6	20.9	6.7	1.50		

Table 2: Drought susceptibility index of *Brassica juncea* parents (2nd year)

S. No.	Cultivar	E_1 (mean seed yield)	E_2 (mean seed yield)	DSI	DSI range	Remarks
1	RH-761	18.2	15.0	0.39	<0.6	Tolerant
2	RB-24	17.8	13.9	0.48		
3	RH-749	18.4	14.4	0.49		
4	RH-1209	13.6	10.2	0.55		
5	RB66	15.0	10.4	0.68		
6	RL-359	15.3	10.1	0.76	0.7-1.1	Moderate tolerant
7	PM-25	17.4	10.1	0.93		
8	DRMR-51	13.8	8.0	0.93		
9	DRMR-4006	15.7	9.0	0.95		
10	PM-195	19.9	11.0	0.99		
11	RB-77	15.9	8.7	1.01		
12	PM-28	18.2	9.5	1.07		
13	RSPR-01	17.3	8.1	1.19		
14	Kranti	18.2	8.2	1.22		
15	Tawari	15.9	7.2	1.22	>1.2	Susceptible
16	Pusa Bold	11.4	5.1	1.22		
17	DRMR-541-46	14.9	5.6	1.39		
18	JM-12-6	21.9	8.1	1.40		

RB24, DRMR-51 × RB24 and RL-359 × RH761 with the respective DSI values of 0.7, 0.74, 0.76, 0.77, 0.8, 0.81, 0.81, 0.81, 0.82, 0.83, 0.89, 0.9, 0.92, 0.93, 0.94, 0.95, 0.96, 0.98, 1.01, 1.01, 1.03, 1.05, 1.06, 1.07, 1.09, 1.11, 1.11, 1.13, 1.14 and 1.14 were categorized into the moderately drought tolerant category as there DSI value lied in between 0.7- 1.20. On the other hand, among whole sum of the hybrids, DSI value of some of the hybrids likes of JM-12-6 × RB761, Kranti × RH-761, DRMR-659-49 × RB24, Pusa Bold × RB-24, PM-195 × RH-761, PM-28 × RH-749, Pusa Bold× RH749, DRMR-659-49 × RH749 and RSPR-01 × RH749 (1.21, 1.28, 1.3, 1.31, 1.34, 1.34, 1.39, 1.43 and 1.58) was recorded above 1.2 and they were categorized as drought susceptible hybrids.

Parents RH-761, RB-24, RH-749, RH-1209 and RB66 and hybrids RH-1209 × RH761, RH-1209 × RB-24, RB-77 × RB-24, RL-359 × RH749, RH-1209 × RH749 and PM-25 × RH761 reflected a good DSI value of below 0.7 mark. These characters could be utilized for the development of drought tolerant cultivars in further breeding programmes. Our results are supported by several previous studies. Alipour and Zahedi (2016) reported that the highest grain yield was obtained by regular irrigation. Also, the oil yield loss can be caused by lack of soil moisture at flowering stage, reducing photosynthesis and photosynthetic production to various plant parts. Singh *et al.* (2014) reported that, the overall mean performance of Brassica progenies was comparatively higher in irrigated environment for days to 50 % flowering, siliquae per plant, 1000 seed weight, seed yield per plant and protein content and genotypes 07-547, 07-515 and 07-510 which showed lower DSI values (< or ~0.00), were rated as drought tolerant. Similarly, Chauhan *et al.* (2007) reported six drought tolerant genotypes with a characteristic feature of combating drought at either or both locations (Bharatpur and Jobner) as JMMWR-941, RC 1446, PSR 20, RH-819, Varuna and RC-53, as reflected by their relatively low DSI value. Singh and Choudhary (2003) used DSI values and yield under drought conditions as a selection measure for drought tolerance in Indian mustard. Akanksha *et al*. (2020) reported genotype RB-50 as drought tolerant for seed yield per plant among parents with the DSI value of 0.38, while as hybrids RB-50×RH-749 and RB-50×Giriraj exhibited tolerant DSI values for siliqua per plant, 1000 seed weight, seed yield per plant and oil content. Similarly, Sodani *et al.* (2017) in a study also reported RH-406 was better under irrigated condition while as RB-50 and RGN-48 with characteristic feature of maintaining higher seed yield and oil quantity under water scarcity stress like conditions due to lesser reduction in yield attributes and tolerance mechanism which is in accord with our study. Genotypes of Brassica species with drought-tolerance traits are known to produce the highest seed yield under drought conditions (Singh *et al.,* 1988).

Table 3: Drought susceptibility index of Brassica juncea hybrids

S. No.	Hybrid	E_2 (mean seed yield)	E_1 (mean seed yield)	DSI	DSI range	Remarks
1	RH-1209 × RH761	8.7	11.0	0.50	<0.6	Tolerant
2	RH-1209 × RB-24	10.3	13.2	0.54		
3	RB-77 × RB-24	12.0	15.8	0.58		
4	RL-359 × RH749	8.0	10.6	0.60		
5	RH-1209 × RH749	12.4	16.6	0.61		
6	PM-25 × RH761	9.6	13.3	0.68		
7	DRMR-51 × RH749	13.1	18.4	0.7	0.7-1.1	Moderate tolerant
8	JM-12-6 × RH-749	10.8	15.6	0.74		
9	PM-195 × RB24	11.0	16.1	0.76		
10	RL-359 × RB24	7.5	11.0	0.77		
11	RB-77 × RH761	8.3	12.4	0.80		
12	Kranti × RH-749	9.6	14.4	0.81		
13	Pusa Bold × RH761	8.6	13.0	0.81		
14	Tawari × RB-24	11.7	17.6	0.81		
15	DRMR-4006 × RH749	10.9	16.5	0.82		
16	DRMR-4006 × RB24	10.3	15.8	0.83		
17	PM-25 × RH749	9.9	15.67	0.89		
18	Kranti × RB24	9.7	15.5	0.9		
19	RB66 × RH749	8.2	13.2	0.92		
20	RB66 × RB24	9.2	15.0	0.93		
21	DRMR-541-46 × RH761	10.7	17.6	0.94		
22	Tawari × RH761	7.4	12.2	0.95		
23	PM-28 × RH-761	9.1	15.1	0.96		
24	DRMR-51 × RH761	10.5	17.7	0.98		
25	RB66 × RH761	13.6	23.4	1.01		
26	RB-77 × RH749	8.2	14.1	1.01		
27	RSPR-01 × RB-24	10.9	19.0	1.03		
28	Tawari × RH749	8.3	14.7	1.05		
29	RSPR-01 × RH761	9.0	16.0	1.06		
30	DRMR-4006 × RH761	7.7	13.9	1.07		
31	PM-25 × RB24	7.5	13.7	1.09		
32	PM-195 × RB761	6.5	12.0	1.11		
33	PM-28 × RB24	12.3	22.7	1.11		
34	JM-12-6 × RB24	8.9	16.6	1.13		
35	DRMR-51 × RB24	7.9	14.9	1.14		
36	RL-359 × RH761	5.9	11.2	1.14		
37	JM-12-6 × RB761	8.8	17.7	1.21	>1.2	Susceptible
38	Kranti × RH-761	8.9	19.1	1.28		
39	DRMR-541-46 × RB24	7.5	16.1	1.3		
40	Pusa Bold × RB-24	5.6	12.2	1.31		
41	PM-195 × RH-761	8.5	19.0	1.34		
42	PM-28 × RH-749	7.9	17.7	1.34		
43	Pusa Bold × RH749	5.7	13.4	1.39		
44	DRMR-541-46 × RH749	9.0	22.1	1.43		
45	RSPR-01 × RH749	3.5	10.2	1.58		

Conclusion

On the basis of mean performance and DSI analysis, lines RH-761, RB-24, RH-1209 and RB66 and hybrids RH-1209 × RH761, RH-1209 × RB-24, RB-77 × RB-24, RL-1359 × RH749 and RH-1209 × RH-749 be utilized for the development of drought tolerant cultivars in further breeding programmes.

References

Akanksha, Srivastava K, Srivastava A and Sinha B. 2020. Analysis of drought susceptibility index in Indian Mustard (*B. juncea*). *Indian J Agric Res* **10**.18805/ IJARe.A-5526.

Alghabari F, Ihsan MZ, Khaliq A, Hussain S, Daur I, Fahad S and Nasim W. 2016. Gibberellin-sensitive Rht alleles confer tolerance to heat and drought stresses in wheat at booting stage. *J Cereal Sci* **70**: 72-78.

Alipour A and Zahedi H. 2016. Difference in drought resistance among three *Brassica* species at different growing stages and application of zeolite. *Indian J Agric Res* **50**: 193-196.

Chauhan JS, Tyagi MK, Kumar A, Nashaat NI, Singh M, Singh NB, Jakhar ML and Welham SJ. 2007. Drought effects on yield and its components in Indian mustard (*B. juncea*). *Plant Breed* **126**: 399-402.

Choudhary RL, Langadi AK, Jat RS, Anupama, Singh HV, Meena MD, Dotaniya ML, Meena MK, Premi OP and Rai PK. 2019. Mitigating the moisture stress in Indian mustard (*B. juncea*) through polymer. *J Oilseed Brassica* **12**: 21–27.

Deikman J, Petracek M and Heard JE. 2012. Drought tolerance through biotechnology: improving translation from the laboratory to farmers' fields. *Curr Opin Biotechnol* **23**: 243-250.

Fanaei HR, Galavi M, Kafi M and Ghanbari Bonjar A. 2012. Amelioration of water stress by potassium fertilizer in two oilseed species. *Int J Plant Prod* **3**: 41-54.

Fischer RA and Maurer R. 1978. Drought resistance in spring wheat cultivars: I. Grain yields responses. *Aust J Agric Res* **29:** 897-907.

Gunasekera CP, Martin LD, Siddique KHM and Walton GH. 2006. Genotype by environment interactions of Indian mustard (*B. juncea*) and canola (*B. napus*) in Mediterranean-type environments: 1. Crop growth and seed yield. *Eur J Agron* **25**: 1-12.

Harris K, Subudhi PK, Borrell A, Jordan D, Rosenow D, Nguyen H, Klein P, Klein R and Mullet J. 2007. Sorghum stay-green QTL individually reduce post-flowering drought-induced leaf senescence. *J Exp Bot* **58**: 327-338.

Hazrati S, Tahmasebi-Sarvestani Z, Mokhtassi-Bidgoli A, Modarres-Sanavy SAM, Mohammadi H and Nicola S. 2017. Effects of zeolite and water stress on growth, yield and chemical compositions of *Aloe vera* L. *Agric Water Manag* **181**: 66-72.

Kaur G and Asthir B. 2017. Molecular responses to drought stress in plants. *Biol Plant* **61**: 201-209.

Kumar S and Upadhyay SK. 2019. Impact of climate change on agricultural productivity and food security in India: A State level analysis. *Indian J Agric Res* **53**: 133-142.

Langadi AK, Choudhary RL, Jat RS, Singh HV, Dotaniya ML, Meena MK, Premi OP and Rai PK. 2021. Effect of superabsorbent polymer on drought Mitigation, and enhancing productivity and profitability of Indian mustard (*B. juncea*). *J Oilseeds Res***38**: 179–186.

Mirzaei A, Naseri R, Moghadam A and Jahromi ME. 2013. The effects of drought stress on seed yield and some agronomic traits of canola cultivars at different growth stages. *Bull Environ Pharmacol Life Sci* **2**: 115-121.

Pandey PK, Maranville JW and Admou A. 2001. Tropical wheat response to irrigation and nitrogen in a Sahelian environment - Grain yield, yield components and water use efficiency. *Eur J Agron* **15**: 93-105.

Passioura J. 2007. The drought environment: physical, biological and agricultural perspectives. *J Exp Bot* **58**: 113-117.

Sharma A, Wang J, Xu D, Tao S, Chong S, Yan D, Li Z, Yuan H and Zheng B., 2020. Melatonin regulates the functional components of photosynthesis, antioxidant system, gene expression, and metabolic pathways to induce drought resistance in grafted *Carya cathayensis* plants. *Sci Total Environ* **713**: 136675.

Singh J, Varma SK, Bhatia JN and Raj L. 2019. Effect of different soil moisture regimes and salinity level on growth and yield in mustard. *Indian J Agric Res* **53**: 488-491.

Singh M, Rathore SS and Raja P. 2014. Physiological and stress studies of different rapeseed-mustard genotypes under terminal heat stress. *Int J Genet Eng Biotechnol* **5**: 133142.

Singh RP, Singh DP and Singh P. 1988. Variation for plant water relations and yield structure in *Brassica juncea* under drought conditions, *Narendra Deva J Agric Res* **3**: 91-98.

Singh SP and Choudhary AK. 2003. Selection criteria for drought tolerance in Indian mustard (*B. juncea)*. *Indian J Genet Plant Breed* **63**: 263-264.

Singh VV, Garg P, Meena HS and Meena ML. 2018. Drought stress response of Indian mustard (*B. juncea*) genotypes. *Int J Curr Microbiol Appl Sci* **7**: 2519-2526.

Sodani R, Seema, Singhal RK, Gupta S, Gupta N, Chauhan KS and Chauhan J. 2017. Performance of yield and yield attributes of ten Indian mustard (*B. juncea*) genotypes under drought stress. *Int J Pure Appl Biosci* **5**: 467-476.