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Comparative Tolerance and Sensitive Response of Indian Mustard (*Brassica juncea* L.) Genotypes to Water Stress

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Abstract A field experiment was conducted to evaluate the performance of various Indian mustard (*Brassica juncea* L.) genotypes under water stress condition. The experiment consisted of ten Indian mustard genotypes viz. RB 50, RGN 48, Urvashi, Geets, RH 819, RGN 229, RH 0406, RH 0749, NRC HB 101 and NRC DR 02 were grown in field under control condition and water stress condition. Under control condition plots were irrigated at flowering and pod formation stages while in water stress plots were maintained under rainfed condition. Different physiological parameters were recorded at flowering and pod formation stages. Results revealed significant differences among Indian mustard varieties, in terms of RWC, chlorophyll and carotenoid content under stress and control conditions. The Indian mustard genotypes RGN 48 and RB 50 behaved as drought tolerant varieties maintained higher RWC, chlorophyll and carotenoid content under water stress condition. The Indian mustard genotypes RH 0749 and RH 0406 varieties maintained higher RWC, chlorophyll and carotenoid content under control condition.

Keywords Chlorophyll, Carotenoid, DSI, Genotypes, Mustard.

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Introduction

Mustard is an important *rabi* season oilseed crop which belongs to family Crucifereae and genus *Brassica*. Mustard is generally grown under rainfed conditions. Nearly 20% area of mustard is under rainfed condition. It requires well drained soil having pH near to neutral but it also moderately tolerant to soil acidity. Mustard has a low water requirement (240–400 mm) which fits well in the rainfed cropping system. Rapeseed mustard contributes 32% total oilseed pro-

Table 1. Effect of water stress and various genotypes on relative water content (%) and chlorophyll content-a (mg/g fw) of Indian mustard.

	Relative water content (%)						Chlorophyll content-a (mg/g fw)					
		Flowering		Pod formation				Flowering		Pod formation		
		Water			Water			Water			Water	
Genotypes	Control	stress	Mean	Control	stress	Mean	Control	stress	Mean	Control	stress	Mean
RB 50	78.25	76.4	77.33	76.2	74.6	75.4	1.29	1.21	1.25	0.9	0.82	0.86
RGN 48	76.5	74.25	75.38	74.5	72.4	73.45	1.38	1.33	1.36	0.98	0.94	0.96
Urvashi	76.75	75.2	75.98	74.2	72.45	73.33	1.23	1.04	1.14	0.91	0.79	0.85
Geeta	75.26	74.25	74.76	73.4	72	72.7	1.25	1.06	1.16	0.91	0.77	0.84
RH 819	76.2	75.3	75.75	73.5	73.2	73.35	1.47	1.23	1.35	1.28	0.83	1.06
RGN 229	76.15	74.5	75.33	75.5	72.2	72.35	1.38	1.21	1.3	0.94	0.8	0.87
RH 0406	76.5	70.2	73.35	74.5	66.4	70.45	1.48	1.06	1.27	1.3	0.74	1.02
RH 0749	85.4	72.4	78.9	80	69.4	74.7	1.86	0.98	1.42	1.35	0.73	1.04
NR CHB 101	77.3	70.4	73.85	75.2	67.4	71.3	1.38	0.99	1.19	1.18	0.74	0.96
NRC DR 02	88.4	73.3	80.85	86.4	71.5	78.95	1.35	0.94	1.15	0.98	0.72	0.85
Mean	78.67	73.62		76.04	71.16		1.41	1.11		1.07	0.79	
		CD			CD			CD			CD	
	SEm±	(p=0.05)		SEm±	(p=0.05)		SEm±	(p=0.05)		SEm±	(p=0.05)	
Genotype (G)	1.56	4.52		1.42	4.11		0.04	0.11		0.032	0.093	
Stress (S)	0.7	2.02		0.64	1.84		0.02	0.05		0.014	0.042	

duction and the second largest indigenous oilseed crop in India. The contribution of India in global rapeseed mustard production is 72.62 lac tonnes occupying 67.17 lac hactares area with average yield of 1,080 kg/ha [1]. The major mustard growing states are Rajasthan, Uttar Pradesh, Madhya Pradesh, Haryana, Gujarat, West Bengal, Assam, Bihar, Punjab and Jammu and Kashmir. Rajasthan ranks first both in area and production of rapeseed and mustard in the country.

Out of the various abiotic stresses, water stress is the most important stress, which can strike a crop at any time and imposed many limitations on growth and development. It has negative impact on physiology of plant and ultimately reduces the yield in all agricultural crops. Mustard crop is very sensitive to water stress during reproductive stage. It is generally grown as a rainfed crop in arid regions so it faces water stage during growing season. In general, the negative impacts of abiotic stresses on agricultural productivity can be minimized by a combination of genetic improvement and agronomic management. Among agronomic practices, irrigation and variety contributes a lot towards the yield potential. Drought stress is considered as one of the primary factor which is responsible for lower agricultural productivity, because it is often linked to other major abiotic stresses such as salinity and heat stress [2]. As mustard is mostly grown in India on light textured soils using water conserved from monsoon rains, it inevitably suffers from drought stress during its reproductive stage, when stored water becomes depleted [3]. Araus et al. [4] observed that among the various abiotic stresses that affect field crops across the world, moisture stress assumes great importance, particularly under a changing climate scenario. Drought stress produced changes in the ratio of chlorophyll 'a' and'b' and carotenoids [5, 6]. In the proposed study, mustard genotypes have been screened for drought tolerance under rainfed condition by employing various physiological parameters.

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Material and Methods

The present investigation was conducted at Agronomy Farm, SKN College of agriculture, Jobner

Table 2. Effect of water stress and various genotypes on chlorophyll content-b (mg/g fw) and total chlorophyll content (mg/g fw) of Indian mustard.

	Chlorophyll content-b (mg/g fw)						Total chlorophyll content (mg/g fw)					
	Flowering			Pod formation			Flowering			Pod formation		
Genotypes	Control	Water stress	Mean	Control	Water stress	Mean	Control	Water stress	Mean	Control	Water stress	Mean
RB 50	0.43	0.41	0.42	0.3	0.27	0.29	1.72	1.62	1.67	1.2	1.09	1.15
RGN 48	0.46	0.42	0.44	0.32	0.31	0.32	1.85	1.75	1.8	1.3	1.25	1.28
Urvashi	0.42	0.34	0.38	0.3	0.26	0.28	1.65	1.38	1.52	1.21	1.05	1.13
Geeta	0.43	0.36	0.4	0.31	0.25	0.28	1.68	1.42	1.55	1.22	1.02	1.12
RH 819	0.49	0.42	0.46	0.43	0.27	0.35	1.96	1.65	1.81	1.71	1.1	1.41
RGN 229	0.46	0.39	0.43	0.31	0.26	0.29	1.85	1.6	1.73	1.25	1.06	1.16
RH 0406	0.49	0.34	0.42	0.43	0.24	0.34	1.97	1.4	1.69	1.73	0.98	1.36
RH 0749	0.62	0.32	0.47	0.45	0.24	0.35	2.5	1.3	1.9	1.8	0.97	1.39
NR CHB 101	0.46	0.34	0.4	0.37	0.25	0.31	1.85	1.33	1.59	1.5	0.99	1.25
NRC DR 02	0.45	0.31	0.38	0.32	0.23	0.28	1.8	1.25	1.53	1.3	0.95	1.13
Mean	0.47	0.37		0.35	0.26		1.88	1.47		1.42	1.05	
		CD			CD			CD			CD	
	SEm±	(p=0.05)		SEm±	(p=0.05)		SEm±	(p=0.05)		SEm±	(p=0.05)	
Genotype (G)	0.014	0.041		0.011	0.033		0.11	0.31		0.05	0.13	
Stress (S)	0.006	0.018		0.005	0.015		0.05	0.14		0.02	0.06	

(260 05´ N latitude, 750 28´ E longitude and at an altitude of 427 m above mean sea level), Jaipur, Rajasthan, India during *rabi* season of 2013-14. The soil of the experimental site was classified as loamy sand in texture and alkaline in reaction. The climate of this region is typically semi-arid which is characterized by the aridity and extremity of temperature fluctuations in summer and winter. During summer, maximum temperature ranges between 35–46 °C while in winter, it may falls down to as low as -1°C. The average rainfall of this locality is approximately 400 mm, most of which is received during rainy season from July to September.

The experiment was conducted in randomized block design with factorial concept with three replications. The experiment consisted of 10 genotypes of *Brassica juncea* namely RB 50, RGN 48, Urvashi, Geeta, RH 819, RGN 229, RH 0406, RH 0749, NRCHB 101 and NRCDR 02 which were sown on October 18th under control and water stress conditions. Under control condition the plants were irrigated at flowering and pod formation stages while in water stress the plants were maintained under rainfed condition. The crop was fertilized with 60 kg N and 40 kg P_2O_5 ha^{-1}.

Procedure and techniques

Relative water content

Fresh weight of the leaves was taken then the leaves were kept in distilled water for 4 hours [7] to obtain turgid weight. The turgid weight was recorded after blotting the excess water on the surface of the sample. Dry weight was obtained after drying the samples in oven at 60°C till constant weight was achieved. The relative water content (RWC) was calculated by the formula given by Slavik [8].

$$\text{RWC } (\%) = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}} \times 100$$

Chlorophyll a, b and total chlorophyll and carotenoids

Samples for chlorophyll and carotenoids determination were taken from mustard leaves using a 0.8 cm diameter cork borer, weighted quickly in pre-weighted clean glass vials 5 cm^3 of dimethylsulfoxide (DMSO) was added to these samples. The leaf material was bleached and decanted off. The optical density was

read at λ = 663 nm, 645 and 470 nm using DMSO as a blank by a spectrophotometer. Content of chlorophyll a, chlorophyll b, total chlorophyll and carotenoids (mg g^{-1} fw) was calculated according to Lichtenthaler and Wellburn [9] using the following formula.

Chlorophyll a = 12.21 OD 663 nm – 2.81 OD 645 nm
Chlorophyll b – 20.13 OD 645 nm – 5.03 OD 663 nm
Total chlorophyll=Chlorophyll a Chlorophyll b
Carotenoids (1000 OD 470 nm – 3.27 Chlorophylla a - 104 chloriphyll b) / 229

Drought susceptibility index

The drought susceptibility index (DSI) was used as a measure of drought tolerance in terms of minimization of the reduction in yield caused by unfavorable compared to favorable conditions. It was calculated according to Fischer and Maurer [10] for each genotype.

$$DSI = \frac{1-(Ys/Yp)}{1-(\bar{Y}s/\bar{Y}p)}$$

Where, Ys = Yield of cultivar under stress, Yp = Yield of cultivar under irrigated condition, Ys = Mean yield of cultivar under stress condition, Yp = Mean yield of cultivar under irrigated condition, respectively and 1 - ($\bar{Y}s/\bar{Y}p$) is the stress intensity.

Results and Discussion

Indian mustard varieties exhibited variable physiological response to water stress induced at flowering and pod formation stages.

Relative water content

Table 1 shows that relative water content varied significantly among genotypes at both flowering and pod formation stages. The relative water content decreased significantly under water stress condition both at flowering and pod formation stages. The reduction in relative water content under the water stress condition as compared to control was 6.85% and 6.85% at flowering and pod formation stages respectively. Under the control condition the highest relative water content at flowering was noted in genotype NRC DR 02 (88.40%) closely followed by other genotypes RH 0749 (85.40%) and RB 50 (78.25%) and at pod formation stage also the same trend was found. While under the water stress condition the highest relative water content at flowering stage and pod formation stage were noted in genotype RB 50 (76.40%) followed by genotypes RH 819 (75.30%) and Urvashi (75.20%) and RB 50 (74.60%) followed by other genotypes RH 819 (73.20%) and Urvashi (72.45%) respectively. Genotypes like RB 50 and RH 819 maintained higher relative water content to other genotypes is important or registering less reduction under water stress compared to control. Genotypes possessed maximum RWC at flowering followed by a gradual decline. High RWC is a resistant mechanism to water stress which is related to higher osmoregulation. Decrease in RWC under water stress has been reported in oil palm [11]. Recently, similar results have been reported in groundnut by Madhusudan and Sudhakar [12]. RWC is a measure of plant water status and reflects the metabolic activity in plant tissues [13].

Chlorophyll a, b and
total chlorophyll

Tables 1 and 2 showed that chlorophyll content varied significantly among genotypes and treatment at both flowering and pod formation stages. The chlorophyll content decreased signifificantly under water stress condition both at flowering and pod formation stages. The reduction in chlorophyll content under the water stress condition as compared to control was 27.90% and 35.24% respectively at flowering and pod formation stages. Under the control condition the highest chlorophyll content at flowering was noted in genotype RH 0749 (2.50 mg/g) closely followed by other genotypes RH 406 (1.97 mg/g) and RH 819 (1.96 mg/g) and at pod formation stage highest chlorophyll content was noted in genotype RH 0749 (1.80 mg/g) closely followed by other genotypes RH 0406 (1.73 mg/g) and RH 819 (1.71 mg/g). While under the water stress condition the highest chlorophyll content at flowering was noted in genotypes RGN 48 (1.75 mg/g) closely followed by other genotypes RH 819 (1.65 mg/g) and RB 50 (1.62 mg/g) and at pod formation stage highest chlorophyll content was noted in genotype RGN 48 (1.25 mg/g) closely followed by other genotypes RH 819 (1.10 mg/g) and

Table 3. Effect of water stress and various genotypes on carotenoids content (mg/g fw) and DSI (%) of Indian mustard.

Genotypes	Carotenoids (mg/g fw)						Drought susceptibility index (DSI)
	Flowering			Pod formation			
	Control	Water stress	Mean	Control	Water stress	Mean	
RB 50	2.4	2.35	2.38	2.03	1.95	1.99	0.64
RGN 48	2.6	2.5	2.55	2.09	1.98	2.04	0.85
Urvashi	2.5	2.21	2.36	2.02	1.86	1.94	0.50
Geeta	2.45	2.2	2.33	2.05	1.84	1.95	0.35
RH 819	2.88	2.4	2.64	2.6	1.96	2.28	0.28
RGN 229	2.6	2.3	2.45	2.25	1.94	2.1	0.07
RH 0406	2.9	2.1	2.5	2.65	1.78	2.22	1.83
RH 0749	3.2	2.2	2.7	2.7	1.68	2.19	2.17
NR CHB 101	2.86	2.3	2.58	2.3	1.75	2.03	1.56
NRC DR 02	2.65	1.98	2.32	2.15	1.3	1.73	1.38
Mean	2.7	2.25		2.28	1.8		
	SEm ±	CD (p=0.05)	SEm±	CD (p=0.05)		SEm± 0.05	
Genotype (G)	0.09	0.26	0.04	0.12		CD (p=0.05)	
Stress (S)	0.04	0.11	0.02	0.05		0.16	

RB 50 (1.09 mg/g). Sun et al. [11] reported decreased chlorophyll a/b in palm plants subjected to moisture stress. The chlorophyll a/b ratio is considered as an index of drought stress tolerance in plants. Therefore, for better yield under stress, higher chlorophyll content might contribute to higher plant productivity [14]. In this study also, the tolerant genotypes exhibited better chlorophyll a/b ratio over susceptible genotypes.

Carotenoids

Under the control condition the highest carotenoids at flowering was noted in genotype RH 0749 (3.20 mg/g) closely followed by other genotypes RH 0406 (2.90 mg/g) and RH 819 (2.88 mg/g) and at pod formation stage highest carotenoids were noted in genotype RH 0749 (2.70 mg/g) closely followed by other genotypes RH 0406 (2.65 mg/g) and RH 819 (2.60 mg/g) (Table 3). While under the water stress condition the highest carotenoids at flowering was noted in genotype RGN 48 (2.50 mg/g) closely followed by other genotypes RH 819 (2.40 mg/g) and RB 50 (2.35 mg/g) and at pod formation stage also followed same trend. The total carotenoids reduced significantly in all the genotypes at flowering as well as pod formation stages under water stress condition. The mean reduction at flowering and pod formation stages were 20 and 26.67% respectively. Water stress condition reduced the carotenoids in crops [5, 6].

Drought susceptibility index

Drought susceptibility index varied significantly among the genotypes. The highest DSI was noted in the genotype RH 0749 (2.17) followed by other genotypes RH 0406 (1.83) and NRC BH 101 (1.56). The lowest DSI was noted in the genotype RGN 229 (0.07) followed by RH 819 (0.28) and Geeta (0.35). Higher mean seed yield along with lower drought susceptibility index values was considered to identify and select the best genotype under drought condition [15]. It was reported that the variability in mustard varieties for yield particularly in drought condition due to difference in morpho-pysiological behavior such as chlorophyll synthesis, water relation parameters, developmental plasticity and mobilization of photosynthates from vegetative plant part to grains. The rainfed condition caused significant reduction in dry matter accumulation, chlorophyll content, relative water content (RWC), yield and oil content over irrigated condition [16].

Conclusion

It can be concluded from the present study that the

morpho-physiological traits like relative water content (RWC), chlorophyll content, carotenoids and drought susceptibility index are important characters under water stress condition. In irrigated condition the performance of Indian mustard genotypes RH 0749 and RH 0406 were better over other genotypes while under rainfed genotypes RGN 48 and RB 50 showed better performance over other genotypes. Current investigations suggested that Indian nustard is much sensitive to water stress at pod formation stage and hence irrigation should not be skipped at this stage for successful production.

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