



Assessment of drought tolerance using drought tolerance indices and their inter relationships in mustard [*Brassica juncea* (L.)]

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Abstract

Drought is the most significant constraint for crop production which limits plant growth and production of field crops more than any other environmental stress. In order to assess drought tolerance among twenty five diverse mustard genotypes using yield based drought tolerance indices, two pot culture experiments were conducted in completely randomized design with three replications each at CSK HPKV, Palampur during *rabi*, 2013-14. Both experiments differed in respect of irrigation regimes. Moisture stress was created by stopping irrigation after establishment of plants from branch initiation stage to siliqua formation stage. The analysis of variance under drought stress environment revealed the significance of mean squares due to genotypes for all components except number of primary branches per plant and seeds per siliqua. Likewise, analysis of variance under non stress environment revealed the significance of mean squares due to genotypes for all parameters except days to 75% maturity, siliqua length and seeds per siliqua. The genotypes; PusaJaikisan and 03-456 exhibited highest seed yield per plant (g) in drought stress and non stress environments, respectively. Based upon drought tolerance indices such as Tolerance Index (TOL), Mean Productivity (MP), Geometric Mean Productivity (GMP), Yield Stability Index (YSI), Stress Susceptibility Index (SSI), Stress Tolerance Index (STI) and Modified Stress Tolerance Indices (K_1 STI and K_2 STI), PusaJaikisan appeared to be the most drought tolerant cultivar as it recorded the highest average ranks since the yield under drought stress and non stress conditions remained the same. Yield under non stress (Y_p) environment showed positive and significant associations with SSI, STI, TOL, MP, GMP and K_1 STI whereas significant negative association was recorded with YSI. Yield under drought stress (Y_s) environment recorded positive and significant associations with STI, MP, GMP, YSI and K_2 STI whereas significant negative correlation was observed with SSI and TOL. Indices such as STI, MP and GMP could therefore, be used to select drought tolerant genotypes with high yield performance under both drought stress and non stress conditions.

Key words: Drought tolerance indices, inter-relationships, Indian mustard, moisture stress

Introduction

Oilseed crops play the second important role next to food grains in the Indian agricultural economy in terms of area and production. In India, rapeseed-mustard is the second most important oilseed crop, next to groundnut, contributing nearly 25-30 per cent of the total oilseeds production. Rapeseed-mustard accounts for 23.2% of the acreage and 26.2% of the production average since 2014-15 to 2018-2019, respectively. The average rapeseed-mustard yield in India is about 1499 kg/ha compared to the combined oilseeds crops average of 1265 kg/ha during 2018-19 (Anonymous, 2020). In Himachal Pradesh, rapeseed-mustard is grown over an area of 8.6 thousand hectares with production of 4.44 thousand tonnes and productivity 520 kg/ha (Anonymous, 2016-17).

Water stress is a serious problem in 45 per cent of world's geographical area which leads to substantial variations

in morphology, anatomy and physiology of plants and ultimately, affects yield potential (Garg *et al.*, 1998). Indian mustard [*Brassica juncea* (L.) Czern & Coss.] is grown as a rainfed crop on conserved moisture received from monsoon rains in 37 per cent of the total area under the crop. The crop is exposed to drought stress at one or more phenological stages depending on sowing time and rainfall received. Indian mustard is much sensitive to moisture stress particularly after flowering which adversely affects the yield and quality.

Several drought tolerance indices have been suggested by different researchers to select drought-tolerant genotypes based on the yield production of genotypes under stress and non-stress conditions. Fernandez (1992) had divided the genotypes into four groups based on their seed yield performance in both stress and non-stress environments: (A) genotypes that are favourable under

both stress and non-stress conditions; (B) genotypes that are favourable only in non-stress environments; (C) genotypes with relatively higher yields under stress conditions and (D) genotypes with lower performance under both conditions. Drought indices provide a measure of drought based on yield loss under drought conditions and are used for screening drought tolerant genotypes. Breeding for drought tolerance involves identification and transfer of morpho-physiological and biochemical traits that may impart drought tolerance as yield and drought tolerance are controlled at separate loci (Blum, 1983 and Morgan, 1984). Clarke *et al.* (1984) suggested that selecting for yield under dry condition should alone be more productive avenue for improvement of drought resistance until more rapid and effective screening procedures could be developed. Drought stress also reduces the oil content as more metabolites are produced and prevent it from oxidation in the cells under stress conditions. These drought-stressed plants consequently exhibit poor growth and yield (Kumari *et al.*, 2019). Moisture stress causes reduction in leaf chlorophyll content of plants (Paknejad *et al.*, 2007 and Sun *et al.*, 2011). Keeping this in view, the present study was undertaken to assess the drought tolerance using drought tolerance indices and their inter relationships in order to identify the drought tolerant genotypes in Indian mustard.

Materials and Methods

In the present study, twenty five genotypes of Indian mustard (local, indigenous and exotic) were raised in pots in completely randomised design with three replications each under moisture stress and non-stress environments in the Department of Genetics & Plant Breeding, CSK HPKV, Palampur during *rabi*, 2013-2014. Recommended package of practices were followed to raise a good crop. Irrigation was stopped after germination of plants, from branch initiation stage to siliqua formation stage. Life saving amount of water was provided at the crucial stage of

wilting. The observations on seed yield/plant (g) were recorded both under moisture stress and non stress conditions. Yield based drought tolerance indices were calculated as per Farshadfar and Geravandi, 2013 (Table 1) in which Y_p and Y_s denote yields of a given cultivar under non stress and stress environments; \bar{Y}_p and \bar{Y}_s are mean yields of all cultivars under non stress and stress environments, respectively.

Results and Discussion

The analysis of variance under moisture stress environment revealed the significance of mean squares due to genotypes for all components except number of primary branches per plant and seeds per siliqua. Likewise, analysis of variance under non stress environment revealed the significance of mean squares due to genotypes for all parameters except days to 75% maturity, siliqua length and seeds per siliqua (data not presented). Two genotypes viz., Pusa Jaikisan and 03-456 exhibited highest seed yield/plant (g) in drought stress and non-stress environments, respectively. Drought indices were calculated on the basis of seed yield of cultivars (Table 2). Based upon indices such as Tolerance Index (TOL), Mean Productivity (MP), Geometric Mean Productivity (GMP), Yield Stability Index (YSI), Stress Susceptibility Index (SSI), Stress Tolerance Index (STI), Modified Stress Tolerance Index-I (K_1 STI) and Modified Stress Tolerance Index-II (K_2 STI), Pusa Jaikisan appeared to be the most drought tolerant cultivar as it recorded the highest average rank (3.8) since the yield under drought stress and non-stress environments remained the same (Table 3). The genotypes; Heera, RH-8544, IC-355337 and Bawal-151 showed the next higher ranks (≤ 7) which indicated their stable yield performance in both environments. Higher levels of STI, MP, GMP and YSI and lower TOL and SSI are the indicators of drought tolerance. The genotypes such as NRC-2, Zem-1, TM-172, IC-355309, IC-355331, TM-136 and RL-1359 were

Table 1: Abbreviations and formula used for calculation of various indices in mustard

Name of index	Abbreviation and formula
Tolerance Index	$TOL = Y_p - Y_s$
Mean Productivity	$MP = (Y_p - Y_s)/2$
Geometric Mean Productivity	$GMP = \sqrt{\bar{Y}_p \times \bar{Y}_s}$
Yield Stability Index	$YSI = Y_s / Y_p$
Stress Susceptibility Index	$SSI = (1 - Y_s / Y_p) / (1 - \bar{Y}_s / \bar{Y}_p)$
Stress Tolerance Index	$STI = (Y_p \times Y_s) / \bar{Y}_p^2$
Modified Stress Tolerance Index-I	$K_1STI = (Y_p^2 / \bar{Y}_p^2) \times [(Y_p + Y_s) / \bar{Y}_p^2]$
Modified Stress Tolerance Index-II	$K_2STI = (Y_s^2 / \bar{Y}_s^2) \times [(Y_p + Y_s) / \bar{Y}_p^2]$

Table 2: Mean seed yield (g) under non stress and stress environments and drought tolerance indices in Indian mustard

Genotypes	Mean seed yield		Drought tolerance indices							
	Y _p	Y _s	TOL	MP	GMP	YSI	SSI	STI	K ₁ STI	K ₂ STI
TM-136	8.2	3.4	4.80	5.80	5.28	0.41	1.42	0.52	1.26	0.63
TM-172	6.2	3.7	2.50	4.95	4.79	0.60	0.98	0.43	0.72	0.74
Geeta	6.8	4.1	2.70	5.45	5.28	0.60	0.96	0.52	0.87	0.91
Heera	7.6	5.0	2.60	6.30	6.16	0.66	0.83	0.71	1.08	1.35
IC-355309	6.9	3.7	3.20	5.30	5.05	0.54	1.12	0.48	0.89	0.74
TM-204	8.4	4.0	4.40	6.20	5.80	0.48	1.27	0.63	1.32	0.87
PusaJaikisan	6.9	6.9	0.00	6.90	6.90	1.00	0.00	0.89	0.89	2.57
IC-355331	7.1	3.7	3.40	5.40	5.13	0.52	1.16	0.49	0.95	0.74
YRN-6	8.1	4.4	3.70	6.25	5.97	0.54	1.11	0.67	1.23	1.05
TM-215	6.8	4.3	2.50	5.55	5.41	0.63	0.89	0.55	0.87	1.00
IC-355337	8.4	4.8	3.60	6.60	6.35	0.57	1.04	0.76	1.32	1.25
TM-224	6.6	4.5	2.10	5.55	5.45	0.68	0.77	0.56	0.82	1.10
IC-347949	7.4	4.2	3.20	5.80	5.57	0.57	1.05	0.58	1.03	0.95
03-456	8.8	4.1	4.70	6.45	6.01	0.47	1.29	0.68	1.45	0.91
Zem-1	6.4	3.3	3.10	4.85	4.60	0.52	1.17	0.40	0.77	0.59
NRC-1	7.1	4.6	2.50	5.85	5.71	0.65	0.85	0.61	0.95	1.14
OMK-3-29	8.2	4.7	3.50	6.45	6.21	0.57	1.03	0.72	1.26	1.19
RCC-4xZem-1	7.0	4.8	2.20	5.90	5.80	0.69	0.76	0.63	0.92	1.25
RH-8544	7.9	4.9	3.00	6.40	6.22	0.62	0.92	0.73	1.17	1.30
Bawal-151	6.8	5.0	1.80	5.90	5.83	0.74	0.64	0.64	0.87	1.35
NRC-2	6.7	2.4	4.30	4.55	4.01	0.36	1.55	0.30	0.84	0.31
Varuna (C)	6.8	4.1	2.70	5.45	5.28	0.60	0.96	0.52	0.87	0.91
Kranti (C)	7.5	4.4	3.10	5.95	5.74	0.59	1.00	0.62	1.06	1.05
RL-1359(C)	7.7	3.8	3.90	5.75	5.41	0.49	1.23	0.55	1.11	0.78
RCC-4(C)	6.8	4.7	2.10	5.75	5.65	0.69	0.75	0.60	0.87	1.19
Grand mean	7.3	4.3	-	-	-	-	-	-	-	-
CD (Pd ^{0.05})	1.5	1.5	-	-	-	-	-	-	-	-
CV (%)	12.4	14.6	-	-	-	-	-	-	-	-

Table 3: Ranks, rank means and standard deviation of ranks (SDR) for Y_p, Y_s and drought tolerance indices

Genotypes	Y _p	Y _s	TOL	MP	GMP	YSI	SSI	STI	K ₁ STI	K ₂ STI	Mean	SD
TM-136	4	23	25	13	18	24	24	18	4	23	17.6	7.66
TM-172	25	20	6	23	23	10	12	23	25	20	18.7	6.48
Geeta	17	15	10	19	18	10	10	18	17	15	14.9	3.42
Heera	9	2	9	6	5	6	6	5	9	2	5.9	2.47
IC-355309	15	20	15	22	22	17	18	22	15	20	18.6	2.84
TM-204	2	18	23	8	9	22	22	9	2	18	13.3	7.81
PusaJaikisan	15	1	1	1	1	1	1	1	15	1	3.8	1.60
IC-355331	12	20	17	21	21	19	19	21	12	20	18.2	3.31
YRN-6	6	11	20	7	7	17	17	7	6	11	10.9	5.01
TM-215	17	13	6	17	16	8	8	16	17	13	13.1	4.06
IC-355337	2	5	19	2	2	14	15	2	2	5	6.8	6.24
TM-224	23	10	3	17	15	5	5	15	23	10	12.6	6.84
IC-347949	11	14	15	13	14	14	16	14	11	14	13.6	1.50
03-456	1	15	24	3	6	23	23	6	1	15	11.7	8.93
Zem-1	24	24	13	24	24	19	20	24	24	24	22	3.49
NRC-1	12	9	6	12	12	7	7	12	12	9	9.8	2.36

OMK-3-29	4	7	18	3	4	14	14	4	4	7	7.9	5.13
RCC-4 x Zem-114		5	5	10	9	3	4	9	14	5	7.8	3.82
RH-8544	7	4	12	5	3	9	9	3	7	4	6.3	2.87
Bawal-151	17	2	2	10	8	2	2	8	17	2	7	5.80
NRC-2	22	25	22	25	25	25	25	25	22	25	24.1	1.37
Varuna (C)	17	15	10	19	18	10	10	18	17	15	14.9	3.42
Kranti (C)	10	11	13	9	11	13	13	11	10	11	11.2	1.33
RL-1359(C)	8	19	21	15	16	21	21	16	8	19	16.4	4.69
RCC-4(C)	17	7	3	15	13	3	3	13	17	7	9.8	5.53

Table 4: Inter relationships among different drought tolerance indices in Indian mustard

Parameter	Y_s	SSI	STI	TOL	MP	GMP	YSI	K_1 STI	K_2 STI
Y_p	0.089	0.351*	0.523**	0.618**	0.694**	0.533*	-0.353*	0.999**	0.043
Y_s		-0.899**	0.893**	-0.728**	0.779**	0.886**	0.898**	0.078	0.984**
SSI			-0.608**	0.952**	-0.429*	-0.598**	-0.999**	0.360*	-0.906**
STI				-0.346*	0.975**	0.996**	0.606**	0.513**	0.857**
TOL					-0.137	-0.333	-0.952**	0.626**	-0.748**
MP						0.976**	0.427*	0.685**	0.738**
GMP							0.596**	0.523**	0.838**
YSI								-0.362*	0.904**
K_1 STI									0.030

the most sensitive cultivars to drought as their mean ranks were relatively very low (≥ 18). The findings were consistent with the previous studies which suggested the reliability of STI, MP and GMP for screening drought tolerant genotypes in rapeseed (Shirani & Abbasian, 2011; Aliakbari *et al.*, 2014; Bakhtari *et al.*, 2017; Singh *et al.*, 2018). Yield under non stress environment (Y_p) showed significant positive associations with SSI, STI, TOL, MP, GMP and K_1 STI while it showed significant negative association with YSI. Likewise, yield under drought stress environment (Y_s) exhibited significant positive associations with STI, MP, GMP, YSI and K_2 STI while it exhibited significant negative associations with SSI and TOL (Table 4). This finding was consistent with the previous studies (Shirani and Abbasian, 2011; Khalili *et al.*, 2012; Aliakbari *et al.*, 2014; Bakhtari *et al.*, 2017). As STI, MP and GMP had positive and significant associations with seed yield under both drought stress and non-stress environments and with each other, they could therefore, be used to select drought tolerant genotypes with high yield performance under both drought stress and non-stress conditions in Indian mustard.

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