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Evaluation of Moisture Stress Indices and Biplot Analysis in Coriander under Normal and Staggered Moisture Regimes

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ABSTRACT: Drought is one of the major abiotic stresses influencing performance of crop plants. Therefore, identification or development of tolerant genotypes is of high importance in crops, that limit the crop production worldwide. The thirty genotypes of coriander was evaluated at two environments *viz.*, normal condition (E1) and limited moisture condition (E2) in RBD with three replications during *rabi* 2016-2017. Eight moisture stress indices as TOL, SSI, STI, MP, GMP, YI, SSPI, Ys, Yp and MSTI were calculated from seed yield per plant under both the conditions for each of the genotype. The MSS due to all the three sources as environments, genotypes and G x E interactions were found highly significant for seed yield on pooled basis indicating interaction among the genotypes and prevailing environmental conditions. The six indices *viz.*, STI, MP, GMP, YI, K_1STI and K_2STI had showed high positive and significant association with seed yield under both the conditions as stress (Ys) and non-stress (Yp) suggesting they would be more effective in screening of stress tolerant genotypes in both the conditions. The combined analysis of variance (AMMI) revealed that majority of the total variation was accounted for by the environments (73.55 %) followed by genotypes (23.84 %) and G × E interaction (2.60 %). Among the thirty genotypes, UD-705, UD-769 and UD-529 recorded best average seed yield along with relatively low scores of PCA-1 indicating small interaction with environment and yield stability over environments. According to overall rank sum method of all indices, genotypes UD-705, UD-529, UD-769, RCr-20 and RCr-475 were found most tolerant. Hence, these genotypes may be used in breeding programmes, especially for development of stress tolerant varieties for drought in coriander.

Keywords: Stress indices, AMMI and biplot, coriander, stress and non stress condition.

INTRODUCTION

Coriander (*Coriandrum sativum* L.) is an important seed spice crop belongs to the Apiaceae family having somatic chromosome number 22 (2n=22). It grows well in tropical and sub-tropical regions with dry climate. The high temperature at maturity phase and insufficient and erratic distribution of rainfall affects seed yield as well oil content. Tolerance of plants against moisture stress is a complex quantitative trait with low heritability (Fereres and Soriano 2007) and thus it halts and complicates the breeding for resistance to drought or moisture stress. An ideal and effective approach for identifying stress tolerant genotypes is based on mean seed yield under drought stress and non-stress environments. Araus *et al*. (2002); White *et al*. (1998) has suggested selection of genotypes based on their yield response in two or more normal and stress environments. The various stress indices that screen or select the genotypes based on their resistant or susceptible (Fernandez, 1992) towards moisture stress have been used by many researcher and plant breeders (Mitra, 2001). Hall, (1993) defined the drought tolerance or resistance as response of genotype in terms of grain yield when they are subjected to same level of moisture stress. Blum, (1998) defined drought stress or susceptibility of a genotype a as function of reduction in yield under drought stress. The index MP (mean productivity) measures the average yield of genotype across the two environments, while TOL (Rosielle and Hamblin 1981) measures the difference in degree of yield response over the stress (Ys) and non-stress (Yp) environments. Another index SSI captures the changes in both potential and actual yields in variable environments (Fischer and Maurer 1978). The larger value of TOL and SSI indicates relatively more sensitivity towards stress, thus a smaller value of TOL and SSI are suitable and indicates tolerance for moisture stress. The value of stress susceptibility index more than one (SSI >1) indicates above average susceptibility, while a value less than one indicates (SSI<1) below-average susceptibility towards moisture stress (Guttieri *et al*., 2001). The index STI selects the genotypes that produce high yield under both stress and non-stress conditions (Fernandez, 1992). The GMP index measures relative yield response of a genotype over two environments since in field environments, the stress level can be vary in severity (Fernandez, 1992). Thus, two indices *viz.*, STI and GMP screen genotypes having high yield potential and stress tolerance (Fernandez, 1992). Similarly, two indices as YI (Gavuzzi *et al.*, 1997) and SSPI (Moosavi *et al.*, 2008) evaluate the genotypes based on yield stability under two environments.

MATERIALS AND METHODS

The present investigation was carried out using thirty genotypes of coriander taken from germplasm center of AICRP on seed Spices, SKNCOA, Jobner. These genotypes were evaluated at Agronomy Farm of S.K.N. College of Agriculture, Jobner in RBD layout with 3 replications during *rabi* 2016-17 in two environments, namely, (i) normal condition (non-stress, E1) and (ii) Limited moisture condition (stress, E2). The required irrigations was supplied in normal condition (E1), while half of the irrigations was provided in limited moisture condition (E2) in staggered manner from sowing to maturity of the crop. The each genotype was sown in a single row plot of 3 m length by maintaining crop geometry of 30 x 10 cm (R x P) in each environment or replication. The Jobner is located in Jaipur district of Rajasthan with typically semi-arid climate and falls in agroclimatic zone III A (Semi-arid Eastern Plain Zone) of Rajasthan. Annually, the place receives 300-400 mm rainfall and temperature during summers goes high as 48^0 C, while extreme low in winter (-1.0^0 C) season. The five randomly plant from each plot/environment selected and average seed yield per plant (g) was worked out for each of the genotype under both the conditions as non-stress (Yp) and stress (Ys).

Statistical Analysis: The analysis of variance was carried out on pooled basis to assess the interaction between genotypes and environments. The variation accounted to each source of variation was estimated as percentage of variance explained of total sum of squares. The ranking of genotypes was carried out according to each of the stress index. Based on indices, the genotype with the highest value for Ys, Yp, MP, GMP, STI, K_1STI, K_2STI and YI and the lowest value for SSI, TOL and SSPI received a rank one. The correlation among the moisture stress indices as well as Yp, Ys were also carried out to determine the most desirable combination of stress indices for screening the best tolerant genotypes. The pooled ANOVA for AMMI and biplot analysis were performed using GEA-R version 4.1 (CIMMYT, Mexico).

RESULTS AND DISCUSSION

A. Pooled ANOVA and mean Comparison

The mean squares (Table 1) due to genotypes were found highly significant for seed yield per plant on pooled basis indicating significant differences among the genotypes. The variance due to environments as well as genotypes x environments interaction for seed yield per plant (g) were also found highly significant indicating differential yield response of genotypes towards the two different environments (E1 and E2) and their role in character expression. The per cent share of each source of variance towards per cent total sum of squares (% TSS) revealed that 69 per cent of total sum of squares was accounted for environments (E) effect indicating most important source of yield variation. Similarly, the per cent share of genotypes (G) and G × E interactions effects was 22.37 per cent and 2.44 per cent of total sum of squares, respectively.

Table 1: The mean sum squares due to different source of variations on pooled basis for seed yield per plant (g) in coriander as well as per cent share of each source of variations total Sum of Squares (TSS).

Source of variation	Genotypes (G)	Environments (E)	Replication within Environment	G × E	Error
d.f.	29	1	4	29	116
Mean Sum of Squares (MSS)	1.113**	99.61**	0.028	0.122**	0.075
TSS (%)	22.37	69.07	0.07	2.44	6.01

** represents significant at 1% level of significance; d.f. *i.e.* Degree of Freedom

The mean seed yield (Yp) was ranged from 4.42 g (UD-554) to 6.15 g (UD-769) in non-stress environment (E1) with the overall mean of 5.01 g. While, mean seed yield (Ys) was ranged from 3.09 g (UD-461) to 4.63 g (UD-705) in stress environment (E2) with the overall mean of 3.52 g. The average seed yield of genotypes in the stress condition (Ys) was found to be 29.74 percent lower than in the non-stress condition. Thus, the genotypes experienced moisture stress during the crop growing period in stress environment (E2) and the stress intensity (Fischer and Maurer) [12] was equal to 0.29. The top five performing genotypes were UD-769, UD-705, RCr-684, UD-529 and RCr-20, whereas the genotypes UD-554, UD-704, UD-461, UD-169 and UD-489 showed lower seed yield in non-stress (E_1) environment. Similarly, genotypes UD-705, UD-769, UD-529, RCr-20 and RCr-684 depicted higher seed yield and UD-461, UD-747, UD-751, UD-23 and UD-566 showed lower seed yield in stress environment (E2).

B. Moisture stress indices

According to stress tolerance index (TOL), higher value of TOL indicates susceptibility of the genotype to stress and fluctuation in response in terms of seed yield in stress and non-stress conditions (Table 3). The genotypes UD-554, UD-580, UD-723, UD-704 and UD-489 were found most tolerant as they occupied lower values TOL index, whereas genotypes UD-513, RCr-684, UD-783, UD-709 and UD-747 were found most sensitive as they displayed higher values of TOL index. In accordance with stress susceptibility index (SSI), genotypes UD-513, UD-783, UD-747, UD-709 and UD-23 had showed higher values of SSI index indicating their minimum tolerance to moisture stress. The genotypes UD-554, UD-580, UD-723, UD-705 and UD-704 were found more tolerance against moisture stress (lower values of SSI). It was found that the SSPI and TOL index resulted the same genotype ranking with different values of their respective index. Similarly, the geometric mean productivity (GMP) resulted the same genotype ranking as stress tolerance index (STI) with different values of their respective index. A relatively similar pattern of ranking of genotypes was observed for the three indices *viz.*, MP, GMP and STI under the study. According to the STI index (high STI), genotypes UD-705, UD-769, UD-529, RCr-684 and RCr-20 were found stress tolerant with high seed yield under both the conditions E1 and E2, while UD-461, UD-169, UD-751, UD-717 and UD-704 were the genotypes with least rank. According to mean productivity (MP), higher value of MP for a genotype is directly proportional to its tolerance towards moisture stress and vice versa thus genotypes UD-705, UD-769, UD-529, RCr-684 and RCr-20 were found most tolerant, whereas, the genotypes UD-461, UD-169, UD-717, UD-751 and UD-704 were found least tolerant towards moisture stress. The yield index (YI) can also serve as a selection criterion as it only ranks cultivars based on their yield (Ys) under stress environment (E2). Thus, according to this index, genotypes UD-705, UD-769, UD-529, RCr-20 and RCr-684 had displayed highest values for YI and Ys, hence proved to be more resilient towards moisture stress. The genotypes UD-461, UD-747, UD-751, UD-566 and UD-23 depicted lower YI and Ys indicating their susceptibility for moisture stress.

C. Correlation analysis

The simple correlation was carried out among the various stress indices including Yp, Ys to know the most desirable combination of indices suitable for screening of tolerant genotypes (Table 2).

Table 2: The Association analysis among the various indices and seed yield (Yp and Ys).

Stress indices	Yp	Ys	TOL	SSI	STI	MP	GMP	YI	SSPI	K_1STI
Ys	0.819**									
TOL	0.559**	-0.007								
SSI	0.100	-0.481**	0.876**							
STI	0.939**	0.970**	0.248	-0.229						
MP	0.959**	0.941**	0.318	-0.161	0.991**					
GMP	0.946**	0.961**	0.268	-0.223	0.999**	0.998**				
YI	0.819**	1.000**	-0.009	-0.483**	0.964**	0.944**	0.961**			
SSPI	0.565**	-0.008	1.000**	0.876**	0.254	0.321	0.267	-0.01		
K_1STI	0.999**	0.834**	0.543**	0.077	0.950**	0.968**	0.953**	0.833**	0.542**	
K_2STI	0.825**	0.998**	0.003	-0.467**	0.967**	0.946**	0.963**	0.998**	0.003	0.840**

* and ** represent significant at 5 % and 1 % level of significance, respectively

Talebi *et al.* (2007) has suggested that those indices are best which have high correlation with seed yield in both non-stress (E1) and stress environment (E2) conditions and would be able to identify potential high yielding and moisture stress tolerant genotypes. A significant association ($r = 0.820^{**}$) was found between seed yield under stress (Ys) and non-stress condition (Yp). These results are found in corroboration with the findings of Fernandez (1992), Mohammadi *et al.* (2010), Farshadfar *et al.* (2012) and Sahar *et al.* (2016). The seed yield under non-stress (Yp) had high significant positive association with the eight indices as TOL, STI, MP, GMP, YI, SSPI and K_1STI and K_2STI and positive non-significant association with SSI. Similarly, index Ys had high significant positive association with STI, MP, GMP, YI and K_2STI, K_1STI and significant negative association with SSI. It was observed that the seed yield in stress (Ys) and non-stress condition (Yp) was significantly and positively correlated with the stress indices STI, MP, GMP, YI, K_1STI and K_2STI indicating that these indices screen genotypes which have uniform superiority or stress tolerance (Fernandez, 1992). Siahsar *et al.* (2010) in lentil, Zare and Saeidi *et al.* (2012) in barley, Singh *et al.* (2015) and Mohammed and Kadhem (2017) in wheat obtained similar results.

D. Ranking method

The screening of tolerant genotypes according to single criteria (indices) was found contradictory and different indices introduced different or same genotypes as stress tolerant. Thus, the sum of rank of all indices including Ys and Yp of genotypes were used to calculate overall rank of genotypes.

Thus, according to this criterion a genotype with least rank sum will be the best genotype. The overall ranks of all the genotypes based on the above criteria are presented in Table 5. The genotypes UD-705, UD-529, UD-769, RCr-20 and RCr-475 occupied rank 1,2,3,4,5 respectively and identified as the most moisture stress tolerant genotypes. The genotypes UD-747, UD-461, UD-751, UD-23 and UD-169 were found most sensitive for moisture stress as they occupied. higher over all rank sum. Farshadfar *et al.* (2012) and Mohammed and Kadhem (2017) used overall rank sum methodology to screen the tolerant genotypes in wheat.

Table 3: The ranking of genotypes according to various indices and overall rank of genotypes

Genotypes	Yp	Ys	TOL	SSI	STI	MP	GMP	YI	SSPI	MSTI (K_1STI)	MSTI (K_2STI)	Sum	Overall rank
UD-23	16	26	25	26	19	18	19	26	25	16	26	242	26
UD-32	14	16	20	23	16	14	16	16	20	14	16	185	17
UD-169	27	24	6	13	29	29	29	24	6	27	24	238	25
UD-280	19	21	16	22	21	21	21	21	16	19	21	218	21
UD-461	28	30	8	16	30	30	30	30	8	28	30	268	29
UD-472	13	12	18	15	11	11	11	12	18	13	12	146	12
UD-488	6	6	23	20	6	6	6	6	23	6	6	114	7
UD-489	26	15	5	7	22	23	22	15	5	26	15	181	16
UD-492	20	17	9	12	18	20	18	17	9	20	17	177	15
UD-513	7	20	30	30	10	10	10	20	30	7	20	194	18
UD-520	15	14	18	18	14	13	14	14	18	15	14	167	13
UD-529	4	3	12	6	3	3	3	3	12	4	3	56	2
UD-554	30	13	1	1	23	25	23	13	1	30	13	173	14
UD-566	17	26	24	25	20	19	20	26	24	17	26	244	27
UD-573	9	9	21	21	9	9	9	9	21	9	9	135	11
UD-580	22	9	2	2	15	17	15	9	2	22	9	124	10
UD-627	23	22	13	17	25	24	25	22	13	23	22	229	23
UD-704	28	17	4	5	26	26	26	17	4	28	17	198	19
UD-705	2	1	14	4	1	1	1	1	14	2	1	42	1
UD-709	12	22	27	27	17	15	17	22	27	12	22	220	22
UD-717	25	24	7	14	27	28	27	24	7	25	24	232	24
UD-723	21	9	3	3	13	16	13	9	3	21	9	120	9
UD-747	18	29	26	28	24	21	24	29	26	18	29	272	30
UD-751	24	28	11	19	28	27	28	28	11	24	28	256	28
UD-769	1	2	22	9	2	2	2	2	22	1	2	67	3
UD-783	10	19	28	29	12	12	12	19	28	10	19	198	19
RCr-20	5	4	15	8	5	5	5	4	15	5	4	75	4
RCr-436	8	7	16	11	7	7	7	7	16	8	7	101	6
RCr-684	3	5	29	24	4	4	4	5	29	3	5	115	8
RCr-475	11	8	10	10	8	8	8	8	10	11	8	100	5

E. AMMI and biplot analysis

The AMMI and biplot analysis was also performed to visualize G × E interactions and to minimize the noise from interaction to clearly examine the yield stability (Ajay *et al.,* 2020) of genotypes. The ANOVA for AMMI (Table 4) analysis revealed that MSS due to genotypes were found highly significant for seed yield per plant indicating non-linear response of genotypes towards the two different conditions.

Table 4: The ANOVA for AMMI analysis on pooled basis.

Source	d.f.	SS	MSS	F	Probability	Percent
Environment (Env)	1	99.636	99.636	1363.203	0.000	73.55
Genotype (Gen)	29	1.114	32.297	15.237	0.000	23.84
Env. × Gen.	29	0.121	3.522	1.662	0.030	2.60
PCA-1	29	0.121	3.522	1.634	0.035	100.0
PCA-2	27	0.000	0.00	0.00	1.00	0.00
Residuals	120	0.073	8.771	-	-	0.00

The bulk of the total variation that explained (Percent) was attributed for by the environments as 73.55 per cent, indicating the environments were diverse. The genotypes shared 23.84 per cent of total variation, while share of interaction was 2.60 per cent. It was also found from the AMMI analysis that PCA-1 captured almost all the share of the interaction sum of squares.

The AMMI biplot (Fig. 1) between PCA-1 and Main effects provides a visual expression of the relationships between the genotypes and interaction with the prevailing environmental condition. The stability or adaptability of the genotypes can be assessed by mean seed yield and PCA scores of genotypes in the AMMI analysis (Purchase, 1997; Martin and Alberts, 2004).

The mean, PCA-1, PCA-2 values of all genotypes are presented in Table 5. Higher PCA scores of a genotype (High responsive) indicated it's the specific adaptability or stability to a certain environment, while lower PCA scores as approximate to zero (low responsive), indicates stability or adaptability over all the environments sampled.

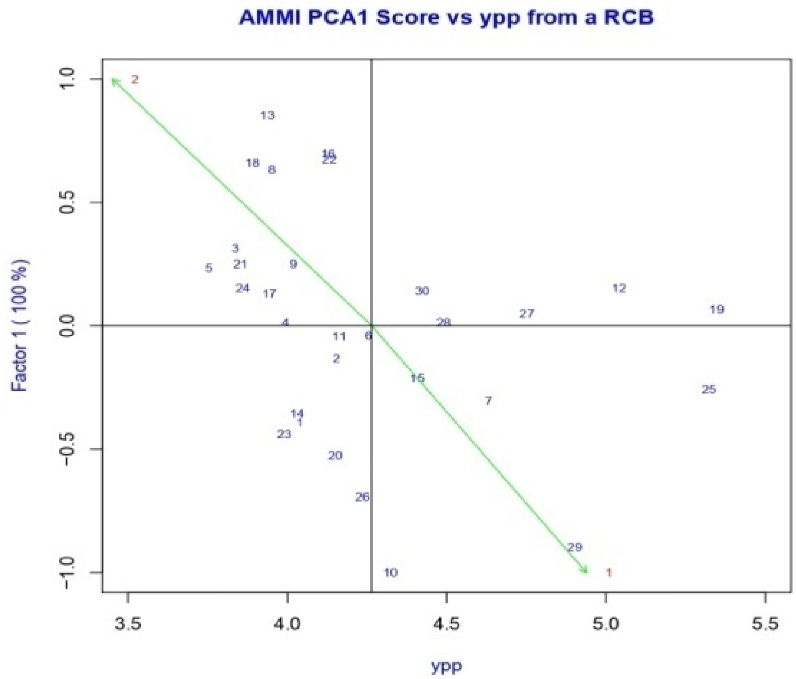

Fig. 1. Biplot between PCA1 and mean seed yield per plant (ypp).

Table 5: Mean and scores of PCA-1 and PCA-2 of thirty genotypes of coriander for seed yield per plant.

Sr. No.	Genotype	Overall Mean	PCA-1	PCA-2
1.	UD-23	4.04	-0.39	4.06
2.	UD-32	4.16	-0.13	-1.31
3.	UD-169	3.87	0.31	-2.12
4.	UD-280	3.99	0.01	-7.07
5.	UD-461	3.76	0.23	1.02
6.	UD-472	4.25	-0.04	-7.21
7.	UD-488	4.63	-0.30	3.36
8.	UD-489	3.95	0.63	-1.11
9.	UD-492	4.02	0.25	-5.38
10.	UD-513	4.32	-1.00	-1.97
11.	UD-520	4.16	-0.04	-2.60
12.	UD-529	5.04	0.15	2.14
13.	UD-554	3.94	0.85	6.86
14.	UD-566	4.03	-0.35	-1.41
15.	UD-573	4.41	-0.21	1.14
16.	UD-580	4.13	0.70	4.30
17.	UD-627	3.94	0.13	-1.26
18.	UD-704	3.89	0.66	-3.38
19.	UD-705	5.35	0.07	1.40
20.	UD-709	4.15	-0.53	-1.33
21.	UD-717	3.88	0.25	6.75
22.	UD-723	4.13	0.68	4.50
23.	UD-747	3.99	-0.44	-2.22
24.	UD-751	3.86	0.15	-3.96
25.	UD-769	5.32	-0.26	-8.40
26.	UD-783	4.24	-0.69	5.70
27.	RCr-20	4.75	0.05	2.00
28.	RCr-436	4.49	0.01	-8.00
29.	RCr-684	4.90	-0.90	4.21
30.	RCr-475	4.42	0.14	-1.27
Non stress-environment (E1)		5.01	-1.00	2.02
Moisture stress environment (E2		3.52	1.00	2.02

The environment E1 located at the right side of the main axis indicating the superiority if the E1 environments or non-stress environment. Similarly, the genotypes 19 (UD-705), 25 (UD-769), 12 (UD-529), 29 (RCr-684), 27 (RCr-20), 7 (UD-488), 28 (RCr-436), 30 (RCr-475), 15 (UD-573) and 10 (UD-513) were found generally high yielding as they were placed on right-hand side of the mid-point representing grand mean. The genotypes 19 (UD-705) followed by 25 (UD-769) and 12 (UD-529) recorded best average seed yield of 5.35, 5.33 and 5.04 gram and attained relatively small values of PCA-1 (0.07, -0.26 and 0.15 respectively) indicating they were stable and widely adapted genotypes. Naroui *et al.* (2013) emphasized stability in addition to seed yield thus, genotypes UD-280, RCr-436, UD-472, UD-520, RCr-20 and UD-705 attained lowest PCA-1 values (0.01, 0.01,-0.04, -0.04, 0.05 and 0.07, respectively) and average seed yield (3.99, 4.49, 4.25, 4.16, 4.75 and 5.35 gram, respectively). The genotypes UD-461(3.76 g) and UD-751(3.86) yielded least seed and attained relatively small PCA-1 values (0.23 and 0.15, respectively) indicating their average adaptability. Similar findings of screening of genotypes using PCA values were also reported by Amir *et al.* (2018) in coriander, Fufa (2018) in cumin, Naik *et al.* (2022); Rao *et al.* (2022) in wheat.

CONCLUSION

The genotypes UD-705, UD-529, UD-769, RCr-20 and RCr-475 were found most tolerant genotypes *i.e.* for moisture stress based on overall rank sum method. The correlation analysis among the indices revealed that the indices STI, MP, GMP, YI, K_1STI and K_2STI were strongly correlated with seed yield under both the environmental condition as non-stress (E1) and stress condition (E_2) and can be used as selection criteria to screen stress tolerant genotypes. The indices TOL, SSI, YI and SSPI could be used as selection criteria for screening of stress tolerant genotypes in stress environment as they exhibited good correlation with seed yield under E2 environment. The tolerant genotypes found under the study may be used in coriander breeding programmes especially for drought stress after further their multi location trials.

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Conflict of Interest. None.

REFERENCES

Ajay, B. C., Bera, S. K., Singh, A. L., Kumar, N., Gangadhar, K. and Kona, P. (2020). Evaluation of genotype x environment interaction and yield stability analysis in peanut under phosphorus stress condition using stability parameters of AMMI model. *Agriculture Research*, *33*: 1–10.

Amir, G., Mostafa, K. and Aram, S. Z. (2018). Evaluation of genotype × environment interaction for essential oil yield of coriander genotypes under different irrigation conditions using GGE biplot method.

Araus, J. L., Slafer, G. A., Reynolds, M. P. and Royo, C. (2002). Plant breeding and drought in C3 cereals: What should we breed for ? *Annals of Botany*, *89*: 925-940.

Blum, A. (1988). Plant breeding for stress environments. CRC Press, Boca Raton, Florida, USA, p. 222.

Farshadfar, E. and Sutka, J. (2002). Multivariate analysis of drought tolerance in wheat substitution lines. *Cereal Research Communications*, *31*: 33-39.

Farshadfar, E., Jamshidi, B. and Aghaee, M. (2012). Biplot analysis of drought tolerance indicators in bread wheat landraces of Iran. *International Journal of Agriculture and Crop Sciences*, *4*(5): 226-233.

Fereres, E. and Soriano, M. A. (2007). Deficit irrigation for reducing agricultural water use. *Journal of Experimental Botany*, *58*: 47-158.

Fernandez, G. C. J. (1992). Effective selection criteria for assessing plant stress tolerance. In: Proceedings of the International Symposium on “Adaptation of Vegetables and other Food Crops in Temperature and Water Stress”, Taiwan, 13-16 August 1992; 257-270.

Fischer, R. A. and Maurer, R. (1978). Drought resistance in spring wheat cultivars and grain yield responses. *Australian Journal of agricultural Research*, *29*(5): 897-912.

Fufa, M. (2018). Agronomic performance, genotype × environment interaction and stability of black cumin genotypes grown in Bale, Southeastern Ethiopia. *Advance in Crop Science Technology*, *6*: 358-365.

Gavuzzi, P., Rizza, F., Palumbo, M., Campaline, R. G., Ricciardi, G.L. and Borghi, B. (1997). Evaluation of field and laboratory predictors of drought and heat tolerance in winter cereals. Canadian Journal of Plant Science, *77*(4): 523-531.

Guttieri, M. J., Stark, J. C., Brien, K. and Souza, E. (2001). Relative sensitivity of spring wheat grain yield and quality parameters to moisture deficit. *Crop Science*, *41*: 327-335.

Hall, A. E. (1993). Is dehydration tolerance relevant to genotypic differences in leaf senescence and crop adaptation to dry environments? *In*: Plant responses to cellular dehydration during environmental stress. American Society of Plant Physiologists, Rockville, Maryland, USA 1993: 1-10.

Martin, J. and Alberts, A. (2004). A comparison of statistical methods to describe genotype x environment interaction and yield stability in multi- locationmaize trials. Faculty of Agriculture, Department of Plant Sciences (Plant Breeding) at the University of the Free State.

Mitra, J. (2001). Genetics and genetic improvement of drought resistance in crop plants. *Current Science*, *80*: 758-762.

Mohammadi, R., Armion, M., Kahrizi, D. and Amri, A. (2010). Efficiency of screening techniques for evaluating durum wheat genotypes under mild drought conditions. *International Journal of Plant Production*, *4*(1): 11-24.

Mohammed, A. K. and Kadhem, F. A. (2017). Screening drought tolerance in bread wheat genotypes (*Triticum aestivum* L.) using drought indices and multivariate analysis. *The Iraqi Journal of Agricultural Sciences*, *48*: 41-51.

Moosavi, S. S., Samadi, B. Y., Naghavi, M. R., Zali, A. A., Dashti, H. and Pourshahbazi, A. (2008). Introduction of new indices to identify relative drought tolerance and resistance in wheat genotypes. *Desert*, *12*:165-178.

Murty, A. R. and Sridhar, T. (2001). Spices in Ayurveda, of Seed Spices Production, Quality and Export. Pointer Publication, Jaipur 2001. p. 140-142.

Naik, A., Wani, S. H., Rafiqee, S., Sofi, M., Sofi, N. R., Shikari, A. B., Hussain, A., Mohiddin F., Jehangir, I.A., Khan, G. H., Sofi, M. A., Sheikh, F. A., Bhat, M. A., Khan, M. N., Dar, Z. A. and Rahimi M. (2022). Deciphering genotype × environment interaction by AMMI and GGE biplot analysis among elite wheat (*Triticum aestivum* L.) genotypes of Himalayan Region. *Ekin Journal of Crop Breeding and Genetics*, *8*(1): 41-52.

Naroui, M. R. R., M. A. Kadir, M. Y. Rafii, Z. E. Hawa Jaafar, M. R. Naghavi and F. Ahmadi (2013). Genotype × environment interaction by AMMI and GGE biplot analysis in three consecutive generations of wheat (*Triticum aestivum* L.) under normal and drought stress conditions. *Australian Journal of Sciences*, *7*(7): 956-961.

Nouri, A., Etminan, A., Teixeira da Silva, J. A. and Mohammadi, R. (2011). Assessment of yield, yield-related traits and drought tolerance of durum wheat genotypes (*Triticum turjidum* var. *durum* Desf.). *Australian Journal of Crop Science, 5*(1): 816.

Purchase, J. L. (1997). Parametric stability to describe G × E interactions and yield stability in winter wheat. PhD Thesis, department of agronomy, faculty of Agriculture University of Orange.

Ramirez-Vallejo, P. and Kelly, J. D. (1998). Traits related to drought resistance in common bean. *Euphytica*, *99*(2): 127-136.

Rao, P. J. M., Sandhyakishore, N., Sandeep, S., Neelima, G., Saritha, A., Rao, P. M., Das, D. M. and Lingaiah, N. (2022). AMMI and GGE biplot analysis for stability of yield in mid-early pigeonpea [*Cajanus cajan* (L.) Millspaugh] genotypes. *Legume Research*.

Rosielle, A. A. and Hamblin, J. (1981). Theoretical aspects of selection for yield in stress and non stress environments. *Crop Science*, *21*: 943-946.

Sahar, B., Ahmed, B., Naserelhaq, N., Mohammed, J. and Hassan, O. (2016). Efficiency of selection indices in screening bread wheat lines combining drought tolerance and high yield potential. *Journal of Plant Breeding and Crop Science, 8*(5): 72-86.

Siahsar, B. A., Ganjali, S. and Allahdoo, M. (2010). Evaluation of drought tolerance indices and their relationship with grain yield of lentil lines in drought-stressed and irrigated environments. *Australian Journal of Basic and Applied Sciences*, *4*(9): 4336-4346.

Singh, S., Sengar, R. S., Kulshreshtha, N., Datta, D., Tomar, R. S., Rao, V. P., Garg, D. and Ojha, A. (2015). Assessment of multiple tolerance indices for salinity stress in bread wheat (*Triticum aestivum* L.). *Journal of Agricultural Science*, *7*(3): 49-57.

Talebi, R., Fayaz, F. and Jelodar, N. B. (2007). Correlation and path coefficient analysis of yield and yield components of chickpea (*Cicer arietinum* L.) under dry land condition in the west of Iran. *Asian Journal of Plant Sciences*, *6*: 1151–1154.

White, J. W., Castillo, J. A., Ehleringer, J. R., Garcia, J. A. and Singh, S. P. (1994). Relations of carbon isotope discrimination and other physiological traits to yield in common bean (*Phaseolus vulgaris*) under rainfed conditions. *Journal of Agricultural Science*, *122*: 275-284.

Zare, M. and Saeidi M. (2012). Evaluation of drought tolerance indices for the selection of Iranian barley (*Hordeum vulgare)* cultivars. *African Journal of Biotechnology*, *11*(93): 15975-15981.

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