Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(4): 3084-3090
Received: 09-05-2018
Accepted: 13-06-2018

Khushboo Chandra
Department of Plant Breeding and Genetics Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India

Anil Pandey
Department of Plant Breeding and Genetics Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India

SB Mishra
Department of Plant Breeding and Genetics Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India

Kavita
Department of Plant Breeding and Genetics Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India

Correspondence
Khushboo Chandra
Department of Plant Breeding and Genetics Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, India

Association and cause: Effect of physiological parameters with seed yield among Indian mustard (*Brassica juncea* L. Czern & Coss) genotypes under climatological drought condition

Khushboo Chandra, Anil Pandey, SB Mishra and Kavita

Abstract
Modern agriculture is facing multiple challenges including the necessity for a substantial increase, in production to meet the needs of a burgeoning human population. Water shortage is a deleterious consequence of both population growth and climate change and is one of the most severe factors limiting global crop productivity. In order to study correlation and cause effect of deficit irrigation on some physiological traits on yield an experiment on Indian mustard (*Brassica juncea* L. Czern & Coss), was conducted in Randomized Complete Block Design (RBCD) accommodating 20 genotypes, from various Rapeseed & Mustard centres located across country, randomly in three replications during *Rabi* 2016-17, one subjected to a drought regime inside the Rainout shelter under residual moisture condition and another one provided with normal irrigated field condition in Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur. Analysis of variance revealed considerably exploitable variability for all the 15 traits. Under both conditions of phenotypic correlation revealed that grain yield per plant showed significant and positive correlation with RWC, LMSI, CC, CA, PERO, PRO, RGR, LAI, SLW, OY except ELWL. Phenotypic path coefficient under both condition revealed that all the physiological parameters showed the low direct effect except oil yield showed high direct effect on grain yield per plot. This indicated that improvement in all the physiological parameters which showed significant positive effect and direct effect on grain yield per plot will ultimately enhances the grain yield.

Keywords: *Brassica juncea* L., physiological traits, climatological drought, root parameters, deficit irrigation

Introduction
Drought stress, as the most important factor limiting growth and yield of crops, affects about 40 to 60 percent of global agricultural lands (Shao *et al*., 2006; Rashidi, 2013) [12, 10]. In total, drought covers areas of 60 million Kilometres. In the context of agriculture, drought can be defined as the situation in which the amount of water available to the plant in the root zone is less than that required to sustain maximum growth and productivity (Deikman *et al.* 2012) [5]. Drought avoidance strategies include deep rooting, conservative use of available water and adjustment of life cycle to match rainfall (Touchette *et al.* 2007) [13]. Among the major food crops, *Brassica crops* are the most affected by drought due to the fact that they are mainly grown in arid and semiarid areas. Hence, the need for a coherent and long-term planning with the aim of achieving self-sufficiency in edible oils production is undeniable. Yield is a complex, dependent character as it is associated with other morpho-physiological traits that are transmitted quantitatively and more prone to environmental fluctuations than ancillary, independent morpho-physiological qualitatively inherited traits which cumulatively affect the yield expression. Any change in component traits likely to affect the whole network of cause and effect. The intern might affect the true association of traits, both in magnitude and direction and tend to vitiate association of yield and yield components (Biradar *et al*., 2007) [4].

Material and Methods
The experiment consisting of 20 Indian mustard genotypes was planted on 15th October 2016 under two conditions i.e. no irrigation and normal (two) irrigations, laid out in Randomized Complete Block Design (RCBD) with three replications during *Rabi* season(2015-16), including check for association and cause-effect study, received from different All India Co-ordinated Research Project- Rapeseed & Mustard centres: DRMR, Bharatpur, Rajasthan, CCSHAU, Hisar, Haryana, BARC, Trombay, Maharashtra, GBPUAT, Pantnagar, Uttarakhand, CSAUAT, Kanpur, U.P, IARI, New Delhi, ARS, RAU, Sriganganagar, Rajasthan and DR.RPCAU, Dholi, Bihar, providing only basal dose of fertilizers i.e.

N:P_2O_5:K_2O:S:: 40:40:40:40 kg/ha under residual moisture conditions inside rainout shelter and 40 Basal dose of fertilizer N:20 P_2O_5:20 K_2O:40 S kg/ha and other at green siliqua stage (E_4,65DAS) required 40 N for top dressing after pre flowering stage at Research Farm of Dr. Rajendra Prasad Central Agricultural University Farm (25.29^0 N, 85.40^0 E and 51.80 m MSL), Pusa, Samastipur, Bihar. Each plot was consisted four rows of 5.0 m length keeping row to row and plant to plant distance 30cm and 10cm, respectively. The spacing between plants was maintained at 10cm by thinning at 14 DAS.

The observations were recorded for Tap Root Length (RL, Root Volume (RV), Root Mass (RM), Relative Water Content (RWC), Leaf Membrane Stability Index (LMSI), Excised Leaf Water Loss (ELWL), Chlorophyll Content (CC), Catalase Activity (CA), Peroxidase Activity (PERO), Proline Accumulation (PRO), Relative Growth Rate (RGR), Leaf Area Index (LAI), Specific Leaf Weight (SLW), Oil Yield(kg/ha) (OY), Grain Yield/Plot (kg/ha) (GY/P). The data were recorded on five randomly selected plants from each genotype in each replication leaving the border rows to avoid the sampling error. The observations were recorded using standard methodology. Readings from five plants were averaged replication-wise and the mean data subjected for analysis by using statistical package WINDOSTAT version 9.2 (INDOSTAT Service, Hyderabad) for yield and its morpho-physio-quality traits**.** The Correlation and Path analysis were calculated following standard statistical methods (Al-Jibouri *et al*., 1958; Dewey and Lu, 1959) [1, 6].

The extraction and determination of proline developed by Bates *et al*. (1973) [3] in soyabean and sorghum for the quantification of proline was used.

The activity of peroxidase was determined by the method of Palmiano and Juliano (1973) [8] in rice.

Relative water content was calculated by placing the observed values in the following formula (Barr and Weatherley, 1962) [2] in *Ricinus communis*

$$RWC = \frac{\text{Fresh mass} - \text{dry mass}}{\text{Turgor mass} - \text{dry mass}} \times 100.$$

The activity of Catalase was determined by the method of Euler and Josephson (1927) [7].

The LMSI was calculated by formula given by Premchandra *et al*. (1990), as modified by Sairam (1994) in wheat.

$$LMSI = (1- C_1/C_2) \times 100$$

Results and Discussion

On perusal of Table 1, 2, 3 & 4; the genotypic correlation coefficient under both the conditions i.e. no irrigation and two irrigations showed higher values than phenotypic correlation coefficient which reflected that traits are more or less influenced by environmental situation.

In table 3 & 4 both condition of phenotypic correlation revealed that grain yield per plant showed significant and positive correlation with RWC, LMSI, CC, CA, PERO, PRO, RGR, LAI, SLW, OY except ELWL. Root parameters like RV and RL; LMSI & RWC are significant positively correlated with each other indicated that under moisture stress condition if root length increases also results in increasing volume of root allows plants to withdraw water in the lower part of the soil whereas, ELWL showed negative and significant correlation with all other parameters except all root parameters under no irrigation condition but in normal irrigation only with RL & RV. Rest of other physiological traits like CC, CA, PERO, PRO, RGR, LAI, SLW and OY also had positive significant correlation with other characters under both conditions, except RL & RV in no irrigation and in normal condition included all root parameters.

On perusal of table 5 & 6 genotypic path coefficient under no irrigation condition revealed that CA and OY had positive direct effect on GYP via SLW and OY; CA and PERO respectively indicated that under stress condition the activity of catalase activity enhances and affects yield whereas SLW positive correlation and negative direct effect on GYP via low to moderate indirect effects of LMSI, ELWL, PERO, RGR; under two irrigation, RL, RV, RWC, ELWL, CC, PRO, SLW, OY showed positive direct effect on grain yield per plot as CC under normal condition enhances the photosynthetic rate of plant which ultimately contributes towards yield but CA, PERO, RGR, LAI had positive correlation with GYP and negative direct effect via negative indirect effect of ELWL, CA, PERO, RGR, LAI.

Phenotypic path coefficient under both condition showed in table 7 & 8 revealed that all the physiological parameters showed the low direct effect except oil yield showed high direct effect on grain yield per plot. RWC showed positive significant correlation with GYP but negative direct effect via RL, ELWL, PERO, LAI and SLW under no irrigation whereas, in two irrigation condition showed negative direct effect via RM, LMSI,LAI and SLW indicated that under water stress root length extended to maximum length. ELWL under no irrigation showed positive direct effect and negative significant effect on GYP but in two irrigation it was observed that ELWL showed negative correlation and direct effect on GYP. This suggested that under normal condition there is no crisis of water potential inside the membrane of leaf of the plant which can directly affect the yield. RM had positive significant correlation with yield but negative direct effect on GYP reflected that water has the direct relationship with water as one of the important part during photosynthesis which directed towards the source and sink of the plant but not directly affects the productivity of plant.

Table 1: Genotypic Correlation coefficient for characters in Indian mustard genotypes under no irrigation condition

No	Character	RL	RV	RM	RWC	LMSI	ELWL	CC	CA	PERO	PRO	RGR	LAI	SLW	OY	GYP^{-1}
1	Tap Root Length(RL)	1.000	0.735	0.065	0.130	0.252	-0.295	0.277	0.144	0.225	0.224	0.153	0.126	0.167	0.321	0.339
2	Root Volume(RV)		1.000	0.061	0.279	0.375	-0.379	0.328	0.317	0.358	0.353	0.287	0.301	0.314	0.490	0.515
3	Root Mass(RM)			1.000	0.428	0.537	-0.602	0.518	0.450	0.566	0.533	0.532	0.441	0.458	0.590	0.607
4	Relative Water Content(RWC)				1.000	0.922	-0.926	0.898	0.981	0.952	0.918	0.981	0.909	0.995	0.960	0.825
5	Leaf Membrane Stability Index(LMSI)					1.000	-0.946	0.869	0.964	0.986	0.995	0.996	0.927	0.932	0.972	0.561
6	Excised Leaf Water Loss(ELWL)						1.000	-0.946	-0.934	-0.966	-0.946	-0.953	-0.930	-0.945	-0.943	-0.824
7	Chlorophyll Content(CC)							1.000	0.872	0.892	0.883	0.867	0.913	0.920	0.892	0.971
8	Catalase Activity(CA)								1.000	0.978	0.968	0.713	0.984	0.979	0.981	0.757
9	Peroxidase Activity(PERO)									1.000	0.979	0.860	0.946	0.962	0.981	0.666
10	Proline Accumulation(PRO)										1.000	0.710	0.935	0.924	0.980	0.871

11	Relative Growth Rate(RGR)											1.000	0.980	0.983	0.941	0.921
12	Leaf Area Index(LAI)												1.000	0.995	0.993	0.857
13	Specific Leaf Weight(SLW)													1.000	0.954	0.621
14	Oil Yield(kg/ha)(OY)														1.000	0.995
15	Grain Yield/Plot (kg/ha)(GYP^{-1})															1.000

Table 2: Genotypic Correlation coefficient for characters in Indian mustard genotypes under two irrigation condition

No	Character	RL	RV	RM	RWC	LMSI	ELWL	CC	CA	PERO	PRO	RGR	LAI	SLW	OY	GYP^{-1}
1	Tap Root Length(RL)	1.000	0.598	0.352	0.298	0.250	-0.432	0.438	0.363	0.341	0.379	0.299	0.299	0.362	0.562	0.589
2	Root Volume(RV)		1.000	0.288	0.222	0.242	-0.365	0.316	0.268	0.256	0.257	0.240	0.247	0.242	0.340	0.405
3	Root Mass(RM)			1.000	0.255	0.192	-0.364	0.368	0.333	0.299	0.343	0.265	0.249	0.362	0.507	0.497
4	Relative Water Content(RWC)				1.000	0.976	-0.959	0.983	0.986	0.959	0.988	0.915	0.918	0.959	0.948	0.910
5	Leaf Membrane Stability Index(LMSI)					1.000	-0.954	0.954	0.958	0.974	0.964	0.991	0.873	0.955	0.710	0.983
6	Excised Leaf Water Loss(ELWL)						1.000	-0.906	-0.987	-0.990	-0.977	-0.908	-0.978	-0.912	-0.865	-0.951
7	Chlorophyll Content(CC)							1.000	0.811	0.974	0.810	0.914	.921	0.903	0.658	0.919
8	Catalase Activity(CA)								1.000	0.965	0.902	0.808	0.714	0.975	0.499	0.968
9	Peroxidase Activity(PERO)									1.000	0.966	0.991	0.963	0.989	0.654	0.929
10	Proline Accumulation(PRO)										1.000	0.913	0.806	0.980	0.599	0.964
11	Relative Growth Rate(RGR)											1.000	0.668	0.985	0.623	0.985
12	Leaf Area Index(LAI)												1.000	0.983	0.867	0.940
13	Specific Leaf Weight(SLW)													1.000	0.965	0.980
14	Oil Yield(kg/ha)(OY)														1.000	0.995
15	Grain Yield/Plot (kg/ha)(GYP^{-1})															1.000

Table 3: Phenotypic Correlation coefficient for characters in Indian mustard genotypes under no irrigation condition

No	Character	RL	RV	RM	RWC	LMSI	ELWL	CC	CA	PERO	PRO	RGR	LAI	SLW	OY	GYP^{-1}
1	Tap Root Length(RL)	1.000	0.727**	0.066	0.131	0.251	-0.289	0.260	0.142	0.221	0.223	0.132	0.118	0.167	0.195	0.210
2	Root Volume(RV)		1.000	0.062	0.275	0.374	-0.372	0.308	0.315	0.352	0.349	0.265	0.283	0.311	0.296	0.322
3	Root Mass(RM)			1.000	0.419	0.534	-0.596**	0.486*	0.445*	0.559**	0.521*	0.501*	0.412	0.446*	0.353	0.374
4	Relative Water Content(RWC)				1.000	0.911**	-0.901**	0.849**	0.966**	0.937**	0.899**	0.920**	0.930**	0.979**	0.741**	0.737**
5	Leaf Membrane Stability Index(LMSI)					1.000	-0.936**	0.816**	0.959**	0.978**	0.978**	0.935**	0.859**	0.920**	0.748**	0.761**
6	Excised Leaf Water Loss(ELWL)						1.000	-0.885**	-0.922**	-0.951**	-0.916**	-0.890**	-0.854**	-0.922**	-0.714**	-0.721**
7	Chlorophyll Content(CC)							1.000	0.819**	0.838**	0.813**	0.791**	0.797**	0.855**	0.659**	0.664**
8	Catalase Activity(CA)								1.000	0.970**	0.952**	0.944**	0.916**	0.969**	0.755**	0.759**
9	Peroxidase Activity(PERO)									1.000	0.961**	0.935**	0.881**	0.947**	0.751**	0.758**
10	Proline Accumulation(PRO)										1.000	0.909**	0.856**	0.901**	0.762**	0.775**
11	Relative Growth Rate(RGR)											1.000	0.885**	0.910**	0.686**	0.693**
12	Leaf Area Index(LAI)												1.000	0.926**	0.705**	0.698**
13	Specific Leaf Weight(SLW)													1.000	0.749**	0.746**
14	Oil Yield(kg/ha)(OY)														1.000	0.995**
15	Grain Yield/Plot (kg/ha)(GYP^{-1})															1.000

Table 4: Phenotypic Correlation coefficient for characters in Indian mustard genotypes under two irrigation condition

No	Character	RL	RV	RM	RWC	LMSI	ELWL	CC	CA	PERO	PRO	RGR	LAI	SLW	OY	GYP^{-1}
1	Tap Root Length(RL)	1.000	0.585**	0.341	0.286	0.214	-0.404	0.400	0.340	0.318	0.365	0.265	0.271	0.317	0.371	0.403
2	Root Volume(RV)		1.000	0.286	0.219	0.226	-0.349	0.303	0.262	0.247	0.252	0.213	0.225	0.224	0.222	0.271
3	Root Mass(RM)			1.000	0.254	0.180	-0.351	0.346	0.329	0.292	0.341	0.244	0.230	0.346	0.303	0.311
4	Relative Water Content(RWC)				1.000	0.925**	-0.909**	0.917**	0.979**	0.930**	0.978**	0.946**	0.913**	0.922**	0.652**	0.654**
5	Leaf Membrane Stability Index(LMSI)					1.000	-0.868**	0.863**	0.899**	0.908**	0.906**	0.887**	0.863**	0.867**	0.636**	0.641**
6	Excised Leaf Water Loss(ELWL)						1.000	-0.903**	-0.925**	-0.934**	-0.933**	-0.866**	-0.892**	-0.934**	-0.694**	-0.713**
7	Chlorophyll Content(CC)							1.000	0.933**	0.887**	0.941**	0.879**	0.875**	0.886**	0.646**	0.659**
8	Catalase Activity(CA)								1.000	0.927**	0.982**	0.941**	0.923**	0.935**	0.671**	0.680**
9	Peroxidase Activity(PERO)									1.000	0.932**	0.872**	0.872**	0.948**	0.734**	0.742**
10	Proline Accumulation(PRO)										1.000	0.926**	0.916**	0.930**	0.676**	0.683**
11	Relative Growth Rate(RGR)											1.000	0.831**	0.904**	0.561**	0.569**
12	Leaf Area Index(LAI)												1.000	0.858**	0.584**	0.590**
13	Specific Leaf Weight(SLW)													1.000	0.704**	0.711**
14	Oil Yield(kg/ha)(OY)														1.000	0.994**
15	Grain Yield/Plot (kg/ha)(GYP^{-1})															1.000

Table 5: Genotypic Path coefficient analysis of characters on grain yield in Indian mustard genotypes under no irrigation condition

No.	Character	RL	RV	RM	RWC	LMSI	ELWL	CC	CA	PERO	PRO	RGR	LAI	SLW	OY
1	Tap Root Length(RL)	0.0097	0.0072	0.0006	0.0013	0.0025	-0.0029	0.0027	0.0014	0.0022	0.0022	0.0015	0.0012	0.0016	0.0031
2	Root Volume(RV)	0.0227	0.031	0.0019	0.0076	0.0116	-0.0117	0.0101	0.0098	0.0111	0.0109	0.0089	0.0093	0.0097	0.0152
3	Root Mass(RM)	0.0033	0.0031	0.0502	0.0215	0.0269	-0.0302	0.026	0.0226	0.0284	0.0268	0.0267	0.0221	0.023	0.0296
4	Relative Water Content(RWC)	-0.022	-0.047	-0.0723	-0.1688	-0.1556	0.1864	-0.1516	-0.1857	-0.1908	-0.155	-0.1856	-0.1903	-0.191	-0.1959
5	Leaf Membrane Stability Index(LMSI)	-0.0074	-0.011	-0.0158	-0.0371	-0.0294	0.0278	-0.0256	-0.0284	-0.029	-0.0293	-0.0294	-0.0273	-0.0274	-0.0345
6	Excised Leaf Water Loss(ELWL)	-0.0649	-0.0834	-0.1324	-0.2138	-0.2081	0.2200	-0.2081	-0.2054	-0.2826	-0.208	-0.2097	-0.3046	-0.2079	-0.2515
7	Chlorophyll Content(CC)	0.0476	0.0567	0.0897	0.0953	0.1503	-0.1436	0.1730	0.1207	0.1043	0.1527	0.15	0.158	0.1614	0.1889
8	Catalase Activity(CA)	0.0661	0.1448	0.206	0.429	0.4412	-0.4272	0.3984	0.4576	0.4076	0.2732	0.3635	0.4505	0.2481	0.5401
9	Peroxidase Activity(PERO)	0.059	0.0937	0.1481	0.1987	0.258	-0.3527	0.1334	0.1171	0.2616	0.256	0.2616	0.2476	0.2516	0.3089

10	Proline Accumulation(PRO)	-0.0142	-0.0223	-0.0337	-0.0681	-0.0628	0.0597	-0.0557	-0.0611	-0.1119	-0.0631	-0.0838	-0.059	-0.0583	-0.0745
11	Relative Growth Rate(RGR)	-0.0182	-0.0341	-0.0633	-0.1367	-0.1486	0.2637	-0.1032	-0.1906	-0.1991	-0.1311	-0.1191	-0.1367	-0.1971	-0.1478
12	Leaf Area Index(LAI)	0.0041	0.0099	0.0145	0.0231	0.0304	-0.0305	0.0299	0.0323	0.031	0.0307	0.0321	0.0328	0.0326	0.0391
13	Specific Leaf Weight(SLW)	-0.0563	-0.1058	-0.1544	-0.3354	-0.3139	0.4184	-0.31	-0.3512	-0.4043	-0.3114	-0.3912	-0.3954	-0.437	-0.389
14	Oil Yield(kg/ha)(OY)	0.3095	0.4722	0.5679	1.0084	0.5585	-1.0012	1.0517	1.0179	1.0375	1.0164	1.0955	1.0488	1.0117	0.9633
15	Grain Yield/Plot (kg/ha)(GYP^{-1})	0.3390	0.5150	0.6070	0.8250	0.5610	-0.8240	0.9710	0.7570	0.6660	0.8710	0.9210	0.8570	0.6210	0.9950

Residual effect = 0.0511

Table 6: Genotypic Path coefficient analysis of characters on grain yield in Indian mustard genotypes under two irrigation condition

No.	Character	RL	RV	RM	RWC	LMSI	ELWL	CC	CA	PERO	PRO	RGR	LAI	SLW	OY
1	Tap Root Length(RL)	-0.304	-0.1818	-0.1071	-0.0905	-0.0761	0.1315	-0.1333	-0.1103	-0.1037	-0.1153	-0.091	-0.0908	-0.1102	-0.1708
2	Root Volume(RV)	0.242	0.4048	0.1166	0.09	0.0979	-0.1477	0.1279	0.1085	0.1036	0.1042	0.097	0.1001	0.0981	0.1377
3	Root Mass(RM)	-0.0962	-0.0787	-0.2732	-0.0696	-0.0526	0.0996	-0.1006	-0.0909	-0.0818	-0.0936	-0.0725	-0.0681	-0.0989	-0.1387
4	Relative Water Content(RWC)	0.1094	0.0817	0.0936	0.3675	0.3585	-0.3525	0.3112	0.3622	0.3524	0.3631	0.3732	0.3706	0.3525	0.3851
5	Leaf Membrane Stability Index(LMSI)	-0.0384	-0.0371	-0.0295	-0.1497	-0.1534	0.1464	-0.1464	-0.147	-0.1494	-0.1479	-0.152	-0.1539	-0.1465	-0.155
6	Excised Leaf Water Loss(ELWL)	-0.4156	-0.3508	-0.3503	-0.9219	-0.9169	0.9612	-0.9667	-0.9484	-0.9608	-0.9393	-0.9689	-0.9404	-0.9725	-1.1199
7	Chlorophyll Content(CC)	0.4984	0.3592	0.4186	1.0173	1.0848	-1.0432	1.1366	1.1499	1.1074	1.1481	1.1524	1.1603	1.1405	1.3163
8	Catalase Activity(CA)	-1.0878	-0.8035	-0.9969	-2.9545	-2.8716	2.9579	-3.0318	-2.9977	-2.8916	-3.0033	-3.0231	-3.0409	-2.9216	-3.2933
9	Peroxidase Activity(PERO)	-0.3913	-0.2938	-0.3434	-1.1001	-1.1171	1.1464	-1.1179	-1.1067	-1.1473	-1.1082	-1.1376	-1.1053	-1.1471	-1.324
10	Proline Accumulation(PRO)	1.0712	0.7269	0.9675	2.791	2.7226	-2.7605	2.7035	2.7299	2.528	2.8246	2.8605	2.842	2.7675	3.1044
11	Relative Growth Rate(RGR)	-0.2459	-0.1967	-0.218	-0.8337	-0.8135	0.8277	-0.8324	-0.828	-0.8141	-0.8315	-0.8211	-0.877	-0.809	-0.9225
12	Leaf Area Index(LAI)	-0.1554	-0.1288	-0.1297	-0.525	-0.5222	0.5094	-0.5315	-0.5281	-0.5016	-0.5238	-0.5561	-0.5206	-0.5119	-0.5553
13	Specific Leaf Weight(SLW)	0.8594	0.5746	0.8584	2.2754	2.2649	-2.4	2.38	2.3118	2.3715	2.2236	2.2373	2.2321	2.2121	2.7636
14	Oil Yield(kg/ha)(OY)	0.5432	0.329	0.4904	1.0138	0.9777	-1.0272	1.1204	1.0628	1.1164	1.0633	1.0869	1.0319	1.127	0.9674
15	Grain Yield/Plot (kg/ha)(GYP^{-1})	0.5890	0.4050	0.4970	0.9100	0.9830	-0.9510	0.9190	0.9680	0.9290	0.9640	0.9850	0.9400	0.9800	0.9950

Residual effect = 0.1430

Table 7: Phenotypic Path coefficient analysis of characters on grain in Indian mustard genotypes under no irrigation condition

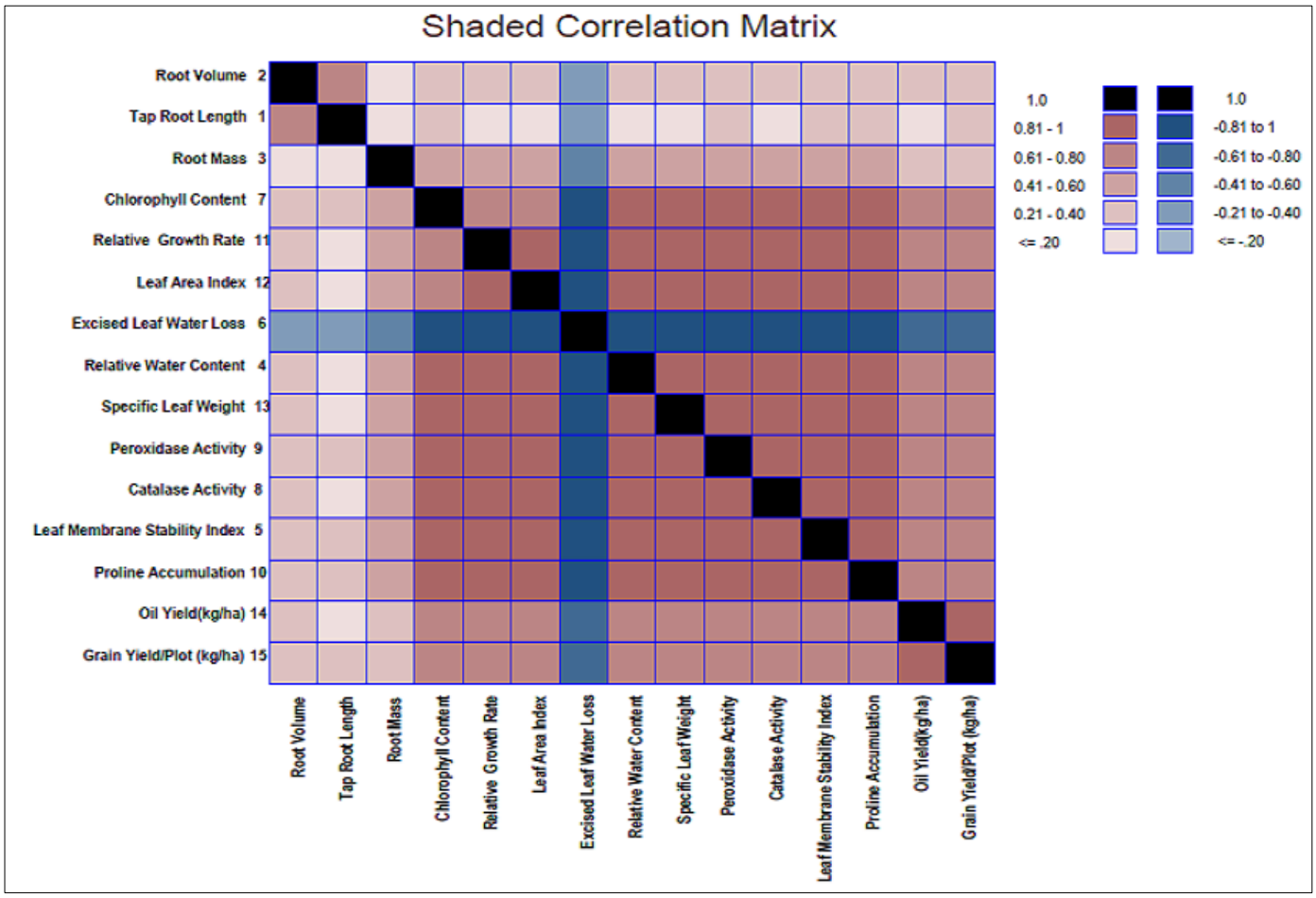
No.	Character	RL	RV	RM	RWC	LMSI	ELWL	CC	CA	PERO	PRO	RGR	LAI	SLW	OY
1	Tap Root Length(RL)	-0.0128	-0.0093	-0.0008	-0.0017	-0.0032	0.0037	-0.0033	-0.0018	-0.0028	-0.0029	-0.0017	-0.0015	-0.0021	-0.0025
2	Root Volume(RV)	0.029	0.0399	0.0025	0.0109	0.0149	-0.0148	0.0123	0.0126	0.014	0.0139	0.0106	0.0113	0.0124	0.0118
3	Root Mass(RM)	0.0022	0.0021	0.0339	0.0142	0.0181	-0.0202	0.0165	0.0151	0.019	0.0177	0.017	0.014	0.0151	0.012
4	Relative Water Content(RWC)	-0.0038	-0.0081	-0.0123	-0.0293	-0.0267	0.0264	-0.0249	-0.0283	-0.0275	-0.0264	-0.027	-0.0273	-0.0287	-0.0217
5	Leaf Membrane Stability Index(LMSI)	0.0192	0.0286	0.0408	0.0696	0.0764	-0.0715	0.0624	0.0733	0.0747	0.0747	0.0714	0.0656	0.0703	0.0571
6	Excised Leaf Water Loss(ELWL)	-0.0079	-0.0102	-0.0163	-0.0247	-0.0257	0.0274	-0.0243	-0.0253	-0.0261	-0.0251	-0.0244	-0.0234	-0.0253	-0.0196
7	Chlorophyll Content(CC)	0.0076	0.0089	0.0141	0.0246	0.0237	-0.0257	0.029	0.0238	0.0243	0.0236	0.0229	0.0231	0.0248	0.0191
8	Catalase Activity(CA)	0.0149	0.033	0.0467	0.1014	0.1006	-0.0967	0.0859	0.1049	0.1017	0.0998	0.099	0.0961	0.1016	0.0791
9	Peroxidase Activity(PERO)	-0.0224	-0.0356	-0.0566	-0.0948	-0.0989	0.0962	-0.0847	-0.0981	-0.1011	-0.0971	-0.0945	-0.0891	-0.0957	-0.0759
10	Proline Accumulation(PRO)	0.0054	0.0084	0.0126	0.0217	0.0236	-0.0221	0.0196	0.023	0.0232	0.0241	0.0219	0.0206	0.0217	0.0184
11	Relative Growth Rate(RGR)	0.0011	0.0022	0.0043	0.0078	0.0079	-0.0076	0.0067	0.008	0.0079	0.0077	0.0085	0.0075	0.0077	0.0058
12	Leaf Area Index(LAI)	-0.0055	-0.0131	-0.0191	-0.0431	-0.0398	0.0396	-0.037	-0.0425	-0.0409	-0.0397	-0.041	-0.0464	-0.043	-0.0327
13	Specific Leaf Weight(SLW)	-0.0074	-0.0138	-0.0199	-0.0436	-0.041	0.0410	-0.0381	-0.0431	-0.0422	-0.0401	-0.0405	-0.0412	-0.0445	-0.0333
14	Oil Yield(kg/ha)(OY)	0.1906	0.2893	0.345	0.7247	0.7313	-0.6976	0.6439	0.7375	0.7341	0.7453	0.6708	0.689	0.7323	0.9777
15	Grain Yield/Plot (kg/ha)(GYP^{-1})	0.2102	0.3223	0.3749	0.7377	0.7612	-0.7219	0.6640	0.7591	0.7583	0.7755	0.6930	0.6983	0.7466	0.9953

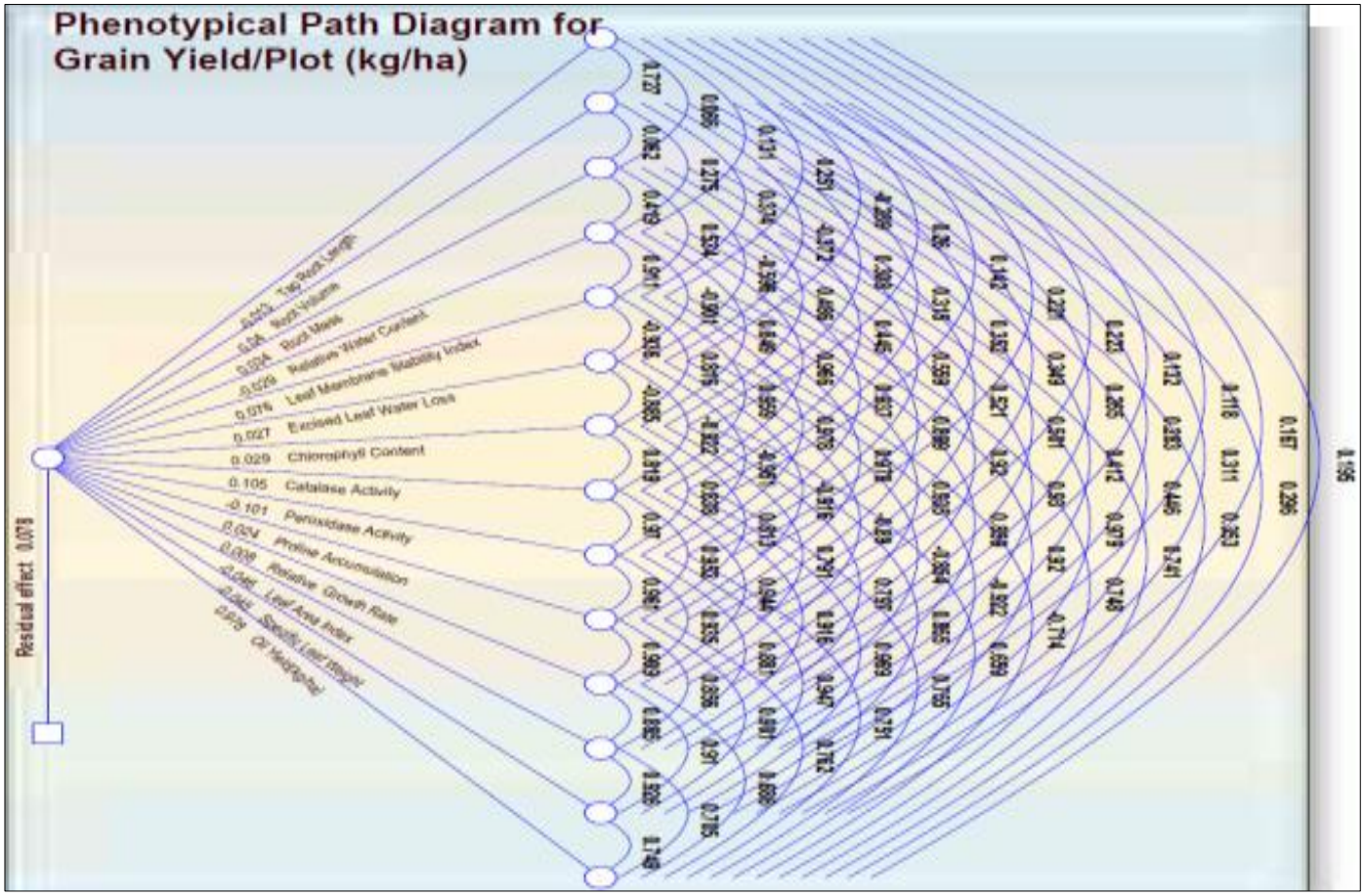
Residual effect = 0.0785

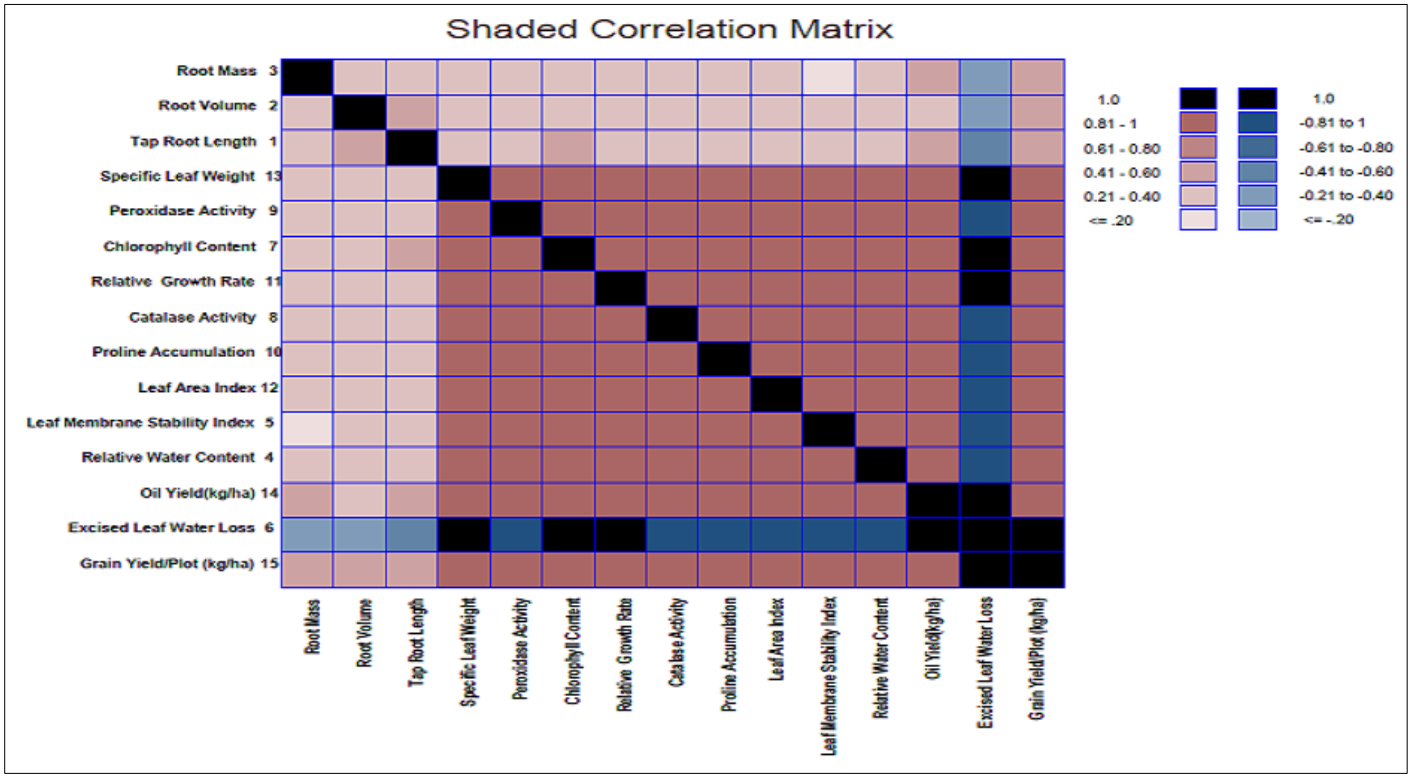
Table 8: Phenotypic Path coefficient analysis of characters on grain in Indian mustard genotypes under two irrigation condition

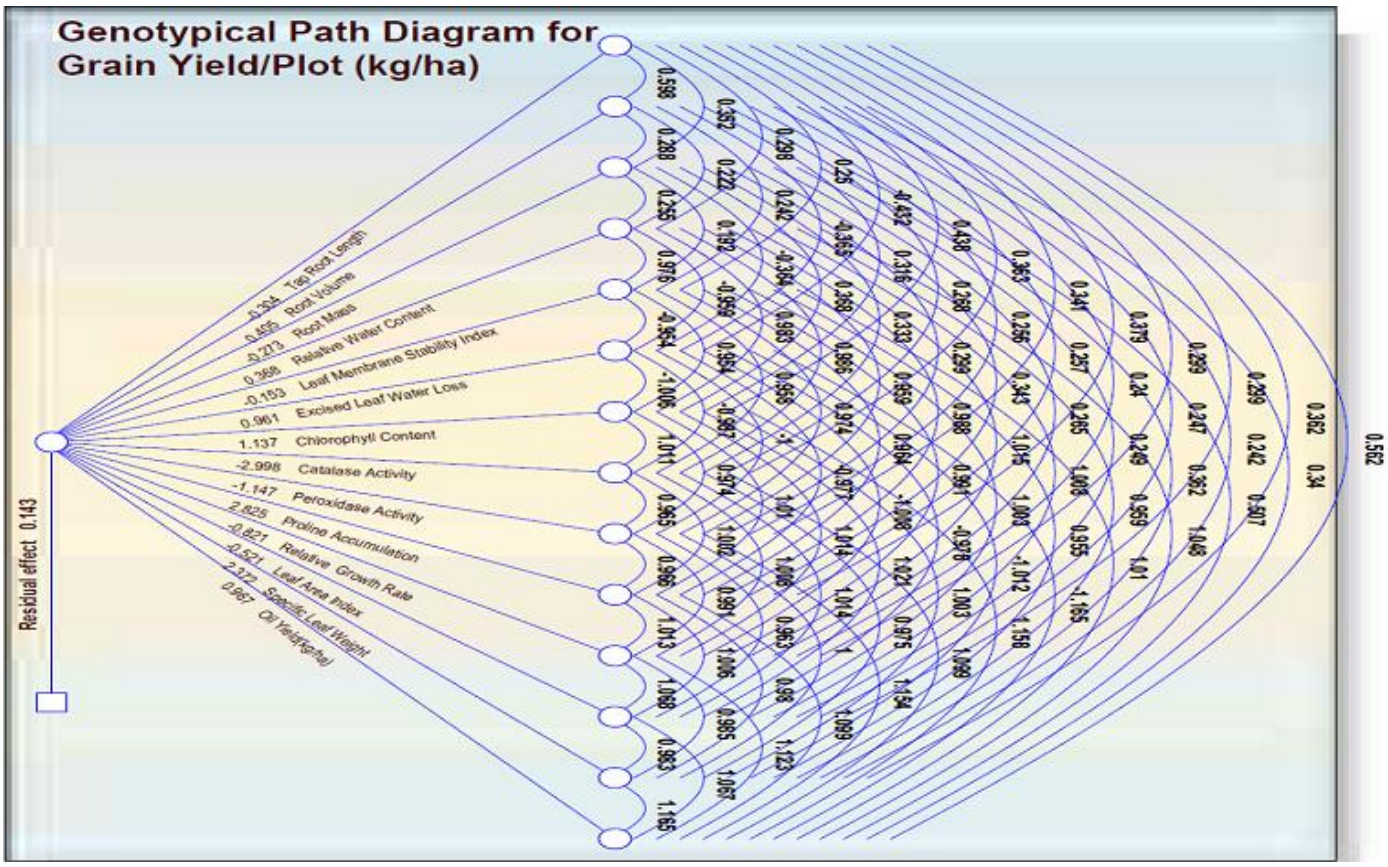
No.	Character	RL	RV	RM	RWC	LMSI	ELWL	CC	CA	PERO	PRO	RGR	LAI	SLW	OY
1	Tap Root Length(RL)	0.0027	0.0016	0.0009	0.0008	0.0006	-0.0011	0.0011	0.0009	0.0009	0.0010	0.0007	0.0007	0.0009	0.0010
2	Root Volume(RV)	0.0214	0.0366	0.0105	0.0080	0.0083	-0.0128	0.0111	0.0096	0.0091	0.0092	0.0078	0.0082	0.0082	0.0081
3	Root Mass(RM)	-0.0067	-0.0056	-0.0197	-0.0050	-0.0035	0.0069	-0.0068	-0.0065	-0.0057	-0.0067	-0.0048	-0.0045	-0.0068	-0.0060
4	Relative Water Content(RWC)	-0.0524	-0.0401	-0.0465	-0.1831	-0.1693	0.1664	-0.1679	-0.1793	-0.1703	-0.1790	-0.1733	-0.1671	-0.1688	-0.1194
5	Leaf Membrane Stability Index(LMSI)	-0.0002	-0.0002	-0.0001	-0.0007	-0.0008	0.0007	-0.0007	-0.0007	-0.0007	-0.0007	-0.0007	-0.0007	-0.0007	-0.0005
6	Excised Leaf Water Loss(ELWL)	0.0346	0.0299	0.0301	0.0778	0.0743	-0.0856	0.0774	0.0792	0.0800	0.0799	0.0742	0.0764	0.0800	0.0594
7	Chlorophyll Content(CC)	0.0028	0.0021	0.0024	0.0065	0.0061	-0.0064	0.0070	0.0066	0.0063	0.0066	0.0062	0.0062	0.0062	0.0046
8	Catalase Activity(CA)	0.0462	0.0356	0.0446	0.1330	0.1222	-0.1257	0.1267	0.1358	0.1259	0.1334	0.1278	0.1254	0.1270	0.0912
9	Peroxidase Activity(PERO)	0.0118	0.0092	0.0108	0.0345	0.0336	-0.0346	0.0330	0.0343	0.0370	0.0345	0.0323	0.0323	0.0351	0.0272
10	Proline Accumulation(PRO)	0.0066	0.0045	0.0061	0.0176	0.0163	-0.0168	0.0169	0.0177	0.0168	0.0180	0.0166	0.0165	0.0167	0.0121
11	Relative Growth Rate(RGR)	0.0030	0.0024	0.0027	0.0104	0.0097	-0.0097	0.0098	0.0105	0.0097	0.0103	0.0112	0.0093	0.0101	0.0063
12	Leaf Area Index(LAI)	-0.0111	-0.0092	-0.0094	-0.0373	-0.0352	0.0365	-0.0357	-0.0377	-0.0356	-0.0374	-0.0339	-0.0409	-0.0350	-0.0239
13	Specific Leaf Weight(SLW)	-0.0119	-0.0084	-0.0130	-0.0346	-0.0325	0.0351	-0.0333	-0.0351	-0.0356	-0.0349	-0.0339	-0.0322	-0.0376	-0.0264
14	Oil Yield(kg/ha)(OY)	0.3559	0.2128	0.2912	0.6261	0.6107	-0.6659	0.6200	0.6444	0.7046	0.6484	0.5385	0.5608	0.6753	0.9599
15	Grain Yield/Plot (kg/ha)(GYP^{-1})	0.4027	0.2712	0.3106	0.6540	0.6405	-0.7130	0.6586	0.6797	0.7424	0.6826	0.5687	0.5904	0.7106	0.9936

Residual effect = 0.0908


Shaded Correlation Matrix
Root Volume 2
Tap Root Length 1
Root Mass 3
Chlorophyll Content 7
Relative Growth Rate 11
Leaf Area Index 12
Excised Leaf Water Loss 6
Relative Water Content 4
Specific Leaf Weight 13
Peroxidase Activity 9
Catalase Activity 8
Leaf Membrane Stability Index 5
Proline Accumulation 10
Oil Yield(kg/ha) 14
Grain Yield/Plot (kg/ha) 15
1.0
0.81 - 1
0.61 - 0.80
0.41 - 0.60
0.21 - 0.40
<= .20
1.0
-0.81 to 1
-0.61 to -0.80
-0.41 to -0.60
-0.21 to -0.40
<= -.20
Root Volume
Tap Root Length
Root Mass
Chlorophyll Content
Relative Growth Rate
Leaf Area Index
Excised Leaf Water Loss
Relative Water Content
Specific Leaf Weight
Peroxidase Activity
Catalase Activity
Leaf Membrane Stability Index
Proline Accumulation
Oil Yield(kg/ha)
Grain Yield/Plot (kg/ha)


Phenotypical Path Diagram for
Grain Yield/Plot (kg/ha)
Residual effect 0.078
0.043 Tap Root Length
0.04 Root Weight
0.024 Root Mass
0.029 Relative Water Content
0.076 Leaf Membrane Stability Index
0.027 Excised Leaf Water Loss
0.029 Chlorophyll Content
0.105 Catalase Activity
-0.101 Peroxidase Activity
0.024 Proline Accumulation
0.039 Relative Growth Rate
0.045 Leaf Area Index
0.078 Specific Leaf Weight
0.078 Oil Yield(kg/ha)





Acknowledgement
Authors are thankful to different All India Coordinated Research Project-Rapeseed & Mustard centres namely, DRMR, Bharatpur, Rajasthan, CCSHAU, Hisar, Haryana, BARC, Trombay, Maharashtra, GBPUAT, Pantnagar, Uttarakhand, CSAUAT, Kanpur, U.P, IARI, New Delhi and ARS, RAU, Sri Ganganagar, Rajasthan for providing genotypes of rapeseed and mustard.

References

1. Al-jibouri A, Miller PA, Robinson HF. Genotype and environmental variation and correlation in an upland cotton crops of the interspecific origin. Agronomy Journal. 1958; 50:626-636.
2. Barr HD, Weatherley PE. A re-examination of therelative turgidity technique for estimating water deficit in leaves. Australian J Biological Science. 1962; 15:413-428.

3. Bates L, Waldren RP, Teare ID. Rapid determination of free proline for water-stress studies. Plant and Soil. 1973; 39:205-207.
4. Biradar KS, Sailmath PM, Ravi kumar RL. Genetic variability for seedling vigour, yield and yield components in local germplasm collections of greengram (*Vigna radiata* (L.) Wilczek). Karnataka J Agric. Sci. 2007; 20(3):608-609.
5. Deikman J, M Petracek, JE Heard. Drought tolerance through biotechnology: improving translation from the laboratory to farmers' fields. Curr. Opin. Bio technol. 2012; 23:243-250.
6. Dewey DR, Lu KH. Correlation and path coefficient analysis of components of crested wheat grass for seed production. Agron. J. 1959; 51:515-518.
7. Euler H, Josephson K. Photometric determination of catalase activity. Annual Chemistry. 1927; 46:21-28.
8. Palmiano EP, Juliano BC. Changes in the Activity of Some Hydrolases, Peroxidase and Catalase in Rice Seed During Germination. Plant Physiol. 1973; 52:274-277.
9. Premchandra GS, Saneoka H, Ogata S. Cell membrane stability, an indicator of drought tolerance as affected by applied nitrogen in soybean. J Agri. Sci. 1990; 115:63-66.
10. Rashidi Sh. Study of tolerance to drought stress morpho-physiologic traits in canola genotypes. Dissertations of Agriculture, Science and Research Branch of Islamic Azad University of Ahvaz, 2013, 225.
11. Sairam RK. Effect of moisture stress on physiological activities of two contrasting wheat genotypes. Indian. J Exp. Biol. 1994; 32:594-597.
12. Shao H, Z Liang, M Shao. Osmotic regulation of 10 wheat (*Triticum aestivum* L.) genotypes at soil water deficits. Colloids and Surfaces B: Bio Interfaces. 2006; 47:132-139.
13. Touchette BW, LR Iannacone, GE Turner, AR Frank. Drought tolerance versus drought avoidance: A comparison of plant-water relations in herbaceous wetland plants subjected to water withdrawal and repletion. Wetlands. 2007; 27:656-667.