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Morpho-physiological Characterization of Maize (*Zea mays* L.) Genotypes against Drought

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ABSTRACT: Maize is an imperative grain crop used as a staple food in several countries around the world. Water deficiency is a serious problem limiting its growing area, production and productivity. Maize is moderately sensitive to drought distressing all aspects of growth and development starting from germination to maturity. Drought stress, particularly at flowering stage, has been recognized as the most crucial factor limiting production and productivity in India. Enlightening drought tolerance in maize has become one of the top urgencies in maize breeding programmes. In present investigation, 80 genotypes of maize including 66 hybrids, 12 parents and 2 checks (drought tolerant HKI1105 and drought susceptible HKI1128) were grown under irrigated and partial irrigated condition in a randomized block design (RBD) with two replications. The observations were recorded for turgid weight (TW), Relative water content (RWC), Saturation water deficit (SWD), Membrane stability index (MSI) and grain yield. Under irrigated condition grain yield per plant ranged from 42.11 to 113.73g with a mean value of 71.06. While under partial irrigated condition grain yield per plant ranged between 40.33 to 105.17g with an average worth of 68.08g.Under both conditions, correlation studies of grain yield per plant showed significant and positive correlation with relative water contents (RWC) while negative correlation was observed with turgid weight (TW), saturation water deficit (SWD) and membrane stability index (MSI). Among all 80-maize genotypes, ten maize genotypes *viz*., IL11 × IL12, IL1 × IL7, IL7 × IL8, IL3 × IL10, IL6 × IL7, IL7 × IL12, IL2 × IL7, IL6 × IL12, IL4 × IL6 and IL3 × IL11 displayed increased values in respect to all morpho-physiological parameters *i.e.*, turgid weight (TW), relative water content (RWC), saturation water deficit (SWD) and membrane stability index (MSI) including grain yield under drought condition. Moreover, Correlation analysis along with other indices was proved to be a useful approach for rapid and cost-efficient screening of large numbers of genotypes against drought stress condition.

Keywords: Maize, drought, RWC, SWD, MSI, TW and grain yield.

INTRODUCTION

Zea mays L. is a staple food possessing the highest yield potential among the cereals and it is known as queen of cereals. It plays an important role in livelihood of millions of poor farmers. Since it is a short-day plant with C_4 type of photosynthesis; the crop has very efficient utilization of solar radiation. However, it is very sensitive to excess or deficit soil moisture. Most of the world maize area is grown under rainfed conditions and it is more susceptible to drought than other cereals (Hall *et al*., 1981). At a cellular level, drought signals promote stomatal closure to save water, stimulate the production of stress-protectant metabolites, upregulate the antioxidant system, and deploy peroxidase enzymes to prevent acute cellular damage and loss of membrane integrity (Gupta *et al.*, 2020; Liu *et al.* 2021; Choudhary *et al*., 2021a; Choudhary *et al*., 2021b; Choudhary *et al*., 2021c; Mishra *et al.*, 2021 a; Mishra *et al.*, 2021 b; Mishra *et al.*, 2021 c; Sharma *et al.*, 2021). Crop yield is vulnerable when drought conditions occur during the reproductive phase of plant growth. Although grain yield (GY) when plants subjected to water stress is the final target trait employed to assess the degree of drought tolerance, correlated traits, such as ASI and kernel number per row (KNR), are considered to have a higher heritability and thus may be more suitable as target traits for improving maize drought resistance (Monneveux *et al*., 2008; Jia *et al*., 2020; Liu *et al*., 2021). About 67% of the total maize production in the developing countries emanates from low and lower middle-incomenations. Moisture stress is one of the major constraints in maize productivity and it is very common in the areas, where, maize is predominantly grown under rainfed condition. Drought at any stage of crop improvement affects production, but maximum damage is inflicted when it occurs during flowering stage. Effect of drought stress includes delayed silking and female sterility caused by embryo abortion (Moss and Downey, 1971, Aslam *et al*., 2013; Bibhu *et al*., 2020) resulting huge reduction in grain yield. It was estimated that annual yield loss due to drought may be close to 24 million tones and it is equivalent to 17 % of a normal year's production in a developing world.

Due to increased demand of maize, there should be an intensive effort should be made to increase maize production in the changing climatic conditions, particularly related to water stress, salinity, extreme temperature regimes *etc*. Selection for best performing genotypes under stress condition is the primary objective for any crop improvement programme (Thiry *et al*., 2016; Wattoo *et al*., 2018; Makwana *et al*., 2021; Mishra *et al*., 2021d; Mishra *et al*., 2021e; Mishra *et al*., 2021f). Assessment of germplasm line (s) against abiotic stresses like heat and drought under natural field conditions is tough owing to uncertain environmental conditions like rainfall and humidity (Zafar *et al*., 2017; Wattoo *et al*., 2018; Choudhary *et al*., 2021a; Choudhary *et al*., 2021b). The task turns into more challenging when dealing with huge number of germplasm lines owing to necessity of large area, labor, resources and long time period. On the other hand, its rapid evaluation can be done at early growth stages under controlled environmental conditions based on many growth and physiological parameters (Zafar *et al*., 2017; Wattoo *et al*., 2018). An array of morphological, physiological and biological features of higher plants show adaptability in response to water stress. Existence of variability for drought tolerance in different plant species has been reported (Frova *et al*., 1999; Guttieri *et al*., 2004; Wattoo *et al*., 2018). Numerous growth related morpho-physiological traits have been potentially employed for evaluating genotypes of different crops against water stress (Taiz and Zeiger, 2006; Ali *et al*., 2009; Chohan *et al*., 2012; Javed, 2012; Wattoo *et al*., 2018; Rajpoot *et al*., 2020; Choudhary *et al*., 2021a; Choudhary *et al*., 2021b; Mishra *et al*., 2021a; Mishra *et al*., 2021b).

Present study was conducted with the objectives to screen genotype (s) on the basis of various morpho-physiological parameters related to drought tolerance which can perform well under limited water conditions.

MATERIALS AND METHODS

A. Plant material and growth conditions

The seeds of 12 maize inbred lines were acquired from Sam Higgonbottom Agriculture Science and Technology University, Prayagraj, U.P., India. A crossing programme initiated with 12 maize inbred lines following half diallel analysis (Jinks and Hayman, 1954) to raise 66 F_1hybrids. These 66 hybrids along with two checks (drought tolerant HKI1105 and drought susceptible HKI1128) and parents total 80 entries were included in this study (Table 1) and were evaluated at Research Farm, Department of Genetics &Plant Breeding, College of Agriculture, Gwalior, M.P. during Rabi season, 2019-20. The experiment was conducted under irrigated and partial irrigated condition and laid out in a randomized block design (RBD) with two replications. Each genotype was sown in 2 rows of 4 meters with a spacing of 60 cm between rows and 20 cm between plant to plant.

Drought stress was imposed from 10 days before flowering by with-holding irrigation. The irrigation was resumed when soil moisture reaches temporary wilting point. The characters like Turgid weight (TW), Relative water content (RWC), Saturation water deficit (SWD) and Membrane Stability Index (MSI) were calculated for samples collected from a single competitive plant per replication per genotypes and grain yield/ plant (GY/P) was calculated on plot basis(g). Relative water content (RWC) is considered one of the important physiological parameters to assess the water content in plants during stressed and control condition and calculated by the formula: RWC = (FW — DW/ TW— DW) × 100 where, Fresh weight of plant (g), DW = Dry weight of plant (g), TW = Turgid weight of plant (g). Turgid weight (TW) was determined after floating of plants on water overnight at room temperature. Saturation water deficit (SWD) (%) was calculated after subtracting the value of RWC from 100. Membrane stability index (MSI) was estimated taking two sets of 200 mgs of leaf sample in test tube containing 10 ml of double distilled water. One set was heated at 40°C for 30 min in a water bath to record the electrical conductivity (C_1) of the solution by an electrical conductivity meter. Second set was subjected to 100°C on a boiling water bath for 15 min to measure its conductivity (C_2) as explained above. Membrane Stability Index was calculated by formulae MSI = [1 — $\{C_1/C_2\}$] × 100 as proposed by Razzaq *et al*. (2013). Where, C_l = electrical conductivity of water containing the leaf sample in set one and C_2 = electrical conductivity of water containing the leaf sample in set two. The cobs from randomly selected five plants were dried, shelled, cleaned and weight of grains was recorded and expressed as grams and considered as grain yield per plant (g).

RESULT AND DISCUSSION

Drought stress encourages an assortment of morpho-physiological changes in plants in order that plants are capable to broaden tolerance mechanisms. Drought tolerance is the result of abundant morphological, anatomical and physiological parameters which interrelate with continuation of growth and developmental progressions. Relative aptitude for drought tolerance of maize genotypes may be arbitrated by guesstimating numerous morpho-physiological traits for instance fresh weight, dry weight, turgid weight, relative water content, saturation water deficit and membrane stability index. Water saturation deficit, relative water content (RWC) and leaf water loss are the main physiological measures that maneuver plant water relations and used to evaluate drought tolerance in plants (Kachre, 2017;Kachre *et al*., 2019; Mishra *et al*., 2021a).

Table 1: List of maize genotypes along with their parentage and source of collection.

Sr. No.	LINES	Parentage	Source of material
1.	IL-1	CM-13	SHUATS, Allahabad
2.	IL-2	CML-193	SHUATS, Allahabad
3.	IL-3	CML-439	SHUATS, Allahabad
4.	IL-4	NBPGR-36417	SHUATS, Allahabad
5.	IL-5	NBPGR-36417 × NBPGR-33000	SHUATS, Allahabad
6.	IL-6	(103) NBPGR-36548 × (97) NBPGR-36407	SHUATS, Allahabad
7.	IL-7	DMR-N 21 × NBPGR-32809	SHUATS, Allahabad
8.	IL-8	LM- 13 × NBPGR-31899	SHUATS, Allahabad
9.	IL-9	CML-224-1 × NBPGR-32809	SHUATS, Allahabad
10.	IL-10	NBPGR-36550 × NBPGR-36407	SHUATS, Allahabad
11.	IL-11	KL- 153237 × VL- 1016536	SHUATS, Allahabad
12.	IL-12	CML- 161 × VL- 1056	SHUATS, Allahabad

A. Morpho-physiological characterization of genotypes under irrigated and partial irrigated conditions

Among all 80 maize genotypes under irrigated condition grain yield per plant ranged between 42.11g to 113.73 g with a mean value of 71.06g. Ten genotypes *viz*., IL1 × IL7, IL11 × IL12, IL3 × IL10, IL6 × IL7, IL7 × IL8, IL7 × IL12, IL4 × IL6, IL2 × IL7, IL6 × IL12 and IL3 × IL11 showed better response in respect to morpho-physiological traits along with grain yield (Table 2). Turgid weight ranged from 0.16 to 0.26 with an average worth of 0.21. Relative water content varied between 48.82% to 89.44% with a mean value of 72.88. While saturation water deficit arrayed between 10.57 to 51.19 with a mean worth of 27.12. Whereas, membrane stability index fluctuated between 1.78 to 58.91 with a mean value of 25.78.

Table 2: Mean performance of different morpho-physiological parameters of maize genotypes.

		Irrigated condition					Partial irrigated condition				
Sr. No.	Genotype	TW	RWC	SWD	MSI	GY/P(g)	TW	RWC	SWD	MSI	GY/P(g)
1.	**IL1 × IL2**	0.18	73.61	26.39	37.74	66.48	0.18	72.11	27.89	16.84	61.28
2.	**IL1 × IL3**	0.16	73.01	27	21.01	63.25	0.17	71.38	28.63	17.15	57.88
3.	**IL1 × IL4**	0.17	77.34	22.67	46.68	88.26	0.17	76.2	23.8	12.87	84
4.	**IL1 × IL5**	0.18	74.05	25.95	48	65.3	0.18	75.62	24.38	13.24	63.23
5.	**IL1 × IL6**	0.17	66.16	33.84	18.69	42.11	0.16	67.18	32.82	9.43	44.61
6.	**IL1 × IL7**	0.23	75.41	24.59	33.16	113.73	0.24	74.6	25.41	8.84	104.98
7.	**IL1 × IL8**	0.21	62.43	37.58	3.29	53.73	0.21	61.68	38.32	21.77	51.97
8.	**IL1 × IL9**	0.21	68.09	31.92	40.86	70.1	0.21	67.27	32.73	55.71	67.21
9.	**IL1 × IL10**	0.18	75	25	30.01	82.5	0.19	73.47	26.53	43.08	79.03
10.	**IL1 × IL11**	0.18	77.26	22.74	25.38	69.2	0.18	75.09	24.91	47.68	68.01
11.	**IL1 × IL12**	0.19	68.03	31.97	23.02	58.4	0.19	68.97	31.03	10.02	62.32
12.	**IL2 × IL3**	0.16	89.44	10.57	55.28	65.18	0.16	90.17	9.83	41.75	67.94
13.	**IL2 × IL4**	0.19	62.59	37.41	37.43	43.78	0.19	61.7	38.3	37.81	47.66
14.	**IL2 × IL5**	0.2	73.77	26.24	30.77	45.46	0.2	72.8	27.21	56.98	46
15.	**IL2 × IL6**	0.19	68.12	31.88	54.04	87.18	0.19	66.67	33.33	58.25	82.75
16.	**IL2 × IL7**	0.22	69.37	30.63	3.62	99.15	0.21	70.6	29.41	78.56	94.13
17.	**IL2 × IL8**	0.2	69.57	30.43	31.44	84.64	0.2	70	30	41.79	80.24
18.	**IL2 × IL9**	0.2	75.1	24.9	38.29	82.27	0.21	73.05	26.96	34.37	79.93
19.	**IL2 × IL10**	0.19	81.13	18.88	36.96	69.5	0.2	78.92	21.09	31.26	63.43
20.	**IL2 × IL11**	0.22	70.09	29.91	58.59	55.73	0.21	71.39	28.62	37.97	60.71
21.	**IL2 × IL12**	0.21	85.08	14.92	21.81	55.41	0.22	83.67	16.34	10.51	54.47
22.	**IL3 × IL4**	0.16	59.09	40.91	32.54	56.8	0.17	58.21	41.79	44.22	53.62
23.	**IL3 × IL5**	0.23	80.23	19.77	37.37	53.78	0.24	78.02	21.98	63.19	51.74
24.	**IL3 × IL6**	0.22	72.34	27.66	54.27	63.4	0.22	71.48	28.53	49.07	59.89
25.	**IL3 × IL7**	0.24	68.57	31.43	24.54	91.69	0.24	68.18	31.82	14	85.13

26.	**IL3 × IL8**	0.18	68.05	31.96	53.23	71.04	0.18	67.58	32.42	44.83	67.02
27.	**IL3 × IL9**	0.18	70.68	29.32	31.86	74.1	0.17	72.32	27.69	14.78	68.51
28.	**IL3 × IL10**	0.19	65.51	34.5	45.6	106.6	0.19	64.61	35.4	53.75	98.23
29.	**IL3 × IL11**	0.19	70.84	29.17	58.91	93.29	0.19	72.86	27.14	53.24	90.25
30.	**IL3 × IL12**	0.23	71.47	28.53	37.98	51.86	0.23	70.3	29.7	59.8	55.8
31.	**IL4 × IL5**	0.23	78.79	21.21	37.31	63.07	0.23	79.67	20.34	66.54	62.12
32.	**IL4 × IL6**	0.19	65.55	34.46	10.66	99.35	0.19	64.25	35.76	13.41	91.45
33.	**IL4 × IL7**	0.22	71.91	28.09	30.18	46.14	0.22	71.51	28.49	43.62	42.57
34.	**IL4 × IL8**	0.26	66.04	33.97	28.7	61.35	0.26	66.04	33.97	28	62.41
35.	**IL4 × IL9**	0.23	66.67	33.33	13.31	71.24	0.22	67.06	32.95	15.25	65.61
36.	**IL4 × IL10**	0.21	71.83	28.18	39.04	67.02	0.21	71.39	28.62	35.85	64.26
37.	**IL4 × IL11**	0.2	61.59	38.41	29.15	93.29	0.2	60.39	39.61	7.9	85.95
38.	**IL4 × IL12**	0.2	67.09	32.91	23.69	77.94	0.2	67.95	32.06	32.4	70.81
39.	**IL5 × IL6**	0.19	75.68	24.32	17.31	63.76	0.19	74.67	25.33	16.98	60.77
40.	**IL5 × IL7**	0.21	72.03	27.97	36.71	43.15	0.21	72.03	27.97	59.94	40.33
41.	**IL5 × IL8**	0.2	68.75	31.25	18.45	43.82	0.21	68.32	31.68	15.64	40.68
42.	**IL5 × IL9**	0.19	68.92	31.08	17.48	81.83	0.2	67.11	32.89	16.79	75.97
43.	**IL5 × IL10**	0.21	69.86	30.15	14.28	85.73	0.21	69.44	30.56	12.73	80.43
44.	**IL5 × IL11**	0.21	70.27	29.74	4.8	81.54	0.21	70.27	29.74	13.77	79.39
45.	**IL5 × IL12**	0.25	77.08	22.93	13.95	90.44	0.25	77.86	22.14	10.17	86.35
46.	**IL6 × IL7**	0.19	72.53	27.48	1.89	104.84	0.19	70.38	29.63	14.11	95.72
47.	**IL6 × IL8**	0.19	81.42	18.59	32.23	71.46	0.19	81.99	18.01	56.39	65.7
48.	**IL6 × IL9**	0.23	72.99	27.01	33.24	60.07	0.22	73.84	26.16	40.16	56.68
49.	**IL6 × IL10**	0.2	63.55	36.46	19.58	89.49	0.19	65.3	34.71	26.21	88.99
50.	**IL6 × IL11**	0.18	75.35	24.65	7.25	63.33	0.19	73.79	26.21	40.58	64.38
51.	**IL6 × IL12**	0.21	71.35	28.66	11.78	95.47	0.2	73.31	26.7	35.44	92.9
52.	**IL7 × IL8**	0.23	65.93	34.07	2.45	103.47	0.23	65.2	34.8	13.94	100.27
53.	**IL7 × IL9**	0.22	63.36	36.65	9.58	80.24	0.22	62.97	37.04	53.55	75.38
54.	**IL7 × IL10**	0.2	80.14	19.87	16.24	75.41	0.21	78.13	21.87	19.68	69.71
55.	**IL7 × IL11**	0.22	71.57	28.44	29.55	91.67	0.22	70.28	29.73	1.34	84.99
56.	**IL7 × IL12**	0.2	85.15	14.85	8.25	103.21	0.2	84.02	15.99	57.33	95.27
57.	**IL8 × IL9**	0.2	71.12	28.89	23.34	77.21	0.2	70.67	29.33	45.69	72.21
58.	**IL8 × IL10**	0.2	81.09	18.92	20.28	66.32	0.21	77.93	22.08	40.13	60.43
59.	**IL8 × IL11**	0.18	78.52	21.48	28.58	66.1	0.17	80.92	19.08	36.68	65.11
60.	**IL8 × IL12**	0.22	78.43	21.58	18.65	79.58	0.23	76.12	23.89	65.56	76.67
61.	**IL9 × IL10**	0.24	82.42	17.58	15.21	86.4	0.24	81.53	18.48	14.37	82.23
62.	**IL9 × IL11**	0.21	76.82	23.19	6.99	63.77	0.21	77.9	22.11	6.67	60.77
63.	**IL9 × IL12**	0.21	81.98	18.03	1.78	69.14	0.21	81.45	18.56	45.22	68.49
64.	**IL10 × IL11**	0.2	81.54	18.47	19.3	72.39	0.2	78.79	21.22	40.77	70.36
65.	**IL10 × IL12**	0.23	80.94	19.06	10.82	62.33	0.23	79.09	20.92	11.42	64.14
66.	**IL11 × IL12**	0.18	77.38	22.63	14.08	113.21	0.18	76.82	23.19	15.63	105.17
67.	**HKI 1105**	0.22	82.14	17.86	15.74	62.93	0.22	80.13	19.88	28.68	65.04
68.	**HKI 1128**	0.2	79.88	20.12	23.65	71.43	0.2	76.79	23.21	55.76	63.21
69.	**IL1**	0.17	69.19	30.82	19.86	65.63	0.17	69.66	30.34	18.31	60.18
70.	**IL2**	0.22	77.29	22.72	12.68	79.28	0.23	74.39	25.61	12.97	72.31
71.	**IL3**	0.19	84.83	15.17	30.77	43.24	0.19	83.53	16.47	15.49	44.77
72.	**IL4**	0.21	68.24	31.76	9.11	43.34	0.21	66.67	33.33	38.14	40.66
73.	**IL5**	0.23	77.17	22.83	37	45.49	0.23	77.6	22.4	56.24	41.1
74.	**IL6**	0.23	75.44	24.56	11.34	54.8	0.23	74.14	25.86	43.12	50.98
75.	**IL7**	0.25	71.14	28.87	27.75	48.58	0.24	72.64	27.37	26.17	48.85
76.	**IL8**	0.22	70.53	29.48	36.53	52.63	0.22	70.53	29.48	22.11	51.35
77.	**IL9**	0.26	71.01	29	33.17	77.19	0.26	71.72	28.28	12.23	74.53
78.	**IL10**	0.2	72.84	27.16	16.84	63.76	0.2	71.96	28.05	11.12	61.49
79.	**IL11**	0.26	48.82	51.19	26.11	42.9	0.26	48.36	51.65	10.68	42.9
80.	**IL12**	0.22	74.93	25.08	23.46	44.5	0.22	74.08	25.93	21.59	47.18
	GM	**0.21**	**72.88**	**27.12**	**25.78**	**71.06**	**0.21**	**72.33**	**27.67**	**31.57**	**68.02**
	CV	**0.45**	**0.62**	**1.65**	**2.24**	**1.55**	**0.45**	**0.61**	**1.60**	**2.65**	**1.61**
	CD	**0.002**	**0.900**	**0.900**	**1.147**	**2.187**	**0.445**	**0.611**	**1.595**	**2.653**	**1.614**

Under partial irrigated condition grain yield per plant arrayed between 40.33g to 105.17g with a mean worth of 68.08g.Ten genotypes *viz*., IL11 × IL12, IL1 × IL7, IL7 × IL8, IL3 × IL10, IL6 × IL7, IL7 × IL12, IL2 × IL7, IL6 × IL12, IL4 × IL6 and IL3 × IL11 displayed better response in respect to different morpho-physiological parameters along with grain yield (Table 2), Turgid weight ranged from 0.16 to 0.26 with an average worth of 0.21. Relative water content varied between 48.36% to 90.17% with a mean value of 72.33%, while saturation water deficit arrayed between 9.83 to 51.65 with an average value of 27.67 and membrane stability index varied between 1.34 to 78.56 with a mean worth of 31.57.

Based on these findings, it is clear that the drought tolerant genotypes giving more yield under drought condition. Similar results were also reported by Homayoun (2011); Kachre *et al*. (2019); Mishra *et al*. (2021 a). Among all 80-maize genotypes under irrigated and partial irrigated conditions, ten genotypes *viz.*, IL11 × IL12, IL1 × IL7, IL7 × IL8, IL3 × IL10, IL6 × IL7, IL7 × IL12, IL2 × IL7, IL6 × IL12, IL4 × IL6 and IL3 × IL11 exhibited better response in terms of all morpho-physiological parameters along with grain yield.

The inter se correlations of grain yield per plant (GY/P) with an individual morpho-physiological trait *e.g.,* turgid weight, relative water content, saturation water deficit and membrane stability index have been presented in (Table 4 and 6). Saturation water deficit revealed significant and positive association with grain yield indicating favorable response towards yield. But turgid weight, relative water content and membrane stability index exhibited significant and negative correlation with grain yield. Similar results were alsoaddressed by Good *et al*. (1993); Magorokosho *et al*. (2003); Kachre *et al*. (2019); Mishra *et al*. (2021a); Sharma *et al.* (2021).

B. Correlation Coefficient (Under Irrigated Condition)

At the phenotypic level. The details of the phenotypic correlation coefficients between grain yield and its attributing characters are presented in the Table 3. Turgid weight displayed significant and positive correlation with SDW (0.0835) while significant and negative correlation with RWC (-0.0835) tracked by MSI (-0.1504) and GY/P (g) (-0.0724). Relative water content showed significant and positive correlation with GY/P (g) (0.0138) while significant and negative correlation with SWD (-1.0002) pursued by MSI (-0.0119). Saturation water deficit exhibited significant and positive correlation with MSI (0.0119) whereas significant and negative correlation with GY/P (g) (-0.0138). MSI displayed significant and negative correlation with GY/P (g) (-0.1638). Whilst grain yield per gram showed significant and positive correlation with RWC (0.0138). Whereas it displayed negative correlation with TW (-0.0724), SDW (-0.0138) and MSI (-0.1638).

At the genotypic level. Correlation coefficients between grain yield and its accrediting parameters have been described in the Table 3. Turgid weight showed significant and positive correlation with SDW (0.0823) while significant and negative correlation with RWC (-0.0823) tracked by MSI (-0.1503) and GY/P (g) (-0.0727). Relative water content revealed significant and positive correlation with GY/P (g) (0.0142) whereas significant and negative correlation with SWD (-1.0002) trailed by MSI (-0.0122). Saturation water deficit exhibited significant and positive correlation with MSI (0.0122) whilst significant and negative correlation with GY/P (g) (-0.0142). Membrane stability indexshowed significant and negative correlation with GY/P (g) (-0.1641). GY/P (g) showed significant and positive correlation with RWC (0.0142). Whereas it had negative correlation with TW (-0.0727), SDW (-0.0142) and MSI (-0.1641).

Table 3: Correlation coefficient among different maize genotypes for different morpho-physiological parameters.

Characters	Correlation	RWC	SDW	MSI	GY/P
TW	**rp**	-0.0835	0.0835	-0.1504	-0.0724
	rg	-0.0823	0.0823	-0.1503	-0.0727
RWC	**rp**		-1.0002*	-0.0119	0.0138
	rg		-1.0002*	-0.0122	0.0142
SDW	**rp**			0.0119	-0.0138
	rg			0.0122	-0.0142
MSI	**rp**				-0.1638
	rg				-0.1641

(r_p = phenotypic correlation coefficients, r_g = genotypic correlation coefficients)rp ≥ 0.1675 (significant at 5%), rg ≥ 0.2252(significant at 1%)

C. Phenotypic path coefficient analysis

Phenotypic path coefficient analysis revealed higher R^2 (0.0365) value and residual effect (0.9816) indicating exploitation of phenotypic variation in response to irrigated condition. The phenotypic direct and indirect effects of various traits on yield per plant are presented in Table 4.

Phenotypic path coefficient analysis revealed that RWC (0.0034) had the highest positive and direct effect on SY/P (g) followed by SWD (0.0002). However, maximum negative and direct effect on seed yield per plant was documented through MSI (-0.1787) and TW (-0.0989). The indirect effects of turgid weight showed a positive and indirect effect on grain yield per plant *via* RWC (0.0083), tracked by MSI (0.0149) and negative and indirect effect on yield per plant *via* SWD (-0.0083). Relative water content displayed a positive and indirect effect on seed yield per plant *via* MSI (0.0003), negative and indirect effect on yield per plant *via* SWD (-0.0034) pursued by TW (-0.0003). Saturation water deficit displayed positive and indirect effect on seed yield per plant *via* RWC(0.0004) trailed by TW (0.0001) and MSI (0.0001). Membrane stability index demonstrated positive and indirect effect on seed yield per plant *via* TW (0.0269) tracked by RWC (0.0021) and it showed negative and indirect effect on seed yield per plant *via* SWD (-0.0021).

Table 4: Phenotypic path-coefficient (Pp) analysis showing direct and indirect effects of different morpho-physiological traits on grain yield per plant of different maize genotypes

Characters	TW	RWC	SDW	MSI	Correlation with GY/P
TW	-0.0989	0.0083	-0.0083	0.0149	-0.0724
RWC	-0.0003	0.0034	-0.0034	0.0003	0.0138
SDW	0.0001	0.0004	0.0002	0.0001	-0.0138
MSI	0.0269	0.0021	-0.0021	-0.1787	-0.1638

R^2 = 0.0365, Residual effect = 0.9816

D. Correlation Coefficient (Under Partial Irrigated Condition)

At the phenotypic level. The details of the phenotypic correlation coefficients between grain yield and its attributing characters are presented in the Table 5. Turgid weight displayed significant and positive correlation with SDW (0.0701) while significant and negative correlation with RWC (-0.0701) tracked by MSI (-0.0109) and GY/P (g) (-0.069). Relative water content displayed significant and positive correlation with MSI (0.1319) followed by GY/P (g) (0.0232) whilst significant and negative correlation with SWD (-1.0002). Saturation water deficit showed significant and negative correlation with MSI (-0.1319) tracked by GY/P (g) (-0.0232). Membrane stability index exhibited significant and negative correlation with GY/P (g) (-0.0871). However, Grain yield per plant in gram displayed significant and positive correlation with RWC (0.0232), whereas it exhibited negative correlation with TW (-0.069), SDW (-0.0232) and MSI (-0.0871).

At the genotypic level. Correlation coefficients between grain yield and its ascribing characters has been designated in the Table 5. Turgid weight exhibited significant and positive correlation with SDW (0.0689) while significant and negative correlation with RWC (-0.0689) followed by MSI (-0.011) and GY/P (g) (-0.0694). Relative water content displayed significant and positive correlation with MSI (0.1323) tracked by GY/P (g) (0.0237) whilst significant and negative correlation with SWD (-1.0002). Saturation water deficit showed significant and negative correlation with MSI (-0.1323) perused by GY/P (g) (-0.0237). Membrane stability index displayed significant and negative correlation with GY/P (g) (-0.0873). Whilst grain yield per plant in gram showed significant and positive correlation with RWC (0.0237). Whereas it exhibited negative correlation with TW (-0.094), SDW (-0.0237) and MSI (-0.0873).

Table 5: Correlation coefficient among different maize genotypes on different morpho-physiological parameters with grain yield.

Characters	Correlation	RWC	SDW	MSI	GY/P
TW	**rp**	-0.0701	0.0701	-0.0109	-0.069
	rg	-0.0689	0.0689	-0.011	-0.0694
RWC	**rp**		-1.0002*	0.1319	0.0232
	rg		-1.0002*	0.1323	0.0237
SDW	**rp**			-0.1319	-0.0232
	rg			-0.1323	-0.0237
MSI	**rp**				-0.0871
	rg				-0.0873

(r_p = phenotypic correlation coefficients, r_g = genotypic correlation coefficients) rp ≥ 0.1675 (significant at 5%), rg ≥ 0.2252(significant at 1%)

Phenotypic path coefficient analysis. Phenotypic path coefficient analysis discovered higher R^2 (0.0134) value and residual effect (0.9933) demon starting exploitation of phenotypic variation in response to under partial irrigated condition. The phenotypic direct and indirect effects of diverse parameters on yield per plant are presented in Table 6. Phenotypic path coefficient analysis exposed that RWC (0.0306) had the highest positive and direct effect on SY/P (g) followed by SWD (0.0001). However, maximum negative and direct effect on seed yield per plant was documented through MSI (-0.0919) and TW (-0.0678). The indirect effects of turgid weight exhibited a positive and indirect effect on grain yield per plant *via* RWC (0.0048), tracked by MSI (0.0007) and negative and indirect effect on yield per plant *via* SWD (-0.0048). Relative water content displayed a positive and indirect effect on seed yield per plant *via* MSI (0.004) and negative and indirect effect on yield per plant *via* SWD (-0.0306) trailed by TW (-0.0021). Saturation water deficit showed positive and indirect effect on seed yield per plant *via* RWC (0.0002) tracked by TW (0.0003) and MSI (0.0002). Membrane stability index exhibited positive and indirect effect on seed yield per plant *via* SWD (0.0121) tracked by TW (0.001) and it showed negative and indirect effect on seed yield per plant *via* RWC (-0.0121).

Table 6: Phenotypic path-coefficient (Pp) analysis showing direct and indirect effects of different morpho-physiological traits on grain yield per plant of different maize genotypes.

Characters	TW	RWC	SDW	MSI	Correlation with GY/P
TW	-0.0678	0.0048	-0.0048	0.0007	-0.069
RWC	-0.0021	0.0306	-0.0306	0.004	0.0232
SDW	0.0003	0.0002	0.0001	0.0002	-0.0232
MSI	0.001	-0.0121	0.0121	-0.0919	-0.0871

R^2 = 0.0134, Residual effect = 0.9933

It was evidenced that water scarcity unpleasantly disturbs plant growth and designate more fluctuations in dry weight of maize. As the stomata close in response to low water supply, there is low CO_2 fixation. Apart from reducing cell division and enlargement, water stress is testified to be restrictive to almost all aspects of cellular metabolism. The result in decrease in dry matter production and yield is apparent in present investigation which is harmony to research of Kachare (2017). Sharifa *et al*. (2015) and Mishra *et al*. (2021a) also recognized decreased fresh weights with drought stress in soybean genotypes. In many other studies, osmotic stress also instigated a significant decrease in fresh weight of soybean genotypes (Hamayun *et al*. 2010; Sepanlo *et al*., 2014; Kachare *et al*., 2019; Mishra *et al*., 2021b).

RWC is considered as a protruding physiological trait to envisage tolerance against drought stress. Drought stress causes water loss within the plant and results in relative water content (RWC) reduction. This parameter is one of the most persistent and broadly employed indicator for defining both the sensitivity and the tolerance to water deficit in plants (Rampino *et al*., 2012). Computation of RWC enables in the approximation of the metabolic action in leaf tissues which is then considered as an integrated measure of plant water standing. In the present investigation, RWC steadily diminished with susceptible genotypes in comparison to tolerant genotypes. The reducing tendency of relative water content for all the genotypes may be accredited towards the reduction in external water potential (Datta *et al*., 2011). All the genotypes displayed significant variations in RWC which advised that diverse cultivars have different threshold levels to retain the water status (Datta *et al*., 2011). In the current investigation, RWC was higher in those genotypes may be drought tolerant as anticipated by Hossain *et al*. (2014); Sepanlo *et al*. (2014); Kachare (2017); Mishra *et al*. (2021b).

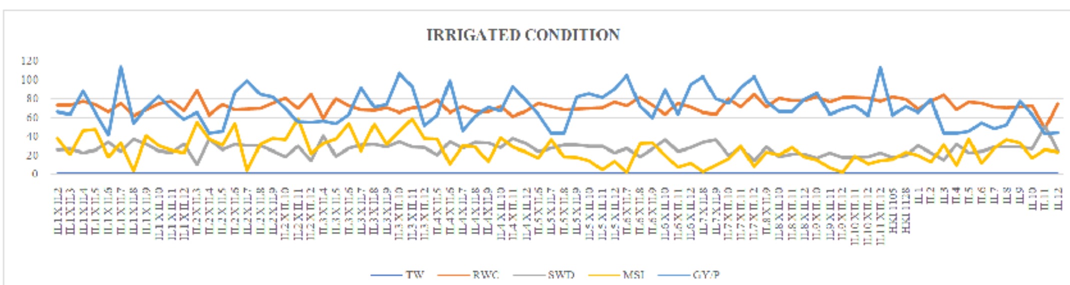

Fig. 1. Mean performance of maize genotypes under Irrigated condition during Rabi 2019-2020.

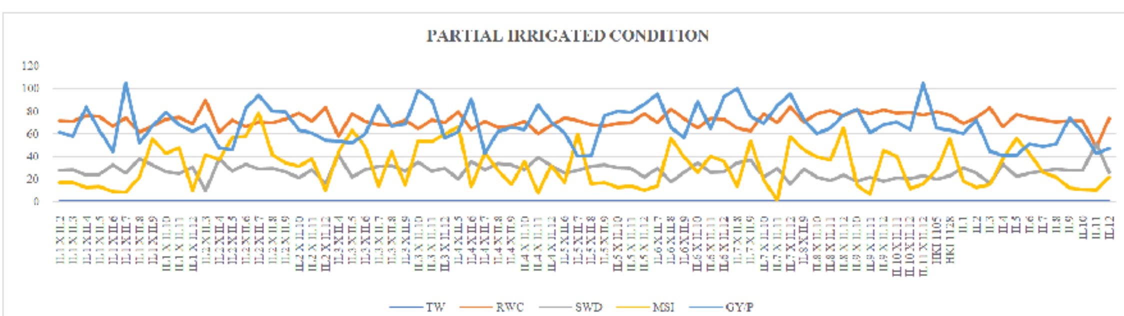

Fig. 2. Mean performance of maize genotypes under partial irrigated condition during Rabi 2019-2020.

In this research, all the susceptible genotypes displayed significant higher values of SWD, nevertheless, tolerant genotypes revealed lower value of SWD as compared to susceptible one. Souza *et al*. (2013); Kachare *et al*. (2019); Mishra *et al*. (2021a) addressed analogous trend in SWD for the soybean genotypes.

On the basis of these findings, it is clear that the drought tolerant genotypes giving more yield under drought condition with increased value of turgid weight relative water content, saturation water deficit and membrane stability index. Similar results were also reported by Homayoun (2011). Under both conditions, correlation studies of grain yield per plant showed significant positive correlation with relative water contents (RWC) while negative correlation was evident with turgid weight, saturation water deficit, and Membrane stability index (MSI). Similar results also reported by Good *et al*. (1993); Magorokosho *et al*. (2003). Furthermore, correlation analysis along with other indices was proved to be a useful approach for rapid and cost-efficient screening of large number of genotypes against drought stress condition.

CONCLUSIONS

Based on mean data, under both irrigated and partial irrigated conditions ten genotypes *namely:*IL11 × IL12, IL1 × IL7, IL7 × IL8, IL3 × IL10, IL6 × IL7, IL7 × IL12, IL2 × IL7, IL6 × IL12, IL4 × IL6 and IL3 × IL11 displayed better response in respect to all studied morpho-physiological parameters along with grain yield. These genotypes may serve as valuable starting materials or parents to develop drought tolerant cultivars with having higher yield potential. Under both conditions, correlation studies of grain yield per plant shows significant positive correlation with relative water contents while negative correlation was observed with turgid weight, saturation water deficit, and membrane stability index.

FUTURE SCOPE

Drought tolerant genotype(s) obtained from this investigation may be employed to breed drought tolerant cultivar(s) in future.

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Conflict of Interest. None.

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