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Physiological characterization of maize inbred lines under moisture deficit condition

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Abstract
Drought is considered to be one of the major abiotic stress factors that severely limit grain yield, often causing extensive economic loss to agriculture. Improving drought tolerance in maize has become one of the top priorities in maize breeding programs. Identification of drought tolerant maize inbreds is therefore an step in maize breeding. Nine inbred lines e.g., UMARKOTE-3, CML-411, CML-122, CML-40, CML-27, CML-336, CML-191, CLO-2450 and CAL-1415 were identified to have higher level of drought tolerance. Tolerant inbred lines maintained higher chlorophyll content, SPAD value, chlorophyll stability index, cell membrane stability index, relative water content and comparatively higher grain yield when subjected to drought stress. These inbreds also showed lower leaf senescence and rolling. In contrast, CML-161 and CML-300 were most sensitive and recorded lowest grain yield among the inbred lines under moisture deficit. Drought tolerant inbred lines identified in this study are intended for utilization as potential donors for development of maize hybrids suitable for water deficit condition.

Keywords: Inbred lines, drought tolerance, physiological traits, maize.

Introduction
Maize (*Zea mays* L.) is a staple food possessing the highest yield potential among the cereals and it is known as queen of cereals. Since, it is a short day plant with C4 type of photosynthesis; the crop has very efficient utilisation of solar radiation. But, it is very sensitive to excess or deficit soil moisture. About 67% of the total maize production in the developing world comes from low and lower middle income countries. Thus, maize plays an important role in livelihood of millions of poor farmers. By 2050, the demand for maize in developing world will be double (Rosegrant *et al*., 2009). The global food supply demand model predicts that global demand for maize will increase from 526 M tons to 784 M tons from 1993 to 2020, with most of the increased demand coming from developing countries (Rosegrant *et al*., 2009). Keeping in mind about the increased demand for maize, there should be much more effort for maize production in the changing climatic conditions, particularly relating to water stress, salinity, extreme temperature regimes etc. 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. Most of the world maize area is grown under rain- fed conditions and it is more susceptible to drought than other cereals (Hall *et al*. 1981).

Drought at any stage of crop improvement affects production. But, maximum damage is inflicted when it occurs during flowering. Effect of drought stress includes delayed silking and female sterility caused by embryo abortion (Moss & Downey 1971, Zamir *et al*., 2013) resulting huge reduction in grain yield. It was estimated that annual yield loss due to drought may be close to 24 million tonnes and it is equivalent to 17 % of a normal year's production in a developing world. Therefore, an experiment was conducted to evaluate a set of 35 inbred lines for drought tolerance under typical moisture deficit threshold condition.

Materials and Methods
Thirty five maize inbreds were evaluated at EB-II section, Department of Plant Breeding and Genetics, College of Agriculture, OUAT, Bhubaneswar during Rabi, 2018-19. The experiment was laid out on 1st December 2018 in a randomized block design (RBD) with two replications. Each inbred was sown in 2 rows of 4 meters with a spacing of 60 cm between rows and 20 cm between plant to plant within a line after thinning. Fertilizers were applied at the rate of 120 kg N, 60 kg P_2O_5 and 60 kg K_2O per hectare in form of Urea, SSP and MOP respectively along with FYM (12 cart loads/ha) and Zinc Sulphate (25kg/ha). In order to ensure uniform plant stand, two seeds were dibbled per hill and later thinned to one seedling per hill. Standard agronomic practices and plant protection measures were followed to raise a successful crop.

Drought stress was imposed for a period of one month starting from 10 days before flowering by with-holding irrigation. The irrigation was resumed when soil moisture reaches permanent wilting point at a depth of 40-60 cm. Chlorophyll intensity (SPAD value), leaf rolling(ROLL), and leaf senescence (SENE.) were recorded on five randomly selected competitive plants per replication of each inbred line. The mean of five plants were computed for statistical analysis. The characters like chlorophyll content(C.CNT), chlorophyll stability index(CSI), cell membrane stability index(CMSI) & relative water content (RWC) were calculated for samples collected from a single competitive plant per replication per inbred line and grain yield/ ha(GY/Ha.) was calculated on plot basis(q/ha.).

Result and Discussion

Among 35 maize inbred lines under water stress condition, only nine genotypes viz. UMARKOTE-3, CML-411, CML-122, CML-40, CML-27, CML-336, CML-191, CLO-2450, and CAL-1415 showed good response with respect to all physiological traits and grain yield (Table 1). Leaf senescence in these test inbreds was as low as 15-30% under drought condition.

Table 1: Assessment of 35 maize inbred lines based on physiological parameters

SL.NO.	Genotype	GY/Ha	SPAD	SENE.	ROLL.	C.CNT	CSI	CMSI	RWC
1	CML323	30.82	22.15	30.00	25.00	0.75	92.14	11.67	86.24
2	UMARKOTE -3	25.35	25.24	30.00	35.00	1.04	94.25	16.02	75.75
3	CML -411	33.65	33.49	35.00	15.00	1.25	96.94	15.03	88.03
4	CML -116	21.34	24.60	35.00	35.00	0.44	73.65	4.66	67.43
5	CML -118	26.17	25.98	10.00	10.00	0.38	93.28	10.30	74.68
6	CML -122	33.38	35.12	20.00	20.00	1.27	98.71	12.07	44.0
7	JSPL-I	28.43	24.34	25.00	30.00	0.53	86.08	8.76	73.11
8	CML -40	34.58	30.06	15.00	35.00	1.16	86.71	13.65	83.21
9	CM-324	28.51	26.97	25.00	40.00	0.44	77.74	2.55	69.05
10	CML – 431	14.54	21.12	50.00	45.00	0.46	71.01	-3.62	71.19
11	CML -114	16.98	19.92	60.00	50.00	0.30	79.92	-2.84	69.15
12	CML -295	11.76	23.36	45.00	60.00	0.6	71.00	1.06	70.05
13	CML -51	16.71	31.47	35.00	30.00	0.24	75.30	-3.86	66.98
14	CML -59	34.40	28.42	25.00	25.00	1.15	86.68	13.98	83.38
15	CML-453	28.64	26.20	35.00	50.00	0.47	77.72	-2.53	67.72
16	CML -27	33.90	28.73	30.00	20.00	1.22	91.82	15.02	86.06
17	CML -487	23.67	24.25	25.00	35.00	0.32	77.50	1.83	68.49
18	CML -336	34.60	28.74	30.00	20.00	1.06	88.35	12.03	85.13
19	CML-161	10.36	15.0	80.00	75.00	0.44	75.29	-5.24	60.10
20	CML -191	34.96	28.9	30.00	30.00	1.03	8160	12.47	79.19
21	CML -468	19.91	27.20	15.00	30.00	1.27	85.99	10.24	75.48
22	V -334	17.36	25.04	55.00	65.00	0.69	75.85	8.82	63.23
23	CML -300	3.85	15.53	75.00	75.00	0.34	74.82	-10.94	73.57
24	CML -113	17.55	27.63	45.00	30.00	0.39	83.67	4.60	70.07
25	CML -412	19.27	25.99	30.00	25.00	0.41	81.71	3.24	69.97
26	CML -194	29.52	23.11	25.00	25.00	0.39	89.78	12.06	75.64
27	CML -470	12.60	14.0	75.00	55.00	0.32	72.06	-1.24	71.43
28	CML -414	30.39	2824	25.00	10.00	1.27	92.21	14.18	76.32
29	BML -06	29.96	21.08	35.00	25.00	0.69	86.68	8.52	77.12
30	CML -359	22.80	25.30	15.00	15.00	0.41	83.90	11.18	61.93
31	CML -469	27.87	27.97	20.00	15.00	0.99	94.71	2.24	69.82
32	CLO -2450	29.17	20.02	30.00	20.00	1.27	83.10	12.00	86.32
33	CAL -1415	36.81	32.56	15.00	1500	1.42	96.65	15.18	89.85
34	BML -07	11.39	30.20	70.00	55.00	0.45	71.08	-2.55	66.67
35	CML -451	17.81	23.19	25.00	45.00	0.42	76.89	-1.76	65.54
	GM	24.26	25.49	35.00	34.00	0.72	83.57	6.25	73.20
	CVe	6.44	13.26	31.29	27.20	3.59	1.76	1.98	11.77
	CD	3.17	6.87	22.25	18.79	0.05	3.00	0.25	17.51

Relative water content was as high as 79.19 % to 89.85% in the above tolerant genotypes resulting more yield. Chlorophyll content ranged from 0.24 to as high as 1.42 and the higher value was revealed in UMARKOTE-3, CML-411, CML-122, CML-40, CML-27, CML-336, CML-191, CLO-2450, and CAL-1415 under drought stress.

The inter se correlations of grain yield with individual physiological traits e.g., SPAD, cell membrane stability index, chlorophyll stability index, chlorophyll content, relative water content, leaf rolling and leaf senescence have been presented in Table 2. SPAD value, chlorophyll stability index and relative water content revealed significant positive association with grain yield indicating favourable response towards yield. But, leaf rolling and leaf senescence exhibited significant negative correlation with grain yield. Similar results were also obtained by Good *et al*. (1993) and Magorokosho *et al*. (2003).

Table 2: Correlation among 35 inbred lines on 7 different physiological parameter with grain yield

Characters	Correlation	SENE.	ROLL.	C.CNT	CSI	CMSI	RWC	Correlation with GY/ha
SPAD	r_p	-0.596**	-0.590**	0.525**	0.519**	0.522**	0.089	0.593**
	r_g	-0.835**	-0.743**	0.599**	0.596**	0.600**	0.072	0.697**
SENE.	r_p		0.817**	-0.456**	-0.643**	-0.674**	-0.247	-0.743**
	r_g		0.885**	-0.502**	-0.711**	-0.743**	-0.317	-0.827**
ROLL.	r_p			-0.528**	-0.773**	-0.732**	-0.384*	-0.765**
	r_g			-0.568**	-0.846**	-0.790**	-0.514**	-0.836**
C.CNT	r_p				0.701**	0.752**	0.487**	0.701**
	r_g				0.708**	0.752**	0.634**	0.708**
CSI	r_p					0.776**	0.365*	0.760**
	r_g					0.782**	0.473**	0.770**
CMSI	r_p						0.496**	0.820**
	r_g						0.652**	0.827**
RWC	r_p							0.490**
	r_g							0.656**

$r_p \geq 0.334$ (significant at 5%)$r_g \geq 0.429$(significant at 1%)

At the genotypic level, the grain yield /ha was positively and significantly correlated with chlorophyll content (0.701), chlorophyll stability index (0.760), cell membrane stability index (0.820), SPAD value (0.593) and relative water content (0.490). At the phenotypic level almost similar trend was observed as of genotypic level, But, grain yield (Kg/ha) was negatively correlated with both leaf rolling (-0.756) and leaf senescence (-0.743) at both genotypic and phenotypic level.

Table 3: Phenotypic path-coefficient (Pp) analysis showing direct and indirect effects of different traits on grain yield per plant of 35 maize inbreds

Characters	SPAD	SENE.	ROLL.	C.CNT	CSI	CMSI	RWC	Correlation with GY/Ha
SPAD	0.133	0.162	0.029	0.060	0.075	0.139	0.014	0.593**
SENE.	-0.068	-0.272	-0.040	-0.052	-0.093	-0.180	-0.038	-0.743**
ROLL.	-0.067	-0.022	-0.049	-0.061	-0.122	-0.195	-0.059	-0.765**
C.CNT	0.060	0.124	0.026	0.115	0.101	0.201	0.074	0.701**
CSI	0.059	0.175	0.038	0.080	0.145	0.207	0.056	0.760**
CMSI	0.059	0.183	0.036	0.086	0.112	0.027	0.076	0.820**
RWC	0.010	0.067	0.019	0.056	0.053	0.132	0.153	0.490**

P(R) = 0.0.085, R^2 (%) =99.28, $r_p \geq 0.334$ (significant at 5%) *, $r_p \geq 0.429$(significant at 1%)**

At phenotypic level, the analysis revealed high R^2 (99.28%) value and very negligible residual effect (PR=0.085) indicating exploitation of almost 99% of phenotypic variation in response to drought stress. Most of the characters like SPAD (0.133), chlorophyll content (0.115), chlorophyll stability index (0.145), cell membrane stability index (0.027) and relative water content (0.076) showed positive direct effects for grain yield/ha(Table 3). Whereas, leaf rolling (-0.272) and senescence (-0.049) showed negative direct effects for yield/ ha.

Chlorophyll content had low level of direct effect i.e. (0.115) on grain yield but, its contribution was maximum on grain yield via cell membrane stability index i.e. (0.201). Such correlative response via other component traits benefited the crop to sustain under moisture stress. In contrast, cell membrane stability index had low level of direct effect i.e. (0.027) on grain yield, but it was shown to have very high indirect effect on grain yield through leaf senescence (0.183) which has negative impact on grain yield(r= -0.743).

Thus, above physiological study, it is clear from above physiological study that the drought tolerant genotypes giving more yield under drought condition are in a trend of having less leaf rolling, less leaf senescence, more chlorophyll content, more relative water content and both more chlorophyll stability index and cell membrane stability index. Similar results were also revealed by Homayoun (2011). On verification of mean data, only nine genotypes i.e. UMARKOTE-3, CML-411, CML-122, CML-40, CML-27, CML-336, CML-191, CLO-2450, CAL-1415 revealed good response with respect to physiological traits e.g., SPAD value, chlorophyll content, chlorophyll stability index, cell membrane stability index and relative water content resulting higher yield. These can serve as valuable materials for development of high yielding hybrids in this crop.

Conflict of Interest Statement

The authors declare that there is no conflict of interest.

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