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RESEARCH ARTICLE Agricultural Science Digest, Volume Issue : ()

Drought Stress-induced Impact on Morpho-physiological Traits in Maize Landraces of Kashmir

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10.18805/ag.D-5593

ABSTRACT

Background: Drought is the critical abiotic stress constraining the productivity of maize and lack of germplasm possessing drought tolerance results in low maize productivity in Kashmir. Because only 15% of the land in Kashmir Valley is irrigated and 85% of the land is rainfed, maize landrace evaluation for drought desirable traits becomes important.

Methods: To identify elite genotypes for drought tolerance, seventy maize landraces designated as K-L 1 to K-L 70 from Kashmir were evaluated for morpho-physiological traits: shoot height, shoot biomass, root depth, root biomass allocation, shoot to total biomass, root to total biomass, relative water content, canopy temperature, cell membrane stability and chlorophyll content.

Result: A significant decrease in root and shoot traits, relative water content, cell membrane stability, chlorophyll content and a significant increase in canopy temperature was recorded under drought conditions. The evaluation led to identifying landraces exhibiting desirable traits for drought tolerance that would prove useful for further crop improvement.

Key words: Cell membrane stability, Drought stress, Elite genotypes, Morphophysiological traits, Relative water content.

INTRODUCTION

The adverse stress conditions, abiotic or biotic, usually hamper the plants from executing their performance to the fullest and often threaten their survival (Suzuki *et al*. 2014). Drought, critical abiotic stress, affects the crops, especially maize, worldwide through freshwater shortages, which are most likely to worsen with changing global climate, necessitating the development of drought-tolerant maize varieties. (Ferguson, 2019; Webber *et al*. 2018). Drought stress at critical stages of maize development like the seedling stage, ear emergence, silking stages limit its productivity (Aslam *et al*. 2015). To provide sufficient crop produce for future generations, the development of drought-tolerant crop varieties from available genetic resources is necessary and many maize improving breeding programs are operative to achieve tolerance to stresses, biotic and abiotic. At the same time, growing demands and changing climate necessitates further quality improvement and extraordinary produce by adopting minimal input-requiring methods. In Kashmir Valley, the erratic rainfall patterns and insufficient irrigation impact maize crops drastically, leading to yield instability. In this backdrop, seventy maize landraces from Kashmir valley were tested for elite genotype existence that exhibited inherent drought tolerance and could be used for future integration of drought tolerance into commercial varieties genetic background.

MATERIALS AND METHODS

Seventy maize landraces from Kashmir valley designated as K-L 1 to K-L 70 were studied for drought resilience wherein morphological traits like shoot height and biomass, rooting depth, root biomass, total biomass allocation to root and shoot, root volume and physiological traits like leaf relative water content, canopy temperature, cell membrane stability and chlorophyll content were determined. The work was done at Dryland Agriculture Research Station, SKUAST-K, Budgam, in 2021. PVC root columns (1.3 m high and 20 cm diameter) were used to grow plants in a completely randomized design with two replications for irrigated and drought treatments. Initially, four seeds properly surface-sterilized were sown in each column and later at the four-leaf stage, only two competitive plants per column were maintained. Imposition of drought through water withholding in drought treatment was done after twenty days and harvesting of shoots and roots after forty-eight days of sowing.

Effect of drought on canopy temperature (Guang-Hua *et al*. 2010) was studied by measuring canopy temperature at two stages, 2 and 4 weeks interval, after drought exposure through the usage of Fluke 68 Max, Fluke Corporation USA (infra-red thermometer). For each replication, a mean of five readings was taken and averaged. RWC (Leaf relative water content) readings were taken at two stages, 2 and 4 weeks

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How to cite this article: Peer, L.A., Dar, Z.A., Lone, A.A. and Bhat, M.Y. (2022). Drought Stress-induced Impact on Morpho-physiological Traits in Maize Landraces of Kashmir. Agricultural Science Digest. DOI: 10.18805/ag.D-5593.

Submitted: 04-04-2022 **Accepted:** 10-06-2022 **Online:** 14-07-2022

after stress exposure from uppermost fully expanded leaves (Dwyer *et al*. 1988). The electrical conductivity method (Sairam *et al*. 2002) was used to estimate the cell membrane stability in maize leaves. SPAD meter (Hanstech, Model CL-01) was used to record the numerical SPAD values proportional to chlorophyll content in leaves and were recorded from the uppermost fully expanded leaves (Nepolean *et al*. 2013).

RESULTS AND DISCUSSION

Table 1 provides the mean performance of the maize landraces for root and shoot traits under irrigated and drought conditions.

In maize landraces under drought conditions, a significant reduction in all shoot and root parameters was found in maize landraces. Drought stress resulted in a decrease of most of the traits except for shoot to total biomass. Top root biomass (287.44%) exhibited the highest percentage decrease with the highest top-root biomass in K-L 43 (16.7 g) and lowest in K-L 48 (1.1 g), followed by root volume (237.62%) with the highest value in K-L 23 (25.4 cm^3) and lowest value in K-L 33 (1.4 cm^3) while rooting depth showed the lowest percentage decrease (24.50%) with highest value in K-L 24 (58.3 cm) and lowest value in K-L 41 (18.2 cm) and shoot to total biomass (10.07%) exhibited an percentage increase with highest value in K-L 48 (0.97 g) and lowest value in K-L 25 (0.43 g), under drought stress. Many researchers have reported similar results, revealing diverse drought tolerance capacities in maize lines of different origins and genetic backgrounds (Dao *et al*. 2017, Dubey *et al*. 2010; Islam *et al*. 2019). Furthermore, an inverse relationship between rooting depth and soil water available occurs under field conditions, while rooting length and density decline under drought conditions (Ogawa *et al*. 2005). However, prolific root systems can help plants extract water from deeper and shallower soil layers under limited water availability, so genotypes exhibiting deep rooting possess this advantage but at the cost of biomass allocation to roots impacting the grain production. Therefore, it would be beneficial to select genotypes with deep roots that efficiently utilize the same biomass through greater specific root length or longer root hairs. Reduced biomass allocation to shoot results in a reduction of transpiration by decreasing leaf area and thus benefits the plant under drought stress. Biomass allocation changes help determine the plant's capability of responding to drought stress through the use of the resources efficiently that would otherwise lead to changes in yield and photosynthate remobilization from shoots to cobs and then from cob to grains acts as an essential drought resistance mechanism. Futhermore some of the landraces like K-L 3, K-L 6, K-L 7, K-L 9, K-L 11, K-L 15, K-L 17, K-L 21, K-L 30, K-L 33, K-L 34, K-L-44, K-L 52, K-L-64, K-L 69 and K-L 70 showed increased shoot height in drought conditions whereas, K-L 11, K-L 19, K-L 28, K-L 35, K-L 43, K-L 53 and K-L 63 exhibited higher shoot biomass under drought than irrigated conditions. This may be attributed to the improved root architechture and water relations maintained by such landraces under drought conditions.

The response of maize landraces regarding relative water content (RWC) after two and four weeks of drought stress showed a decrease across stages in all landraces except K-L 24, K-L 41, K-L 35 and K-L 66 (Table 2). The results revealed a significant reduction in RWC under drought conditions coincided with the results from other authors (Chen *et al*. 2012; Wattoo *et al*. 2018). The higher the value of RWC under irrigated and drought conditions, the more plant tissues can hold water, determining the plant's capability to limit water loss and leaf dehydration, thereby the drought resistance evaluation. Therefore, RWC is a screening tool for selecting genotypes with more resistance to drought stress at later stages.

The canopy temperature of maize landraces, recorded after two and four weeks of drought stress, was relatively higher in drought treatments (Table 3). K-L 32 (37.4°C) exhibited the highest CT mean value across stages, followed by K-L 49 (36.43°C), K-L 65 (36.36°C) and K-L 13 (36.23°C), while K-L 14 (31.32°C) showed the lowest, followed by K-L 43 (31.74°C), K-L 27 (31.85°C) and K-L 21(32.38°C), with a mean value of 34.19°C, under drought conditions. The increase in mean percent across genotypes and two stages is 9.88%, with K-L 36 (16.25%) exhibiting the highest increase, while K-L 27 (3.06%) showed the lowest value. Estimation of drought stress through CT measurement is based on CT's inverse relationship with transpiration cooling and a negative correlation between CT and yield suggests higher yields from lines able to maintain low CT (Kumar *et al*. 2015). Genotypes with lower CT values indicate better water absorption capability and water status maintenance, representing an integrated response to high temperature and drought.

Under drought treatment, K-L 18 (71.87%) showed the highest values for CMS, followed by K-L 5 (71.7%), K-L 12 (71.4%) and K-L 59 (71.21%), while K-L-6 (41.33%) showed the lowest value, followed by K-L 1 (45.61%), K-L 45 (46.28%) and K-L 15 (46.45%) (Table 4). CMS decrease results from lipid peroxidation caused by ROS production under water deficit conditions (Sairam and Saxena, 2000). Thus, the genotypes with lower CMS values are vulnerable to water deficit conditions, while those with higher CMS values depict drought-tolerant behaviour. Therefore, the genotypes with less than 50% values are incredibly susceptible to drought, while 71-80% grow with full potential under water deficit. SPAD values that quantify the relative chlorophyll content showed a significant difference under drought conditions and K-L 12 (30.7) showed the highest SPAD unit value, followed by K-L 67 (30.56), K-L 37 (30.49) and K-L 36 (29.46) while K-L 45 (18.31) exhibited the lowest value, followed by K-L 60 (18.43), K-L 20 (18.46) and K-L 29 (18.64) (Table 4). Under drought stress, chloroplast content decreases by reducing the apoprotein, LHCP (light-harvesting chlorophyll a/b protein and destruction of chloroplasts by increased oxidative stress (Kumar *et al*. 2015). Thus, SPAD

Table 1: Mean performance of maize landraces for the shoot and root traits under different water regimes and effect of drought under greenhouse conditions.

Geno- -types	Shoot height (cm)		Shoot biomass (g)		Rooting depth (cm)		Top root biomass (g)		Bottom root biomass (g)		Root volume (cm^3)		Shoot to total biomass		Root to total biomass	
	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought
K-L 1	19.9	12.2	59.6	18.2	35.5	28.2	10.1	5.3	3.0	1.7	20.3	4.5	0.8	0.7	0.2	0.3
K-L 2	74.0	27.3	40.5	12.3	26.2	20.1	13.5	4.1	5.4	3.2	29.4	6.8	0.7	0.6	0.3	0.4
K-L 3	18.5	22.8	40.5	27.0	26.0	28.3	14.2	3.5	4.9	1.0	25.5	5.1	0.7	0.9	0.3	0.1
K-L 4	17.0	16.3	59.1	15.5	35.5	26.3	25.2	3.8	7.9	1.9	35.4	5.1	0.6	0.7	0.4	0.3
K-L 5	21.4	10.3	83.5	8.2	38.4	15.6	22.5	1.5	5.8	0.8	29.1	8.9	0.8	0.8	0.3	0.2
K-L 6	18.2	23.4	53.3	27.5	31.1	24.3	16.1	4.2	4.8	2.0	27.5	7.3	0.7	0.8	0.3	0.2
K-L 7	35.0	41.0	107.0	28.5	39.4	17.5	14.0	1.9	4.8	0.6	26.1	4.1	0.9	0.9	0.2	0.1
K-L 8	21.0	20.5	67.4	38.2	26.2	29.6	19.6	6.5	7.6	4.5	52.3	10.2	0.7	0.8	0.3	0.2
K-L 9	31.0	43.2	97.4	17.3	42.4	35.1	14.2	8.3	5.5	1.5	29.5	14.1	0.8	0.6	0.2	0.4
K-L 10	34.0	28.8	125.4	19.6	40.4	24.6	23.5	4.9	11.0	4.4	39.2	11.0	0.8	0.7	0.2	0.3
K-L 11	14.2	19.6	21.0	32.0	26.0	33.6	15.3	5.4	4.9	4.4	21.6	20.3	0.5	0.8	0.5	0.2
K-L 12	24.4	20.1	69.3	45.6	32.5	21.6	18.5	2.1	2.0	0.9	58.5	13.5	0.8	0.9	0.2	0.1
K-L 13	23.0	19.9	140.0	67.4	49.1	38.2	18.6	4.5	12.9	3.3	49.1	10.1	0.8	0.9	0.2	0.1
K-L 14	67.2	35.8	110.5	22.7	51.3	22.6	30.4	3.6	23.3	2.1	67.9	5.3	0.7	0.8	0.3	0.2
K-L 15	17.7	22.3	99.5	41.2	28.3	33.4	11.2	4.5	8.5	3.0	21.1	9.4	0.8	0.9	0.2	0.2
K-L 16	21.4	16.3	49.2	19.1	39.4	33.5	19.2	5.3	4.1	5.2	26.4	14.1	0.7	0.7	0.3	0.4
K-L 17	20.3	24.1	53.6	30.5	36.3	35.5	21.1	3.5	4.5	3.4	26.5	19.1	0.7	0.8	0.3	0.2
K-L 18	19.4	17.1	56.3	29.3	24.4	22.5	9.5	4.1	7.4	1.8	19.9	7.3	0.8	0.8	0.2	0.2
K-L 19	26.2	16.4	45.2	43.4	38.1	46.8	33.5	4.2	14.5	3.5	86.9	16.1	0.5	0.9	0.5	0.2
K-L 20	23.2	16.0	87.5	28.3	39.3	28.2	17.1	3.5	5.3	2.0	27.3	5.5	0.8	0.8	0.2	0.2
K-L 21	15.0	17.3	43.2	43.2	40.2	39.0	37.0	9.5	10.0	6.0	58.9	13.8	0.5	0.7	0.5	0.3
K-L 22	69.2	38.1	48.3	25.1	38.2	26.1	13.2	2.1	4.1	1.8	19.9	7.0	0.7	0.9	0.3	0.1
K-L 23	49.2	51.1	60.2	33.2	34.1	36.6	14.3	8.6	4.5	4.0	23.8	25.4	0.8	0.7	0.2	0.3
K-L 24	25.3	25.2	84.5	43.1	58.3	27.1	19.3	3.1	7.3	1.4	32.5	10.2	0.8	0.9	0.2	0.1
K-L 25	18.3	11.1	62.4	7.9	53.1	40.2	17.3	10.2	11.2	0.3	55.1	15.3	0.7	0.4	0.3	0.6
K-L 26	23.0	18.1	64.2	25.5	45.1	27.7	17.5	4.7	8.3	2.1	29.4	11.6	0.7	0.8	0.3	0.2
K-L 27	21.6	14.5	81.0	29.1	38.2	29.1	19.3	3.9	6.1	0.4	33.4	6.2	0.8	0.9	0.2	0.1
K-L 28	52.5	19.3	26.1	33.2	35.2	28.2	20.1	6.3	3.8	4.6	24.7	10.3	0.5	0.8	0.5	0.3
K-L 29	38.2	12.0	108.0	10.2	34.5	20.3	17.4	1.7	6.2	0.7	28.4	10.5	0.8	0.8	0.2	0.2
K-L 30	15.5	23.4	56.2	40.4	28.0	27.1	9.8	3.8	1.7	2.6	15.5	7.9	0.8	0.9	0.2	0.1
K-L 31	26.3	18.0	69.2	29.1	49.5	33.8	24.9	2.9	4.8	2.5	60.1	8.9	0.7	0.8	0.3	0.2
K-L 32	19.1	9.6	68.4	5.6	36.0	23.5	29.6	1.9	6.2	0.8	42.3	5.8	0.7	0.7	0.3	0.3
K-L 33	12.5	27.0	31.5	16.9	29.5	27.7	23.6	5.9	14.0	1.9	38.3	1.4	0.5	0.7	0.5	0.3
K-L 34	17.1	22.3	34.5	19.3	34.4	34.2	12.5	3.0	2.2	0.9	25.4	9.1	0.7	0.8	0.3	0.2

Table 1: Continue...

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K-L 35	20.6	19.7	59.3	65.5	39.2	48.3	16.5	11.9	3.8	2.7	25.1	19.1	0.8	0.8	0.3	0.2
K-L 36	29.3	18.2	106.0	54.2	47.5	24.2	16.3	5.5	5.2	1.9	39.6	7.1	0.8	0.9	0.2	0.1
K-L 37	24.5	19.1	118.2	51.4	43.5	39.6	18.1	3.7	3.6	1.9	27.3	8.1	0.9	0.9	0.2	0.1
K-L 38	22.1	18.4	59.2	36.1	32.3	32.3	17.2	5.8	3.3	1.9	20.3	12.1	0.7	0.8	0.3	0.2
K-L 39	26.3	20.1	72.4	31.3	35.3	22.2	17.6	4.2	3.6	1.6	26.2	14.7	0.8	0.8	0.2	0.2
K-L 40	21.1	18.3	47.4	22.1	26.6	29.1	13.5	5.6	2.8	1.9	20.1	5.8	0.7	0.8	0.3	0.3
K-L 41	31.6	25.1	60.3	33.8	18.2	23.1	9.8	1.9	3.9	1.8	17.2	5.0	0.8	0.9	0.2	0.1
K-L 42	33.4	23.6	62.4	51.5	32.7	28.8	7.3	3.1	1.8	0.6	18.1	6.8	0.9	0.9	0.1	0.1
K-L 43	27.4	24.1	69.3	83.4	37.1	35.6	19.2	16.7	5.1	3.3	45.1	18.9	0.7	0.8	0.3	0.2
K-L 44	27.3	37.1	49.5	32.6	37.2	19.4	9.2	2.0	1.7	1.7	16.1	7.1	0.8	0.9	0.2	0.1
K-L 45	27.4	13.5	74.6	17.1	33.7	27.4	19.4	1.6	3.2	0.9	28.8	6.2	0.8	0.9	0.2	0.1
K-L 46	26.7	18.1	88.5	35.5	32.7	34.1	14.2	6.7	6.1	4.5	27.3	20.1	0.8	0.8	0.2	0.2
K-L 47	22.4	17.6	43.3	18.9	34.6	28.1	9.8	3.3	2.6	1.7	16.3	6.1	0.8	0.8	0.2	0.2
K-L 48	35.5	18.7	95.7	48.1	40.4	15.1	20.3	1.1	5.2	0.3	27.7	3.9	0.8	1.0	0.2	0.0
K-L 49	43.5	19.0	129.5	41.4	38.7	33.1	18.4	6.5	8.6	0.9	57.3	15.1	0.8	0.9	0.2	0.2
K-L 50	24.1	17.3	64.2	31.4	23.6	33.2	15.5	6.0	3.7	2.4	26.2	9.1	0.8	0.8	0.2	0.2
K-L 51	22.5	16.3	48.5	23.2	20.5	24.3	6.9	3.7	6.7	1.4	19.1	7.5	0.8	0.8	0.2	0.2
K-L 52	38.7	42.7	102.1	26.2	38.2	31.1	25.5	5.9	8.1	2.1	39.1	17.1	0.8	0.8	0.3	0.2
K-L 53	29.4	22.3	19.1	60.2	36.3	29.1	11.4	2.6	4.5	1.6	20.2	15.3	0.6	0.9	0.5	0.1
K-L 54	22.3	16.6	59.2	9.7	42.5	22.8	22.5	2.8	6.5	1.2	45.0	6.6	0.7	0.7	0.3	0.3
K-L 55	28.3	19.5	70.1	32.4	26.2	33.2	17.5	3.2	3.6	2.5	25.5	11.6	0.8	0.9	0.2	0.2
K-L 56	29.8	13.0	144.1	26.0	39.3	18.2	35.2	1.6	18.0	0.4	82.5	9.8	0.7	0.9	0.3	0.1
K-L 57	110.5	34.5	43.2	15.1	42.5	26.4	28.3	3.5	11.2	3.0	54.7	8.0	0.5	0.7	0.5	0.3
K-L 58	82.4	16.8	38.2	22.7	34.4	27.7	12.7	5.1	3.7	1.8	20.4	6.1	0.7	0.8	0.3	0.2
K-L 59	16.4	18.2	54.3	31.5	27.3	33.4	11.7	3.9	7.1	1.3	29.7	6.8	0.7	0.9	0.3	0.1
K-L 60	26.2	19.7	69.5	29.1	44.2	23.2	27.1	2.8	16.1	1.5	89.8	4.7	0.6	0.9	0.4	0.1
K-L 61	24.2	20.1	82.4	49.6	46.1	26.2	19.2	3.9	12.1	3.5	54.1	16.0	0.7	0.9	0.3	0.1
K-L 62	19.2	19.7	59.5	19.0	28.7	24.1	12.3	3.7	2.1	3.5	20.2	8.0	0.8	0.7	0.2	0.3
K-L 63	16.1	19.4	33.4	44.2	24.3	32.4	13.1	7.8	3.5	2.9	16.5	14.0	0.7	0.8	0.3	0.2
K-L 64	24.3	28.0	97.5	19.4	33.6	31.4	24.7	14.1	5.9	2.5	28.5	14.1	0.8	0.5	0.2	0.5
K-L 65	25.4	8.4	99.1	8.5	40.1	19.5	22.6	1.9	9.4	0.4	29.3	4.6	0.8	0.8	0.2	0.2
K-L 66	22.5	28.1	92.6	47.3	29.5	24.2	18.5	3.6	9.7	2.5	37.0	5.7	0.8	0.9	0.2	0.1
K-L 67	27.6	26.0	102.5	40.1	28.6	24.1	12.2	3.5	3.6	1.5	20.1	4.6	0.9	0.9	0.1	0.1
K-L 68	25.0	23.1	75.4	58.2	35.2	36.7	16.5	4.5	3.5	1.7	20.0	10.5	0.8	0.9	0.2	0.1
K-L 69	20.2	23.2	41.5	26.0	21.5	22.0	14.3	3.9	1.7	1.5	16.2	5.2	0.7	0.8	0.3	0.2
K-L 70	32.3	43.5	119.0	24.8	37.2	26.0	15.3	3.7	6.9	1.5	29.0	9.1	0.8	0.8	0.2	0.2
Min	12.5	8.4	19.1	5.6	18.2	15.1	6.9	1.1	1.7	0.3	15.5	1.4	0.5	0.4	0.1	0.0
Max	110.5	51.1	144.1	83.4	53.3	48.3	37.0	16.7	23.3	6.0	89.8	25.4	0.9	1.0	0.5	0.6
Mean	28.6	22.1	70.1	31.5	35.5	28.5	17.9	4.6	6.2	2.1	33.5	9.9	0.7	0.8	0.3	0.2
Percent change under drought		-29.7		-122.5		-24.5		-287.4		-190.9		-237.6		10.1		-37.9

Table 2: Relative water content (RWC) across stages and percent reduction in RWC in maize landraces.

Genotypes	Relative water content percentage						Mean per cent change across stages
	2 weeks after stress		4 weeks after stress		Mean across stages		
	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought	
K-L 1	63.1	52.1	71.4	44.1	67.3	48.1	-40.0
K-L 2	81.0	80.0	81.5	78.0	81.3	79.0	-2.9
K-L 3	86.1	63.6	77.7	72.0	81.9	67.8	-20.8
K-L 4	60.0	49.0	61.1	47.4	60.6	48.2	-25.6
K-L 5	74.0	68.0	73.0	67.2	73.5	67.6	-8.8
K-L 6	55.0	41.0	51.0	45.1	53.0	43.1	-23.1
K-L 7	76.1	71.2	89.5	57.1	82.8	64.2	-29.0
K-L 8	69.1	58.0	59.3	68.2	64.2	63.1	-1.7
K-L 9	68.2	60.1	69.2	60.0	68.7	60.1	-14.4
K-L 10	63.0	61.0	72.1	52.3	67.6	56.7	-19.2
K-L 11	65.1	55.3	65.3	55.2	65.2	55.3	-18.0
K-L 12	82.4	72.8	82.4	72.6	82.4	72.7	-13.3
K-L 13	85.5	64.4	79.6	70.0	82.6	67.2	-22.8
K-L 14	71.0	56.2	78.2	49.0	74.6	52.6	-41.8
K-L 15	63.0	53.0	69.9	45.6	66.4	49.3	-34.8
K-L 16	72.1	56.2	65.1	63.0	68.6	59.6	-15.1
K-L 17	71.2	69.1	79.7	61.3	75.4	65.2	-15.7
K-L 18	80.2	72.4	77.1	74.8	78.7	73.6	-6.9
K-L 19	83.3	61.2	74.1	69.2	78.7	65.2	-20.7
K-L 20	64.2	52.1	69.1	46.4	66.7	49.3	-35.3
K-L 21	73.1	66.9	77.2	63.1	75.2	65.0	-15.6
K-L 22	63.3	55.3	66.2	54.2	64.8	54.8	-18.2
K-L 23	67.3	56.0	77.0	45.0	72.2	50.5	-42.9
K-L 24	63.1	72.1	65.2	68.0	64.2	70.1	8.4
K-L 25	64.2	62.3	73.0	54.3	68.6	58.3	-17.6
K-L 26	65.2	55.0	63.4	57.2	64.3	56.1	-14.7
K-L 27	68.8	64.4	68.3	63.9	68.5	64.1	-6.9
K-L 28	81.2	64.2	73.2	71.2	77.2	67.7	-14.1
K-L 29	61.0	49.8	60.2	50.5	60.6	50.2	-20.9
K-L 30	68.2	49.3	61.3	55.2	64.8	52.2	-24.0
K-L 31	70.6	58.3	67.4	61.6	69.0	59.9	-15.1
K-L 32	80.3	69.0	80.1	69.1	80.2	69.1	-16.1
K-L 33	68.9	56.6	70.1	54.3	69.5	55.5	-25.3
K-L 34	70.5	71.5	78.3	64.3	74.4	67.9	-9.5
K-L 35	66.3	66.3	65.0	68.0	65.6	67.1	2.2
K-L 36	53.5	58.7	59.2	52.4	56.4	55.6	-1.5
K-L 37	79.1	69.4	82.3	66.1	80.7	67.8	-19.0
K-L 38	67.4	55.1	71.6	51.7	69.5	53.4	-30.1
K-L 39	69.3	66.0	72.1	64.2	70.7	65.1	-8.6
K-L 40	70.3	63.1	70.6	62.0	70.5	62.6	-12.7
K-L 41	64.1	62.0	59.2	67.0	61.7	64.5	4.4
K-L 42	62.0	55.2	65.1	52.0	63.6	53.6	-18.6
K-L 43	63.3	60.8	63.7	60.0	63.5	60.4	-5.2
K-L 44	68.7	62.0	68.0	61.5	68.3	61.8	-10.6
K-L 45	64.2	50.8	59.6	55.1	61.9	53.0	-16.9
K-L 46	68.3	56.2	68.5	57.7	68.4	56.9	-20.1
K-L 47	74.1	68.8	78.1	69.1	76.1	68.9	-10.4
K-L 48	65.1	44.2	57.6	52.0	61.3	48.1	-27.5
K-L 49	70.2	54.4	67.2	57.2	68.7	55.8	-23.2
K-L 50	58.1	57.5	67.2	49.1	62.6	53.3	-17.5
K-L 51	60.0	57.0	60.0	57.0	60.0	57.0	-5.3

Table 2: Continue...

Table 2: Continue...

K-L 52	51.9	47.0	54.0	45.1	53.0	46.1	-15.0
K-L 53	71.2	54.6	61.3	66.7	66.3	60.6	-9.3
K-L 54	70.7	64.2	74.5	59.9	72.6	62.1	-17.0
K-L 55	63.2	66.4	66.8	63.3	65.0	64.8	-0.2
K-L 56	82.2	51.5	70.1	63.3	76.2	57.4	-32.7
K-L 57	81.1	62.1	76.2	67.1	78.7	64.6	-21.8
K-L 58	69.9	58.1	76.4	52.1	73.1	55.1	-32.7
K-L 59	73.1	70.0	71.5	72.4	72.3	71.2	-1.6
K-L 60	60.1	53.1	66.5	48.1	63.3	50.6	-25.1
K-L 61	59.2	58.3	73.4	45.2	66.3	51.7	-28.2
K-L 62	57.6	58.9	65.3	50.0	61.5	54.5	-12.9
K-L 63	68.7	63.1	69.3	62.4	69.0	62.7	-10.0
K-L 64	67.4	55.1	66.2	55.2	66.8	55.2	-21.0
K-L 65	66.1	58.2	66.2	57.9	66.2	58.0	-14.0
K-L 66	52.9	66.1	65.1	55.1	59.0	60.6	2.7
K-L 67	47.9	49.1	55.2	43.0	51.6	46.1	-11.9
K-L 68	80.3	67.2	76.4	70.9	78.4	69.0	-13.5
K-L 69	70.2	64.9	72.2	63.8	71.2	64.3	-10.7
K-L 70	61.4	53.1	65.3	49.6	63.4	51.3	-23.4
Mean	68.3	60.0	69.3	59.0	68.8	59.5	-16.5
	Genotypes						3.2
C.D	Water regime						0.6
(≤0.05)	Genotype × water regime						4.8
	Stage of measurement						0.6
	Genotype × stages of measurement						4.8
	Water regime × stages of measurment						0.8
	Genotype × water regime × stages of measurement						6.3

Table 3: Canopy temperature across two growth stages under irrigated and drought conditions in maize landraces.

Genotypes	Canopy temperature (°C)						Per cent change across stages
	2 weeks after stress		4 weeks after stress		Mean across stages		
	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought	
K-L 1	31.2	35.4	30.3	34.3	30.8	34.9	11.8
K-L 2	30.2	34.7	31.9	33.7	31.0	34.2	9.3
K-L 3	31.1	35.2	31.4	33.6	31.3	34.4	9.1
K-L 4	31.3	34.2	32.4	33.6	31.9	33.9	5.9
K-L 5	33.3	35.5	32.4	35.6	32.9	35.6	7.6
K-L 6	31.7	35.6	31.7	34.0	31.7	34.8	8.8
K-L 7	29.7	34.3	29.8	33.7	29.8	34.0	12.4
K-L 8	31.1	35.2	32.3	34.2	31.7	34.7	8.7
K-L 9	30.4	35.3	31.6	34.1	31.0	34.7	10.7
K-L 10	30.1	33.4	30.6	33.1	30.3	33.3	8.8
K-L 11	31.2	34.1	30.4	34.6	30.8	34.3	10.3
K-L 12	31.2	36.1	32.4	34.6	31.8	35.4	10.0
K-L 13	31.2	36.4	31.7	36.1	31.5	36.2	13.2
K-L 14	29.7	31.3	30.1	31.3	29.9	31.3	4.6
K-L 15	29.8	33.1	29.9	33.1	29.9	33.1	9.8
K-L 16	32.3	35.7	32.4	35.6	32.4	35.6	9.2
K-L 17	31.1	34.2	30.9	34.0	31.0	34.1	9.1
K-L 18	30.4	34.6	32.1	33.1	31.3	33.9	7.7
K-L 19	31.8	35.3	32.4	34.9	32.1	35.1	8.5
K-L 20	30.8	34.1	30.2	33.8	30.5	33.9	10.1
K-L 21	29.1	32.7	29.5	32.1	29.3	32.4	9.5
K-L 22	29.8	33.1	28.9	33.8	29.4	33.4	12.2

Table 3: Continue...

Table 3: Continue...

K-L 23	29.0	34.7	29.1	34.5	29.0	34.6	16.2
K-L 24	29.6	33.9	30.1	33.2	29.8	33.6	11.1
K-L 25	31.1	34.7	30.9	34.9	31.0	34.8	10.9
K-L 26	31.2	35.8	32.4	34.7	31.8	35.3	9.8
K-L 27	32.1	30.9	29.7	32.9	30.9	31.9	3.1
K-L 28	29.9	34.1	28.8	34.8	29.3	34.4	14.8
K-L 29	32.5	35.8	31.4	36.7	31.9	36.2	11.8
K-L 30	32.1	35.0	31.1	35.1	31.6	35.0	9.9
K-L 31	32.0	35.1	32.1	34.9	32.0	35.0	8.4
K-L 32	31.5	37.4	31.2	37.5	31.3	37.4	16.2
K-L 33	30.2	34.7	31.1	34.2	30.6	34.4	11.0
K-L 34	31.7	35.1	31.1	35.8	31.4	35.4	11.4
K-L 35	30.0	33.9	31.9	32.0	30.9	32.9	6.1
K-L 36	29.5	35.1	29.3	35.1	29.4	35.1	16.3
K-L 37	28.6	35.4	31.1	33.0	29.8	34.2	12.7
K-L 38	32.7	35.1	31.6	35.9	32.1	35.5	9.6
K-L 39	29.7	33.1	30.8	31.9	30.3	32.5	6.9
K-L 40	30.5	33.6	30.8	33.1	30.6	33.3	8.2
K-L 41	31.1	33.5	31.4	33.0	31.2	33.2	6.0
K-L 42	30.4	35.7	31.5	34.6	31.0	35.2	12.0
K-L 43	29.1	32.6	30.9	30.9	30.0	31.7	5.5
K-L 44	29.7	35.7	31.1	34.5	30.4	35.1	13.3
K-L 45	32.4	35.7	31.9	36.3	32.2	36.0	10.7
K-L 46	29.9	33.9	30.8	32.9	30.3	33.4	9.1
K-L 47	30.5	32.6	30.8	32.4	30.7	32.5	5.6
K-L 48	30.3	34.5	31.1	34.0	30.7	34.3	10.5
K-L 49	30.2	36.8	31.1	36.1	30.6	36.4	15.9
K-L 50	30.4	32.0	29.7	32.8	30.1	32.4	7.3
K-L 51	29.6	33.9	29.9	33.6	29.8	33.8	11.8
K-L 52	30.4	33.9	30.0	34.2	30.2	34.1	11.3
K-L 53	31.3	36.3	31.6	36.1	31.4	36.2	13.1
K-L 54	30.9	34.3	31.2	33.9	31.1	34.1	9.0
K-L 55	30.4	33.4	31.4	32.5	30.9	33.0	6.4
K-L 56	30.7	32.5	29.5	33.6	30.1	33.1	8.9
K-L 57	30.6	33.8	31.3	33.1	30.9	33.5	7.5
K-L 58	31.7	32.7	31.0	33.6	31.4	33.1	5.4
K-L 59	30.3	33.6	31.6	32.0	31.0	32.8	5.7
K-L 60	29.6	34.1	29.3	34.1	29.5	34.1	13.5
K-L 61	30.1	35.3	30.7	34.4	30.4	34.9	12.8
K-L 62	31.6	35.3	32.1	34.8	31.9	35.1	9.0
K-L 63	31.0	34.0	30.2	34.8	30.6	34.4	10.9
K-L 64	30.0	34.7	30.6	33.8	30.3	34.2	11.6
K-L 65	33.0	36.1	32.4	36.7	32.7	36.4	10.0
K-L 66	28.4	32.6	28.8	32.4	28.6	32.5	12.1
K-L 67	30.1	34.7	31.8	33.1	31.0	33.9	8.7
K-L 68	30.9	33.1	30.8	33.3	30.9	33.2	7.1
K-L 69	30.0	33.0	29.7	33.1	29.8	33.0	9.7
K-L 70	30.4	34.1	30.8	33.6	30.6	33.9	9.6
Mean	30.7	34.4	30.9	34.0	30.8	34.2	9.9
	Genotypes						1.3
C.D	Water regime						0.2
(≤0.05)	Genotype × water regime						1.8
	Stage of measurement						0.2
	Genotype × stages of measurement						1.8
	Water regime × stages of measurement						0.3
	Genotype × water regime × stages of measurement						2.6

Table 4: Cell membrane stability and chlorophyll content under irrigated and drought conditions in maize landraces.

Genotypes	Cell membrane stability (%)		Chlorophyll content (SPAD units)	
	Irrigated	Drought	Irrigated	Drought
K-L 1	71.9	45.6	34.8	20.4
K-L 2	81.7	71.1	38.3	28.2
K-L 3	78.1	64.2	31.2	23.3
K-L 4	67.2	52.3	33.1	20.3
K-L 5	76.3	71.7	33.1	29.1
K-L 6	66.2	41.3	30.8	28.4
K-L 7	81.2	61.1	31.2	29.2
K-L 8	71.1	55.1	30.2	18.9
K-L 9	73.0	56.1	34.1	20.1
K-L 10	75.1	55.2	39.2	20.4
K-L 11	77.1	54.8	34.6	22.7
K-L 12	84.2	71.4	37.1	30.7
K-L 13	79.2	53.2	33.1	29.0
K-L 14	71.1	51.3	34.0	21.5
K-L 15	72.5	46.5	35.3	19.5
K-L 16	70.8	52.3	31.0	20.4
K-L 17	76.4	59.2	33.1	24.1
K-L 18	77.3	71.9	29.0	28.4
K-L 19	81.1	59.2	33.0	19.4
K-L 20	77.2	50.6	34.2	18.5
K-L 21	79.2	54.7	38.1	18.8
K-L 22	80.4	50.8	37.7	21.4
K-L 23	72.0	52.2	36.0	22.4
K-L 24	67.0	64.1	30.6	21.8
K-L 25	71.6	56.0	32.9	22.4
K-L 26	69.7	57.0	32.8	21.3
K-L 27	70.7	63.9	33.6	22.4
K-L 28	72.4	68.2	30.4	23.3
K-L 29	70.5	52.2	32.4	18.6
K-L 30	69.2	53.2	30.5	19.4
K-L 31	71.6	59.3	32.4	20.3
K-L 32	76.9	57.4	30.3	19.3
K-L 33	70.9	55.1	32.5	20.3
K-L 34	77.2	59.8	35.6	22.5
K-L 35	70.5	60.6	32.9	28.7
K-L 36	66.2	63.2	34.3	29.5
K-L 37	80.7	70.5	33.8	30.5
K-L 38	70.7	49.7	35.0	19.3
K-L 39	72.7	60.1	30.7	22.4
K-L 40	76.0	59.2	32.7	23.6
K-L 41	70.4	57.1	32.4	28.3
K-L 42	70.9	48.6	33.5	21.8
K-L 43	72.4	58.2	33.6	22.4
K-L 44	74.6	59.2	30.6	21.3
K-L 45	70.4	46.3	31.4	18.3
K-L 46	72.9	49.6	30.5	19.3
K-L 47	79.2	61.5	34.5	22.4
K-L 48	68.5	51.2	32.3	20.4
K-L 49	74.0	57.2	29.2	29.4
K-L 50	71.0	51.1	32.5	28.1
K-L 51	66.2	57.9	29.7	28.8
K-L 52	66.8	51.2	30.5	19.5
K-L 53	71.2	50.8	30.6	18.8
K-L 54	73.2	58.9	32.6	19.8
K-L 55	70.6	58.1	33.8	22.4
K-L 56	65.2	59.0	33.6	23.6
K-L 57	70.8	56.1	34.6	21.6
K-L 58	71.7	50.8	33.5	22.6
K-L 59	78.1	71.2	32.4	20.4
K-L 60	66.1	48.2	29.6	18.4
K-L 61	67.0	56.2	30.3	22.5
K-L 62	65.0	55.0	32.7	21.5
K-L 63	73.6	58.6	30.4	29.2
K-L 64	70.7	51.0	33.8	28.8
K-L 65	76.2	57.1	39.0	22.5
K-L 66	64.0	55.0	30.8	28.9
K-L 67	68.2	51.1	34.8	30.6
K-L 68	83.1	71.1	40.7	29.0
K-L 69	75.1	60.2	40.0	23.8
K-L 70	70.8	55.2	30.9	22.5
Mean	72.9	56.9	33.1	23.2
Mean per cent		-28.1		-42.6

Table 4: Continue...

Table 4: Continue...

values are used to evaluate genotypes with better drought tolerance; the greater the value, the more chlorophyll content.

CONCLUSION

Maize landraces tested against the drought stress showed much significant variation and K-L 25 for rooting depth, root biomass allocation and root to total biomass, K-L 35 for shoot biomass, root depth, root biomass allocation, root volume, RWC and chlorophyll content, K-L 43 for shoot biomass, root biomass allocation and root volume exhibited better parameters for drought stress signifying their utilization as donors for integration of drought tolerance into the genetic makeup of popular varieties.

Author contribution

The idea of the work was given by Zahoor A Dar and Aijaz A Lone, the work was done and manuscript preparation was done by Latif Ahmad peer. Mohd Yaqub Bhat guided throughout the research and manuscript preparation. All authors reviewed and finalized the manuscript.

Conflict of interest: None.

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