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Morpho-physiological characterization maize (*Zea mays* L.) under terminal heat stress

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Abstract
An investigation was carried out at experimental research farm of Wheat and Maize Research station, Parbhani during 2024-25. Fifty-three genotypes of maize were studied to characterize fifty-three maize inbred lines for their heat tolerance ability on the basis of morpho-physiological traits. These genotypes were evaluated during 2024-25 in randomized block design with two replications at experimental farm Wheat and Maize Research Station, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (Maharashtra). Data was recorded for different heat stress related primary and secondary plant traits i.e. days to 50% tasseling, days to 50% silking, anthesis-silking interval, plant height, thousand grains weight, grains yield per plant, LAI, MSI and SCMR value. The result revealed based on performance of different inbred lines for day to 50% tassel genotype IMLSB 2037 and CML 74 were identified as heat tolerant. Genotype with lower days to 50% silking are generally early maturing which helps the plant to avoid heat stress. The lowest meant value of days to 50% silking was observed in genotype VS 143 during *rabi*. The genotype IMLSB 2037 and VS 143 were identified as highly tolerant to heat in case of days to 50% silking. The increase in ASI was less in genotype IMLSB 2013. In case of plant height and ear height the genotype EC 656087⊗⊗⊗⊗ were identified as highly tolerant to heat stress. The genotypes DML 1276, EC 655966(B) ⊗⊗⊗, IAMI 27-⊗⊗⊗, V1489-13 and VL172416 shows minimum reduction in case of thousand grains weight. In terms of grains yield per plant the genotype EC 656087(B)⊗⊗⊗ were identified as tolerant to high temperature.
Leaf area index significantly influenced by high temperature which reduced photosynthetic surface area and consequently the potential for yield reduced. The maximum leaf area index was observed in genotype VL172416 (2.76). The genotype EC 656087(B)⊗⊗⊗⊗ and VL172416 were identified as heat tolerant. SCMR value (chlorophyll reading) during *rabi* was maximum in genotype VL172416 (67.01) while, minimum in genotype IMLSB 537-2 (33.055). The genotype EC 656087⊗⊗⊗⊗ and VL172416 were identified as highly tolerant under heat stress. Membrane stability index reduced during high temperature due to increase kinetic energy of molecules across membrane. In genotype CM 144 the MSI reduction was more while, in 118760 it was less as compared to all other genotypes. The genotypes EC 672603⊗⊗⊗, IMLSB 2013, IMLSB 2166 and V1489-10 shows notable increase MSI as compared to *kharif*.

Keywords: Maize, heat stress, genotypes, MSI, LAI, SCMR

1. Introduction

Maize (*Zea mays* L., 2n = 2x = 20), a member of the *Poaceae* family and tribe *Maydeae*, originated in North America. After rice and wheat, maize is the third most significant food crop in the world. The "Queen of Cereals," maize, is a staple crop that is used for animal feed as well as human consumption. In addition to its use in the beverage, pharmaceutical and cosmetic industries as well as the generation of bioenergy, it has emerged as a vital resource for industrial uses such as corn oil, corn starch and corn syrups (Chen *et al*., 2012) [8]. One of the most adaptable and multipurpose crops in the global agricultural economy, its use in human food, animal feed, chicken feed, fuel, the starch industry and the possibility of exports has increased demand of maize in India and all over the world. According to Singh *et al*. (2019) [26], the percentage of maize used for food, animal feed, poultry feed, starch and seed is 34, 40, 12, 10 and 2% respectively. Under ideal crop management and environmental circumstances, maize yields a lot of grain. However, it is extremely vulnerable to heat and drought. These stressors cause an average of 15 to 20 percent of the world's potential maize yield to be lost annually (FAO STAT 2006-2008). The timing of the stress (plant growth stage), its length and its intensity all affect the overall yield loss.

Maize is the third most important crop in India after Rice and Wheat. In the world, India's ranks 5th in acreage and 8th in production of maize. Globally, total area of Maize was 186.86 M ha, production 1078.56 mt. In India, during 2023-24, area under Maize has been sown in around 112.41 lakh hectares as compared to 107.44 lakh hectares during kharif 2022-23. Major maize growing states in India are Karnataka, Madhya Pradesh, Maharashtra, Bihar. Maharashtra area cover under Maize cultivation is 13.26 lack ha and the production of maize during the year 2024-25 was 42.66 lack tonnes.

Maize output and productivity are known to be limited by heat stress and yields are predicted to decrease by 7.4% for every 1.0 °C increase in ambient temperature. Temperature variations cause a 20% reduction in corn output in India. Maize growth is negatively impacted by temperatures above 32 °C. This results in a decreased net photosynthetic rate, a higher transpiration rate, slower plant growth, tassel blasting, an increase in ASI, poor silk receptivity, pollen abortion and ultimately poor seed set. Another common abiotic stressor that could cause 15% of the possible loss in maize output worldwide is drought (Edmeades, 2000) [13]. Due to stomatal closure, metabolic constraints, and oxidative damage to chloroplasts, drought impairs the morphological, physiological and molecular aspects of maize growth and development. These effects include delayed lowering, decreased dry matter accumulation, decreased partitioning and decreased photosynthetic capacity. Therefore, it is imperative to breed maize to withstand heat and drought.

According to Thompson (1966) [27], raising the temperature from 22 to 28 degrees Celsius during the grain filling stage reduces yield by 10% and raising mean daily temperatures by 6 degrees Celsius reduces yield by 42% (Badu-Apraku *et al*., 1983) [4]. According to Lobell *et al*. (2011) [19], the productivity of maize declined linearly for each degree day when temperatures rose above 30 °C. In heat-stressed maize production, phenology is also important (Muchow *et al*., 1990) [21]. Reproductive and vegetative tissues react differently to heat stress. Under extreme heat stress, even the reproductive tissues of men and women differ (Dupis and Dumas, 1990) [12]. A recent study found that grain yield under heat stress depends critically on the time between silk pollination and ovarian fertilization (Cicchino *et al*., 2010) [9]

A phenomenon known as "leaf burning" occurs when developing leaves are exposed to extremely high temperatures, causing irreversible tissue damage and rapid drying out of the damaged tissues. Additionally, it may result in tassel blasting, which is the desiccation of tassel tissues. Severe leaf fire and tassel blasting plants generate undersized ears, exhibit decreased kernel set and weight and lose a significant amount of photosynthetic leaf area. Significant yield loss results from moderate heat stress during the early phases of reproduction, which lowers pollen production, pollination rate, kernel set and kernel weight (Shaw 1983) [25].

2. Materials and Methods

2.1 Experimental material, design and location

The present investigation was conducted during 2024-2025 at Wheat and Maize Research Unit, VNMKV, Parbhani. Site of experiment is located at 19.2608ºN and 76.7748ºE at height of 357 m above the sea level and the soil are loamy type with clay. Fifty-three inbred lines were laid out under randomized block design having spacing of 60 x 25 cm. The lines were sown under *kharif* season on 9th July 2024 while during rabi season on 28th November 2024.

2.2 Data acquisition and statistical analysis

Data for different phonological traits i.e. days to 50% tasseling, days to 50% silking, anthesis silking interval, leaf area index, membrane stability index and SCMR value was recorded at suitable phenophases. At physiological maturity, data was also recorded for plant height (PH), thousand grains weight (TGW) and grain yield per plant (GY). Data was statistically analyzed for analysis of variance (ANOVA). Two statistical packages, OPSTAT and GRAPES were used to analyzed the data.

3. Results and Discussion

3.1 Analysis of variance

Pooled data of all morpho-physiological and yield-attributing traits were used to calculate coefficient of variance (CV) at 5 percent level of significance for *kharif* and rabi conditions. In *kharif* season, significant difference was observed within genotype for all morpho-physiological. Anthesis silking interval and 100 grains weight accounted for maximum coefficient of variance of 19.99 and 17.10 respectively. Minimum coefficient of variance of 0.89 was observed in LAI followed by MSI (0.73).

During *rabi* season, significant difference was observed within genotypes for all morphological characters. ASI (15.23) accounted for maximum coefficient of variance. Minimum coefficient of variance of 0.92 was observed in LAI followed by MSI (1.44)

Table 1: Analysis of variance for various morpho-physiological traits under *kharif* season.

SoV	Df	DT	DS	ASI	PH	TGW	GY	SPAD	MSI	LAI
Treatment	52	5725.51**	1215.57**	235.36**	23350.85**	5436.96**	790248.33**	9182.41**	12973.26**	21.50**
Replication	1	16.64	0.6	0.34	8.04	9.98	46.174	48.26	0.01	0
Error	52	857.36	750.40	15.66	2835.35	1282.27	858.055	777.22	8.07	0.02

Table 2: Analysis of variance for various morpho-physiological traits under *rabi* season.

SoV	Df	DT	DS	ASI	PH	TGW	GY	SPAD	MSI	LAI
Treatment	52	1520.04**	2675.06**	63.66**	20039.46**	4717.29**	781010.78**	7286.59**	11326.59**	17.52**
Replication	1	3.06	25.51	0.15	20039.46	19.68	27.45	25.41	0.05	0.00
Error	52	564.94	622.49	7.85	3507.49	271.93	835.46	446.38	4.03	0.03

**-significance at 5% level (0.05)

3.2 Days to 50% tassel (Days)
Genotype requiring a smaller number of days to 50% tassel are highly desirable. Mean value of this trait during *kharif* varied from 56 days (VL192697) to 74.5 days (DML 1276) while, in *rabi* it ranged from 61.5 days (EC 656087(B)⊗⊗⊗) to 95.5 days (VS 143). Number of days required to 50% tassel during *Kharif* for check Phule Maharshi 66 days, Rajashri 63 days and Phule Champion 67 days while, in *rabi* it is 83 days, 65 days and 73 days for Phule Maharshi, Rajashri and Phule Champion respectively. Days to 50% tassels varied significantly among fifty-three different genotypes in both under *kharif* and *rabi* planting season. Percent increases from *kharif* to *rabi* season in days to 50% tassel of genotype IMLSB 2037 (0.76%) was significantly lower than all other genotypes but it was maximum in case of genotype VS 143 (49.21%).
This finding is in accordance with Badu-Apraku *et al*. (1983) [4], Ahmed *et al*. (2000) [2], William (2008) [29] and Amjadian *et al*. (2013) [3]. The high-temperature thresholds for maize have been reported as 39.2 °C (±0.6 °C) from emergence to the end of tassel initiation, 37.3 °C (±1.3 °C) in anthesis and 36.0 °C (±1.4 °C) in the grain filling period (Sanchez *et al*., 2014). Variation in phenological stages of hybrid had also been reported by Tsimba *et al*. (2013) [28].

3.3 Days to 50% silking (Days)
Days to 50% silking during *Kharif* ranged from 55.5 days (SNL 18966) to 75.5 days (IMLSB 537-2) while, in *rabi* it varied from 69.5 days (VS 143) to 82.5 days (HKI 1105). Number of days to 50% silking in *kharif* for check Phule Maharshi, Rajashri and Phule Champion was 61.5 days, 62.5 days and 69.5 days respectively. During *rabi* number of days required to 50% silking for check Phule Maharshi was 71 days, Rajashri was 68 days and Phule Champion was 71 days. Percent increase from *kharif* to *rabi* in days to 50% silking of genotype KL154667 (35.08%) was maximum than all other genotype but it was minimum in case of genotypes IMLSB 2037 (0.68%) and VS 143 (0.72%).
Days to 50% silking is an important trait with respect to heat stress response as the inbred lines with lower days to 50% silking are generally early maturing which helps the plants to avoid heat stress. Time to silking can vary as much as 20 days for the same hybrid when average temperature increases from 20 °C to 32 °C during the growing season as reported by Bonhomme *et al*. (1994)

3.4 Anthesis-silking interval (ASI)
ASI of all fifty-three genotypes significantly increased under *rabi* season as compare to *kharif* and a significant difference was observed in temperature and genotype interaction on ASI. The increase was prominent in case of genotype IMLSB 393-1 and IMLSB 2077 with 1 day in *kharif* to 5.5 days in *rabi*. The increase in ASI was less in genotypes IMLSB 2013 as compare to other genotypes.
Significant increases in ASI under heat stress were noted in the current study as compared to normal conditions. Similar results were reported by Mhike *et al*. (2012) [20], who suggested that the significant increases in ASI in maize under heat stress may be caused by a delay in silking. This means that when the temperature rises by + 30 °C, pollen shedding begins much earlier than the emergence of silks and silking is delayed. As a result, the silking period does not correspond with anthesis/tasseling, which leads to poor flowering synchronization.

3.5 Plant height (cm)
A comparison was made between the plant heights of the fifty-three genotypes produced under heat stress (*rabi*-planted maize) and under ideal conditions (*kharif*-planted maize). For each of the fifty-three genotypes of maize, comparing *rabi* planting to *kharif* planting, there was a considerable fall in plant height. The fifty-three genotypes' mean plant height decreased from 159.5 cm during *kharif* to 147.25 cm during *rabi*. The genotype EC 672609⊗⊗⊗ showed the least reduction 0.66%, but genotype HKI 1105 (20.67%) showed a noticeably larger reduction. The genotype EC 656087⊗⊗⊗⊗ shows some tolerance to heat, plant height increases in spring as compared to *kharif* from 139.55 cm to 187.5 cm.
Season and genotype interaction on plant height (S X G) showed a significant difference. This outcome is in line with findings reported by Sabiel *et al*. (2014) [22] in their study, which examined significant difference for plant height among the genotypes across two different environments in Sudan. Under heat stress, reduction of plant height and girth was also observed by Cairns *et al*. (2013) [7].

3.6 Thousand grains weight (g)
Under *kharif* season, thousand grain weight of the fifty-three genotypes ranged from 16.5 g (V1489-10) to 46.85 g (IMLSB 393-1) with an overall mean of 29.04 while, under high temperature stress, it ranged from 13.85 g (IMLSB-1025-1) to 43.425 g (CML 420) with an overall mean of 26.44. High temperature (in spring season) had significant influence on thousand grains weight among fifty-three different genotypes.
The results under heat stress showed that percent change in case of genotype CM 144 was minimum (0.017%) and maximum in case of genotype IMLSB 393-1 (40.12%). In experiment, genotype DML 1276, EC 655966(B) ⊗⊗⊗, EC 672591⊗⊗⊗, IAMI 27-⊗⊗⊗, V1489-13 and VL172416 shows the minimum reduction as compared to other fifty-three genotypes.
Kernel weight is influenced by source-sink relationships during grain fill with increased kernel weight being caused by irradiance level, grain-fill duration, and plant and kernel growth rate. The reduction of thousand kernel weight in agreement with findings.

3.7 Grains yield per plant (g)
Grains yield per plant was lower under high temperature than that of optimum temperature (*kharif* season) in all fifty-three genotypes. The experimental data of grains yield per plant showed that during *kharif* it ranged from 29.24 g to 645.05 g with mean value 76.52 while, in *rabi* it ranged from 17.75 g to 629.1 g with the mean value 58.65. Under *rabi* maximum reduction in grains yield per plant was observed in genotype DML 1010 (1.96%), while in case of genotype DQL 2017-1-1-2 (69.34%) minimum reduction was observed. In case of EC 656087(B)⊗⊗⊗ the grains yield per plant was increase as compare to *kharif*.
The area of the grain sink and eventually, yield were decreased when maize kernels exposed to temperatures above 30 °C experienced damage to cell division and amyloplast replication (Commuri and Jones, 2001) [10]. Lobell and Field (2007) [18] demonstrated that, without any complicating effects from water stress, maize yields fell 8.3% for every 1 °C increase. Low pollen viability, silk receptivity and a longer ASI duration under heat stress may be the causes of the 70% loss in grain yield that Khodarahmpour *et al*. (2012) [17] reported.

Table 3: Influence of different planting season on days to 50% tasseling, days to 50% silking, anthesis silking interval and plant height of fifty-three maize genotypes.

Genotypes	*Kharif*				*Rabi*			
	DT	**DS**	**ASI**	**PH**	**DT**	**DS**	**ASI**	**PH**
CML 342	69	73.5	2	165.25	70.5	77.5	2.5	151.0
CML 420	64.5	71.5	3.5	167.965	73.5	73.5	5.5	165.0
CML 74	69	59	1.5	166.55	69.5	76	2.5	150.5
DML 1010	59.5	61	1.5	155.72	62	70	5.5	142.5
DML 1276	74.5	71	1	164.55	75	77	2	134.5
DML 1432	71	59.5	1	176.87	78.5	78.5	4	145.5
DML 1820	69.5	74	1	165.45	85	75	2	148.5
DML 2037	60	62	1.5	170.15	65	74	4.5	160.5
DQL 2017-1-1-2	66.5	59.5	1	156.4	74	76	3	158.5
DQL 2186	69	73.5	2	166.4	73.5	78	2	159.0
CM 144	65.5	65	3	151.5	67.5	72	3	145.5
KDMI 15	61	67.5	1	143.2	78.5	77	3.5	132.5
EC 655729	65	69.5	2	157.775	68.5	74	3	148.5
EC 655740B-1	64.5	67	1	167.8	75.5	74	3.5	136.5
EC 655966(B) ⊗⊗⊗	61	65.5	1.5	176.25	84	79	2.5	162.5
EC 656087⊗⊗⊗	58.5	69.5	1	153.7	70.5	75.5	1	152.0
EC 656087(B)⊗⊗⊗	65	64	1	184.95	61.5	74.5	2.5	152.5
EC 656087⊗⊗⊗⊗	66	66.5	3	139.55	72	77	3.5	187.5
EC 672486⊗⊗⊗	65	71.5	1.5	154.9	69.5	72.5	5	129.0
EC 672591⊗⊗⊗	68.5	69.5	3	130.2	81	72	4	144.5
EC 672603⊗⊗⊗	68.5	69.5	2	144.75	73.5	78.5	6	119.0
EC 672609⊗⊗⊗	68	72.5	2	157.55	82.5	82	2	156.5
VL153192	66	71.5	4	133.45	69.5	77	4.5	128.5
VL109579	62	65.5	1.5	165.8	66.5	72.5	2	148.0
KL154667	58	57	2	153.45	83.5	77	4.5	121.9
VL109507	69	72.5	3	168.3	72.5	73.5	7	154.5
VL181521	69.5	73.5	2	149.25	73	81.5	2	143.0
VL181513	59	61.5	2.5	167.8	64	74	5	157.5
HKI 1105	65.5	71	2	175.85	74	82.5	3	139.5
HKI 1344	68	70.5	2.5	128.75	69	81.5	3	109.5
VS 88	65	71.5	2	145.0	74	81.5	4	128.0
IAMI 27-⊗⊗⊗	64	68.5	1	175.5	62.5	73.5	1	168.0
VS 143	64	69	3	167.7	95.5	69.5	4	156.0
IMLSB 2013	67	69	0.5	146.85	71.5	73	1	136.5
IMLSB 2037	65	72.5	3	159.65	65.5	73	3	150.0
IMLSB 2077	67	68.5	1	148.15	69	77	5.5	138.5
IMLSB 2166	69	74	3	167.65	82.5	82	4	165.2
IMLSB 219-1	67.5	71	2	157.9	69	77.5	4	149.005
IMLSB 375-1	66	69.5	2.5	177.65	80.5	76	3.5	164.1
IMLSB 393-1	69.5	74.5	1	163.55	70	78.5	5.5	152.5
IMLSB 46-1	64	67.5	2	135.55	74.5	73.5	3.5	124.5
IMLSB 537-1	60.5	68.5	2	155.5	82	79.5	5.5	142.5
IMLSB 537-2	68	75.5	2	165.7	69.5	79.5	4	145.0
IMLSB 814-2	69	73.5	1.5	177.55	77.5	77	1.5	167.5
IMLSB-1025-1	64	67	2.5	182.55	87.5	76	5.5	170.0
V1489-10	65	72	2	162.35	76.5	78.5	3.5	151.5
V1489-13	69	72.5	2	140.0	60	74	1	129.85
VL172416	68.5	72	1.5	159.75	76.5	76	4.5	148.5
VL192697	56	58.5	3.5	133.7	86.5	75.5	4.5	123.25
SNL18966	58	55.5	2	156.2	72.5	72	6	146.2
Phule Maharshi	66	61.5	2	172.11	83	71	2.5	157.9
Phule champion	63	62.5	2	173.535	65	68	6.5	165.5
Rajashri	67	69.5	1.5	169.135	73	71	3	140.0
Mean	65.43	68.09	1.94	159.5	73.72	75.77	3.60	147.25
SE±	2.33	2.45	0.27	5.81	2.87	2.69	0.39	5.22
CD	6.61	6.94	0.78	16.48	8.14	7.62	1.10	14.82
CV%	5.04	5.08	19.99	5.15	5.51	5.01	15.23	5.01

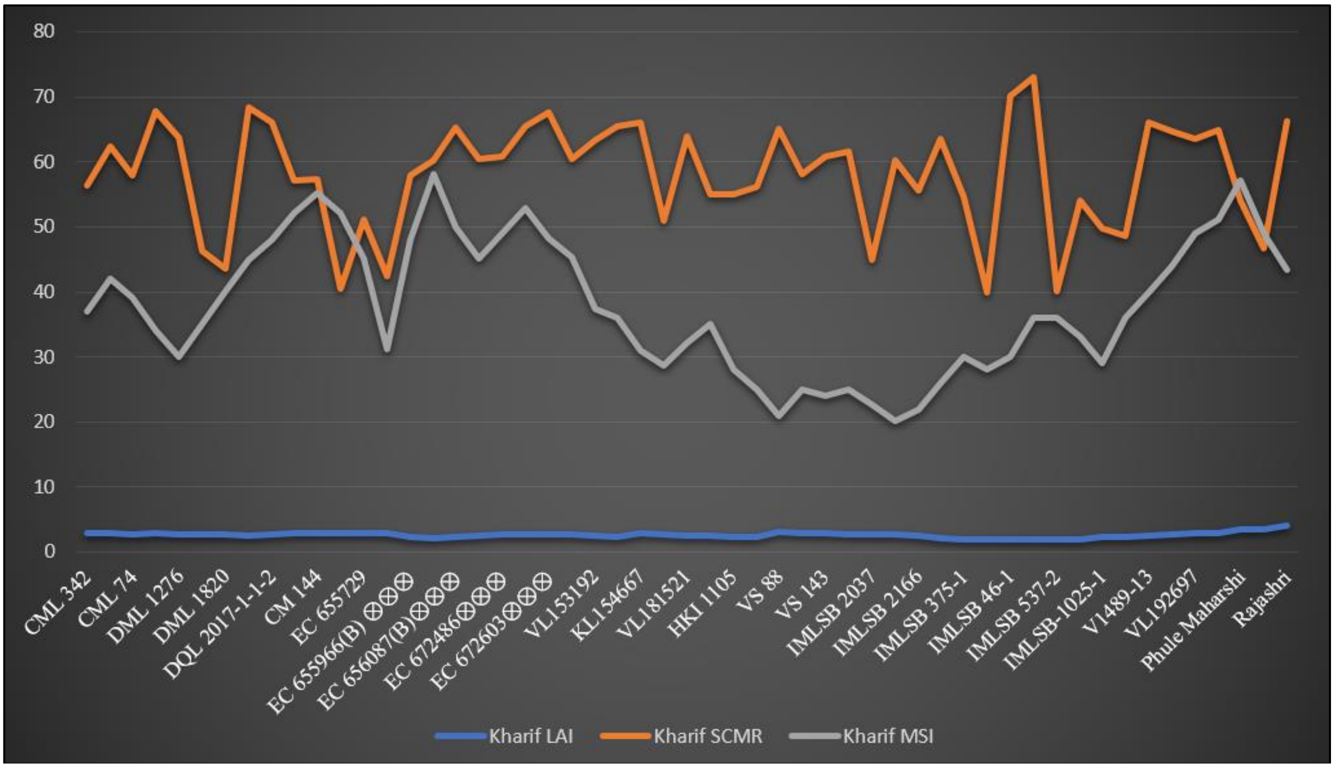

Fig 1: Mean performance of fifty-three maize genotypes on traits under *kharif* season.

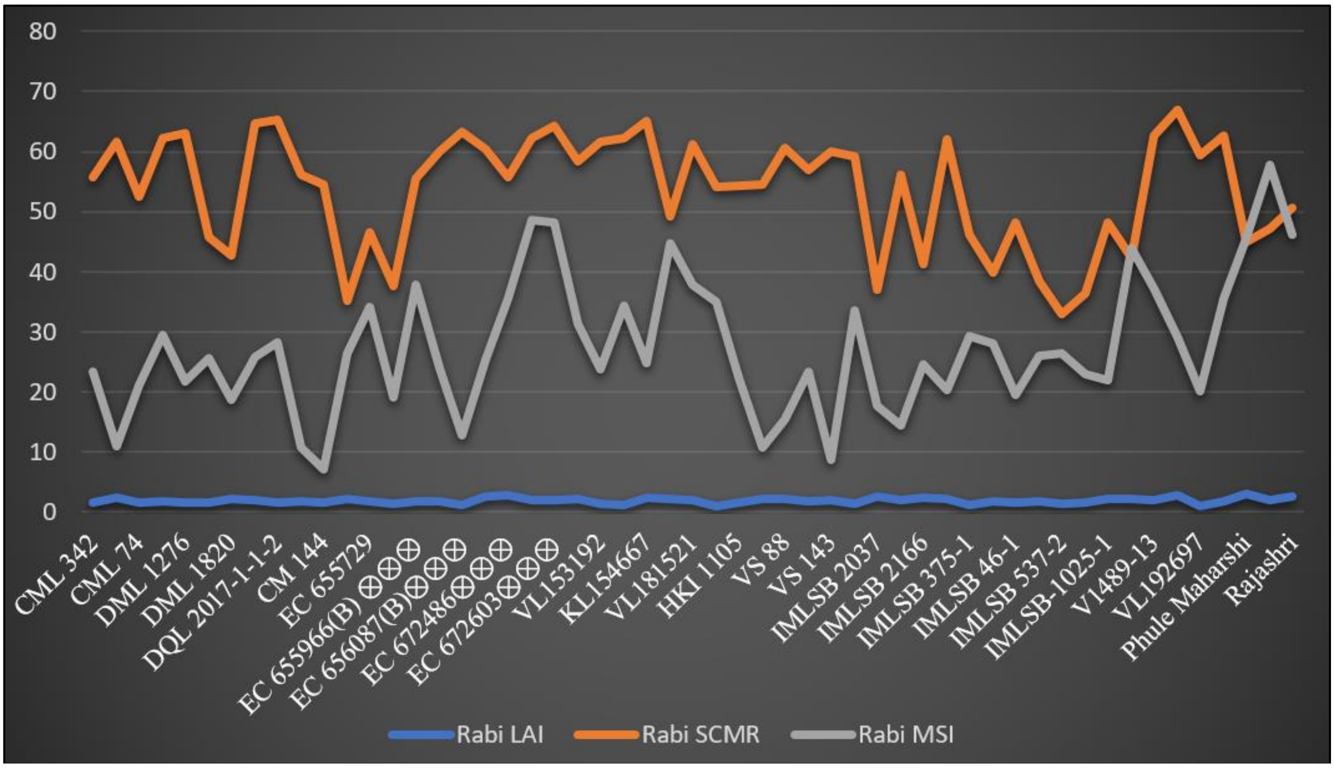

Fig 2: Mean performance of fifty-three maize genotypes on traits under *Rabi* season.

3.8 Leaf area index (LAI)

In *rabi* season, leaf area index was found to be lower than that under *kharif* season in all fifty-three genotypes. The experimental data revealed that this ranged from 1.865 to 4.005 with mean value 2.65 during *kharif*, while in *rabi* it ranged from 1.045 to 2.98 with mean value 1.89. Under *rabi* maximum reduction in leaf area index was found in VL 192697 (64.47%), while minimum reduction was found in EC 672486⊗⊗⊗ (1.80%). This finding was agreement with earlier finding reported by (Danalatos *et al*. 1994) [11]. Karim *et al*., (2000) [16] also noted that leaf area and day time leaf expansion rate were good thermo-tolerance trait of tropical maize under heat stress condition. In experiment the genotype VL172416 and EC 656087⊗⊗⊗⊗ were identified as heat tolerant in term of LAI.

Leaf area index of the decreases was observed after severe heat waves due to leaf growth pattern of maize increases in rang of temperature 0-35 °C with decline at 35-40 °C. Leaf area expansion is of great importance for light interception and for photosynthesis; it varies with the quantity of assimilates allocated to the production of leaves and the ratio of the leaf area produced per unit of leaf dry matter. Heat stress causes translocation of the photosynthetic products cannot fully match the increased rates of carbon fixation under the prevailing conditions, this results in the thickening of the existing leaves and the formation of thicker new leaves, and therefore in a sharp decrease of leaf area in the pre-anthesis period. It can also be noted that the LAI is maximum at tasseling or later and further slight decrease.

3.9 SCMR value

Heat stress less influenced on chlorophyll content as compare to other traits of maize. The experimental data revealed ranged of SCMR value (chlorophyll content) from 40 to 73.04 with a mean value 58.14 in *kharif* while, under high temperature it ranged from 33.055 to 67.01 with mean value 55.69. In *kharif* maximum chlorophyll content was observed in genotype IMLSB 537-1 (73.04) followed by genotype IMLSB 46-1 (70.065), DML 1010 (67.885), EC 672603⊗⊗⊗ (67.595) and V1489-13 (66.075). During *rabi* percent decrease of SCMR value was maximum of genotype IMLSB 537-1 (47.42%) while, in genotype EC 656087⊗⊗⊗⊗ (60.4) it remains same for both seasons.

Remarkably, the outcomes of this trait align with those reported by Balbaa *et al*. (2022) [5], who conducted research on maize to evaluate growth, yield and its components under stress. The congruence between our finding and the study by Balbaa *et al*. (2022) [5] highlights the less influenced of heat stress on chlorophyll content as compare to other character. In our experiment were genotype EC 656087⊗⊗⊗⊗ identified as highly tolerant under heat stress as compared to all other fifty-three genotypes.

3.10 Membrane stability index (MSI)

Significant differences were observed between all the fifty-three genotypes for MSI under heat stress as compare to *kharif*. At *kharif* season MSI varied from 20.135 to 58.04 with mean value 38.01 and maximum MSI was found in genotype EC 656087⊗⊗⊗ (58.04) followed by genotypes CM 144 (55.255) and KDMI 15 (52.1). In *rabi*, under heat stress MSI ranged from 7.14 to 57.855 with mean value 27.29 and maximum percent reduction of MSI was observed in genotype CM 144 from 55.255 to 7.14 (87.07%) but, some genotypes like EC 672603⊗⊗⊗ (0.08%), IMLSB 2013 (34.05%), IMLSB 2166 (11.77%), and V1489-10 (21.71%) showed increase MSI as compared to *kharif*.

The outcome line with the study of Savchenko *et al*. (2002) [24] who states that the kinetic energy of molecules across membranes increases due to an increase in unsaturated fatty acids or protein denaturation at high temperatures, which causes the membrane to loosen. In our experiment, we also found a significant decrease in membrane stability, which was greater in genotype CM 144 than in *kharif*.

Table 4: Influence of different planting season on leaf area index, SCMR value and membrane stability index of fifty-three maize genotypes.

Genotypes	*Kharif*			*Rabi*		
	LAI	SCMR	MSI	LAI	SCMR	MSI
CML 342	2.985	56.29	37	1.495	55.75	23.355
CML 420	2.855	62.325	42.135	2.29	61.665	10.995
CML 74	2.77	57.995	39.065	1.665	52.45	21.13
DML 1010	2.9	67.885	34.085	1.765	62.215	29.515
DML 1276	2.775	63.65	30	1.48	63.00	21.74
DML 1432	2.765	46.32	35.05	1.525	45.7	25.605
DML 1820	2.675	43.55	40.05	2.21	42.755	18.67
DML 2037	2.585	68.45	45.005	1.96	64.615	25.875
DQL 2017-1-1-2	2.69	66.1	48.05	1.525	65.395	28.18
DQL 2186	2.97	57.165	52.05	1.765	56.115	10.64
CM 144	2.87	57.375	55.255	1.645	54.58	7.14
KDMI 15	2.985	40.405	52.1	2.12	35.2	26.35
EC 655729	2.875	51.165	45.095	1.825	46.605	34.055
EC 655740B-1	2.89	42.355	31.21	1.46	37.53	19.03
EC 655966(B) ⊗⊗⊗	2.34	57.945	48.095	1.755	55.485	37.8
EC 656087⊗⊗⊗	2.225	60.325	58.04	1.81	60.05	23.965
EC 656087(B)⊗⊗⊗	2.365	65.185	50.05	1.175	63.2	12.795
EC 656087⊗⊗⊗⊗	2.535	60.4	45.085	2.535	60.4	25.45
EC 672486⊗⊗⊗	2.775	60.855	49.05	2.725	55.64	35.675
EC 672591⊗⊗⊗	2.635	65.375	52.91	2.055	62.3	48.625
EC 672603⊗⊗⊗	2.775	67.595	48.145	2.005	64.2	48.185
EC 672609⊗⊗⊗	2.665	60.46	45.25	2.21	58.35	31.2
VL153192	2.575	63.35	37.47	1.455	61.665	23.7
VL109579	2.315	65.44	36.1	1.095	62.19	34.395
KL154667	2.865	66.05	31.095	2.35	65.1	24.76
VL109507	2.645	50.935	28.7	2.095	49.15	44.755
VL181521	2.535	63.9	32.095	1.895	61.255	37.835
VL181513	2.475	55.11	35.00	1.045	54.015	34.89
HKI 1105	2.385	55.06	28.045	1.65	54.35	22.395
HKI 1344	2.35	56.2	25.09	2.095	54.55	10.695
VS 88	3.1	65.12	21.00	2.21	60.63	15.44
IAMI 27-⊗⊗⊗	2.985	58.16	25.05	1.875	56.855	23.29
VS 143	2.885	60.82	24.00	1.94	60.03	8.685
IMLSB 2013	2.775	61.6	25.045	1.41	59.115	33.575
IMLSB 2037	2.74	44.85	22.72	2.65	37.03	17.645
IMLSB 2077	2.685	60.2	20.135	1.96	56.13	14.395
IMLSB 2166	2.475	55.52	21.995	2.34	41.26	24.585
IMLSB 219-1	2.225	63.595	26.00	2.25	62.11	20.33
IMLSB 375-1	1.985	54.72	30.05	1.075	46.245	29.225
IMLSB 393-1	1.875	40	28.05	1.855	39.93	28.05
IMLSB 46-1	1.865	70.065	30.00	1.54	48.11	19.4
IMLSB 537-1	1.965	73.04	36.05	1.875	38.4	25.935
IMLSB 537-2	1.885	40.015	36.09	1.45	33.055	26.38
IMLSB 814-2	2.045	54.115	33.075	1.53	36.44	22.87
IMLSB-1025-1	2.285	49.71	29.00	2.23	48.16	21.87
V1489-10	2.335	48.55	36.05	2.095	42.26	43.88
V1489-13	2.565	66.075	40.00	1.95	62.63	37.195
VL172416	2.745	64.715	44.05	2.76	67.01	29.1
VL192697	2.885	63.62	49.00	1.025	59.46	20.125
SNL18966	2.985	64.965	51.05	1.785	62.58	35.605
Phule Maharshi	3.415	54.095	57.115	2.98	44.905	45.55
Phule champion	3.56	46.62	49.05	2.05	47.23	57.855
Rajashri	4.005	66.275	43.425	2.65	50.72	46.22
Mean	2.65	58.14	38.01	1.89	53.69	27.29
SE±	0.02	2.07	0.20	0.01	2.73	0.28
CD	0.05	5.88	0.56	0.03	7.76	0.79
CV%	0.89	5.04	0.73	0.92	7.20	1.44

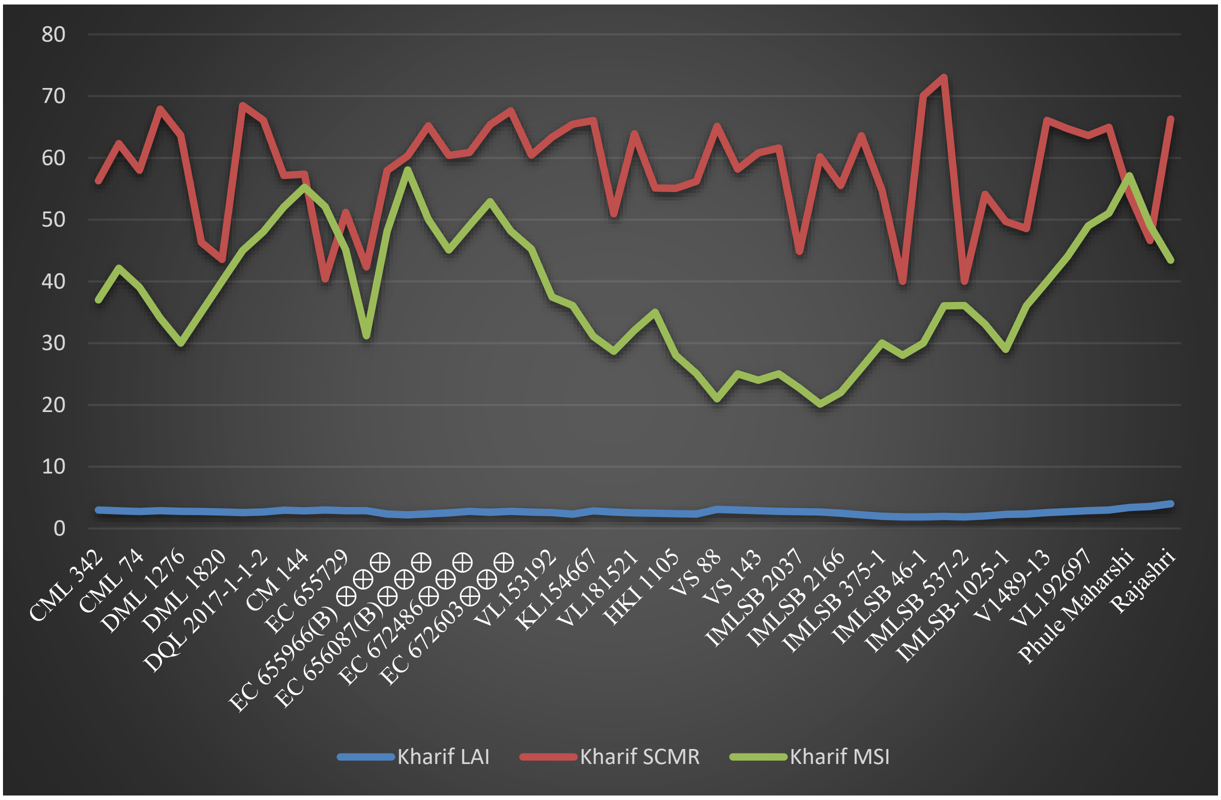

Fig 3: Mean performance of fifty-three maize genotypes on traits under *kharif* season.

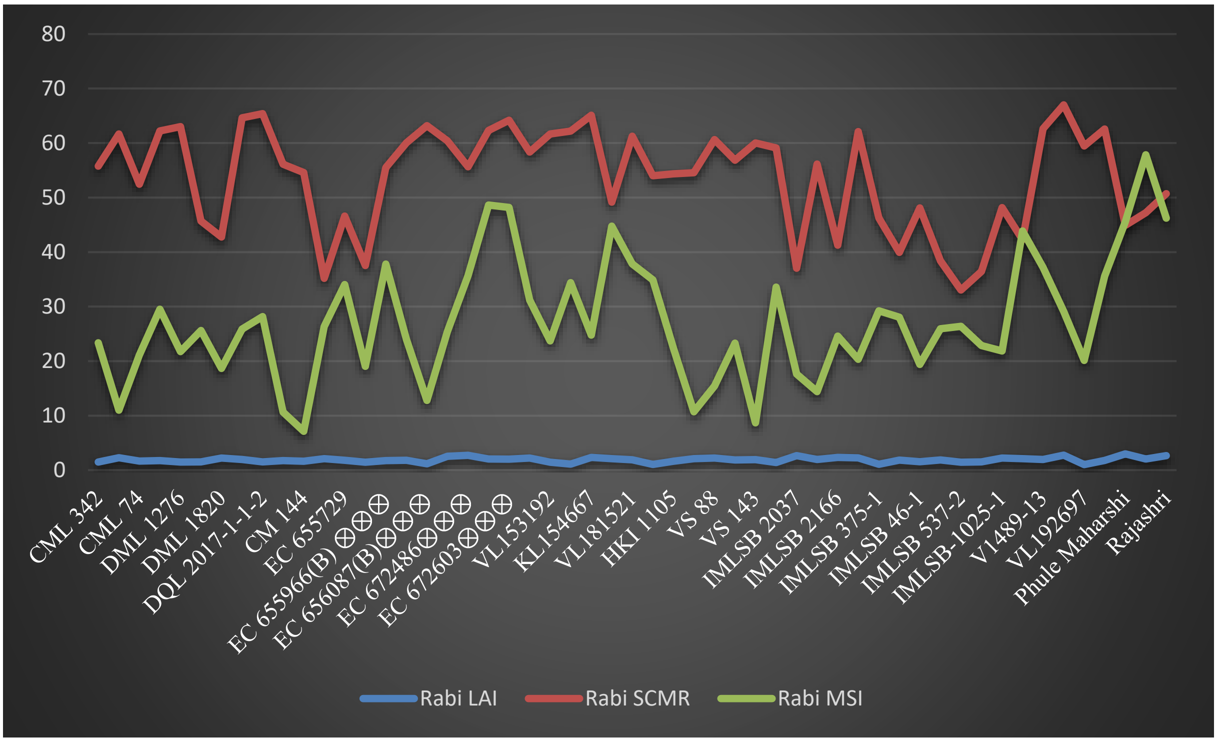

Fig 4: Mean performance of fifty-three maize genotypes on traits under *Rabi* season.

4. Conclusion

Based on the performance of different inbred lines for days to 50% tassel genotype IMLSB 2037 was identified as heat tolerant. During *kharif* high mean value and low mean value was observed in genotype DML 1276 (74.5 days) and VL192697 (56 days) respectively, while in *rabi* the highest mean value was observed in genotype VS 143 (95.5%). Genotypes with lower days to 50% silking are generally early maturing which helps the plant to avoid heat stress. The lowest mean value of days to 50% silking was observed VS 143 (69.5 days) during *rabi*. The genotypes IMLSB 2037 and VS 143 were identified as highly tolerant under heat stress. Anthesis silking interval was significantly influenced by heat stress. The high mean value of ASI was observed in genotype CML 420 (3.5 days) during *kharif* while, in *rabi* high mean value observed in genotype VL109507 (7 days). The increase in ASI was less in genotype IMLSB 2013. The genotype IMLSB 2037, IAMI 27-⊗⊗⊗, VL181521, EC 672609⊗⊗⊗, CM 144 and DQL 2186 were identified as heat tolerant. Based on the plant height the genotype EC 656087⊗⊗⊗⊗ were identified as highly tolerant to heat stress. In terms of plant height maximum reduction was observed in genotype HKI 1105. Thousand grains weight, which is indicative of seed weight was significantly influenced by heat stress. The genotypes DML 1276, EC 655966(B) ⊗⊗⊗, IAMI 27-⊗⊗⊗, V1489-13 and VL172416 shows minimum reduction as compared to all other genotypes. Grains yield per plant was lowest in genotype IMLSB 219-1 while highest in genotype EC 656087(B)⊗⊗⊗. The minimum reduction was observed in DML 1010 from 61.05 to 59.85 g. The genotype EC 656087(B)⊗⊗⊗ shows observable increase of grains yield per plant in *rabi* as compared to *kharif*. Leaf area index significantly influenced by high temperature which notably reduced photosynthetic surface area and, consequently the potential for yield reduced. The maximum leaf area index was observed in genotype VL172416 (2.76). The genotype EC 656087⊗⊗⊗⊗ and VL172416 were identified as heat tolerant. SCMR value (chlorophyll reading) during *kharif* was highest in genotype IMLSB 537-1 (73.04) and lowest in genotype IMLSB 393-1 (40). In *rabi* the maximum SCMR value was observed in genotype VL172416 (67.01) while minimum in genotype IMLSB 537-2 (33.055). The genotype EC 656087⊗⊗⊗⊗ and VL172416 were identified as highly tolerant under heat stress. Membrane stability index reduced during high temperature due to increase kinetic energy of molecules across membrane. In genotype CM 144 the MSI reduction was more while, in 118760 it was less as compared to all other genotypes. The genotypes EC 672603⊗⊗⊗, IMLSB 2013, IMLSB 2166 and V1489-10 shows notable increase MSI as compared to *kharif.*

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