Maize Journal (April 2025) 14(1): 35-39

RESEARCH PAPER

Association between yield and morpho-physiological trait of maize (*Zea mays* L.) under late sown spring conditions

Kiran[1] • Preeti Sharma[1] • M. C. Kamboj[1] • Narender Singh[1] • Kuldeep Jangid[1] • Swati Verma[1] • Satish Manda[2]

Abstract Terminal heat stress is a significant abiotic constraint affecting maize (*Zea mays* L.) production, particularly under late-sown spring conditions. The present study evaluates the impact of elevated temperatures on physiological traits, yield attributes, and stress tolerance indices using 40 diverse maize inbred lines. The experiment was conducted under field conditions at CCS RRS Karnal under late sown spring conditions using a randomized block design (RBD) with two replications during spring 2024. Inbred lines were evaluated for anthesis silking interval (ASI), canopy temperature depression (CTD), tassel blast percentage (TB%), leaf firing percentage (LF%) and barrennes percentage (B%), grain yield per plant (gm) (GY/Pl.), seed setting percentage (SS%) and hundred grain weight (gm) (HGW). Terminal heat stress substantially reduces maize grain yield per plant via direct and indirect effects of traits under study. The grain yield per plant had positive and significant phenotypic correlation with canopy temperature depression (0.449), hundred grain weight (0.324) and seed setting percentage (0.531) whereas it was significant and negatively correlated with tassel blast, anthesis-silking interval and leaf firing under heat stress condition. Traits such as hundred grain weight (0.196), canopy temperature depression (0.220) and seed setting percentage (0.248) showed highest values for direct and positive effect on grain yield per plant and also showed positive and significant correlation hence, they are be statistically considerable.

✉ Kiran: mehrakiran.0331@gmail.com

[1]CCS Regional Research Station, Uchani, Karnal, Haryana, India

[2]Maharana Horticulture University, Karnal, Haryana, India

Received: 11 February 2024/ Accepted: 26 March 2025

Keywords: Maize inbred lines • Terminal heat stress • Late-sown conditions • Tassel blast • Leaf firing • Grain yield

Introduction

Maize is a globally significant cereal crop, serving as a staple food and industrial raw material. However, its production is increasingly constrained by climate change-induced temperature elevations. Heat and drought stress have emerged as a common problem worldwide which can reduce maize crop productivity (Ali *et al*., 2015). In the 2023-24, India's maize cultivation covered approximately 11.24 million hectares, with production of about 37.67 million metric tons, having an average productivity of 3.35 metric tons per hectare (Anonymous, 2024a). Rising temperature, erratic rainfall and extreme weather significantly affects the maize yield particularly when heat stress occurs during critical growth stages. Heat stress particularly during the reproductive phase, leading to reduced photosynthetic efficiency, pollen sterility, and lower grain filling rates and late sown conditions further exacerbates terminal heat stress advancing its adverse effect on maize grain yield. A report by Asian Development Bank warns that if the current trends persist until 2050 major food crop yields and food production capacity of south Asia could decline by 17% for maize, 12% for wheat and 10% for rice (Anonymous, 2009b). It was also predicted that maize yield might be reduced up 70% due to increasing temperatures (Khodarahmpour *et al.,* 2011). Furthermore, pollen viability dropped by 40–60% under heat stress, directly correlating with poor seed set and reduced grain yield (Khan *et al.,* 2022).

This study focusses on analysing the correlation and path coefficient analyses between the yield related traits under late sown spring conditions. Understanding this association is crucial for the development of heat-resilient inbred lines and improving productivity under late-sown conditions.

Materials and methods

The experiment was conducted at Chaudhary Charan Singh Regional Research Station, Uchani Karnal using a randomized block design (RBD) with two replications during spring 2024. A diverse panel of forty maize inbred lines (names and source mentioned below) were sown under late planting conditions to assess heat stress effects. The inbred lines were planted using 60 x 20 cm^2 row to row and plant to plant spacing respectively. Data on anthesis silking interval (ASI), canopy temperature depression (CTD), tassel blast percentage (TB%), leaf firing percentage (LF%) and barrenness percentage (B%) were recorded on plot basis whereas, grain yield per plant (g) (GY/Pl.), seed setting percentage (SS%) and hundred grain weight (g) (HGW) were recorded on five selected representative plants. The data recorded on different parameters was first tabulated and analysed using OP Stat software and SPSS Program.

- ASI was calculated by subtracting the number of days taken for 50% anthesis from the number of days taken to 50% silk emergence (Bänziger *et al.,* 2020).
- CTD were calculated by subtracting canopy temperature from the ambient air temperature (Lepekhov, 2022).
- TB % = {Number of Affected Tassels} / {Total Tassels} *100 (Krishnaji *et al.,* 2018)
- LF % = {Number of plants that showed leaf firing symptoms (younger leaves near tassel burnt or dried)}/ {Total plants} *100 (Krishnaji *et al.,* 2018)
- (B%) = {Number of barren plants} / {Total plants} *100 (Edmeades *et al.,* 1997)

Results and discussion

Weather data during crop growth period indicated that the most of the cropping period was under heat stress as indicated by the prevalence of high temperature to proper evaluation of hybrids under heat stress. Maximum temperature >35 °C were recorded during the month of April, May and June (Table 1).

Under late sown spring conditions, flowering in maize starts during the month of April and may extends upto the may month, subjecting plants under high temperature stress conditions at their flowering stage. This exposure gives clear distinction between heat tolerant and susceptible maize inbred line for the traits under consideration. To access the genetic variability present in the material under study analysis of variance (ANOVA) was performed for all traits. Analysis of variance of mean square comparison

Table 1. Weather data of spring 2024

Month	Temperature (°Celcius)	
	Maximum	Minimum
January	13.1	6.1
February	21.7	7.9
March	27.5	12.1
April	35.8	17.8
May	39.8	24.2
June	40.1	27.0

List of inbred lines sourced from CCS HAU Regional Research station, Karnal

S.No.	Inbred Line	S.No.	Inbred Line
1.	HKI 163	21.	HKI 1659
2.	HKI 1354-2	22.	HKI 1651
3.	HKI 1651-14-3	23.	HKI 1664
4.	HKI 1078-4	24.	MBR 139
5.	HKI 193-1	25.	DQL 2327
6.	HKI 164-7-2	26.	HKI 1105
7.	HKI 1332	27.	HKI 327 T
8.	HKI 1025	28.	HKI 1128
9.	HKI 1015-6	29.	HKI 1126
10.	HKI 1011	30.	PMIQ 323
11.	IMR417	31.	HKI 1354-7
12.	HKI 1663-5-ER4	32.	HKI 1348-8-2
13.	HKI L287	33.	HKI 1035-6
14.	HKI 1040-7	34.	HKI 1344
15.	HKI 1654-15-ER-1-1-1	35.	DQL 2303
16.	HKI 193-2	36.	DQL 2575
17.	HKI 1558-4	37.	HKI 488-T
18.	HKI 488-1 RG	38.	HKI 1651-14-3 WINK 11
19.	DQL 2344	39.	HKI 1654-7-6
20.	DQL 2336	40.	HKI 288-2

Table 2. Mean square comparison for different traits in 40 inbred lines of maize under high temperature stress at CCS RRS Karnal (Spring 2024)

Source of Variation	df	Mean Sum of Squares							
		Gy/plant	ASI	CTD	HGW	SS%	TB%	LF%	B%
Replication	1	1.805	0.2^{ns}	0.078 ^{ns}	1.25 ^{ns}	0.612 ^{ns}	2.112 ^{ns}	0.313 ^{ns}	0.001 ^{ns}
Treatment	39	593.66*	45.95*	21.95*	165.95*	1,046.39*	1,940.89*	1,497.19*	7,155.00*
Error	39	30.473	21.8	4.587	96.75	653.8	26.366	12.188	200.0

described significant difference among 40 maize inbred lines for traits as shown in Table 2.

Correlation analysis

The grain yield per plant had positive and significant phenotypic correlation with canopy temperature depression, hundred grain weight and seed setting percentage conversely, it was significantly and negatively correlated with tassel blast, anthesis-silking interval and leaf firing under heat stress condition as shown in Table 3 and Figure 1. These finding suggests that selection for high yielding inbred lines under stress conditions can be effectively based on high values of seed setting percentage, hundred grain weight and canopy temperature depression. Seed setting percentage showed significant negative correlation with anthesis silking interval, leaf firing and tassel blast. This indicates longer anthesis and silking interval leads to reduced kernels formation or seed setting percentage, thereby, lowering grain yield. Additionally, seed setting percentage exhibited positive correlation with canopy temperature depression, suggesting that inbred lines capable of maintaining greater difference between ambient air temperature and canopy temperature possess enhanced thermotolerance, enabling them to sustain high yield potential under heat stress conditions.

Similar results were obtained by Kandel *et al.* (2018) for grain yield showed positive and significant phenotypic correlation with silk receptivity, shelling percentage, cob length and diameter, number of kernel ear, number of kernel ear, SPAD chlorophyll, and thousand kernel weight. Similarly, significant and negative correlation of grain yield with tassel blast, anthesis-silking interval, leaf area index, leaf firing under heat stress condition had been reported by Kandel *et al.* (2018). Khodarahmpour and Choukan (2011) reported similar finding in a study of fifteen inbred line under heat stress condition reported that grain yield had positive and significant correlation with number of kernels per ear, no. of kernel per row, 1000-grain weight, and cob diameter. Kaur *et al.* (2010) reported similar result significant negative association leaf firing and tassel blast with grain yield under heat stress. Cairns *et al.* (2012) reported significant correlation between grain yield and ASI and SPAD reading was negatively correlated. Taiwo *et al.,* 2020 showed number of plants per plot, number of plants harvested, number of ears harvested and field weight correlated positively and significantly both phenotypically and genotypically with grain yield.

This diagram will visually represent the strength and direction of correlations among the variables.

The nodes represent variables, and the edges indicate significant correlations (above 0.3 in absolute value).

Table 3. Correlation coefficient among different traits under late sown spring conditions

	GY/Pl.	ASI	CTD	HGW	SS%	TB%	LF%
GY/Pl.	1						
ASI	-0.367*	1					
CTD	0.449**	-0.535**	1				
HGW	0.324*	-0.16	0.205	1			
SS%	0.531**	-0.456**	0.488**	0.061	1		
TB%	-0.453**	0.307	-0.255	-0.097	-0.534**	1	
LF%	-0.441**	0.313*	-0.251	-0.054	-0.529**	0.980**	1
B%	-0.11	0.015	0.039	-0.04	-0.114	0.284	0.207

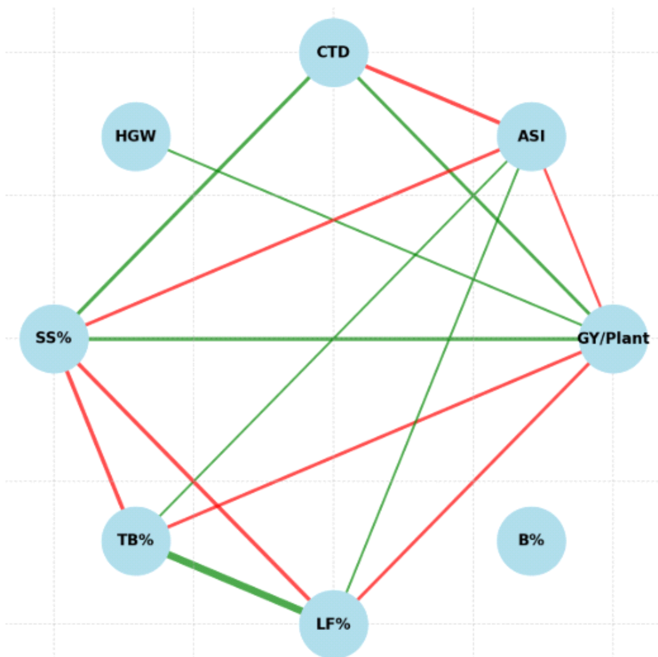

Figure 1. Diagrammatic representation of correlation between traits

- Green edges: Positive correlations
- Red edges: Negative correlations
- Thicker edges: Stronger correlations

Path coefficient analysis

Traits such as hundred grain weight (0.196), canopy temperature depression (0.220) and seed setting percentage (0.248) showed highest values for direct and positive effect on grain yield per plant and also showed positive and significant correlation hence, they are be statistically considerable traits (Table 4 and Figure 2). Similar results were obtained by El-Badawy *et al.* (2011) reported similar result highest positive direct effect of 100 grain weight on yield per plant in maize. Krishnaji *et al.* (2017) found similar result high positive direct effect of shelling percentage and number of kernel per ear under heat stress condition and Kandel *et al.* (2018) for thousand kernal weight, shelling percentage, kernal per ear and silk receptivity on grain yield. Similarly, high values of negative direct effect of tassel blast percent (-0.158). The negative and significant correlation between grain yield per plant and anthesis silking interval, tassel blast, leaf firing resulted more due to indirect influence via canopy temperature depression and seed setting percentage on the mentioned traits. Similar results were obtained by Taiwo *et al.* (2020).

Conclusion and future perspectives

Terminal heat stress poses a formidable challenge to maize production under late-sown conditions. Identification of heat-tolerant maize inbred lines based on physiological

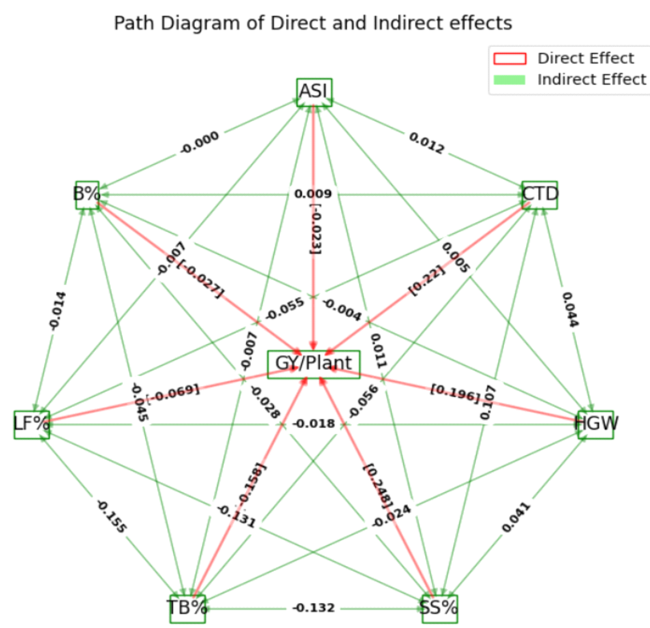

Figure 2. Diagrammatic representation of path coefficient analysis

Table 4. Direct (diagonal) and indirect effects of different traits on grain yield per plant

	ASI	CTD	HGW	SS%	TB%	LF%	B%
ASI	-0.023	0.012	0.005	0.011	-0.007	-0.007	0
CTD	-0.118	0.220	0.044	0.107	-0.056	-0.055	0.009
HGW	-0.043	0.039	0.196	0.041	-0.024	-0.018	-0.004
SS%	-0.113	0.121	0.052	0.248	-0.132	-0.131	-0.028
TB%	-0.049	0.04	0.02	0.085	-0.158	-0.155	-0.045
LF%	-0.022	0.017	0.006	0.036	-0.067	-0.069	-0.014
B%	0	-0.001	0.001	0.003	-0.008	-0.006	-0.027
GY/pl.	-0.367*	0.449**	0.324*	0.531**	-0.453**	-0.441**	-0.11

and agronomic parameters is essential for breeding programs. In present investigation, traits namely anthesis silking interval, canopy temperature depression, seed setting percentage, tassel blast, leaf firing, hundred grain weight were most yield determinative traits as revealed from correlation analysis and hence, simultaneous selection for these traits might bring improvement in maize grain yield under heat stress. Future research should integrate genomic selection and biotechnological interventions to enhance heat stress resilience. Beside the correlation analysis, path coefficient analysis also provides huge support on these traits from all other yield components. Path analysis using grain yield per plant as dependent variable revealed that of hundred grain weight, canopy temperature depression and seed setting percentage exerted maximum positive direct effect on grain yield per plant and these traits could be relied upon for selection of genotypes to improve grain yield. On contrary, tassel blast percentage, leaf firing and anthesis silking interval reported negative significant correlation and high values of negative direct effect on grain yield per plant. Thus, selection of maize inbred lines having maximum hundred grain weight, canopy temperature depression, seed setting percentage values and minimum tassel blast percentage, leaf firing percentage, anthesis silking interval values is pre requisite for attaining improvement in grain yield under heat stress conditions.

References

Anonymous (2009b). ADB: Climate Change Threatens Water, Food Security of 1.6 Billion South Asians. www.adb.org

Anonymous (2024a). https://ipad.fas.usda.gov

Bänziger, M., Edmeades, G. O., Beck, D. & Bellon, M. (2000). Breeding for Drought and Nitrogen Stress Tolerance in Maize: From Theory to Practice. Mexico, D.F.: CIMMYT.

Cairns, J. E., Sonder, K., Zaidi, P. H., Verhulst, N., Mahuku, G., Babu, R. & Rashid, Z. (2012). Maize production in a changing climate: impacts, adaptation, and mitigation strategies. *Advances in Agronomy*, **114**(1).

Edmeades, G. O., Bänziger, M., Mickelson, H. R. & Peña-Valdivia, C. B. (eds.). (1997). Developing Drought- and Low N-Tolerant Maize. Proceedings of a Symposium, March 25-29, 1996, CIMMYT, El Batán, Mexico. Mexico, D.F.: CIMMYT

El-Badawy, M. E. M. & Mehasen, S. (2011). Multivariate analysis for yield and its components in maize under zinc and nitrogen fertilization levels. *Australian Journal of Basic and Applied Sciences*, **5**(12): 3008 3015.

Kandel, M., Ghimire, S. K., Ojha, B. R. & Shrestha, J. (2018). Correlation and path coefficient analysis for grain yield and its attributing traits of maize inbred lines (*Zea mays* L.) under heat stress condition. *International Journal of Agriculture, Environment and Food Sciences*, **2**(4): 124-130.

Kandel, M., Ghimire, S. K., Ojha, B. R., & Shrestha, J. (2018). Correlation and path analysis for grain yield and its attributing traits of maize inbred lines (*Zea mays* L.) under heat stress condition. *International Journal of Agriculture Environment and Food Sciences,* **2(**4): 124-130.

Kaur, R., Saxena, V. K. & Malhi, N. S. (2010). Combining ability for heat tolerance traits in spring maize (*Zea mays* L.). *Maydica,* **55**(3): 195.

Khan, I., Wu, J. & Sajjad, M. (2022). Pollen viability-based heat susceptibility index (HSIpv): A useful selection criterion for heat-tolerant genotypes in wheat. *Frontiers in Plant Science,* 13: 1064569.

Khodarahmpour, Z. & Choukan, R. (2011). Genetic variation of maize (*Zea mays* L.) inbred lines in heat stress condition. *Seed and Plant Improvement Journal*, **27**(4): 539-554.

Krishnaji Jodage, Kuchanur, P. H., Zaidi, P. H., Patil, A., Seetharam, K., Vinayan, M. T. & Arunkumar, B. (2018). Genetic analysis of heat adaptive traits in tropical maize (*Zea mays* L.). *International Journal of Current Microbiology and Applied Sciences,* **7**(1): 3237-3246.

Krishnaji, J., Kuchanur, P. H., Zaidi, P. H., Ayyanagouda, P., Seetharam, K., Vinayan, M. T. & Arunkumar, B. (2017). Association and path analysis for grain yield and its attributing traits under heat stress condition in tropical maize (*Zea mays* L.). *Electronic Journal of Plant Breeding*, **8**(1): 336-341.

Lepekhov, S. B. (2022). Canopy temperature depression for drought- and heat stress tolerance in wheat breeding. *Vavilovskii Zhurnal Genet Selektsii*, **26**(2): 196-201

Taiwo, O., Nwonuala, A. I., Isaiah, B., Olawamide, D. & Agbugba, I. (2020). Correlation and path coefficient analysis studies on grain yield and its contributing characters in maize (*Zea mays* L.). *International Journal of Plant & Soil Science*, 7-13.