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Stress resistance in hybrid maize for yield traits

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Abstract
This research evaluates the yield and related characteristics of maize inbred lines and hybrids under drought conditions. Forty two maize genotypes were assessed for different characters, including, days to 50 percent tasselling, days to 50 percent silking, days to 75 percent dry husk, plant height, cob height, cob length, cob diameter, kernels per row, kernel rows per cob, cob weight, 100 seed weight, initial plant count, final plant count, number of ears per plot, grain yield per plant and in addition of proline as biochemical traits. Traits including cob length, cob weight, cob diameter, and number of kernels per row showed strong positive correlations and direct effects on grain yield, underlining their importance in yield enhancement. Higher PCV than GCV for most traits indicates notable environmental influence, but several traits still show sufficient genetic control to allow effective selection. High heritability of proline content and its correlation with yield confirm its utility as a physiological marker for drought tolerance in maize. This study highlights the significance of choosing appropriate maize genotypes that are able to tackle environmental challenges and guides future breeding strategies aimed at enhancing drought tolerance and stable yield performance.

Keywords: Maize, inbred lines, drought, yield traits, environment

Introduction
Maize among cereals ranked at third number after wheat and rice worldwide (Ali F. *et al*., 2014) [4]. Maize (*Zea mays* L.) It is a vital cereal crop worldwide, essential for food security, economic growth and agricultural diversity (FAO, 2019; Muthusamy *et al*., 2018) [12, 19]. Its adaptability to a wide range of environmental conditions has made it a staple food crop in many parts of the world (Bänziger & Cooper, 2001) [6]. Despite its adaptability, water deficit, or drought stress, is a major abiotic factor that severely limits plant growth and yield. Drought stress is particularly detrimental to crops, as it decreases their quality, yield, and stability, especially when experienced during critical stages of growth (Khan *et al*. 2025) [15]. This challenge is especially prominent in India, where states like Maharashtra, heavily reliant on rainfed agriculture and face frequent droughts and unpredictable rainfall patterns.
By 2050, demand for maize in developing countries is predicted to quadruple, while worldwide production is expected to peak in 2025, with the majority of that production coming from developing countries (Shiferaw *et al*., 2011) [28]. Nonetheless, maize yields have been severely constrained in a number of developing countries due to a variety of abiotic and biotic stresses, as well as other causes (Salika and Riffat, 2021) [25]. Drought, heat, and flooding are becoming more common, putting a burden on a number of vital crops, as a result of rising urbanization and habitat degradation as well as other unpredictable extreme climatic phenomena (Javed *et al*., 2020; Ahmad *et al*., 2021, Chowdhury *et al*., 2021; Salika and Riffat, 2021; Shabbir *et al*., 2021; Akhtar *et al*., 2022) [13, 1, 11, 25, 26, 2]. The heavy dependence on monsoonal precipitation makes maize crops in these regions vulnerable to water stress, leading to substantial losses in productivity (Bhan *et al*., 2018) [10]. Considering crop's significance for both food and income security, it is essential to evaluate the performance of different maize hybrids under varying moisture conditions, including both drought-stressed and well-watered environments (Sharma *et al*., 2021) [27].
The intensity of the drought, duration of the exposure, and growth stage influence maize yield loss (Kamali *et al*., 2022) [14]. Such evaluations are key to breeding programs aimed at developing drought-tolerant varieties (Araus *et al*., 2002) [5]. Identifying inbreds and hybrids that maintain yield and yield-related traits under water-limited conditions is crucial for

improving the resilience and sustainability of maize cultivation in drought-affected areas (Rao *et al*., 2020) [22]. The present study was structured to access genetic analysis of promising maize inbred/hybrids for drought tolerance under managed stress conditions, aims to investigate the genetic variability of maize genotypes under drought stress and their response to water scarcity. The study was conducted at a location chosen for its representative climate and the importance of maize cultivation in the region. This research seeks to provide valuable insights into the performance of different maize inbreds and hybrids, identify those with strong drought tolerance and high yield potential. Phenotypic stability of traits over multiple seasons could help us to identify the genes that inherit to next progenies, to achieve the desired product in next seasons Ali *et al*., 2017) [3].

Materials and Methods

The experimental material for the current study comprised of 42 genotypes of maize. Field study was also conducted at field place during rabi 2023 under managed stress condition. The water stress was given to crop during its reproductive growth stage. The experiment was laid out in a randomized block design with two replications. An observation for each character is recorded as per norms given by ICAR-IIMR, New Delhi. While the biochemical analysis of Proline is estimated by acid-ninhydrin method.

Results and Discussion

The results of the comparative study of 42 maize genotypes in drought and normal conditions for all the 16 characters *viz*., days to 50 percent tasselling, including days to 50 percent tasseling, days to 50 percent silking, days to 75 percent dry husk, plant height (cm), cob height (cm), cob length (cm), cob diameter (cm), kernels per row, kernel rows per cob, cob weight(g), test weight (g), initial plant count, final plant count, number of ears per plot, grain yield per plant (g) and proline content(mg/g) is presented in the Tables.

Table 1: Estimates of different genetic parameters of variability for 16 characters of 42 genotypes

Sr. No.	Characters	Range		Mean	Coefficient of Variation (%)		Heritability in Broad sense (h^2 b. s.)%	Genetic Advance (GA)	Genetic Advance as percent of mean (GAM)
		Min.	Max		GCV	PCV			
1	Days to 50 percent tasseling	60	77	67.65	6.21	6.31	96.90	8.52	12.60
2	Days to 50 percent silking	61	80	70.58	6.72	6.85	96.34	9.60	13.60
3	Days to 75 percent Dry husk	102	119	113.47	4.07	4.15	96.34	9.60	8.23
4	Plant height (cm)	125.6	178	146.76	8.57	9.59	79.95	23.18	15.79
5	Cob height (cm)	69.5	99	81.57	8.58	9.62	79.63	12.87	15.78
6	Cob length (cm)	11	21.5	16.89	14.57	15.12	92.81	4.88	28.92
7	Cob diameter (cm)	3.5	6.85	5.38	14.57	15.12	92.79	1.55	28.91
8	No. of kernel per row	24	38	31.89	9.84	10.24	92.29	6.21	19.47
9	No. of kernel rows per cob	11	17.5	14.69	10.07	11.12	82.06	2.76	18.80
10	Cob Weight (g)	73.9	225.1	165.60	14.72	16.20	82.55	45.65	27.56
11	100 seed weight(g)	26	38.5	31.72	9.82	10.56	86.45	5.96	18.81
12	Initial plant count	22	29	25.88	4.50	6.41	49.41	1.68	6.52
13	Final plant count	22	29	25.41	3.12	5.95	27.52	0.85	3.37
14	Number of ears/plot	23	29	25.36	4.45	6.73	43.78	1.54	6.07
15	Proline content (mg/g)	0.38	0.71	0.54	15.92	16.03	98.69	0.17	32.59
16	Grain yield per Plant (g)	61.74	184.39	136.22	13.93	15.37	82.11	35.42	26.00

Genetic variability

The results indicate that environmental factors significantly influenced trait expression, as evidenced by higher phenotypic coefficient of variation (PCV) compared to genotypic coefficient of variation (GCV). Traits like cob weight (16.20), proline content (16.03), and grain yield per plant (15.37) showed higher phenotypic variability, while traits like proline content (15.92) and cob weight (14.72) showed higher genotypic variability. This result indicating that these traits offer substantial variation and are valuable for maize improvement programs. On the other hand, traits such as days to 75 percent dry husk (4.15) had low phenotypic coefficient of variation (PCV) and final plant count (3.12) had low genotypic coefficient of variation (GCV), suggesting limited potential for genetic improvement in these traits.

Heritability and Genetic advanced

Several characters showed high heritability estimates coupled with high genetic advance, suggesting that these are ideal candidates for selection in breeding programs. The study found high heritability estimates for most traits, particularly proline content (98.69%) and days to 50 percent tasseling (96.90%), indicating that genetic factors predominantly contribute to trait variation. Traits like cob weight, grain yield, and cob length also showed strong genetic control, suggesting they are suitable for selection and genetic improvement. However, traits such as number of ears per plot (43.78), initial plant count (49.41) and final plant count (27.52) exhibited lower heritability, indicating more environmental influence.

The study observed high genetic advance (GA) for traits like cob weight (45.65) and grain yield per plant (35.42), indicating that these traits are primarily controlled by additive genetic effects, making them amenable to improvement through selection. Traits such as proline content (0.17), Final plant count (0.85) and number of number of ears per plot (1.54) showed lower genetic advance, indicating limited potential for genetic improvement through selection for these traits.

Correlation

The correlation analysis revealed that grain yield per plant showed strong positive correlations with several yield components, including the number of kernels per row (0.948), cob weight (0.928), and cob length and diameter

(0.884), suggesting that these traits play a crucial role in enhancing grain yield. Additionally, moderate correlations with plant height, proline content, and silking and tasseling duration highlight the importance of these traits in breeding for higher yield. The findings underscore the value of selecting multiple traits to improve overall grain yield.

Table 2: Genotypic (above diagonal) correlation of 16 characters of 42 genotypes of Maize

	DFT	DFS	DDH	PH	CH	CL	CD	NKR	NKRC	CW	HSW	IPC	FPC	NEPP	PL	GY
DFT	1.000	0.980**	0.980**	0.093	0.089	0.225**	0.225**	0.233*	0.287**	0.227*	0.141	-0.291**	-0.253*	0.065	-0.020	0.299**
DFS		1.000	1.000**	0.120	0.117	0.209	0.208	0.213	0.336**	0.247*	0.188	-0.164	-0.125	0.183	0.013	0.322**
DDH			1.000	0.120	0.117	0.209	0.208	0.213	0.336**	0.247*	0.188	-0.164	-0.125	0.183	0.013	0.322**
PH				1.000	1.000**	0.405**	0.405**	0.410**	0.407**	0.487**	0.206	0.387**	0.302**	0.393**	0.323**	0.461**
CH					1.000	0.410**	0.410**	0.411**	0.411**	0.490**	0.210	0.389**	0.299**	0.395**	0.328**	0.464**
CL						1.000	1.000**	0.908**	0.744**	0.970**	0.171	0.211	0.268*	0.411**	0.591**	0.884**
CD							1.000	0.908**	0.744**	0.971**	0.970**	0.210	0.267*	0.411**	0.591**	0.884**
NKR								1.000	0.760**	0.974**	0.341**	-0.047	0.016	0.350**	0.562**	0.948**
NKRC									1.000	0.736**	0.159	0.248*	0.369**	0.365**	0.277*	0.755**
CW										1.000	0.381**	0.164	0.271*	0.599**	0.692**	0.928**
HSW											1.000	-0.303**	-0.291**	-0.061	0.443**	0.522**
IPC												1.000	0.838**	0.611**	0.110	0.076
FPC													1.000	0.778**	0.237*	0.315**
NEPP														1.000	0.433**	0.641**
PL															1.000	0.624**
GY																1.000

Similar findings were reported by Kumar and Kumar (2000), who found significant positive correlations between plant height, cob weight, and the number of kernels per row. Umakanth and Khan (2001) [30] also identified positive associations with cob width, cob length, and plant height. Studies by Tang *et al*. (2004) [29] and Mohan *et al*. (2002) [18] also reported significant positive correlations between plant height, cob length, cob height, cob width, and the number of kernels per row with grain yield, consistent with the current study's observations.

Furthermore, Wannows *et al*. (2010) [31] found that the number of kernels per row and ear length were positively correlated with grain yield, suggesting that selecting for longer ears and more kernels per row could enhance maize yield. Beiragi *et al*. (2011) [8] similarly noted significant positive correlations between kernel number per row and ear length with total yield at the genotypic level, highlighting the importance of these traits in improving yield.

In line with these findings, Nataraj *et al*. (2014) [20], and Reddy and Jabeen (2016) [24] observed similar correlations for traits such as plant height, cob height, cob length, cob width, the number of kernels per row, and cob weight. Barua *et al*. (2017) [7] also reported significant correlations between traits like thousand kernel weight, plant height, cob length, cob height, and the number of kernels per row with grain yield.

Days to 50 percent tasseling is strongly correlated with both days to 50 percent silking and days to 75 percent dry husk, followed by grain yield and the number of kernel rows per cob. It has a strong negative correlation with initial plant count and moderate negative correlations with final plant count. The correlations with test weight, plant height, cob height, and the number of ears per plot are positive but non-significant. These correlations highlight how the timing of tasseling can influence both vegetative and reproductive traits in maize.

Days to 50 percent silking showed a highly significant positive correlation with days to 75 percent dry husk (1.000), indicating a strong relationship between these traits. It also had moderate positive correlations with the number of kernel rows per cob (0.336) and grain yield (0.322), suggesting potential associations with yield components. Other traits showed weaker or non-significant correlations, emphasizing the importance of silking and dry husk maturation timing in crop management and breeding programs. Plant height showed a highly significant positive correlation with cob height (1.000), indicating a strong relationship between these traits. It also had moderate positive correlations with grain yield (0.461), cob width (0.487), and other yield components. The results suggest that plant height is an important trait for breeding programs aimed at improving yield, although correlations with test weight and days to 75 percent dry husk were weak and non-significant.

Cob height showed a highly significant positive correlation with cob weight (0.490) and grain yield (0.464), suggesting its importance in determining yield. It also had moderate positive correlations with other yield components, such as the number of kernel rows per cob and cob diameter. The results indicate that cob height is a key trait for improving yield, though its correlation with test weight and days to 75 percent dry husk was weak and non-significant.

Cob length exhibited a highly significant positive correlation with cob diameter (1.000) and strong correlations with cob weight (0.970) and grain yield (0.884), highlighting its importance in yield determination. It also showed moderate correlations with proline content and the number of ears per plot. These results suggest that cob length is a crucial trait for improving yield, although its correlation with other traits like test weight was weak and non-significant.

Cob diameter showed a highly significant positive correlation with cob weight (0.971) and strong correlations with grain yield (0.884) and the number of kernels per row (0.908), indicating its key role in determining yield. It also showed moderate correlations with proline content and the number of ears per plot. These findings suggest that cob diameter is an important trait for improving yield, though its correlation with other traits like test weight was weak and non-significant.

Cob weight showed a highly significant positive correlation with the number of kernels per row (0.974) and grain yield (0.928), highlighting its strong influence on yield. It also exhibited positive correlations with other traits such as the number of kernel rows per cob and proline content. These results suggest that cob weight is a critical trait for improving yield, although its correlation with initial plant count was weak and non-significant.

Initial plant count showed a highly significant positive correlation with final plant count (0.838) and the number of ears per plot (0.611), indicating its role in determining plant establishment and yield. It had a moderate positive correlation with the number of kernel rows per cob but weak or non-significant correlations with proline content and grain yield. Additionally, its negative correlation with test weight (-0.303) suggests an inverse relationship with seed weight, emphasizing the complexity of its effects on yield components. Final plant count showed a highly significant positive correlation with the number of ears per plot (0.778) and moderate positive correlations with the number of kernel rows per cob (0.369) and grain yield (0.315), indicating its importance in determining yield. The negative correlation with test weight (-0.291) suggests an inverse relationship with seed size, while its weak correlations with other traits highlight its limited influence on some yield components. The number of ears per plot showed a highly significant positive correlation with grain yield (0.641), indicating its strong influence on yield. It also had moderate positive correlations with proline content (0.433), the number of kernel rows per cob (0.365), and the number of kernels per row (0.350). The negative correlation with test weight (-0.061) was weak and non-significant, suggesting minimal impact on seed size, while the weak correlation with days to 75 percent dry husk indicates limited effect on maturity.

The number of kernels per row showed a highly significant positive correlation with yield per plant (0.948) and the number of kernel rows per cob (0.760), indicating its crucial role in determining yield. It also had moderate positive correlations with proline content (0.562) and test weight (0.341). The weak non-significant correlation with days to 75 percent dry husk suggests limited influence on maturity, reinforcing its importance in yield-related traits.

The number of kernel rows per cob showed a highly significant positive correlation with yield per plant (0.755) and moderate correlations with days to 75 percent dry husk (0.336) and proline content (0.277). Its weak non-significant correlation with test weight suggests minimal effect on seed size, highlighting its role in yield determination.

Cob weight showed a highly significant positive correlation with yield per plant (0.522) and proline content (0.443). It also had a weak, non-significant correlation with test weight (0.188), suggesting its key role in influencing yield and proline levels, but minimal impact on seed size. Days to 75 percent dry husk showed a significant positive correlation with yield per plant (0.322) and a weak, non-significant correlation with proline content, indicating its moderate influence on yield. Proline showed a highly significant positive correlation with yield per plant.

Path analysis

The study identified traits with the highest positive direct effects on maize yield, with cob length (126.52) having the strongest impact, followed by cob height and days to 50 percent silking, suggesting that selecting for these traits could improve yield in breeding programs. In contrast, traits like cob diameter, plant height, and days to 50 percent tasseling showed negative direct effects on yield. A residual effect of 0.168 indicates that other factors may also influence yield, requiring further investigation to better understand their role.

Days to 50 percent tasseling showed a positive direct effect on yield (0.298) and positive indirect effects through traits like cob length, cob height, and cob weight. While it had negative indirect effects via cob diameter and plant height, the overall impact on yield remained positive, suggesting its potential value in breeding programs. Days to 50 percent silking showed positive indirect effects on yield through traits like cob length, cob height, and number of ears per plot. However, it also had negative indirect effects via traits like cob diameter and plant height. Despite these negative effects, the positive contributions suggest that days to 50 percent silking could still play a role in enhancing yield, but further research is needed to optimize its impact.

Plant height positively affected yield through traits such as cob length, cob height, number of ears per plot, cob weight, days to 50 percent silking, number of kernel rows per cob, and test weight. However, it had a negative impact on yield through traits like cob diameter, initial plant count, number of kernels per row, days to 50 percent tasseling, final plant count, and proline.

Cob height positively influenced yield indirectly through traits like cob length, number of ears per plot, cob weight, days to 50 percent silking, number of kernel rows per cob, and test weight. However, it also had negative indirect effects on yield through traits such as cob diameter, plant height, initial plant count, number of kernels per row, days to 50 percent tasseling, final plant count, and proline.

Table 3: Direct (diagonal) and Indirect (above and below diagonal) path effects of different characters towards grain yield at genotypic level in maize.

	DFT	DFS	PH	CH	CL	CD	CW	IPC	FPC	NEPP	NKR	NKRC	HSW	DDH	PL
DFT	-0.863	-0.845	-0.081	-0.077	-0.194	-0.194	-0.196	0.251	0.218	-0.056	-0.201	-0.248	-0.122	-0.845	0.017
DFS	0.700	0.714	0.086	0.083	0.149	0.149	0.176	-0.117	-0.089	0.131	0.152	0.240	0.134	0.714	0.009
PH	-0.699	-0.896	-7.450	-7.452	-3.019	-3.019	-3.630	-2.883	-2.251	-2.931	-3.056	-3.031	-1.536	-0.896	-2.407
CH	0.675	0.887	7.594	7.593	3.113	3.114	3.722	2.951	2.273	3.000	3.123	3.147	1.599	0.887	2.490
CL	28.453	26.387	51.270	51.878	126.519	126.519	122.717	26.697	33.914	52.062	114.923	94.140	21.661	26.387	74.717
CD	-28.268	-26.222	-51.011	-51.618	-125.873	-125.873	-122.173	-26.539	-33.623	-51.726	-114.326	-93.652	-21.532	-26.222	-74.396
CW	0.082	0.089	0.176	0.177	0.349	0.350	0.360	0.059	0.098	0.216	0.351	0.265	0.137	0.089	0.249
IPC	0.139	0.078	-0.185	-0.185	-0.101	-0.101	-0.078	-0.477	-0.400	-0.291	0.023	-0.118	0.145	0.078	-0.052
FPC	0.057	0.028	-0.069	-0.068	-0.061	-0.061	-0.061	-0.190	-0.227	-0.177	-0.004	-0.084	0.066	0.028	-0.054
NEPP	0.034	0.094	0.203	0.204	0.212	0.212	0.309	0.314	0.401	0.515	0.180	0.188	-0.031	0.094	0.223
NKR	-0.080	-0.073	-0.140	-0.141	-0.311	-0.311	-0.333	0.016	-0.006	-0.120	-0.342	-0.260	-0.117	-0.073	-0.192
NKRC	0.049	0.057	0.069	0.071	0.127	0.127	0.125	0.042	0.063	0.062	0.129	0.170	0.027	0.057	0.047
HSW	0.018	0.024	0.027	0.027	0.022	0.022	0.049	-0.039	-0.038	-0.008	0.044	0.021	0.129	0.024	0.057
DDH	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
PL	0.002	-0.001	-0.027	-0.028	-0.050	-0.050	-0.059	-0.009	-0.020	-0.037	-0.048	-0.023	-0.037	-0.001	-0.085
GY	0.299	0.322	0.461	0.464	0.883	0.884	0.929	0.076	0.315	0.641	0.948	0.755	0.522	0.322	0.624

Cob length positively influenced yield indirectly through traits like cob height, cob weight, ear count, days to 50 percent silking, kernel rows per cob, and test weight. However, it also had negative indirect effects on yield via traits such as cob diameter, plant height, kernels per row, days to 50 percent tasseling, plant counts and proline.

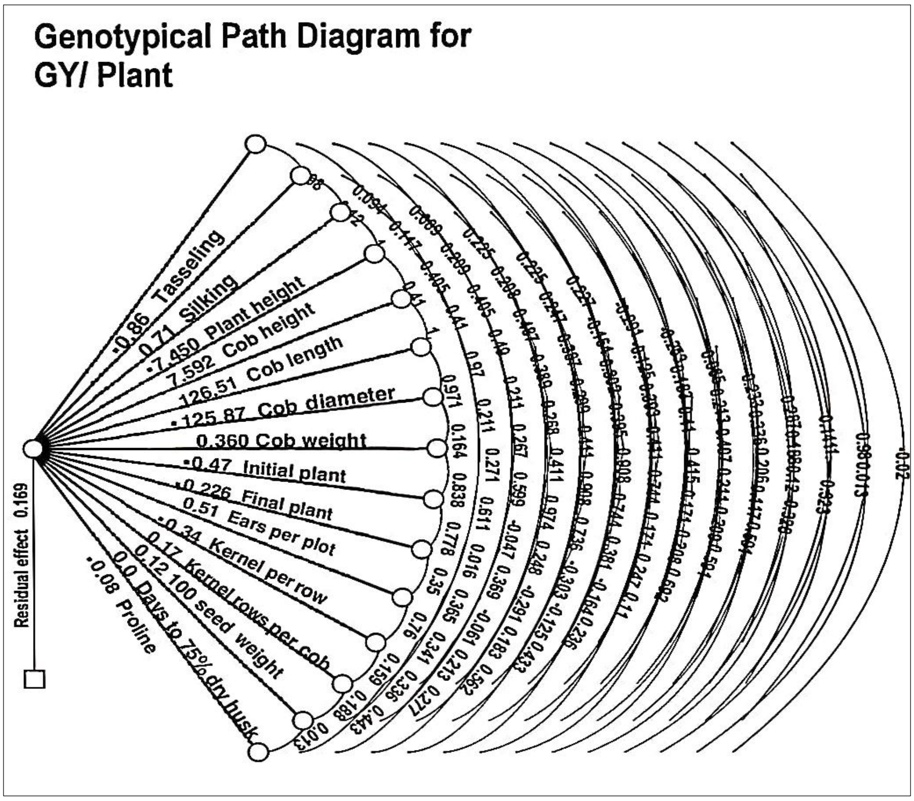

Fig 1: Genotypic path diagram for yield per plant in Maize

Cob diameter had a positive indirect effect on grain yield through traits such as cob length, cob weight, cob height, ear count, days to 50 percent silking, number of kernel rows, and test weight. However, it also had negative direct effects on yield through traits like plant height, kernels per row, days to 50 percent tasseling, plant counts, and proline. Cob weight positively influenced grain yield indirectly through traits such as cob length, cob height, ear count, days to 50 percent silking, number of kernel rows, and test weight. However, it had negative direct effects on yield through traits like cob diameter, plant height, kernels per row, days to 50 percent tasseling, plant counts, and proline levels.

The initial plant count positively influenced grain yield indirectly through traits such as cob length, cob height, ear count, days to 50 percent tasseling, cob weight, number of kernel rows, and the number of kernels per row. However, it had negative direct effects on yield through traits like cob diameter, days to 50 percent silking, plant height, final plant count, test weight, and proline levels. The final plant count had a positive indirect effect on grain yield through traits such as cob length, cob height, ear count, days to 50 percent tasseling, cob weight, and number of kernel rows. However, it showed negative direct effects on yield through traits like cob diameter, days to 50 percent silking, plant height, initial plant count, test weight, number of kernels per row, and proline levels.

The number of ears per plot positively influenced grain yield indirectly through traits such as cob length, cob height, cob weight, days to 50 percent silking, and number of kernel rows. However, it also exhibited negative direct effects on yield through traits like cob diameter, plant height, plant counts, kernels per row, days to 50 percent tasseling, proline, and test weight.

The number of kernels per row positively influenced grain yield indirectly through traits like cob length, cob height, cob weight, ear count, days to 50 percent silking, kernel rows per cob, test weight, and initial plant count. However, it also showed negative direct effects on yield through traits such as cob diameter, plant height, days to 50 percent tasseling, proline levels, and final plant count. The number of kernel rows per cob positively influenced grain yield indirectly through traits such as cob length, cob height, cob weight, days to 50 percent silking, number of ears per plot, and test weight. However, it also showed negative direct effects on yield through traits like cob diameter, plant height, days to 50 percent tasseling, number of kernels per row, initial and final plant count, and proline levels.

Test weight positively influenced grain yield indirectly through traits such as cob length, cob height, initial plant count, cob weight, days to 50 percent silking, final plant count, and number of kernel rows. However, it showed negative direct effects on yield through traits like cob diameter, plant height, days to 50 percent tasseling, number of kernels per row, proline levels, and number of ears per plot. Days to 75 percent dry husk positively influenced grain yield indirectly through traits such as cob length, cob height, days to 50 percent silking, cob weight, initial plant count, final plant count, and number of kernel rows. However, it also showed negative direct effects on yield through traits like cob diameter, plant height, days to 50 percent tasseling, number of kernels per row, number of ears per plot, and proline levels.

Proline positively influenced grain yield indirectly through traits such as cob length, cob height, cob weight, number of ears per plot, test weight, number of kernel rows per cob, and days to 50 percent silking and tasseling. However, it also had significant negative indirect effects on yield, particularly through traits like cob diameter, plant height, number of kernels per row, and both initial and final plant count.

These results are consistent with the findings of Reddy *et al.* (2022) [23], who highlighted the traits like cob weight, number of kernel rows per cob, and 100 kernel weight had a higher direct effect on grain yield. These results align with studies by Bello *et al*. (2010) [9] and Raghu *et al*. (2011) [21], who reported the influence of traits like the number of kernels per cob, plant height, cob height, and cob width on maize yield. Matin *et al*. (2017) [17] similarly showed the negative direct effect of plant height, cob diameter on maize yield.

Soil moisture Probe

Soil moisture data was collected using the Delta T Moisture Meter HH-2 at probe depths of 10 cm, 20 cm, 30 cm, 40 cm, 60 cm, and 100 cm. Maize was planted on 14 December 2023, with irrigation applied on 12, 14, and 15 December 2023. Irrigation was stopped 51 days after sowing, on 2 February 2024, and resumed on 8 March 2024, once the soil moisture reached 16.89% of the Permanent Wilting Point (PWP). The irrigation break lasted for 35 days during the maize growing period, which notably impacted the soil moisture levels at various depths, as shown in Table 4.

Table 4: Soil moisture percent across different depths (in cm) for specific meteorological weeks.

Probe level	Meteorological weeks				
	6 (6/02/24)	7 (13/02/24)	8 (20/02/24)	9 (27/02/24)	10 (5/03/24)
10 cm	30.93%	8.17%	0.63%	0.00%	0.00%
20 cm	36.27%	13.67%	5.90%	4.90%	3.07%
30 cm	59.00%	39.17%	19.03%	13.87%	12.27%
40 cm	61.00%	57.53%	30.33%	23.23%	22.43%
60 cm	70.00%	69.07%	67.30%	47.67%	37.57%
100 cm	87.57%	88.50%	89.03%	88.65%	89.70%

Soil moisture content at various depths showed a notable decrease over the meteorological weeks. At the shallowest depth of 10 cm, the moisture percentage dropped sharply from 30.93% in week 6 to 0% by weeks 9 and 10, indicating rapid drying of the surface.

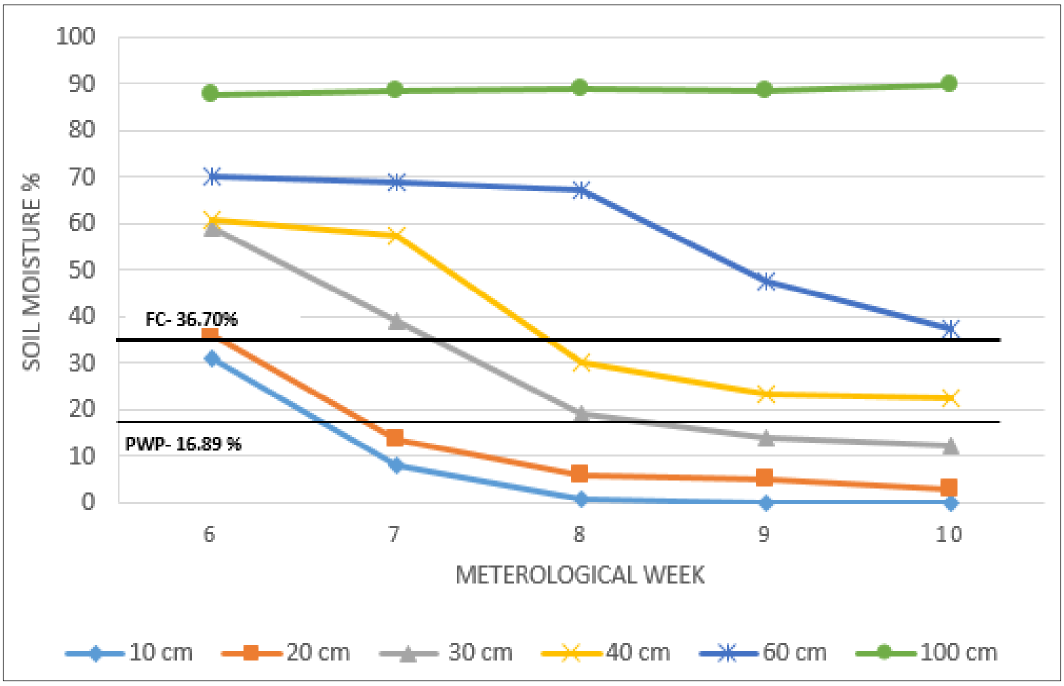

Fig 2: Graph representing soil moisture percent across different depths (in cm) for specific meteorological weeks

A similar pattern was observed at 20 cm, where moisture levels fell from 36.27% to 3.07% during the same period**.**

At 30 cm, moisture content decreased significantly from 59.00% in week 6 to 12.27% by week 10, although it remained higher than at the shallower depths. Deeper layers, such as 40 cm and 60 cm, retained moisture for a longer period, with more gradual declines, from 61.00% and 70.00% in week 6 to 22.43% and 37.57% by week 10, respectively.

The 100 cm depth exhibited the highest moisture retention, staying nearly constant throughout the period, with values slightly fluctuating between 87.57% and 89.70%. This shows that deeper soil layers are more effective at conserving moisture, while shallower layers deplete moisture more rapidly.

Conclusion

The study revealed highly significant differences among the 42 maize genotypes across all traits, indicating a wide genetic base suitable for drought tolerance breeding. Traits like proline content, cob weight, and grain yield per plant exhibited both high heritability and high genetic advance, suggesting strong additive gene action and potential for effective selection.

Traits including cob length, cob weight, cob diameter, and number of kernels per row showed strong positive correlations and direct effects on grain yield, underlining their importance in yield enhancement. Higher PCV than GCV for most traits indicates notable environmental influence, but several traits still show sufficient genetic control to allow effective selection. High heritability of proline content and its correlation with yield confirm its utility as a physiological marker for drought tolerance in maize. Traits like cob length, cob height, and days to 50 percent silking had strong positive direct effects on yield, indicating that selecting for these can enhance productivity under drought conditions.

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