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Comparative study of yield and yield-contributing characters of maize under drought and normal conditions

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Abstract
This research evaluates the yield and related characteristics of maize hybrids under drought and normal conditions at the Maize Improvement Project in Kasba Bawda, Kolhapur, Maharashtra, India. Seventeen maize genotypes were assessed for different characters, including days to 50 percent tasselling, days to 50 percent silking, plant height, cob height, days to 75 percent dry husk, cob length, cob width, number of cobs per plot, number of kernel rows per cob, number of kernel per row, cob weight, 100 kernel weight and yield per plant, in addition with two biochemical traits: proline and protein. Under drought conditions, DKC 9164 and IMH-221 performed best with yields of 124.41 g and 100.25 g per plant while, DMRH-1305 had the lowest yield of 87.73 g. In optimal conditions, DKC 9164 and 11023 X LM15 yielded 144.67 g and 135.22 g, respectively. Significant variations in traits were observed between two conditions, with better performance in optimal conditions. DMRH-1305 and 11260 X LM16 were more vulnerable to drought, highlighting the need for targeted breeding strategies. This study underscores the importance of selecting suitable maize hybrids to tackle environmental challenges and informs future breeding efforts for improved drought resistance and yield consistency.

Keywords: Maize, drought, normal, yield, comparative study

Introduction
Maize (*Zea mays* L.) is a vital cereal crop worldwide, essential for food security, economic growth and agricultural diversity (FAO, 2019; Muthusamy *et al*., 2018) [12, 24]. Its ability to adapt to various environmental conditions makes it a key staple in numerous regions (Bänziger & Cooper, 2001) [5]. However, the productivity of maize is significantly hindered by drought, which adversely impacts critical growth phases and leads to diminished yields.
In India, the issue of drought is particularly severe, notably in rainfed agricultural areas such as Maharashtra, where maize is widely cultivated (Sharma *et al*., 2020) [30]. The dependency on monsoon rains renders this region susceptible to precipitation variability, resulting in substantial crop stress and reduced harvests (Bhan *et al*., 2018). Given maize's importance as a food source and its economic implications for farmers, it is crucial to assess the performance of various maize hybrids under both drought and normal growing conditions (Sharma *et al*., 2021) [29]. This evaluation is vital for guiding breeding initiatives focused on creating maize varieties that exhibit improved resilience to drought (Araus *et al*., 2002) [3]. By identifying hybrids capable of sustaining yield and yield-related traits during periods of water scarcity, researchers can play a pivotal role in enhancing thesustainability of maize cultivation in drought-prone regions (Rao *et al*., 2020) [27].
The current study was carefully structured to assess the yield and associated traits of multiple maize hybrids under both controlled drought and normal, well-watered environments. The research took place at the Maize Improvement Project in Kasba Bawda, Kolhapur, Maharashtra, India. A site selected for its representative climatic characteristics and the significance of maize production in the area. Through this investigation, we aim to deliver critical insights into the performance of various maize hybrids, facilitating the identification of superior varieties capable of enduring drought stress while, optimizing yield potential. The results will not only assist local farmers in enhancing their adaptability to climate fluctuations but also contribute to broader agricultural strategies aimed at ensuring food

security under changing environmental circumstances (Nagarajan *et al*., 2021) [25].

Materials and Methods

The experimental material for the current study comprised of 17 genotypes of maize. The experimental material has been obtained from Maize Improvement Project, Kasba Bawda, Kolhapur. Field study was also conducted at same place during *rabi*, 2023. The experiment was laid out in a randomized block design with three replications. An observation for each character is recorded as per norms given by ICAR-IIMR, New Delhi. While the biochemical analysis of Protein done by Micro-kjeldahl method and proline is estimated by acid-ninhydrin method.

Results and Discussion

The results of the comparative study of 17 maize genotypes in drought and normal conditions for all the 15 characters *viz*., days to 50 percent tasselling, days to 50 percent silking, plant height, cob height, days to 75 percent dry husk, cob length, cob width, number of cobs per plot, number of kernel rows per cob, number of kernel per row, cob weight, weight of 100 kernel and yield per plant, in addition with two biochemical traits: proline and protein is presented in the Table 3 and Table 4.

Days to 50 percent tasselling

The days to 50 percent tasselling ranged from 57 to 70 days under drought conditions and from 60 to 73 days under normal conditions, with means of 60.49 days and 64.43 days, respectively. The variation in days to 50 percent tasselling could be attributed to genotypic differences and the stress imposed by drought conditions. Similar results were reported by Gozubenli *et al*., (2014) [13], who found significant variability in tasselling time among maize genotypes under water stress conditions. Mugo *et al*., (2011) [23] also observed a delay in tasselling in drought-tolerant maize genotypes, supporting the current findings. Khan *et al*., (2019) [18] noted that drought stress accelerates phenological development, leading to early tasselling in some genotypes.

Days to 50 percent silking

Days to 50 percent silking varied from 59 to 73 days in normal conditions and 59 to 70 days under drought, with respective means of 67.10 and 63.08 days. Silking was delayed in drought-stressed genotypes, likely due to physiological disruptions caused by water scarcity. Several studies, such as by Edmeades *et al*., (1999) [11] confirmed the delay in silking under drought conditions, which aligns with the current results.

Plant height (cm)

The plant height varied significantly across both conditions, ranging from 126.67 cm to 166.67 cm (mean of 147.16 cm) in drought and 131.67 cm to 190.67 cm (mean of 159.20 cm) under normal conditions. Drought conditions generally stunted plant growth due to water deficit, which affects cell elongation and turgidity. Similar reductions in plant height under stress have been reported by Tollenaar and Lee (2002) [32].

Cob height (cm)

Cob height showed significant variation, with a mean of 66.65 cm under drought and 73.29 cm under normal conditions. The reduced cob height under drought is consistent with the findings of Kamara *et al*., (2003) [16], who reported lower cob positioning in water-stressed maize due to limited stem elongation. Moser *et al*., (2006) [22] also noted similar observations, suggesting a relationship between cob height and drought resistance traits. Dhliwayo *et al*., (2009) [10] reported that genotypes with lower cob height under drought exhibit better adaptation to stress conditions.

Days to 75 percent dry husk

Under drought, days to 75 percent dry husk ranged from 101.33 to 112.00 days and in normal conditions, it ranged from 103.67 to 115.67 days. A delay in drying of the husk in drought conditions is expected, as reported by Hallauer and Miranda (1988) [15] and Abdulai *et al*., (2007) [1], who observed similar delays due to slower physiological maturation under stress. Genotypic variability plays a crucial role in determining days to 75 percent dry husk in different moisture conditions, as highlighted by Badu-Apraku *et al*., (2012) [4].

Cob length (cm)

Cob length was shorter under drought (12.27 cm to 16.43 cm) compared to normal conditions (14.90 cm to 18.93 cm), showing a significant reduction in cob development. Reduced cob length is a common response to drought stress, as indicated by Magorokosho *et al*., (2003) [20]. Similar findings were also observed by Khan *et al*., (2019) [18], who reported that water scarcity reduces assimilate partitioning to reproductive organs, limiting cob growth.

Table 1: Analysis of variance for 15 characters of maize in drought condition

Sr. No.	Characters	Mean sum of squares (MSS)		
		Replications df=2	Treatments df=16	Error df= 32
1	Days to 50 percent tasselling	1.25	39.80**	2.10
2	Days to 50 percent silking	1.02	42.19**	1.82
3	Plant height (cm)	7.07	385.37**	117.76
4	Cob height (cm)	22.29	223.56**	38.12
5	Days to 75 percent dry husk	3.58	33.89**	3.25
6	Cob length (cm)	0.70	3.87**	0.46
7	Cob width (cm)	0.46	1.14**	0.29
8	Number of cobs per plot	8.07	25.21**	3.32
9	No. of kernel per row	4.25	19.19**	1.96
10	Number of kernel rows per cob	0.31	9.57**	1.81
11	Cob weight (g)	50.18	405.98**	68.96
12	100 kernel weight (g)	2.31	9.44**	0.95
13	Proline (mgg^{-1})	0.00014	0.0087**	0.00022
14	Protein (%)	0.24	16.79**	0.13
15	Yield per plant (g)	2.09	324.86**	75.34

*, ** significant at 5 and 1 percent, respectively.

Table 2: Analysis of variance for 15 characters of maize in normal condition

Sr. No.	Characters	Mean sum of squares (MSS)		
		Replications df=2	Treatments df=16	Error df= 32
1	Days to 50 percent tasselling	1.19	41.99**	2.00
2	Days to 50 percent silking	4.49	45.28**	2.03
3	Plant height (cm)	18.01	626.79**	145.16
4	Cob height (cm)	1.11	214.74**	49.57
5	Days to 75 percent dry husk	0.41	34.89**	7.89
6	Cob length (cm)	0.73	3.76**	0.63
7	Cob width (cm)	0.64	0.92**	0.36
8	Number of cobs per plot	0.96	8.87**	2.81
9	No. of kernel per row	4.07	23.14**	2.72
10	Number of kernel rows per cob	0.54	3.20**	1.38
11	Cob weight (g)	1.61	561.34**	68.40
12	100 kernel weight (g)	1.23	8.39**	0.81
13	Proline (mgg^{-1})	0.00024	0.0033**	0.00015
14	Protein (%)	0.177	2.87**	0.103
15	Yield per plant (g)	11.73	515.75**	98.72

*, ** significant at 5 and 1 percent, respectively.

Cob width (cm)

The cob width ranged from 11.67 cm to 14.00 cm under drought conditions and from 12.50 cm to 14.57 cm under normal conditions, with means of 12.47 cm and 13.36 cm, respectively. The effect of drought on cob width has been extensively documented by Below *et al*., (2000) [7] and Monneveux *et al*., (2006) [21], who reported similar reductions in cob width due to limited carbon allocation. Kamara *et al*., (2003) [16] also found comparable reductions under drought conditions.

Number of cobs per plot

Number of cobs per plot ranged from 18.67 to 30.00 under drought stress, with a mean of 22.80 and from 23.33 to 29.00 under normal conditions (mean 25.20). Drought stress significantly reduced the number of cobs per plot due to poor pollination and kernel set. Similar observations were made by Campos *et al*., (2004) [9] and Barker *et al*., (2005) [6], who found that drought significantly reduces reproductive success in maize. These results are also in agreement with Kebe *et al*., (2016) [17], who demonstrated a direct impact of drought on cob formation.

Number of kernel rows per cob

The number of kernel rows per cob was higher under normal conditions, with a mean of 14.78, compared to 13.96 under drought conditions. This result reflects reduced reproductive development under stress. Similar findings were reported by Barker *et al*., (2005) [6], who found that drought significantly affects the number of kernel rows in maize. Additionally, Monneveux *et al*., (2006) [21] reported that reduced photosynthesis under drought limits kernel row development.

Number of kernels per row

The number of kernels per row followed a similar trend, with a mean of 29.57 under drought and 31.92 under normal conditions. The reduction of kernel number per row under drought stress aligns with findings by Ribaut *et al*., (2002) [28], who highlighted the impact of water scarcity on kernel set.

Cob weight (g)

Cob weight showed a significant reduction under drought, with a mean of 119.07 g, compared to 140.50 g under normal conditions. These findings are supported by Zhao *et al*., (2013) [33], who observed lower cob weight under water deficit due to reduced photosynthate translocation. Khan *et al*., (2019) [18] and Anjum *et al*., (2011) [2] also noted that water stress at critical growth stages limits cob development, leading to reduced cob weight.

100 kernel weight (g)

Hundred kernel weight decreased from 23.23 g in normal conditions to 24.24 g under drought. Drought stress reduces kernel weight, which has been well-documented by Ribaut *et al*., (2002) [28]. Below *et al*., (2000) [7] also reported a significant drop in kernel weight under drought conditions due to impaired grain filling and assimilate transport.

Proline (mgg^{-1}) and Protein (%)

Proline content was higher under drought conditions, reflecting the plant's adaptive response to osmotic stress, as suggested by Gunes *et al*., (2008) [14]. The higher proline accumulation is consistent with findings by Slama *et al*., (2015) [31], who reported that proline plays a critical role in maintaining osmotic balance under drought stress. Protein content, on the other hand, showed only slight variations between the two environments. Rao *et al*., (2006) [26] noted that protein accumulation in grains can be influenced by drought, but this effect depends on the stage at which stress occurs.

Yield per plant (g)

Yield per plant was significantly reduced under drought stress, ranging from 87.73 g to 124.41 g with a mean of 98.16 g, compared to 99.61 g to 144.67 g (mean 118.84 g) under normal conditions. The reduction in yield per plant has also been reported by Campos *et al*., (2004) [9] and Barker *et al*., (2005) [6].

Table 3: Mean performance of 15 characters for 17 genotypes of maize in drought condition

Sr. No.	Genotypes	DFT	DFS	PH	CH	DDH	CL	CW	NCPP	NKRC	NKR	CWE	HKW	PL	PT	YPP
1	IMH-221	61	63	150.33	63.33	102.00	16.07	12.50	28.33	16.67	34.00	125.87	26.31	0.42	9.90	100.25
2	DMRH-1305	59	62	131.00	60.67	103.33	13.70	11.83	21.67	12.67	28.00	109.27	22.25	0.46	7.90	87.73
3	PMH 7-222	60	63	158.33	61.67	103.33	13.70	11.80	22.67	13.33	29.00	112.30	23.23	0.50	10.10	90.42
4	11023 X LM15	61	64	145.67	66.00	103.33	15.50	13.17	18.67	16.00	32.00	131.57	24.57	0.58	14.30	110.19
5	11197 X LM16	61	63	156.00	79.67	104.67	12.80	11.77	20.00	11.33	26.67	107.87	20.54	0.52	12.00	89.85
6	11242 X LM16	58	61	163.67	76.33	101.33	13.43	12.17	22.00	12.67	28.00	112.03	22.09	0.48	11.60	91.21
7	11260 X LM16	59	61	134.33	58.67	102.33	14.47	12.53	24.33	14.67	29.67	110.23	23.37	0.48	13.20	89.45
8	11289 X LM16	59	62	146.33	66.33	102.00	15.37	12.30	20.00	16.00	32.00	128.40	24.53	0.54	12.27	100.47
9	11328 X V373	58	60	126.67	63.33	105.33	13.57	12.30	22.67	14.00	28.00	110.87	22.40	0.51	9.10	92.97
10	11341 X LM16	57	59	148.67	70.00	102.00	14.90	13.19	22.67	14.67	30.33	117.41	24.11	0.56	9.90	97.95
11	11370 X V391	59	61	135.00	58.33	104.00	14.00	12.10	23.33	13.33	28.67	113.53	22.92	0.49	16.10	91.85
12	11399 X LM15	65	68	153.00	59.33	109.33	12.27	11.67	19.67	11.33	26.00	109.20	20.26	0.51	13.87	92.21
13	11687 X LM16	70	73	154.67	68.00	111.00	13.97	13.10	24.00	13.33	29.00	122.27	22.47	0.53	10.90	102.51
14	DKC 9164	60	63	166.67	90.67	105.33	16.43	14.00	30.00	17.33	35.33	146.33	27.03	0.64	9.50	124.41
15	DKC 7074	67	70	148.33	59.33	112.00	14.60	12.47	22.00	14.67	30.00	140.37	24.00	0.58	10.10	117.65
16	Rajarshi (C)	57	59	137.33	63.00	101.33	13.13	12.30	21.67	12.00	27.00	111.07	21.88	0.46	7.70	93.57
17	Phule Maharshi(C)	58	61	145.67	68.33	101.33	14.00	12.73	24.00	13.33	29.00	115.67	22.99	0.48	8.50	96.00
	Mean	60.49	63.08	147.16	66.65	104.35	14.23	12.47	22.80	13.96	29.57	119.07	23.23	0.51	11.00	98.16

DFT= Days to 50 percent tasselling, DFS= Days to 50 percent silking, PH= Plant height, CH= Cob height, DDH= Days to 75 percent dry husk, CL= Cob length, CW= Cob width, NCPP= Number of cobs per plot, NKRC= Number of kernel rows per cob, NKR= Number of kernel per row, CWE= cob weight, HKW= 100 kernel weight, PL= Proline, PT= Protein and YPP= Yield per plant.

Table 4: Mean performance of 15 characters for 17 genotypes of maize in normal condition

Sr. No	Genotypes	DFT	DFS	PH	CH	DDH	CL	CW	NCPP	NKRC	NKR	CWE	HKW	PL	PT	YPP
1	IMH-221	64	66	163.67	68.00	108.33	18.93	14.22	29.00	16.67	38.33	152.15	27.87	0.44	7.80	128.36
2	DMRH-1305	60	62	141.67	65.00	104.00	15.80	13.37	24.00	14.00	30.33	121.91	22.94	0.38	8.50	99.61
3	PMH 7-222	62	65	169.67	71.00	108.33	15.97	13.43	24.67	14.67	30.67	121.40	23.86	0.37	9.20	100.49
4	11023 X LM15	65	67	157.00	72.00	107.33	16.93	13.54	26.33	16.00	33.33	158.37	24.95	0.48	8.63	135.22
5	11197 X LM16	64	67	165.67	87.67	108.67	15.50	12.87	24.00	14.67	30.00	122.90	22.93	0.37	9.97	104.67
6	11242 X LM16	62	65	169.33	80.00	103.67	15.70	13.50	24.33	14.67	30.67	133.27	23.62	0.46	8.60	107.81
7	11260 X LM16	63	66	147.00	66.33	107.33	15.97	12.97	25.00	13.33	31.00	131.90	23.89	0.37	11.20	109.84
8	11289 X LM16	63	66	158.33	74.67	105.33	16.53	12.87	25.33	15.33	31.67	146.23	24.22	0.41	10.00	128.13
9	11328 X V373	63	65	131.67	71.67	109.00	15.07	13.83	23.67	14.67	29.67	139.23	22.81	0.41	10.40	115.28
10	11341 X LM16	67	70	167.33	78.00	111.33	16.80	13.67	26.00	14.67	32.67	145.19	24.90	0.43	7.60	119.76
11	11370 X V391	64	67	141.33	62.67	108.00	15.90	12.93	25.00	15.33	31.00	130.87	24.27	0.38	8.50	110.25
12	11399 X LM15	64	67	167.67	67.67	109.67	15.80	13.33	24.33	15.33	31.00	130.50	23.60	0.43	9.30	109.37
13	11687 X LM16	73	76	175.33	74.67	113.33	15.60	13.80	23.67	15.33	30.00	145.56	22.64	0.41	8.47	124.52
14	DKC 9164	69	72	190.67	96.00	114.33	18.43	14.57	29.00	16.00	38.33	170.08	28.01	0.45	9.20	144.67
15	DKC 7074	72	75	157.33	66.67	115.67	17.27	12.64	26.67	13.33	34.67	155.70	25.95	0.40	9.20	134.75
16	Rajarshi (C)	60	62	148.67	70.33	105.33	14.90	12.50	23.33	12.67	29.33	139.53	22.39	0.41	7.72	120.87
17	Maharshi(C)	61	64	154.00	73.67	107.33	15.23	13.10	24.00	14.67	30.00	143.73	23.24	0.44	8.50	126.67
	Mean	64.43	67.10	159.20	73.29	108.65	16.25	13.36	25.20	14.78	31.92	140.50	24.24	0.41	8.99	118.84

DFT= Days to 50 percent tasselling, DFS= Days to 50 percent silking, PH= Plant height, CH= Cob height, DDH= Days to 75 percent dry husk, CL= Cob length, CW= Cob width, NCPP= Number of cobs per plot, NKRC= Number of kernel rows per cob, NKR= Number of kernel per row, CWE= cob weight, HKW= 100 kernel weight, PL= Proline, PT= Protein and YPP= Yield per plant.

Conclusion

In conclusion, the results demonstrate that specific genotypes, notably DKC 9164 and 11023 X LM15, possess promising traits for drought tolerance and high yield potential under normal conditions. These findings provide a foundation for future breeding programs aimed at improving drought resilience in maize. The study underscores the importance of multiple traits, including kernel-related factors, flowering synchrony and cob characteristics, as key contributors to yield stability under varying environmental conditions. Continuous selection for these traits, as highlighted in previous studies (Edmeades *et al*., 1999; Araus *et al*., 2002) [11, 3], is essential for developing high-yielding, drought-tolerant maize hybrids suitable for diverse agro-ecologies.

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