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PERFORMANCE OF MAIZE HYBRIDS UNDER CHANGING ENVIRONMENTAL CONDITIONS

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ABSTRACT

Uncertainty in maize growth and yield caused by varying environmental conditions and sowing times. There is a need to identify maize genotypes and optimal sowing periods that can perform well under changing climates to ensure sustainable productivity. This study was conducted to evaluate the effect of different maize genotypes and sowing weeks on key growth, yield and yield attributes. The present field experiment was laid out in field no. 64 at the farm section, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S), India. The experiment was laid out in a split plot design with three replications, comprising 12 treatment combinations of four sowing window and three genotype. Results indicated that both genotypes and sowing times had significant effects on all measured growth and yield traits. Among the genotypes, hybrid H_3 (Bio-9682) consistently showed superior growth and yield performance, particularly when sown in the first week of July or normal sowing time (S_1), demonstrating maximum plant height, no of leaves, leaf area, dry matter accumulation, No. of grain row cob^{-1}, No. of grains row^{-1}, No of grains cob^{-1}, grain weight plant^{-1}, test weight., grain yield, stover yield, biological yield and harvest index. Delayed sowing, especially beyond the third week of June, resulted in reduced growth due to suboptimal temperature and moisture conditions. The findings highlight the critical role of genotype selection and appropriate sowing time in maximizing maize growth and development under varying agro-climatic conditions. Such insights can support farmers and researchers in adopting climate-resilient practices for improved maize cultivation.

***Keywords*: Growing environment, growth attributes, maize hybrid, sowing time.

Introduction

Maize (*Zea mays*) popularly known as "Corn' is one of the most versatile emerging cash crops having wider adaptability under varied climatic conditions. It is called the queen of cereals globally. In India, maize is the third most important crop after wheat and rice. It is cultivated in wider diversity of soil, climate, biodiversity and management practices that contributes 37% (1148 MT) in global grain production (Anonymous, 2021).

In Maharashtra, the total area under *kharif* maize cultivation was 8.73 lakh ha which produced 23.32 lakh tonnes with a productivity of 2670 kg/ha. the total area under *rabi* maize cultivation was 3.63 lakh ha which produced 11.07 lakh tonnes with a productivity of 3050 kg ha^{-1} (Anonymous, 2021-22). In recent times Vidarbha saw a jump in maize cultivation as farmers have shown an inclination to grow maize.

As with any other crop, maize production is sensitive to climate, and climate is changing in ranges that are expected to alter maize crop efficiency (FAO, 2012). It is therefore important that we understand how maize growth will be affected by changing climate/weather factors. Given that future climate may be different in many maize cropping regions from what has ever been observed, especially as far as rainfall, temperature and CO_2 are concerned. Therefore, field and model-based studies are important to understand how maize growth will be affected by changing weather factors/climate.

Materials and Method

The experiment was laid out in split-split plot design with three replications in year 2021-22, in field no. 64 at the farm section, Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (M.S), India, India during *kharif* 2021-22. Experimental field was fairly uniform and levelled in depth and topography. Akola is geographically situated in the subtropical region at 22º42' North latitude and 77º02' East longitude and at an altitude of 307.42 m above mean sea level. The experimental site was slightly alkaline in nature with pH 7.82, medium in organic carbon 0.49%, low in available nitrogen (210.78 kg ha^{-1}), low in available phosphorus (15.71 kg P_2O_5 ha^{-1}) and high in available potassium (343.13 kg K_2O ha^{-1}). The physical composition of soil was bulk density 1.28 mg/m^{-3}, field capacity 33.10% and Permanent wilting point 15.80%. The treatment with 4 growing environments in main plot and 3 maize hybrids in sub plot replicated three times. Growing environment constituted of four sowing times (S_1) normal sowing time (July 03), (S_2) 10 days after normal sowing (July 13), (S_3) 20 days after normal sowing (July 26) and (S_4) 30 days after normal sowing (August 03). In sub plot treatment comprised with three maize hybrids viz H_1- BIO 605 (early maturing), H_2- ADV 756 (mid-late) and H_3-BIO 9682 (late duration). The size of the plot, row-row and plant-plant distance was same throughout the experiment.

Maize hybrid and seed material

Maize hybrids used in the present investigation were BIO-605, ADV 756 and BIO 9682. The seed material for all the cotton genotypes was obtained from Hyderabad. Characteristics of respective maize hybrids are presented in Table 1.

Table 1 : Characteristics of maize hybrids used for experimentation

Particulars	Maize hybrid		
	BIO 605	ADV 756	BIO 9682
Source	Bioseed Research India Pvt. Ltd, Hyderabad	Advanta Seeds India (UPL), R & D, Hyderabad	Bioseed Research India Pvt. Ltd., Hyderabad
Year of release	2013	2018	2012
Crop duration	Early (80-90 days)	Mid-late (90-100 days)	Late (100-110 days)
Characteristic	Orange-yellow, flint	Orange-yellow, semi-flint	Orange-yellow, semi-flint
Recommended zone	Maharashtra, HP, AP, Tamil Nadu, Karnataka, Uttarakhand, Arunachal Pradesh, Sikkim, Manipur, Meghalaya, Mizoram (*Kharif*)	Karnataka, AP, Maharashtra, MP, Tamil Nadu, Telangana, Rajasthan, Gujarat, and Chhattisgarh	Madhya Pradesh, Rajasthan, Maharashtra Gujarat, Uttar Pradesh, Punjab and Haryana (*Kharif*)
Seed rate	18-20 Kg/ha	18-20 Kg/ha	18-20 Kg/ha
Yield potential	6400 kg/ha	7500 kg/ha	7600 kg/ha

Result and Discussion

Effect of different growing environment and maize hybrid on growth attributes of maize

Plant height (cm)

Both sowings at S_1-3 July and S_2-13 July being statistically at par and recorded significantly higher plant height (201.88 and 202.93 cm, respectively) over S_3-26 July and S_4-03 August sowings (190.28 and 182.38 cm, respectively) which showed progressive decrease in plant height with successive delayed sowings shown in Fig. 1. The reason for increased plant height in early sowing may be the enhanced vegetative development of crop due to the favourable weather condition, particularly favorable rainfall and hence soil moisture regime, more favourable temperature and photoperiod regime throughout the growing period that facilitated better shoot growth. These results are in conformity with, Shingne *et al.* (2021). Among the genotypes significantly higher plant height was recorded with late maturing hybrid H_3-BIO-9682 (200.61 cm) over early matureing genotype i.e. H_1-BIO-605 (186.62 cm) however, it was at par with mid-late hybrid i.e. H_2-ADV-756 (195.87 cm). Differences observed for plant height among maize hybrids can be primarily attributed to variation in genetic makeup of plants. Moreover, different genotypes respond in different degrees to the abiotic and biotic factors. Similar results were earlier by Hemalata *et al.* (2013) and Shah *et al.* (2012).

Number of functional leaves plant^{-1}

Different sowing times had a significant influence on number of functional leaves plant^{-1} during all the growth stages presented in Fig. 2. Statistically sowing at S_1-03 July recorded significantly greater number of functional leaves plant^{-1} (17.27) but, it was at par with sowing 10 days after NS i.e. S_2-13 July (16.69) and both recorded significantly more functional leaves plant^{-1} over later sowings e.e. S_3-26 July and S_4-03 August (13.56 and 12.07, respectively). It might be due to favourable weather conditions encountered by the crop which induced better shoot growth, enhanced cell division in the meristematic region which might have increased the nodes and resultantly a greater number of leaves plant^{-1}. Similar results were reported by Zaker *et al.* (2014) and Shingne *et al.* (2021). As regards to hybrids, late maturing hybrid (H_3-BIO-9682) produced significantly higher number of functional leaves plant^{-1} (16.20) and it was at par with mid-late hybrid (H_2-ADV-756) (15.25) and were significantly higher than early i.e. H_1- BIO-605 (13.23). The higher number of leaves with late maize hybrids might primarily be attributed to the inherent ability of these hybrids to generate more leaves.

Leaf area plant^{-1} (dm^2)

As demonstrated in Fig. 3. different sowing times had significant influence on the leaf area plant^{-1} in maize crop. Normal sowing time (S_1 - 03 July) and 10 days after normal sowing time (S_2 –13 July) produced equivalent and higher leaf area plant^{-1} (69.91 and 68.87 dm^2, respectively) than most delayed sowing i.e. S_4-03 August but it was statistically at par with sowing at S_3-26 July. Progressive decrease in leaf area with later sowings was due to better growth and more functional leaves of plants under favorable weather and soil moisture regime prevailed across earlier sown growing period and a sort of inadequate situation in terms of soil moisture and weather regime in late sown crop. Similar response of sowing time to leaf area were noted by Solanki *et al.* (2015) and Muhammad *et al.* (2018). Among the hybrids, late maturing hybrid i.e. H_3-BIO-9682 produced significantly higher number of functional leaves plant^{-1} (63.27 dm^{-2}) over early maturing hybrid i.e. H_1-BIO-605 (52.02 dm^{-2}) which was at par with mid-late hybrid (H_2-ADV-756). Differences observed for leaf area among maize hybrids could primarily be ascribed to inherent genetic makeup of plant coupled with different degree of favourable weather encountered relative to the respective phenophase of different maize hybrids. This is in conformity with findings of Jadhav *et al*. (2015).

Leaf area index

Growing environment significantly influenced the leaf area index (Fig. 4). Sowing at S_1 - 03 July recorded significantly higher leaf area index (5.83) over sowing at S_3-26 July (50.96) and S_4-03 August (43.98), and it was at par with sowing at S_2 –13 July (68.87). Early sowings at S_1 and S_2 comparatively greater in leaf area resulted in greater value of leaf area index, which decreased in the delayed sowings (S_3 and S_4) as a consequence of reduced leaf area. The findings are in agreement with Muhammad *et al.* (2018). Differences among maize hybrids were statistically significant in respect of leaf area index. Late maturing hybrid (H_3-BIO-9682) produced significantly higher leaf area index over early maturing hybrid (H_1-BIO-605) and it was being at par with (H_2 -ADV-756). Higher number of functional leaves with resultantly higher leaf area per plant caused more LAI with greater duration maize hybrids. Similar variability was also reported by Jadhav *et al*. (2015) and Ayman *et al.* (2019).

Dry matter plant^{-1} (g)

According to Fig. 5. Normal sowing time (S_1-03 July) accumulated significantly higher dry matter plant^{-1} (220.86 g) over delayed sowing i.e. S_3-26 July (176.74 g) and S_4-03 August (148.50 g) however, it was at par with treatment S_2-13 July (215.21 g). The observed trend could be attributed to comparatively less favourable weather conditions and soil moisture regime encountered along the growing period by later sown crops (especially S_3 and S_4) that decreased the dry matter accumulation. Earlier sown crop i.e. S_1 and S_2 had more optimum environmental conditions comparatively that allowed the plant to gain more vegetative and reproductive growth and hence more dry matter accumulation plant^{-1}. Besides, growth period of the crop also decreased with each successive delayed sowing which also caused reduced dry matter accumulation in later sowings. This corroborates the findings of Shah *et al*. (2012), and Shrestha *et al.* (2018). Among the hybrids late maturing hybrid i.e. H_3-BIO-9682 produced significantly higher dry matter weight plant^{-1} (202.15 g) over the mid-late (H_2-ADV-756) and the early maturing hybrid i.e. H_1-BIO-605 (190.78 and 178.07 g, respectively). The differential dry matter accumulation among varieties may mainly be attributed to their genetic potential rather than the major effect of external weather parameters though weather encountered by different might have slightly differed during varied phenophase duration along the growing period of different maize hybrids. These results are in line with Girijesh *et al.* (2011) and Jadhav *et al.* (2015).

Effect of different growing environment and maize hybrid on yield and yield attributes of maize

Number of grain rows cob^{-1}

Normal sowing time, S_1-03 July recorded maximum number of grain rows cob^{-1} (15.20) which was statistically similar to the subsequent delayed sowings i.e. S_2-13 July and S_3-26 July. Significantly lowest number of grain rows cob^{-1} (13.27) was recorded when the crop was sown at S_4-03 August (13.27) which was at par with S_3-26 July. This indicates that more favourable weather regime of normal growing period of has major role to increase the ovules which are then converted in to no. of gains rows^{-1}. Differences in number of grain rows cob^{-1} among different maize hybrids i.e. late maize hybrid H_3 -BIO-9682 (14.88), mid-late hybrid H_2-ADV-756 (14.45) and early hybrid H_1-BIO-605 (14.05) were statistically not significant.

Number of grains row^{-1}

Among the growing environments, S_1 sowing time (03 July) recorded maximum number of grains row^{-1} (34.07) and it proved statistically at par with S_2 sowing time (13 July) (33.16 grain row^{-1}). Both these treatments recorded significantly higher number grains row^{-1} over the delayed sowing i.e. S_3-26 July and S_4-03 August (25.64 grains row^{-1} and 22.75 grains row^{-1}, respectively). Among the hybrids, the differences observed as regards the number of grains row^{-1} were statistically not significant. Numerically, H_3-BIO-9682 recorded maximum number of grains row^{-1} (29.84) followed by H_2-ADV-756 (29.04) and the least by H_1-BIO-605 (27.83).

Number of grains cob^{-1}

Normal sowing time, S_1-03 July recorded significantly higher number of grains cob^{-1} (512.09) which was at par with S_2-13 July (496.29). Both S_1 and S_2 sowings were significantly superior to S_3-26 July (370.22) and S_4-03 August (300.76) sowing times. The maximum number of grains cob^{-1} (445.55) was recorded with late maize hybrid i.e. H_3-BIO-9682 which was significantly more over both mid-late hybrid i.e. H_2-ADV-756 (422.28) and early hybrid i.e. H_1-BIO-605 (391.68).

Grain weight plant^{-1}

Among different sowing times that created varied growing environment, normal sowing time (S_1-03 July) recorded the maximum grain weight plant^{-1} (89.00 g) which was statistically at par with (S_2-13 July) i.e. sowing 10 days after normal sowing (86.06 g). Both S_1 and S_2 were significantly higher grain weight plant^{-1} over the subsequent delayed sowings i.e. S_3-26 July (62.50 g) and S_4-03 August (48.64 g). As regards to hybrids, late maturing hybrid (H_3-BIO-9682) produced the maximum number grain weight plant^{-1} (80.66 g) which was significantly more over both mid-late hybrid i.e. H_2-ADV-756 (70.80 g) and early hybrid i.e. H_1-BIO-605 (63.19 g).

Test weight (g)

Among the growing environments second sowing time i.e. S_2 (13 July) recorded highest test weight (24.63 g) over S_4-03 August (23.20 g), but it was at par with S_1-03 July (24.44) and S_3-26 July (23.80 g). Higher yield contributory characters in earlier two sowings S_1 (July 03) and S_2 (July 13) might be due to better expression of growth characters like plant height, dry matter production and leaf area due to favourable weather and soil moisture regime encountered across different phenophase by these two sowing times as compared to later sowings of S_3 (26 July) and S_4 (03 August). Later sowings had availability of progressively shorter rainy season and comparatively less favourable weather conditions particularly across reproductive phenophases. These results are in accordance with Shingne *et al.* (2021). Among the maize hybrids, H_3-BIO-9682 recorded maximum test weight (24.51 g) than H_1-BIO-605 (23.55 g), and it was statistically at par with H_2-ADV-756 (24.00 g). Yield contributory characters are primarily and strongly influenced by inherent genetic traits. Late maize hybrid with greater leaf area and dry matter accumulation translated to greater number of grain cob^{-1}, grain weight plant^{-1} with bold grains. This is in conformity with the findings of Barakatullah, *et al.* (2021).

Grain yield (kg ha^{-1})

Different sowing time that created varied growing environment had a profound influence on the grain yield. Normal sowing time (S_1-03 July) recorded significantly higher seed yield (5110 kg ha^{-1}) which was statistically at par with subsequent 10 days delayed sowing S_2-13 July (4925 kg ha^{-1}). Both were significantly more over S_3-26 July (3402 kg ha^{-1}) and S_4-03 August (2359 kg ha^{-1}) sowings. The grain yield reduction of maize due to delayed sowing was to an extent of 3.62%, 33.42% and 46.16 % in crop sown after 10, 20 and 30 days after normal sowing, respectively. It might be due to relatively better expression of vegetative and reproductive attributes indicating that these earlier sowings enabled the crop to express the inherent potential to the maximum as compared to later sowings (26 July and 03 August) where crop growing period was also squeezed limiting crops potential output. Other authors Maresma *et al.*

(2019), Sharma *et al.* (2022) have noted similar decisive effect of sowing time on maize growth and development and reported reductions in various morpho-physiological attributes with delayed sowing due to reduced soil moisture regime and less favourable weather variables. In general grain yield decreased with maturity duration of maize hybrids. Among the hybrids, late maturing maize hybrid, H_3-BIO-9682 recorded significantly higher seed yield (4354 kg ha^{-1}) than mid-late hybrid, H_2-ADV-756 (3971 kg ha^{-1}) and early hybrid, H_1-BIO-605 (3521 kg ha^{-1}). Grain yield is the outcome of yield attributing traits namely number of grains row^{-1}, number of grains cob^{-1} and test weight have important role for yield. The genetic potential of particular genotypes can be judged by the yield attributing traits and observed variation may be attributed to differences at their genotypic level. Therefore, superior yield level with late maize hybrid BIO-9682 was primarily due to better expression of yield components as compared to ADV-756 and BIO-605. Barakatullah, *et al.* (2021) and Subrahmanyam *et al.* (2021) also found highly significant differences among different maturity group genotypes for yield contributing traits and grain yield which strongly support the present finding.

Stover yield (kg ha^{-1})

Stover yields were statistically comparable in sowing at S_2-13 July (8865 kg ha^{-1}) and S_1-03 July sowings (8745 kg ha^{-1}) and significant decline in stover yield was noticed under S_3-26 July (6862 kg ha^{-1}) and S_4-03 August (5151 kg ha^{-1}) sowings. The higher stover yield under S_1 and S_2 treatments might be due to increased vegetative growth in terms of plant height, number of leaves/leaf area and dry matter accumulation. Differences in stover yield due to different maturity group hybrids were significant. Significantly higher stover yield was obtained with late maize hybrid, H_3-BIO-9682 (7829 kg ha^{-1}) which was at par with mid-late hybrid, H_2-ADV-756 (7431 kg ha^{-1}). The latter was at par with early hybrid H_1-BIO-605 (6957 kg ha^{-1}). This might be mainly due to increased vegetative attributes inherently of longer duration maize hybrids.

Biological yield (kg ha^{-1})

Crop sown on normal sowing time (S_1-03 July) recorded significantly higher biological yield (13855 kg ha^{-1}) at par with subsequent 10 days delayed sowing i.e. S_2-13 July (13789 kg ha^{-1}). Progressive significant decrease in biological yield was noticed beyond 10 days delayed (S_2), sowing under (S_3-26 July) 20 days delay (10264 kg ha^{-1}) and (S_4-03 August) 30 days delay (7510 kg ha^{-1}). The aforesaid biological yield outturn could be due to better vegetative expression and in turn better promotion of yield and yield components in earlier sown crops (S_1 and S_2) as compared to subsequent delayed sowings (S_3 and S_4). These results are substantiated by the findings of the study by Shrestha *et al.* (2018). Late duration maize hybrid (H_3-BIO-9682) recorded highest biological yield (12124 kg ha^{-1}) which was significantly superior over intermediate duration hybrid (H_2-ADV-756) (11402 kg ha^{-1}) and early duration hybrid (H_1-BIO-605) (10478 kg ha^{-1}). The observed differences in the biological yield of maize hybrids could be the reflection of observed values of vegetative and reproductive parameters in biomass production of respective the maize hybrids.

Harvest index

Maize crop subjected to variable growing environment through different sowing time exhibited differences in terms of harvest index; which decreased with successive later sowings. Maximum harvest index was recorded with (S_1-03 July) (36.94%) sowing time which was nearest with (S_2-13 July) (35.67%). (S_3-26 July) sowing recorded harvest index of 33.10% whereas (S_4-03 August) recorded the least harvest index of 31.47%. Relatively higher harvest index in earlier sowings (S_1 and S_2) could be due to comparatively better translocation efficiency. The above results are in conformity with Sharma *et al.* (2022), whereas Dahmardeh (2012) reported higher harvest index with intermediate sowing time than early or late sowing. Among the maize hybrids, late hybrid (H_3-BIO-9682) recorded the maximum harvest index (35.44%) followed by mid-late hybrid, H_2-ADV-756) (34.47%) and early hybrid, H_1-BIO-605 (32.97).

Conclusion

Maize crop sown during first week (03 July) to second week (13 July) of July availed higher recorded significantly higher growth and yield attributes, higher grain and biomass yield. delayed sowings beyond mid-July (26 July and 03 August) experienced reduced rainfall and elevated temperature regimes during the critical reproductive phase, adversely affecting yield and yield attributing chrematistics. Among the tested genotypes, the late-maturing hybrid BIO 9682 outperformed others by achieving the highest grain and biomass yield indicating its suitability for enhanced productivity under optimal sowing windows.

Table 2 : Effect of different yield and yield attributes as influenced by growing environment and maize hybrid

Treatment	No. of grain rows cob^{-1}	No. of grains row^{-1}	No. of grains cob^{-1}	Grain wt. plant^{-1} (g)	Test wt. (g)	Grain yield (kg/ha)	Stover yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)
Growing environment									
S_1- Normal sowing time	15.20	34.07	512.09	89.00	24.44	5110	8745	13855	36.94
S_2- 10 days after normal sowing	15.04	33.16	496.29	86.06	24.63	4925	8865	13789	35.67
S_3- 20 days after normal sowing	14.47	25.64	370.22	62.50	23.80	3402	6862	10264	33.10
S_4- 30 days after normal sowing	13.27	22.75	300.76	48.64	23.20	2359	5151	7510	31.47
SE(m)$\pm$	0.69	1.28	12.32	2.62	0.19	103	164	220	--
CD (P=0.05)	1.40	4.42	42.64	9.05	0.65	355	566	760	--
Maize hybrid									
H_1- BIO - 605	14.05	27.83	391.68	63.19	23.55	3521	6957	10478	32.97
H_2- ADV - 756	14.45	29.04	422.28	70.80	24.00	3971	7431	11402	34.47
H_3- BIO - 9682	14.88	29.84	445.55	80.66	24.51	4354	7829	12184	35.44
SE(m)$\pm$	0.40	0.87	7.68	1.89	0.17	122	207	215	--
CD (P=0.05)	NS	NS	23.02	5.66	0.51	366	620	644	--
Interaction									
SE(m)$\pm$	0.79	1.73	15.35	3.77	0.34	244	414	430	--
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	--
GM	**14.49**	**28.90**	**419.84**	**71.55**	**24.02**	**3949**	**7406**	**11355**	**34.29**

S_1:03 July, S_2:13 July, S_3:26 July, S_4: 03 August

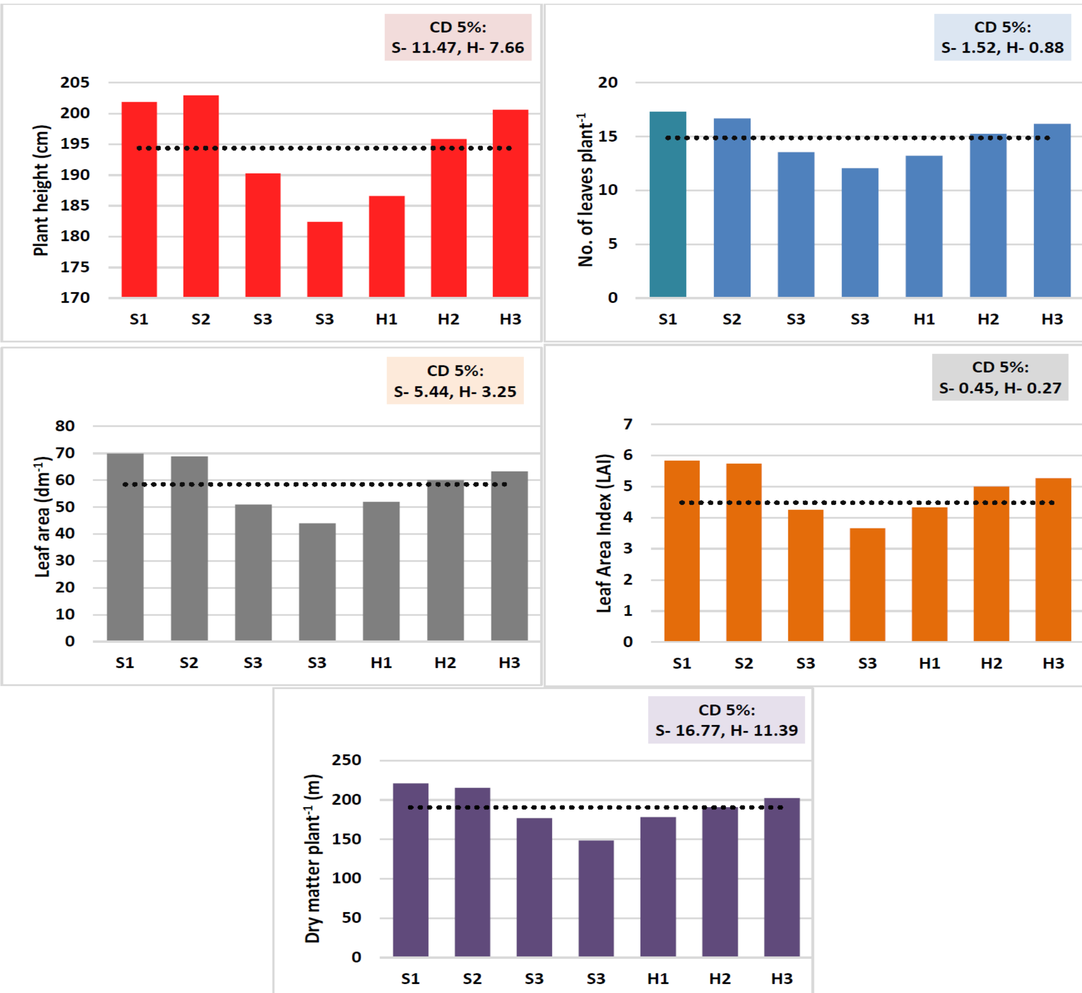

Fig. 1: Effect of different growing environment and maize hybrid on growth attributes of maize

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