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Effect of different growing environments on growth and development of maize crop (*Zea mays* L.)

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Abstract
A field experiment was carried out at Agrometeorological Research Farm, Acharya Narendra Deva University of Agriculture & Technology, Kumarganj, Ayodhya (U.P.) during kharif season of 2021-22 and 2022-23 to study the effect of crop growing environment on growth and Development of *kharif maize* (*Zea mays L.*) cultivars. The experiment comprised nine treatment combinations and conducted in Randomized block design and replicated four times. Treatment consisted of three crop growing environment *viz.* 1st July, 11th July and 21st July with three cultivars *viz,* Shweta, type-41 and Tarun. Results reveal that Plant height (cm), dry matter accumulation (gm^{-2}) and leaf area index increased significantly at all the stages of crop growth except 15 DAS. Highest values are recorded with the crop growing environment on 1st July followed by 11th July. Lowest values of all were recorded in 21st July of crop growing environments. Among the varieties, Shweta took relatively longer duration and ultimately matured 4 days delayed over Tarun and Type-41 when it was sown on 1st July crop growing environment. This study may help to select the suitable sowing time under climatic condition of eastern Uttar Pradesh.

Keywords: Maize, growing environment, growth, phenophase, plant height, leaf area index, dry matter accumulation

Introduction
Maize (*Zea mays* L.) belongs to family poaceae is one of the 3rd most important cereal crops in the world after rice and wheat. It is one of the world's principal food crops, feeding both human and livestock (Tahir *et al*., 2008) [16]. It is known as 'Queen of Cereals' because of its special characteristics that include its carbon pathway (C4), wider adaptability, higher multiplication ratio, desirable architecture, superior transpiration efficiency, high versatile use *etc*. Ramasamy *et al.,* (2017) [13]. Over 85% of maize produced in the country is consumed as human food. Green cobs are roasted and consumed by people with great interest. Several food dishes including chapaties are prepared out of maize flours and grains. Green maize plants are used as succulent fodder. Popping the corn is a method of starch cookery. Thus it is used as one of the important sources of carbohydrates for human consumption and as feed for livestock (Undie *et al.,* 2012) [17]. The importance of maize lies in its wide industrial applications besides serving as human food and animal feed. Maize seed contains 10% protein, 4% oil and 2-3% crude fiber Kumar *et al.,* (2020) [10]. Maize is a raw material for a number of products viz., starch, glucose, dextrose, sorbitol, dextrine, high fructose syrup, malto dextrine, germ oil, germ meal, fiber rand gluten products which have application in industries such as alcohol, textile, paper, pharmaceuticals, organic chemicals, cosmetics and edible oil Kumar *et al.,* (2020) [10]. Maize has got very high yield potentiality and wide adaptability under various agro climatic conditions than any other cereal crops. It is traditionally a rainy season crop in India and is extensively grown as an important Kharif crop under rainfed or irrigated condition, but Kharif crop suffers due to vagaries of monsoon, excessive rainfall leading to water stagnation, poor drainage, erratic and insufficient rainfall leading to moisture stress condition, severe infestation of insect pest-diseases, fertilizer losses, greater weed menace and high temperature throughout the growth period which tend to reduce grain yield in Kharif maize.

On the contrary, the risk of damage to the crop from excessive rainfall, water stagnant, less soil moisture, insect pest-diseases during winter season is less. *Rabi* maize may either be grown with residual soil moisture or with the supply of irrigation water which can be controlled relatively better during winter season. *Rabi* maize makes best use of low temperature, bright sunshine and has longer duration than Kharif maize. Winter maize crop which makes the best use of low temperature and sunshine hours has longer growth duration of about 150-170 days than 100-120 days under Kharif crop. As such in winter it synthesizes more food material resulting in higher yields Singh, 2013. In India, maize is grown in diverse environments-from the dry area of Chitradurga, Karnataka to the warm wet plateau of Chindwara, (M.P). Since maize is largely grown under rainfed conditions during the rainy season, the crop is sown with the onset of the monsoon. Sowing window of maize occurs during Ist fortnight of June to the Ist fortnight of July depending upon the onset of the monsoon. Maize yields during the winter season are higher than yields during the rainy season. During winter, maize enjoys a favorable environment of cool temperatures, clear sky and higher solar radiation interception with less infection of insect pests and there by better yields Joshi *et al.*, 2005 [8].

In India, the area of maize in 2016-17 was about 9.63 million hectare with a production of 25.90 million tons and productivity 2689 kg/hectare, In 2017-18 the area was about 9.38 million hectares with a production of 28.75 million tons and productivity was 3065 kg/hectare, In 2018-19 the area was about 9.03 million hectares with a production of 27.72 million tons and productivity was 3070 kg/hectare, In 2019-20 the area was 9.57 million hectares with a production of 28.77 million tons and productivity was 3006 kg/ha (Directorate of Economics and Statistics, 2022) [4]. In Uttar Pradesh cultivation of maize is done for both human consumption and fodder. Maize is grown in all the three seasons of the year i.e., kharif, rabi and summer season. The area of maize in 2019-20 was 0.77 million hectares with a production of 1.80 million tons and productivity was 2331 kg/ha, in 2020-21 the area was 0.73 million hectares with a production of 1.69 million tons and productivity was 2323 kg/ha (Directorate of Economics and Statistics, 2022) [4]. Environmental factors such as temperatures, radiation and their seasonal trend results in the uncertainty in crop growth, development and yield (Prasad *et al*., 2008) [12]. The key challenge is to determine the favorable planting condition for higher production (Harrison *et al*., 2011) [7]. The ideal planting time of maize hybrids is different due to differences in maturity and length of growing season as it is temperature dependent (Hammad *et al*., 2017) [6]. To maximize the yield, it is essential to select the maize hybrids with right maturity according to planting window (Butler and Huybers, 2015) [2]. Warm growing season affected the crop yield by accelerating the crop growth that shorten the time for grain formation (Funk *et al*., 2008) [5].

Materials and methods

The experiment was conducted at Agro-meteorological Research Farm of Acharya Narendra Deva University of Agriculture & Technology, Narendra Nagar (Kumarganj), Ayodhya (UP), India, which is geographically situated between 26° 47' N latitude and 82° 12' E longitude and at an altitude of 113 meters above mean sea level. Geographically experimental site falls under a sub-tropical climate of Indo-Gangetic plains having alluvial soil. The average annual precipitation is about 1001 mm of which 85-90 percent received during monsoon period during May. The average weekly weather data during crop period obtained from Agro meteorological observatory of Acharya Narendra Deva University of Agriculture & Technology, Narendra Nagar (Kumarganj), Ayodhya (UP). For physico-chemical properties of the experimental field and its fertility status, the soil samples were collected randomly from the field with help of a soil auger to a depth of 0-15cm prior to Sowing. These samples were mixed together and a composite soil sample representing whole field was taken and analyzed properly. The experiment was conducted in Randomized Block Design with four replications. Nine treatment combinations comprised three Crop growing environments viz. July 1st (D1) (33 °C), July 11th (D2) (31.75 °C) and July 21st (D3) (30.5 °C) along with three cultivar viz. Shweta (V1), Type-41 (V2) and Tarun (V3) were used under this investigation. The experimental field was prepared thoroughly by ploughing twice with country plough followed by blade harrow to achieve fine tilth. Subsequently plots were laid out as per the layout plant. Healthy and matured seeds of maize treated with Mancozeb @ 3.0 g Kg^{-1} seed to protect the crop from seed borne diseases were used for sowing. As per the Treatments seed were sown to get desired plant population the seeds were dibbled at a depth of 5 cm in conventionally tilled soil on flat beds. Gap filling was done after 10 DAS to maintain desired plant population. The Recommended dose of fertilizer (120-50-40 kg ha$^{-1;}$ N: P_2O_5: K_2O) was applied to maize crop. Full dose of P_2O5, K_2O and one-fourth dose of nitrogen was applied as basal and half N was applied as topdressing after 35 DAS while the remaining one-fourth N was applied at tasseling stage. The sources of N, P, and K were Urea, SSP and MOP respectively. Atrazine @ 1.5 kg *a. i.* ha^{-1} was applied as pre-emergence spray immediately after sowing and it was followed by one-hand weeding in rows done at 30 DAS. Chloropyriphos @ 2 ml lit^{-1} was applied in order to control the incidence of leaf folder at 25 DAS. Irrigation was applied as per requirement of the crop during Kharif season. Harvesting was done when the sheaths of the cob were dried completely. The border rows were harvested firstly. Later, the crop from the net plot was harvested. The cobs from the net plots were sundried and shelled with a mechanical hand Sheller and the seeds were separated and sun-dried on an open threshing floor to a moisture level of 12 per cent. Stover was sun-dried to a constant weight in the plots itself. Seed and stover yield was recorded plot-wise and finally converted in kg ha^{-1}.

Plant height (cm)

Plant height was recorded from the five randomly tagged plants at different intervals viz., 15, 30, 45, 60, 75 DAS and at harvest by measuring from the base of the stem (ground level) to the growing tip of the top most leaf up to tasseling stage and thereafter the height was recorded from the base of the stem to the tip of the tassel and the mean plant height was calculated and expressed in cm.

Leaf area index

Leaf area of five sampled plants from border rows was measured at 15, 30, 45, 60, 75 DAS by using leaf area meter. After computing the leaf area as explained above, LAI was calculated by using the following formula as suggested by Watson (1952) [18].

$$LAI = \frac{\text{Leaf area}}{\text{Ground area}}$$

Dry matter accumulation (gm^{-2})

Dry matter accumulation at 15, 30, 45, 60, 75 DAS and at harvest was recorded from five plants of the border rows left for destructive sampling. After oven drying to a constant weight at 65 °C, the dry matter was weighed expressed as dry matter production in gm^{-2}.

Results and Discussions

Plant height (cm)

The data in the table show that plant height was significantly affected by different dates of sowing/weather variability and maize cultivars at all stages of crop growth, except 15 days after sowing in both the cases *i.e.* date of sowing and cultivars. Sowing on 1st July recorded significantly taller plants at all the stages except 15 DAS and superior over 21st July (sowing delayed by 20 days over normal) and at par with 11th July during the year 2021 and 2022, respectively. Among the varieties Shwetha had the highest plant height among the cultivars, and it was significantly superior over Type-41 and at par with Tarun at all growth stages except 15 days after sowing. It could be attributed to the fact that due to higher plant density, it would certainly reduce the amount of light availability to the individual plant, especially to lower leaves due to greater shading. As the mutual shading increases at high plant densities, the plant tends to grow taller. The results are in conformity with the findings of Kosgasago (2006) [9] and Amjadian *et al*. (2013) [1] in maize.

Table 1: Plant height (cm) of Kharif maize cultivars as affected by crop growing environments

Treatment	Plant height											
	15 DAS		30 DAS		45 DAS		60 DAS		75 DAS		At har	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Crop growing environments												
1st July	25.53	26.43	66.57	68.90	110.97	114.83	147.90	153.10	184.90	191.37	192.60	199.33
11th July	25.03	25.93	64.30	66.53	107.13	110.90	142.87	147.90	178.57	184.80	186.00	192.53
21st July	24.53	25.40	60.87	63.00	101.43	105.00	135.30	140.03	169.07	174.97	176.13	182.30
SEm±	0.548	0.540	1.41	1.46	2.334	2.708	3.137	3.247	3.889	4.513	4.084	4.227
CD at 5%	1.600	1.577	4.119	4.26	6.811	7.903	9.155	9.477	11.352	13.172	11.920	12.337
Cultivars												
Shwetha	25.30	26.20	66.27	68.57	110.40	114.27	147.20	152.37	184.00	190.43	191.67	198.40
Type -41	24.70	25.57	60.63	62.73	101.07	104.63	134.77	139.50	168.43	174.30	175.47	181.60
Tarun	25.10	226.00	64.83	67.13	108.07	111.83	144.10	149.17	180.10	186.40	187.60	194.17
SEm±	0.548	00.54	1.411	1.46	2.334	2.708	3.137	3.247	3.889	4.513	4.084	4.227
CD at 5%	1.600	11.58	4.119	4.26	6.811	7.903	9.155	9.477	11.352	13.172	11.920	12.337

Leaf area index

The data in the table shows that the leaf area index was considerably affected by varying dates of sowing/ weather variability and cultivars at all phases of crop growth except 15 DAS. LAI successively increased till 75 DAS and there after it gradually declined till the harvest of crop due to leaf senescence. Sowing on 1st July recorded significantly higher LAI at all the stages except 15 DAS and superior over 21st July (sowing delayed by 20 days over normal) and at par with 11th July during the year 2021 and 2022, respectively. Among the varieties Shwetha had the highest LAI among the cultivars, and it was significantly superior over Type-41 and at par with Tarun at all growth stages except 15 days after sowing. Increase in LAI was due to increased plant density which accommodates more number of plants per unit area thereby increased the functional leaves and in turn enhanced the LAI. Similar variability was also reported by Dahmardeh and Dahmardeh, (2010) [3]. The leaf area index (LAI) of maize increased- progressively with the advance in the age of the crop up to 60 DAS, beyond which it was found to decline up to harvest.

Table 2: Leaf area index of Kharif maize cultivars as affected by crop growing environments:

Treat	LAI											
	15 DAS		30 DAS		45 DAS		60 DAS		75 DAS		At har	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Crop growing environments												
1st July	0.56	0.58	1.00	1.03	2.28	2.35	2.61	2.71	2.35	2.44	1.06	1.10
11th July	0.55	0.57	0.97	1.00	2.20	2.27	2.52	2.61	2.27	2.35	1.02	1.06
21st July	0.54	0.56	0.91	0.95	2.08	2.15	2.39	2.48	2.15	2.23	0.97	1.00
SEm±	0.012	0.014	0.021	0.022	0.048	0.055	0.055	0.057	0.05	0.057	0.023	0.023
CD at 5%	0.035	0.041	0.062	0.064	0.140	0.162	0.162	0.168	0.14	0.168	0.066	0.068
Cultivars												
Shwetha	0.56	0.58	0.99	1.03	2.26	2.34	2.60	2.70	2.34	2.42	1.05	1.09
Type -41	0.54	0.56	0.91	0.94	2.07	2.14	2.38	2.47	2.14	2.22	0.96	1.00
Tarun	0.55	0.57	0.97	1.01	2.22	2.29	2.55	2.64	2.29	2.37	1.03	1.07
SEm±	0.012	0.014	0.021	0.022	0.048	0.055	0.055	0.057	0.05	0.057	0.023	0.023
CD at 5%	0.035	0.041	0.062	0.064	0.140	0.162	0.162	0.168	0.14	0.168	0.066	0.068

Dry Matter accumulation

The results in the table show that variable dates of sowing and maize cultivars had a substantial impact on dry matter accumulation (gm^{-2}) at all stages of crop growth except 15 DAS. At all stages of crop growth, an increased dry matter accumulation (gm^{-2}) was recorded with the 1st July date of sowing, which was comparable to the 11th July date of sowing but significantly superior over 3rd date of sowing. (*i.e.* 1st

July). In terms of cultivars, Shwetha had the highest dry matter accumulation (gm^{-2}) at all phases of crop growth, which was comparable to Tarun and significantly superior over Type-41. Higher dry matter production was due to more plant height and increased LAI together produced higher dry matter production. Similar results were reported by Nielson *et al*. (2002) [11] and Sulochana *et al*. (2015) [15].

Table 3: Dry matter accumulation (gm^{-2}) of Kharif maize cultivars as affected by crop growing environments

Treat	DMA											
	15 DAS		30 DAS		45 DAS		60 DAS		75 DAS		At harvest	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Crop growing environments												
1st July	103.60	105.20	170.23	170.03	425.60	425.10	654.77	654.03	1091.30	1090.00	1399.07	1397.47
11th July	102.03	103.63	164.33	164.33	410.93	410.93	632.17	632.17	1053.60	1053.60	1350.77	1350.77
21st July	100.53	102.10	154.83	154.83	387.03	387.03	595.43	595.43	992.43	992.43	1272.33	1272.33
SEm±	2.238	2.524	3.606	3.606	8.928	10.029	13.869	13.862	22.892	25.715	29.635	29.620
CD at 5%	6.532	7.367	10.525	10.525	26.059	29.273	40.481	40.461	66.817	75.057	86.499	86.455
Cultivars												
Shwetha	103.83	105.43	170.20	170.13	425.53	425.37	654.63	654.40	1091.07	1090.63	1398.80	1398.27
Type -41	100.10	101.67	152.40	152.33	381.03	380.87	586.20	585.93	977.00	976.57	1252.57	1252.03
Tarun	102.23	103.83	166.80	166.73	417.00	416.83	641.53	641.30	1069.27	1068.83	1370.80	1370.27
SEm±	2.238	2.524	3.606	3.606	8.928	10.029	13.869	13.862	22.892	25.715	29.635	29.620
CD at 5%	6.532	7.367	10.525	10.525	26.059	29.273	40.481	40.461	66.817	75.057	86.499	86.455

Conclusion

The plant height, Dry matter accumulation and LAI were highest for July 1st sowing (D_1) followed by July 11th (D_2) and July 21st (D_3) and among varieties, Shweta (V_1) followed by Tarun (V_2) and Type-41 (V_3). Plant height (cm), dry matter accumulation (gm^{-2}) increased significantly at all the stages of crop growth while leaf area index increased significantly at all the stages up to 60 DAS of crop growth and further it decreased gradually till the maturity. This study may help to select the suitable sowing time under climatic condition of eastern Uttar Pradesh.

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