Original Research article

Sowing Environments and yield of maize (*Zea mays* L.) cultivars under changing climate conditions of North Western Himalayan Region

Abstract

Sowing dates, as one of the primary agronomic practices have significant influence over yield of maize especially during the times of climate change.Therefore, the present field investigation was conducted during the *Kharif* cropping seasons of 2013 and 2014 to evaluate different sowing dates for their influence over maize (*Zea mays* L.) yield.The field experiment was conducted in a randomized block design with factorial arrangement consisting of four dates of sowing and three maize cultivars. The study results revealed that sowing of crop by 10th June can have taller plants (261.5 and 265.2 cm for 2013 and 2014, respectively) significantly better yield contributing characters of maize such as number of cobs per plant (1.1 and 1.1 for 2013 and 2014, respectively) number of grains per cob(258.7 and 268.3 for 2013 and 2014, respectively)and test weight(268.5 and 271.6grams for 2013 and 2014, respectively). Similarly, the significantly higher maize grain (57.3 and 60.1 quintal/hectare for 2013 and 2014, respectively) andstover yield (108.8 and 109.2 quintal/hectare for 2013 and 2014, respectively) was recorded with sowing of maize crop by 10th June. Among the maize cultivars, HQPM-1 resulted in substantially higher maize grain(53.9 and 56.5 quintal/hectare for 2013 and 2014, respectively) and stove yield(102.9 and 104.1 quintal/hectare for 2013 and 2014, respectively).Based on the present field investigation, it can be concluded that sowing of maize by 10th June and maize cultivar HQPM-1 can be recommended for better yield levels under the givenconditions of North-western Himalayas.

Keywords: Cobs, Grain, Growth, *Kharif*, Phenology

Introduction

Maize (*Zea mays* L.)is the most widely cultivated cereal in theworld with considerable utilization as food, feed grain as well as industrial feedstock(Kumar *et al.*, 2023). Maize has been cultivated across 170 countries with an area of 203.5 million hectares and production of around 1163.5 million tonnes (FAOSTAT, 2024). Worldwide presence of maize can be attributed to highest production potential among cereals, substantially higher water use efficiency, wider edaphic and environment adaptability (Choudhary *et al.*, 2020). Similarly, maize is significant crop of *Kharif*season in India cultivated on an area of 9.9 million hectares and production of 33.7 million tonnes (FAOSTAT, 2024). Maize has wider cultivation in North-western Himalayan states of India, especially Himachal Pradesh wherein it is cultivated in *Kharif* season. Maize productivity is significantly controlled with innate cultivar genetic potential as well as agronomic practices adopted (Rizzo *et al.*, 2022). Optimizing the choice of suitable cultivar for prevailing environmental conditions can be a critical factor to harvest considerable grain from maize crop especially under the times of climate change(Tiwari *et al.*, 2022). Climate change has been seen as a critical factor influencing affecting crop productivity especially in 20th century (Mrabet*et al.*, 2023).In Himachal Pradesh, decreasing trends of rainfall and on contrary increase in maximum and minimum temperatures have already been reported to impact crop production especially maize (Rana *et al.*, 2012; Rana *et al.*, 2013; Rana *et al.*, 2018).

Among agronomic practices, such as fertilizer application, seed rate and spacing, planting dates have significant influence over maize productivity(Chandel *et al.*, 2022; Pareek *et al.*, 2023).During the times of climate change, it is imperative to study the response of crops to varying atmospheric conditions (Sharma *et al.*, 2024).Optimizing planting dates offers an opportunity to enhance maize productivity with enhanced utilization of environmental resources such as sunlight, rainfall, and temperatureunder varying atmospheric conditions (Djaman*et al.*, 2022). Varying planting dates expose the crop to variable climatic conditions and therefore may alter the crop productivity. Early as well as late planting of the crop may results in significant decline in crop productivity. Growers in rainfed regions of the world depend heavily on deciding suitable planting dates in order to maximize utilization of available rainwater(Jaramillo *et al.*, 2020). Therefore, critically investing a particular planting date is significant to enhance crop productivity. Variable planting dates even for crop cultivars exert significant influence over their productivity (Abbas *et al.*, 2019). However, for a same planting date, variable crop cultivars behave differently in terms of biomass accumulation and grain productivity.

There is a significant lack of scientific information on effect of planting dates and maize cultivars over maize growth and productivity under North-western Himalayan conditions. Therefore, the study was conducted to analyze theeffect of variable planting dates and maize cultivars over maize growth, phenology, yield attributes and yield. The novelty of the study lies in its exploration of optimizing maize production through the interplay of planting dates and cultivar selection which remains a relatively underexplored area in maize agronomy. The present study will address effect of climatic variability and cultivar specific response over maize productivity.

Material and methods

The field experiments were conducted during *kharif* seasons of 2013 & 2014 at research farm of Department of Agronomy,CSK HPKV, Palampur (Himachal Pradesh) ($32^0 6'$ N, $76^0 3'$ E) at an elevation of about 1290.8 m above mean sea level.Experimental treatments were distributed in randomized block design with factorial arrangementinvestigating four dates of sowing and three maize cultivars (*Girija*, *Bajaura Makka* and HQPM-1), replicated three times.During crop growing season from May to September, the weekly maximum and minimum temperature ranged between 24.0 to 32.4 ^{0}C and 12.9 to 20.8 ^{0}C during 2013 and 23.4 to 33.6 ^{0}C and 11.8 to 21.2 ^{0}C during 2014, respectively with rainfall of 1333 mmduring 2013 and 2629.4 mm during 2014 and sunshine duration ranged 9.1 hours during 2013- and 11.7-hours day^{-1} respectively.

In case of observations recorded, crop development parameters such as days to complete emergence, days to knee high stage, days to tasselling and days to physiological maturity were recorded. For growth and yield attributes plant height, leaf area index, number of cobs plant^{-1}, number of grains cobs $^{-1}$, 1000-grain weight, grain yield and stover yield were recorded.

Statistical analysis

The data presented in the present research manuscript has been subjected to analysis of variance (ANOVA) procedure prescribed by Gomez and Gomez (1984) for randomized block design with factorial arrangement. The differences among treatment means were assessed at 5% level of significance using least significance differences.

Results and discussion

The data for effect of maize cultivars and dates of sowing on number of days taken to different phenological stage during 2013 and 2014 have been presented in Table 1. A perusal of the data revealed that maize cultivars were not significantly different in terms of number of days to complete different phenological stages such as complete emergence, knee high stage, tasselling and physiological maturity.

However, significant influence of different dates of sowing over number of days to attain different phenological stages was observed. The crop sown on 30th May and 10th June attained different phenological stages such as complete emergenceknee high stage, tasselling and physiological maturity in statistically equivalent number of days. However, crop sown on 20th and 30th June completed various phenological stages such as complete emergence, knee high stage, tasselling and physiological maturity in comparably shorter duration. Especially, crop sown on 30th June has shorter reproductive duration in terms of tasselling and physiological maturity. Reduction in number of days or duration of reproductive stages was significantly reduced with delayed sowing of maize was also observed by Shrestha and his co-workers in 2016. Similarly, Cao et al. 2024 reported similar findings to the present study wherein accelerated reproductive growth or shortened reproductive period of maize was observed with delayed sowing.

Table 1. Effect of sowing dates on number of days taken to different phenological stage of maize cultivars during 2013 and 2014.

	Days taken to							
Cultivars	**Complete emergence**		**Kneehigh stage**		**Tasselling**		**Physiological maturity**	
	2013	2014	2013	2014	2013	2014	2013	2014
Girija	7.8	6.6	34.7	34.3	58.6	57.1	109.8	106.7
Bajaura Makka	7.1	5.8	34.3	33.8	58.4	56.2	108.8	106.0
HQPM-1	7.1	6.1	34.8	34.4	59.8	57.7	110.9	108.0
CD (5%)	NS	NS	NS	NS	NS	NS	NS	NS
Sowing dates								
30thMay	7.4	6.2	36.0	35.8	61.0	59.9	113.8	109.6
10th June	7.0	5.8	34.4	34.4	60.1	57.1	112.1	108.3
20th June	7.1	6.0	34.1	33.3	59.2	56.2	108.8	106.1

30th June	7.8	6.7	33.8	33.2	56.3	54.4	106.7	104.6
CD (5%)	NS	NS	1.63	1.94	3.30	2.85	3.00	2.85

Growth and yield attributes

Plant height

The data for plant height of maize crop plants for *Kharif* 2013 and 2014under the influence of various planting dates and maize cultivars has been presented in Table 2. Plant height was significantly influencedby different sowing dates. However, no significant influence was observed with different maize cultivars over plant height.

The crop sown on 10th June recorded plant height of 261.5 and 265.2 cm; for 2013 and 2014*Kharif* seasonwhich were the tallest plantsfor maize crop, however on the other hand crop sown on rest of sowing dates such as 30th May (251.3 and 255.0 cm; for 2013 and 2014), 20th (251.0 and 255.0 cm; for 2013 and 2014) and 30th June (250.9 and 254.6 cm; for 2013 and 2014) resulted in comparatively shorter plants. It was observed that advanced as well as delayed sowing before and after 10th June, respectively resulted in significant decrease in plant height of maize cultivars. The results of the present investigation are in harmonywith thosereported by Akther et al. 2024 whomreported decrementsinplant height with delayed sowing. They added that significantly higher plant height for optimized date of sowing was attributed to considerable growth duration available for biomass accumulation and contributing to increased stature of crop plants.Optimized sowing dates affect resource utilization efficiency in terms of radiant energy utilization and enhance crop production(Pokhariyal*et al.*,2021).

Yield attributes

Various dates of sowing exerted significant influence over yield attributes of maize whereas no significant influence of various maize cultivars was observed over the yield attributes such as cobs per plant, grains per cob and test weight(Table 2).

The cobs per plant of maize were recorded to be the highest for the crop sown on 10th June for both the cropping seasons of 2013 (1.1) and 2014 (1.1) whereas the crop sown on 30th May (1.0 and 1.0; for 2013 and 2014), 20th June (1.0 and 1.0; for 2013 and 2014) and 30th June (1.0 and 1.0; for 2013 and 2014) resulted in comparatively lower values for various yield attributes in both the cropping seasons of 2013 and 2014. The grains per cob for maize were recorded to be the highest for the crop sown on 10th June (258.7 and 268.3 for 2013 and 2014) for both the cropping seasons of 2013 and 2014 whereas the crop sown on30th June (229.9 and 237.9 for 2013 and 2014) resulted in the lowest values for grains per cob. The test weight for maize were recorded to be the highest for the crop sown on 10th June (268.5 and 271.6 g for 2013 and 2014) for both the cropping seasons of 2013 and 2014 whereas the crop sown on30th June (258.7 and 261.7 g for 2013 and 2014) resulted in the lowest values for grains per cob. Reduction in yield attributing characters of maize with delayed sowing can be attributed to shortened reproductive period duration for late planting windows. Recently, similar trend was observed by Akther et al. (2024), and previously by Buriri et al. (2015) for maize yield attributing characters of maize with delayed sowing.

Yield levels

The data for effect of maize cultivars and different sowing dates on maize yield levels(grain and stover)have been presented in Table 2. A perusal of the data revealed that significant effects of maize cultivars and different sowing dates were observed on maize grain and stover yield.

Maize grain yield was recorded to be the highest for maize cultivar HQPM-1 (53.9 and 56.5 q/ha for 2013 and 2014, respectively) for both the cropping seasons of 2013 and 2014. However, Maize cultivars such as *Girija*(47.9 and 50.1 q/ha for 2013 and 2014, respectively) and *BajauraMakka*(47.4 and 49.5 q/ha for 2013 and 2014, respectively) preformed significantly inferior toHQPM-1 in terms of maize grain yield for the cropping seasons of 2013 and 2014. Similarly, performance in terms of maize stover yield was recorded with various maize cultivars i.e., highest yield for HQPM-1 (102.9 q/ha and 104.1 q/ha for 2013 and 2014, respectively) and significantly inferior for *Girija* (97.6 and 98 q/ha for 2013 and 2014, respectively) and *BajauraMakka* (92.1 and 95.9 q/ha for 2013 and 2014, respectively).

Among different dates of sowing, crop sown on 10th June resulted in significantly higher grain (57.3 and 60.1 q/ha for 2013 and 2014, respectively) and stover yield (108.8 and 109.2 q/ha for 2013 and 2014, respectively) for both the cropping seasons of 2013 and 2014 whereas considerably lower maize grain and stover yield was recorded for the crop sown on 30th May, 20th and 30th June (Table 2).Substantially lower maize yield for delayed planting windows can be attributed to lower values of growth and yield attributing characters such as plant height, number of cobs per plant, number of grains per cob and test weight for maize. A field study reported by Rana and his co-workers in 2018 revealed that maize crop sown after 20th June resulted in 2.48 and 3.66 q/ha higher yield as compared to crop sown in 1-10th sowing window. Furthermore, optimized song windows can be seen as an adaptation measure to offset the malign impacts of climate change and enhance crop climatic resilience of maize to climate change especially in mountainous regions (Rana et al., 2021). Reduction in yield of maize with delayed sowing was also reported by Cao et al. 2024 during a field study investigating effect of sowing dates on yield of maize in subtropical monsoon region of China. Zhiipao et al. 2023 also reported reduction in maize yield levels with delayed sowing of maize.

Table 2. Effect of sowing dates and varieties on growth yield attributes and yield of maize cultivarsduring 2012-13 and 2013-14.

Cultivars	Plant height (cm)		Number of cobs plant^{-1}		Number of grains cobs^{-1}		1000 grain weight (g)		Grain yield (q ha^{-1})		Stover yield (q ha^{-1})	
	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Girija	254.3	258.0	1.0	1.0	242.4	250.4	264.0	267.0	47.9	50.1	97.6	98.0
Bajaura Makka	252.5	256.2	1.0	1.0	242.1	250.1	261.5	264.5	47.4	49.5	92.1	95.9
HQPM-1	254.6	258.3	1.1	1.1	246.5	255.7	265.3	268.3	53.9	56.5	102.9	104.1
CD (5%)	NS	NS	NS	NS	NS	NS	NS	NS	3.07	5.52	6.7	6.10
Sowing dates												
30th May	251.3	255.0	1.0	1.0	242.8	250.8	263.1	266.1	47.9	50.0	94.8	98.0
10th June	261.5	265.2	1.1	1.1	258.7	268.3	268.5	271.6	57.3	60.1	108.8	109.2
20th June	251.2	255.0	1.0	1.0	243.3	251.3	264.1	267.1	48.1	50.3	98.1	99.9
30th June	250.9	254.6	1.0	1.0	229.9	237.9	258.7	261.7	44.6	46.6	88.4	90.2
CD (5%)	8.2	8.2	0.09	0.06	5.89	6.62	4.81	4.81	3.50	6.37	7.7	7.04

Conclusion

Based on the present field investigation, it can be concluded that 10th June can be recommended as the optimum sowing date for significantly considerable yield levels for maize under the conditions of North-western Himalayas of India. Growth, yield contributing characters and yield were significantly higher with sowing date of 10th June. Among, maize cultivars, HQPM-1 performed significantly superior in termsof maize yield levels over others.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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