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Research Paper

Assessment of sowing dates and spacing for indogangetic plain zone *kharif* maize (*Zea mays*) cultivars to achieve higher productivity in Western IGP

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ABSTRACT

An experiment was conducted to study the effect of sowing dates and spacing on the productivity of newly developed maize cultivars at 2 locations, *viz*. Punjab Agricultural University, Ludhiana, and ICAR-Indian Institute of Maize Research, Ladhowal, Punjab during *kharif* 2021 and 2022. Results revealed that the optimum range of temperature during the growth period had favourable impact on dry matter accumulation at the silking stage with sowing dates of 15 June and 30 June. At Ludhiana and Ladhowal, maize sown on 15 June and 30 June recorded significantly higher yield attributes such as cob weight, grains/ cob and 1000-grains weight as compared to maize sown on 1 June and 15 July. Sowing dates of 15 June and 30 June recorded at par grain yield of maize in loamy sand soil at Ludhiana in both years. On the other hand, at Ladhowal in sandy loam soil, the maize sowing on 15 June recorded the highest maize grain yield followed by on 30 June in both years. Likewise, a yield penalty of 27.16–28.59% and 21.69–24.43% was registered with maize sown on 15 July as compared to maize sown on 15 June at Ludhiana and Ladhowal, respectively over the years. New cultivars of maize outperformed at various planting densities at both locations. Planting density of 67.5 cm × 15 cm having 98,765 plants/ha gave a higher grain yield compared to 67.5 × 18 cm (82,305 plants/ha) at both locations. Among the different cultivars, 'JH 19014' (5.35–5.03 t/ha) and 'JH 17011' (5.31–5.17 t/ha) performed superior over 'PMH 13' (5.18–4.87 t/ha) at both locations.

Key words**:** Dates of sowing, Growing degree days, New maize cultivars, Planting density

In India, maize (*Zea mays* L.) is the third most important food grain crop after rice and wheat. The area of maize is 9.89 m ha having a production of 31.64 million tonnes withan average productivity of 3.2 t/ha (FAO, 2022). Maize has been utilized as food, feed, and fodder besidesprovidingraw material for manufacturing various industrial products such as food (25%), starch (12%), brewery (1%), animal feed (12%), and poultry feed (49%) (IIMR, 2022). It has the highest yield potential among the cereals. Yet, the productivity of maize is very low owing to poor agronomic practices coupled with a high incidence of insect pests and diseases. In Punjab and Haryana, many efforts have been going on to diversify rice with maize production. Interestingly, in Punjab, the average productivity of maize is comparatively high (3.65 kg/ha) as compared to the average productivity of rice (3.33 kg/ha) (Jat *et al*., 2021). With assured minimum support price for rice in grain markets has major favourable impact on farmers than maize. However, The Government of India has set a target for 20% ethanol blending in petroleum products by 2025 through high starch grain products has generated a lot of interest in maize production (Sepat *et al*., 2024). Hence, to achieve the high yield potential of maize, it is required to put major emphasis on better agronomic management practices along with high-yielding varieties of maize to break the yield barriers (Shingne *et al*., 2018; Meena *et al*., 2024). Identification of the optimum date of sowing in maize is crucial to harness the higher yield levels with assured availability of sunlight, and other growth resources. Likewise, to harness the high dry matter in maize it is essential to modify the existing plant architecture of maize such as a reduction in cob angle on plants, straight and upright leaf orientation for high radiation interception, anda higher number of cobs per plant. (Zhao and Yang 2018). A lot of effort has been put into

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breeding such kind of maize varieties particularly for Punjab. In general, maize is sown at wider spacing with the existing varieties thereby leaving unutilized space with low yield (Sepat *et al*., 2022). On the other hand, maize sown at closer spacing might be attacked with the heavy incidence of insect pests and diseases owing to modification of micro-climate with limited aeration and high humidity (Basavanneppa and Kuchanur 2020). The productivity of newly released maize varieties needs to be evaluated at various planting densities with a wide range of sowing dates at different locations. Therefore, an experiment was conducted to study the suitability of various sowing dates and spacing options in newly developed cultivars on the productivity of maizeto combat changing climatic conditions during 2021 and 2022.

MATERIALS AND METHODS

The field experiment was conducted at Research Farm, Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana and Research Farm (30.90° N and 75.80° E and 247 mean sea level), ICAR-Indian Institute of Maize Research, Ladhowal (30.59° N and 75.44° E and 247 mean sea level) during *kharif* 2021 and 2022. At Ladhowal and Ludhiana, the climate of the site is semi-arid tropical having maximum and minimum temperature varied from 17–43°C in 2021 and 15–45°C in 2022. The average rainfall during the growing season (February-June) was 168 mm and 200 mm in 2021 and 2022, respectively. The soil of the experimental site at Ludhiana is loamy sand having initial available N 284.2 kg/ha, P_2O_5 47.45 kg/ha and K_2O 241 kg/ha, and organic carbon content of 0.48% with a pH of 7.4. Whereas, at Ladhowal is sandy loam having initially available N 183 kg/ha, P_2O_5 34.4 kg/ha and K_2O 450 kg/ha with a *p*H of 7.9 and organic carbon content of 0.49%. The experiment was laid out in a split-split plot design with three replications. The date of sowing, *viz.* 1 June, 15 June, 30 June, and 15 July were taken in main plots; while spacing of 67.5 × 18 cm and 67.5 × 15 cm in subplots. Three cultivars such as 'JH 19014', 'JH 17011' and 'PMH 13' were taken in sub-sub plots. Before sowing, seed treatment was done with imidachloropid 70 WS @ 6 g/kg of seed to protect the crop from stem borer incidence. The mentioned varieties were sownon the ridge accordingly spaced as per treatments on 1 June, 15 June, 30 June and 15 July. Irrigation was applied as per the crop demand. The recommended dose of 180 kg N, 60 kg P_2O_5, and 40 kg K_2O through urea, di-ammonium phosphate and muriate of potash, respectively was applied in spring maize. A full amount P_2O_5 and K_2O was applied at sowing time while N was given in three equal splits at sowing, knee height (35 DAS), and tasseling stage (45 DAS). Urea, diammonium phosphate, and muriate of potash were used as a source of N, P, and K. Pendimethalin PE @ 1 kg/ha followed by hand weeding at 35 DAS was done for effective weed control. Fall armyworm incidence was controlled by a spray of chlorantraniliprole 18.5 SC at 15 and 25 DAS. The crop was harvested during the first fortnight of October for 1 June and 15 June while during the second fortnight of October for 30 June and 15 July in both years. Yield attributing characters were determined using standard procedures. The growing degree days (GDD) are calculated by subtracting the lower base or threshold temperature of 10°C from the average daily air temperature in °C. Average daily air temperature is calculated by averaging the daily maximum and minimum air temperatures measured in any 24 hours. Grain yield was calculated and expressed as t/ha after being adjusted to a 14.2% moisture level. Analysis of variance was computed by using SAS version 9.4 software. For treatment mean comparison, the least significant difference values were obtained at a 95% confidence interval.

RESULTS AND DISCUSSION

Growing degree days

In maize, phenological development is strongly related to the accumulation of heat or temperature units above a threshold or base temperature (Alam *et al.,* 2020). In maize, growing degree days (GDD) were significantly influenced by the date of sowing and cultivars at Ludhiana and Ladhowal during 2020 and 2021 (Table 1). In general, it was noticed that early sown maize recorded less GDD and matured early at the end of the season at both locations. On the other hand, late-sown maize had accumulated higher values of GDD to reach the physiological maturity stage. At the knee-high stage, maize sown on 15 July accumulated higher values of GDD followed by maize sown on 30 June and 15 June at Ladhowal and Ludhiana. Likewise, maize sown on 15 June and 30 June had more or less similar values of GDD at the anthesis stage of maize at both locations. Maize sown on 15 July recorded higher values of GDD and was delayed by 5–6 days compared to maize sown on 15 June for the silking phase. Maize requires specific units of GDD to reach maturity and the growth of maize is directly related to the accumulation of heat units over time rather than the number of days taken to reach maturity. Maize sown on 1 June accumulated lesser GDD (2,086) and matured by the end of September at both locations as early as possible. On the other hand, maize sown on 15 June and 30 June had the optimum accumulation of GDD (2,147 and 2,178) and matured by the end of October while maize sown on 15 July was harvested in the first fortnight of November.

Table 1. Effect of sowing dates, spacing and cultivars on dry-matter accumulation (g/plant) at various stages of *kharif* maize

Treatment	Knee-high stage				Silking stage				Dough stage			
	Ludhiana		Ladhowal		Ludhiana		Ladhowal		Ludhiana		Ladhowal	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Dates of sowing												
1 June	58.0	59.8	58.7	60.4	162.5	163	169	178	510	555	590	560
15 June	64.2	62.3	65.2	64.2	178.0	195	176	188	550	580	610	600
30 June	60.0	60.5	61.8	63.5	168.5	178	166	182	520	560	600	589
15 July	51.0	57.0	56.7	55.2	158.2	152	157	160	490	540	588	521
SEm±	1.18	1.32	1.11	0.93	2.45	2.55	2.86	2.65	4.00	4.50	2.76	3.00
CD (P=0.05)	3.80	4.22	3.54	2.98	7.89	8.20	9.24	8.54	12.89	14.56	8.88	9.87
Spacing (cm)												
67.5 × 18	59.6	60.9	61.8	61.9	169.1	173	170	178	510	515	598	573
67.5 × 15	57.0	58.9	59.4	59.8	164.5	171	164	176	495	500	596	562
SEm±	0.67	0.88	0.65	0.60	2.20	2.30	2.57	2.32	2.89	3.12	1.79	1.82
CD (P=0.05)	2.14	2.80	2.09	1.89	NS	NS	NS	NS	9.25	9.99	5.74	5.84
Cultivar												
'JH 19014'	56.9	62.5	63.0	60.3	162.0	175	170	189	540	530	603	577
'JH 17011'	60.0	60.0	58.8	62.4	167.2	169	167	170	510	540	599	565
'PMH 13'	58.0	57.2	60.0	59.8	171.2	172	164	172	489	525	589	561
SEm±	0.35	0.43	0.59	0.49	1.73	2.00	1.84	2.00	1.88	2.10	1.50	1.71
CD (P=0.05)	1.12	1.32	1.89	1.54	5.59	6.52	5.89	6.57	6.02	6.74	4.81	5.49

Changes in temperature and availability of sunshine hours significantly influenced the GDD accumulation in maize to reach maturity at both locations. Irrespective of the growth stages of maize, spacing at 67.5 × 18 and 67.5 × 15 had no significant influence on GDD accumulation in maize. Irrespective of stages, cultivars, *viz*. 'JH 19,014' and 'JH 17,011' had higher GDD accumulation than 'PMH 13' at both locations. A higher accumulated GDD in JH 19014 and 'JH 17011' resulted in the early onset of physiological maturity than 'PMH 13'. Hence, it can be ascribed that early maturing maize cultivars should be sown in the optimum time range to obtain higher dry-matter accumulation and yield.

Dry matter accumulation

Dry matter accumulation (DMA) was recorded at knee-high, silking, and dough stages of maize during both years (Table 2). At the knee-high stage, higher DMA was recorded with maize sown on 15 June followed by maize sown on 30 June at knee-high stage. The silking stage of maize is highly sensitive to management inputs, sunshine hrs, and temperature (Sepat *et al*., 2022). The optimum range of temperature during the growth period had favourable impact on DMA at the silking stage when maize was sown on 15 June and 30 June. Maize sown on 1 June had higher respiration which decreased the DMA accumulation at knee-high, silking, and dough stages of maize. So, maize sown on 15 July recorded the lowest DMA across the maize growth stage at both locations. In addition, the onset of monsoon rains in July onwards stagnated the growth of maize, and therefore a low DMA was recorded, irrespective of locations (Lashkari *et al*., 2011). Irrespective of growth stages, low competition for resources such as light, nutrients and water enhanced the DMA accumulation at wider spacing (67.5 × 18) as compared to closer spacing (67.5 × 15). Among the cultivars, the upright orientation of leaves with sturdy stem, 'JH 19014' recorded the higher DMA as compared to 'PMH 13' at knee-high, silking and dough stages of maize at both locations.

Yield attributes

The yield components such as cob weight, no. of grains/cob, and test weight were significantly ($p \geq 0.05$) influenced by sowing dates, spacing and mention cultivars (Table 3). At Ludhiana, the sowing of maize on 15 June, 30 June and 1 June recorded higher cob weight in 2020 and 2021. However, at Ladhowal, the sowing of maize on 15 June and 30 June recorded higher cob weight followed by 1 June in both years. At both locations, the sowing of

Table 2. Effect of sowing dates, spacing and cultivars on growing degree days in *kharif* maize.

Treatment	Knee-high stage				Anthesis				Silking				Total			
	Ludhiana		Ladhowal		Ludhiana		Ladhowal		Ludhiana		Ladhowal		Ludhiana		Ladhowal	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Dates of sowing																
1 June	391	413	410	423	790	802	786	780	878	898	888	878	2,059	2,113	2,084	2,081
15 June	421	429	426	438	812	820	799	792	900	912	913	898	2,133	2,161	2,138	2,128
30 June	432	440	442	439	822	830	805	810	912	920	919	900	2,166	2,190	2,166	2,149
15 July	444	454	450	452	832	844	826	826	922	934	932	920	2,198	2,232	2,208	2,198
SEm±	2.79	2.29	2.91	2.68	2.89	3.30	2.60	2.81	3.83	3.62	4.13	3.96	5.80	6.32	7.04	6.84
CD (P=0.05)	8.92	7.39	9.32	8.59	9.25	10.56	8.32	8.98	12.25	11.58	13.20	12.68	18.56	20.21	22.52	21.89
Spacing (cm)																
67.5 × 18	421	432	430	436	812	822	802	805	901	920	910	900	2,134	2,174	2,141	2,140
67.5 × 15	423	436	434	440	816	826	806	799	905	912	916	898	2,144	2,174	2,157	2,138
SEm±	1.97	1.68	2.26	1.95	2.57	2.27	2.06	2.27	3.20	3.20	3.75	3.20	4.77	5.39	6.10	5.82
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Cultivar																
‘JH 19014’	434	444	444	448	830	835	812	815	911	932	919	920	2,175	2,198	2,175	2,183
‘JH 17011’	421	431	426	435	810	824	801	798	902	910	911	891	2,133	2,161	2,138	2,124
‘PMH 13’	411	427	426	431	802	813	799	793	896	906	909	886	2,109	2,263	2,134	2,110
SEm±	1.60	1.52	1.65	2.07	1.75	1.88	1.74	1.95	2.89	2.58	3.20	3.06	4.45	5.28	5.79	5.45
CD (P=0.05)	5.12	4.89	5.28	6.62	5.59	6.00	5.58	6.25	9.25	8.25	10.25	9.78	14.25	16.89	18.54	17.45

Table 3. Effect of sowing dates, spacing and cultivars on yield attributes of *kharif* maize

Treatment	Cob weight (g/plant)				Grains/cob				Test weight (g)			
	Ludhiana		Ladhowal		Ludhiana		Ladhowal		Ludhiana		Ladhowal	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Dates of sowing												
1 June	142.2	148.7	139.0	142.0	788	820	795	789	428.4	428.2	420	425
15 June	150.0	155.3	148.5	151.0	800	825	810	800	430.8	435.0	430	429
30 June	148.7	152.3	146.5	148.0	797	824	808	794	434.2	432.0	428	428
15 July	138.1	146.9	130.0	139.0	755	799	783	777	417.0	411.0	410	418
SEm±	2.75	2.42	2.00	2.30	0.69	0.58	0.61	0.64	0.75	0.95	1.00	0.90
CD (P=0.05)	8.85	7.85	6.55	7.40	2.21	1.89	2.00	2.10	2.44	3.10	3.23	2.89
Spacing (cm)												
67.5 × 18	146.5	152.7	142.0	146.0	795	819	798	793	428.7	430.5	424	420
67.5 × 15	143.0	148.8	140.0	144.0	785	815	800	787	426.5	423.0	420	430
SEm±	2.00	1.82	1.00	1.12	0.61	0.46	0.54	0.61	0.57	0.85	0.90	0.47
CD (P=0.05)	NS	NS	NS	NS	2.00	1.52	1.85	1.99	NS	2.80	2.90	1.55
Cultivar												
'JH 19014'	145.0	152.3	142.0	145.0	789	813	805	795	429.0	428.8	424	423
'JH 17011'	147.3	150.6	142.6	147.0	793	818	799	793	427.6	428.9	423	432
'PMH 13'	142.0	149.5	138.5	143.0	788	820	793	782	426.3	425.6	419	420
SEm±	1.02	0.70	0.44	0.46	0.47	0.37	0.40	0.46	0.34	0.33	0.61	0.34
CD (P=0.05)	3.34	2.25	1.45	1.52	1.54	1.23	1.32	1.51	1.12	1.09	2.0	1.14

maize on 15 July coincided with rainfall so maize suffered from stagnation of water during the initial stages of crop growth. Thereby, lower values of growth components were recorded with late sowing in both years at both locations. Meanwhile, maize sowing on 15 June gave the highest no. of grains/cob followed by maize sowing on 30 June at both locations in 2020 and 2021. A higher test weight of maize was recorded with sowing dates of 15 June and 30 June in 2020 and 2021. Maize spaced at 67.5 x 18 recorded higher no. of grains/cob and test weight as compared to spacing at 67.5 × 15 cm. Maize at closer density have severe competition for space, sunlight interception, and nutrients (Namakka *et al*., 2008). Under such circumstances, the production of lanky cob with barren, shrivelled grain is high, and it has a drastic impact on the overall productivity of maize (Prodhan 2001). At both locations, among the cultivars, 'JH 17011' and 'JH 19014' recorded higher cob weight, no. of grains/cob and test weight as compared to 'PMH 13' in 2020 and 2021.

Yield

The yield of maize was remarkedly influenced by various sowing dates, spacing, and cultivars at Ludhiana and Ladhowal during 2020 and 2021 (Table 4). Maize sown on 15 June and 30 June recorded at par grain yield of maize at Ludhiana (6.01 and 5.69 t/ha, respectively) in 2020 and 2021. On the other hand, at Ladhowal, the sowing of maize on 15 June recorded the highest maize grain yield (5.59 t/ha) followed by 30 June (5.32 t/ha) in both years. In maize, it is a well-known fact that heat stress decreases seed-filling period duration owing to the low translocation of photosynthates into the grain formation (Raghavendra *et al.,* 2020). Additionally, a higher respiration rate with high temperature decreased the grain yield with maize sown on 1 June at both locations in 2020 and 2021 (Sepat and Kumar 2007). On the other hand, favourable temperatures with sowing dates on 15–30 June gave higher translocation of photosynthates from source to sink and therefore higher grain yield of maize at both locations (Sepat *et al*., 2013). On both locations, sowing on 15 July recorded the lowest grain yield during 2020 and 2021. A yield penalty of 27.16–28.59% and 21.69–24.43% was registered with 15 July as compared to maize sown on 15 June at Ludhiana and Ladhowal over the years. In terms of stover and biomass (grain + stover) yield, maize sown on 15 June and 30 June recorded at par values at Ludhiana and Ladhowal locations in 2020 and 2021. At both locations, the lowest stover and biomass yield was recorded with 15 July 2020 and 2021. Maize spaced at wider spacing faced less competition for resources such

Table 4. Effect of sowing dates, spacing, and cultivars on yields (t/ha) of *kharif* maize

	Grain yield				Stover yield				Biomass yield			
	Ludhiana		Ladhowal		Ludhiana		Ladhowal		Ludhiana		Ladhowal	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Dates of sowing												
1 June	5.04	5.12	4.76	4.99	6.14	6.25	6.03	6.11	11.18	11.37	10.79	11.10
15 June	6.11	5.91	5.44	5.73	7.22	7.05	6.71	6.91	13.33	12.96	12.15	12.64
30 June	5.92	5.45	5.17	5.47	6.98	6.55	6.55	6.54	12.90	12.00	11.72	12.01
15 July	4.45	4.22	4.26	4.33	5.55	5.34	5.44	5.51	10.00	9.56	9.70	9.85
SEm±	0.09	0.11	0.10	0.10	0.14	0.16	0.19	0.20	0.16	0.14	0.18	0.17
CD (P=0.05)	0.30	0.35	0.30	0.32	0.45	0.52	0.59	0.62	0.52	0.47	0.58	0.56
Spacing (cm)												
67.5 × 18	6.00	5.48	4.97	5.21	7.08	6.60	6.21	6.31	13.08	12.08	11.18	11.52
67.5 × 15	4.76	4.87	4.84	5.06	5.86	6.00	6.16	6.23	10.63	10.87	11.00	11.28
SEm±	0.10	0.11	0.09	0.08	0.10	0.12	0.14	0.15	0.14	0.12	0.17	0.15
CD (P=0.05)	0.30	0.32	NS	NS	0.33	0.39	0.45	0.49	0.46	0.39	0.56	0.49
Cultivar												
'JH 19014'	5.43	5.27	4.91	5.15	6.53	6.37	6.34	6.26	11.96	11.42	11.64	11.41
'JH 17011'	5.52	5.10	5.01	5.32	6.55	6.24	6.25	6.42	12.07	11.34	11.34	11.74
'PMH 13'	5.20	5.15	4.79	4.94	6.35	6.28	5.96	6.13	11.55	11.64	11.43	11.07
SEm±	0.07	0.07	0.06	0.06	0.07	0.09	0.07	0.07	0.11	0.09	0.12	0.11
CD (P=0.05)	0.23	0.23	0.20	0.22	0.24	0.30	0.24	0.23	0.33	0.30	0.39	0.34

as nutrients, water, and sunlight (Zhao and Yang 2018). Hence, irrespective of location, maize spaced at 67.5 × 18 cm had the highest grain, stover and biomass yield as compared to 67.5 × 15 cm in 2020 and 2021. In 2020 and 2021, the varieties viz., 'JH 19014' and 'JH 17011' outperformed the 'PMH 13' in terms of grain, stover and biomass yield of maize at Ludhiana and Ladhowal. An increase of 3.28% was registered with 'JH19014' as compared to 'PMH 13' at Ludhiana and Ladhowal in both years.

Overall, it was concluded that maize cultivars viz., 'JH 19014' and 'JH 17011' may achieve high yield potential spaced at 67.5 × 18 cm of plant density. Additionally, the optimum sowing window period is 15 to 20 June for kharif maize for attaining higher productivity under changing climatic scenarios for northern parts of India.

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