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Yield Response of Maize Hybrids on Different Spacing Patterns under Irrigated Areas of Punjab

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ABSTRACT

Background: The present study was conducted at the Agricultural Research Farm, Lovely Professional University, Phagwara (Punjab), during the *kharif* seasons of 2022 and 2023. It was titled as "Maize varieties yield response on different spacing patterns under irrigated areas of Punjab". It was an experiment to assess the effect of three maize varieties namely AHC-233, P-1899 and NHM-589 and four spacing patterns S_1: 60 cm × 25 cm, S2: 70 cm × 20 cm, S_3: 70 cm × 30 cm and S_4: 70 cm × 25 cm, on growth, yield, physiological parameters, quality attributes and economic feasibility.

Methods: The experiment was conducted in a split-plot design (SPD) with three replications.

Result: The experiment result shows that, the highest performance was found in P-1899 (V_2), which was significantly greater than AHC-233 (V_1) and NHM-589 (V_3) in terms of number of cob/plant, cob length and number of rows/cob, number of grains/row, number of grains/cob and grain yield. Interaction between varieties and spacing patterns further revealed that the best results were obtained when V_2 (P-1899) was combined with S_2 (70 cm × 20 cm). The findings show that V_2 (P-1899) with S_2 (70 cm × 20 cm) is the most promising strategy for the maximum yield in irrigated conditions of Punjab.

Key words: Cob, Grain, Hybrid, Maize, Yield.

INTRODUCTION

Maize, popularly called "Queen of Cereals," is a crop of vital international importance from various points of view, such as adaptability, food value and multipurpose applications. This crop originated in Central America and has been a staple for agricultural systems all over the world, far from just the regions of origin, but remains most important for world food security (Kaushal *et al.,* 2023). The genetic diversity and ability of maize to grow under diverse agroclimatic conditions make it an equally indispensable crop for developed and developing countries. Maize grows well on a variety of environments, from arid to semi-arid zones to sub-humid and tropical areas (Tiwari and Yadav, 2019). Maize is a key crop in agriculture all over the world, providing a crucial basis of food security, industrial applications and economic sustainability (Tanumihardjo *et al.,* 2020). In terms of importance, it is ranked third, after wheat and rice and over time has grown to be an essential food for millions. In India, maize is placed very importantly, being considered the third of all cereals and cultivated in an area of greater significance, mainly during the kharif, about 82% of the area sown to this crop (Muramatti, 2023). However, due to favourable climatic conditions, lesser biotic stresses and assured irrigation, the highest productivity is obtained in the rabi season. Despite being important, the average productivity of maize in India is very much lower than that at the global level, suggesting a wide gap that, under present-day circumstances, would require adoption of some innovative agronomic practices and technological interventions (Ram *et al.,* 2023).

The 2nd advance estimates for the year 2023-24 state that maize crop has been estimated as 376.65 lakh tones, as compared to 380.85 lakh tones in 2022-23. The area of maize in India for 2023-24 broadly covers 23.72 lakh hectares. The predominant maize growing states in India are Bihar, Maharashtra, Tamil Nadu, Telangana, West Bengal and Gujarat (Anonymous, 2024). Maize diversity in cultivation in India ranges between both traditional and emerging maize-growing states (Murdia *et al.,* 2016). Longtime traditional states like Madhya Pradesh, Rajasthan and Uttar Pradesh have been predominant in maize cultivation for many decades; however, nontraditional states like Andhra Pradesh and Karnataka have turned out to be major contributors in the last couple of decades or so (Pavithra *et al.,* 2018). Also, there has been an increasing dimension that is spring maize, particularly in the northern states of Uttar Pradesh, Haryana and Punjab regarding maize farming in India. In addition to diversifying cropping systems, spring maize opens up opportunities for residual soil moisture and land use optimization during an otherwise lean agricultural period (Layek *et al.,* 2018). It points towards the dynamic role that maize production generates in India

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for its ability to smoothen agricultural and economic disbalances on the given regional basis (Erenstein *et al.,* 2022).

Despite steady growth, the average maize productivity in India stands at about 2,965 kg/ha, substantially below the world average. This is attributed to the dominance of rainfed conditions, less than optimal agronomic practices and other factors, such as pest infestations and nutrient imbalance. The driving force in alle*vi*ating this gap in productivity will therefore be the use of improved maize hybrids with suitable agronomic practices and the application of modern technology. Together, maize varieties and plant spacing provide means of optimizing resource-efficient growth and yield (Wani *et al.,* 2021). The hybrid maize varieties also have different responses to spacing due to genetic diversity and physiological traits. Correct spacing will determine light interception, air circulation, root development and nutrient uptake, thus determining the overall architecture of the plant and biomass accumulation. It has been reported in several studies that the appropriate spacing pattern utilizes all available resources and maximizes production without substantial internal competition among plants. For example, more room for plant growth (60 cm × 20 cm) would support bigger cobs; however, while grain weight without resource competition may increase with lower density spacing, the increase in population and biomass per plant is much greater under denser populations. On the flip side, close spacing may increase shading and limit light availability, posing potential threats to pest and disease outbreak (Bulungu, 2012).

Maize hybrids significantly boost crop yield, resilience and profitability. They offer improved resistance to pests, diseases and environmental stresses. By enhancing uniformity and maturity rates, hybrids support mechanized farming and food security. Their adoption has revolutionized modern agriculture, especially in developing regions, by increasing productivity and reducing farming risks. Satisfactory spacing maximizes the balancing of productive attributes with resource usage, thereby increasing the productivity and profitability. Scientific evidence shows that increased spacing between plants enhances the growth parameters of plant height, cob size and grain weight (Ali *et al.,* 2017). According to Vijayalakshmi *et al. (*2020*)*, spacing among others is an important factor involved in improving resource use efficiency associated with water and nutrients for productivity in different environments (Testa *et al.,* 2016).

MATERIALS AND METHODS

The current study was conducted at the Lovely Professional University Agriculture Research Farm, Phagwara (Punjab), during two consecutive *kharif* seasons of 2022 and 2023. The crops are sown on the mid of June for the consecutive years and harvested 95 DAS. The research farm is situated at a latitude of 31°.14′ N and longitude of 75°.42′ E and an altitude of 247.52 m above mean sea level. A field of research farm having homogeneous fertility and uniform textural make-up was selected for the field experimentation. Being the region of Punjab, it usually experiences subtropical climate conditions-seasons categorized as summer, monsoon and winter. The monsoon season further sets in by the first week of July and stays through August mid, when rainfall is usually recorded as 730 mm from the south-west monsoon currents and comes in heavy showers mainly within the months of July and August. The presence of cold temperature characterizes winter, which comes in late November and lasts to February, with January usually showing the lowest temperatures. The winter and pre-monsoon summer retain a dry climate. After the harvest of previous crop, the land was ploughed once with mould board plough. Soil was brought to fine tilth by crushing the clods and harrowing two times, later the land was smoothened with wooden plank. Recommended doses of fertilizers were 80 kg N, 40 kg P_2O_5 and 40 kg K_2O per ha. And the full dose of P and K and half dose of N were applied through urea, single super phosphate and muriate of potash at the time of sowing and remaining half dose of N was applied after 25-30 DAP. The seeds were treated with thirum. Seed was sown at 3-4 cm depth and covered with soil. Sowing was done on last week of June, 2022 and 2023 by dibbling 2 seeds per hill. Seeds were sown as per spacing treatments in each plot. To protect the crop from stem borer infestation the granular application of Carbofuran 3% GR was done after 47 DAS. Spraying of Chlorpyriphos 25 EC at the concentration of 0.01% was undertaken at 70 DAS to protect the crop from corn borer. Use 30 kg seed per acre.

Treatment details

The hybrid varieties which were used in this experiment are AHC-2033-the first yellow seeded early maturing hybrid maize variety which is earlier by 15 days in milking, P1899- The plants of this hybrid variety are tall with broad leaves. Its' ear placement is medium. Ears are long, thick and cylindrical. Grains are white, bold and semi flint to semi dent. It is moderately resistant to leaf blight. Its' average green fodder yield is about 150 quintal per acre and NHM-589- Its' plants are tall, vigorous and narrow leaved. It is moderately resistant to brown stripe downy mildew diseases. Its' ear placement is medium. Ears are short, thick and cylindrical. The grains are white and bold. It yields about 148 quintal of green fodder per acre. We proceeded this experiment with four different spacings: 60 cm × 25 cm, 70 cm × 20 cm, 70 cm × 30 cm and 70 cm × 25 cm.

RESULTS AND DISCUSSION

Number of cobs per plant

The number of cobs per plant was significantly influenced by maize varieties and spacing patterns during both years and in the pooled analysis and data are presented in Table 1. Among the varieties, V_2 (P-1899) consistently recorded the highest number of cobs per plant, with 1.46 in 2022-23, 1.49 in 2023-24 and 1.48 in pooled results. This was followed by V1 (AHC-233), which revealed 1.40 cobs per plant in 2022-23, 1.43 in 2023-24 and 1.41 in pooled data. The lowest number of cobs per plant was observed in V_3 (NHM-589), which recorded 1.31 in 2022-23, 1.33 in 2023-24 and 1.32 in pooled basis. The spacing patterns also significantly affected the number of cobs per plant. The S_4 (70 cm × 25 cm) produced the highest number of cobs per plant with 1.58 in 2022-23, 1.60 in 2023-24 and pooled of 1.59. However, S_4 was followed by S_2 (70 cm × 20 cm), with values of 1.51, 1.54 and 1.53 at 2022, 2023 and pooled of both years, respectively, while the lowest number of cobs per plant was observed in S_1 (60 cm × 25 cm), with pooled values of 1.15. The wider spacing in S_4 likely facilitated better resource availability, resulting in enhanced cob formation. Results are corroborated with Azam *et al.* (2007) and Mathukia *et al*. (2014).

Length of cob

Cob length demonstrated a significant influence of both variety and spacing (Table 1). Among the varieties, V2 (P-1899) resulted the longest cob length with 19.65 cm in 2022-23, 19.72 cm in 2023-24 and pooled of 19.68 cm. This was followed by V_1 (AHC-233), which recorded values of 19.29 cm in 2022-23, 19.35 cm in 2023-24 and pooled value of 19.32 cm. The shortest cob length was observed in V_3 (NHM-589), with pooled values of 18.31 cm. Spacing patterns had a pronounced effect on cob length during the experimentation. The S_4 (70 cm × 25 cm) produced the longest cobs, with values of 20.64 cm in 2022-23, 20.69 cm in 2023-24 and pooled value of 20.66 cm. This was followed by S_2 (70 cm × 20 cm), which recorded pooled values of 20.12 cm, while the shortest cobs were observed in S_1 (60 cm × 25 cm), with pooled values of 17.28 cm. The longer cob lengths under wider spacing in S4 can be attributed to reduced competition for light, nutrients and water, allowing for better cob development, these results are corroborated with Mathukia *et al.* (2014) and Hasan *et al.* (2018).

Number of grain rows per cob

The data related to number of grain rows per cob presented in Table 2 was significantly influenced by maize varieties and spacing patterns during both years and pooled analysis. Among the varieties, V_2 (P-1899) recorded the highest number of grain rows per cob, with values of 13.32 in 2022-23, 13.40 in 2023-24 and pooled of 13.36. The V_2 was followed by V_1 (AHC-233) with pooled values of 13.08,

Table 1: Number of cobs per plant and length of cob of maize hybrids under various spacings.

Treatments	Number of cobs per plant			Length of cob (cm)		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
A: Varieties						
V_1- AHC-233	1.40	1.43	1.41	19.29	19.35	19.32
V_2- P-1899	1.46	1.49	1.48	19.65	19.72	19.68
V_3- NHM-589	1.31	1.33	1.32	18.28	18.34	18.31
CD @5%	0.09	0.05	0.06	0.66	0.97	0.45
B: Spacing						
S_1- 60 cm × 25 cm	1.13	1.16	1.15	17.24	17.31	17.28
S_2- 70 cm × 20 cm	1.51	1.54	1.53	20.09	20.15	20.12
S_3- 70 cm × 30 cm	1.34	1.36	1.35	18.32	18.38	18.35
S_4- 70 cm × 25 cm	1.58	1.60	1.59	20.64	20.69	20.66
CD @5%	NS	NS	NS	NS	NS	NS

Table 2: Number of rows per cob, number of grains per row and number of grains per cob of maize hybrids as affected by various spacings.

Treatments	Number of grain rows per cob			Number of grains per row			Number of grains per cob		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
A: Varieties									
V_1- AHC-233	13.03	13.13	13.08	19.06	19.10	19.08	250.12	252.59	251.36
V_2- P-1899	13.32	13.40	13.36	19.38	19.43	19.41	259.92	262.12	261.02
V_3-NHM-589	12.55	12.64	12.59	17.60	17.67	17.64	221.88	224.23	223.06
CD @5%	0.29	0.55	0.21	0.99	1.19	0.53	16.04	17.34	14.34
B: Spacing									
S_1- 60 cm × 25 cm	11.68	11.76	11.72	16.18	16.24	16.21	189.15	191.02	190.08
S_2- 70 cm × 20 cm	13.54	13.60	13.57	19.99	20.03	20.01	270.89	272.74	271.81
S_3- 70 cm × 30 cm	12.71	12.83	12.77	17.86	17.92	17.89	227.18	230.13	228.66
S_4- 70 cm × 25 cm	13.93	14.02	13.98	20.69	20.75	20.72	288.68	291.38	290.03
CD @5%	0.65	0.72	0.49	1.53	1.19	0.97	26.98	16.79	15.71

while V_3 (NHM-589) recorded the lowest (12.59) during the experimentation. These results highlight the superior productivity potential of V_2 in terms of cob row formation. Spacing patterns also significantly affected the number of grain rows per cob during the experimentation. The S4 (70 cm × 25 cm) revealed the highest number of grain rows per cob, with 13.93 in 2022-23, 14.02 in 2023-24 and pooled of 13.98 followed by S_2 (70 cm × 20 cm) with pooled values of 13.57. The lowest number of rows per cob was recorded in S_1 (60 cm × 25 cm) (11.72). Wider spacing (S_4) likely provided favourable growing conditions for improved grain row development, corroborated with the results of Antony *et al.* (2024).

Number of grains per row

The number of grains per row was significantly influenced by maize varieties and spacing patterns during both years and in the pooled analysis and data presented in Table 2. Among the varieties, V_2 (P-1899) recorded the highest number of grains per row, with values of 19.38 in 2022-23, 19.43 in 2023-24 and a pooled value of 19.41 and it was followed by V_1 (AHC-233) with pooled values of 19.08, while V_3 (NHM-589) recorded the lowest with pooled values of 17.64. Spacing patterns significantly affected the number of grains per row during the investigation. The S_4 (70 cm × 25 cm) revealed the maximum number of grains per row (20.72) followed by S_2 (70 cm × 20 cm) (20.01) based on the pooled of both years. The lowest number of grains per row (16.21) was observed in S_1 (60 cm × 25 cm). The increased number of grains per row in wider spacing treatments like S_4 can be attributed to reduced interplant competition, positively correlated with Biswas *et al.* (2014) and Jithendra *et al*. (2013).

Number of grains per cob

The number of grains per cob was significantly influenced by maize varieties and spacing patterns during both years and in the pooled analysis (Table 2). Among the varieties, V_2 (P-1899) recorded the highest number of grains per cob *i.e*., 259.92 in 2022-23, 262.12 in 2023-24 and a pooled value of 261.02. However, V_2 was followed by V_1 (AHC-233) with the pooled value of 251.36, while V_3 (NHM-589) recorded the lowest (223.06) during the investigation. Spacing patterns had a significant effect on the number of grains per cob during the experimentation. The S_4 (70 cm × 25 cm) exhibited the highest number of grains per cob, with pooled values of 290.03, followed by S_2 (70 cm × 20 cm) (271.81). While, the lowest number of grains per cob was observed in S_1 (60 cm × 25 cm) (190.08). The wider spacing in S_4 provided plants with better access to resources, allowing for more grain development per cob, correlated with the results of Biswas *et al.* (2014) and Niveditha and Nagavani (2016).

Grain yield

Grain yield was significantly influenced by maize varieties and spacing patterns during both years and in the pooled analysis and related data are presented in Table 3. Among the varieties, V_2 (P-1899) recorded the highest grain yield *i.e*., 157.47 q/ha in 2022-23, 161.96 q/ha in 2023-24 and 159.71 q/ha of pooled of both years. This was followed by V_1 (AHC-233) recorded pooled grain yield of 150.92 q/ha. While, V_3 (NHM-589) recorded the lowest grain yield (136.81 q/ha) as per pooled of both the years. The superior performance of V_2 may be attributed to its higher productivity potential, as reflected in the better cob parameters and grain yields. Spacing patterns significantly influenced grain yield as well during the experimentation. The S_2 (70 cm × 20 cm) produced the highest grain yield *i.e*., 193.44 q/ha in 2022-23, 198.00 q/ha in 2023-24 and pooled of 195.72 q/ha. However, S_2 followed by S_4 (70 cm × 25 cm) and observed grain yield of 166.49 q/ha based on pooled of both years. While, the lowest grain yield was recorded in S_3 (70 cm × 30 cm) with pooled values of 109.62 q/ha. The higher grain yield in S_2 can be attributed to optimal plant density, which allowed for efficient resource utilization. The results are corroborated with Lashkari *et al.* (2011), Khalil *et al.* (2011) and Magar *et al.* (2021).

Straw yield (q/ha)

The data related to straw yield are presented in Table 3 and varied significantly among maize varieties and spacing

Table 3: Grain and straw yield of maize hybrids under various spacings.

Treatments	Grain yield (q/ha)			Straw yield (q/ha)		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
A: Varieties						
V_1- AHC-233	148.76	153.08	150.92	154.75	155.54	155.14
V_2- P-1899	157.47	161.96	159.71	158.82	159.96	159.39
V_3- NHM-589	134.83	138.78	136.81	145.72	146.73	146.23
CD @5%	11.64	9.06	6.50	8.86	9.68	7.88
B: Spacing						
S_1- 60 cm × 25 cm	122.22	127.29	124.76	143.62	144.81	144.21
S_2- 70 cm × 20 cm	193.44	198.00	195.72	191.93	192.99	192.46
S_3- 70 cm × 30 cm	108.13	111.10	109.62	114.36	115.31	114.84
S_4- 70 cm × 25 cm	164.28	168.69	166.49	162.46	163.21	162.84
CD @5%	8.65	16.39	9.37	11.04	8.21	8.48

Table 4: Economics as influenced by treatments.

Treatments	Grain yield (kg ha^{-1})		Stover yield (kg ha^{-1})		Gross realization (` ha^{-1})		Total cost of production (` ha^{-1})		Net realization (` ha^{-1})		BCR	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
Varieties : (V)												
V_1	14876	15308	15475	15554	286338	294209	36106	36106	250232	258103	6.93	7.15
V_2	15747	16196	15882	15996	302504	310723	36106	36106	266399	274617	7.38	7.61
V_3	13483	13878	14572	14673	260180	267412	36106	36106	224075	231306	6.21	6.41
Spacing : (S)												
S_1	12222	12729	14362	14481	237230	246499	34228	34228	203003	212272	5.93	6.20
S_2	19344	19800	19193	19299	371224	379559	34228	34228	336996	345331	9.85	10.09
S_3	10813	11110	11436	11531	208357	213817	33691	33691	174666	180126	5.18	5.35
S_4	16428	16869	16246	16321	315199	323227	34228	34228	280972	289000	8.21	8.44

patterns during both years and in the pooled analysis. Among the varieties, V_2 (P-1899) recorded the highest straw yield *i.e.*, 158.82 q/ha in 2022-23, 159.96 q/ha in 2023-24 and pooled of 159.39 q/ha. V_2 treatment was followed by V_1 (AHC-233), which recorded a pooled straw yield of 155.14 q/ha. While, V_3 (NHM-589) recorded the lowest straw yield with pooled values of 146.23 q/ha. The higher straw yield in V_2 reflects its superior vegetative growth and biomass production. Spacing patterns also significantly influenced straw yield during the investigation. The S_2 (70 cm × 20 cm) exhibited the highest straw yield *i.e.*, 191.93 q/ha in 2022-23, 192.99 q/ha in 2023-24 and pooled of 192.46 q/ha. The S_4 (70 cm × 25 cm) treatment followed S2 with pooled straw yield of 162.84 q/ha. While, the lowest straw yield was recorded in S_3 (70 cm × 30 cm) with pooled values of 114.84 q/ha. The higher straw yield in S_2 can be attributed to its optimal spacing, which resulted in enhanced biomass accumulation. These results are correlated with the results of Mekuanint *et al.* (2018) and Reddy *et al.* (2020).

Economics

Table 4 assesses the performance of three maize varieties (V_1, V_2 and V_3) and four spacing treatments (S_1 to S_4) over two consecutive years (2022 and 2023). Grain output, gross and net realisation and benefit-cost ratios (BCR) were highest for V_2, which yielded the best results for all the measures of performance and economic outcome. V_1 was second for both measures, while V_3 was always worst. S_2 (widest spacing) was the better of the spacing, with the highest stover and grain yields and significantly high BCRs of 10.09 and 9.85 respectively in 2022 and 2023. This would have likely correlated with better light interception, increased amount of food and less plant-plant competition. For S_3 with the tightest spacing, results were worse. The results provide important information for improving crop management techniques and resource use efficiency, indicating that the V_2 and S_2 spacing combination is ideal for optimising maize yield and profitability under the conditions under study.

CONCLUSION

The results highlight the importance of variety and spacing interactions in determining how well maize parameters work. The best variety was P-1899 (V_2), particularly when spaced at S_4 (70 cm × 25 cm), which continuously produced better results for all attributes measured, such as cob length, cob number, grain rows and grain count. Crop performance was improved by wider spacing because it made resource allocation easier and decreased competition. Closer spacing (S_1 and S_2) and NHM-589 (V_3), on the other hand, were less advantageous and limited the total yield components.

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Disclaimers

The opinions and findings articulated in this article are exclusively those of the writers and do not always reflect the perspectives of their connected institutions. The writers bear responsibility for the truth and completeness of the material presented; nevertheless, they disclaim all duty for direct or indirect damages arising from the use of this content.

Conflict of interest

All authors declare that they have no conflict of interest.

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