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An Assessment of the Effect of Sowing Methods and Spacing on Growth and Yield Attributes of Maize (*Zea mays* L.)

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ABSTRACT

Background: The present investigation was undertaken during the *Kharif* season of 2025 at the Agricultural Research Farm of Doon School of Modern Agriculture and Forestry, DBS Global University, Dehradun, to evaluate the impact of different sowing methods and plant spacing on the growth, yield attributes and productivity of maize (*Zea mays* L.).

Methods: The study employed a randomized block design (RBD) with three replications, comprising two sowing methods-flat drilling and ridge sowing and three spacing treatments: 70 × 15 cm, 70 × 20 cm and 70 × 25 cm. The maize hybrid VL Maize 57 was used for the experiment.

Result: The results demonstrated that both sowing method and spacing significantly influenced physiological and agronomic performance. Ridge sowing produced taller plants, higher leaf area index (LAI), greater dry matter accumulation and superior yield attributes compared to flat sowing. Among the spacing treatments, 70 × 25 cm exhibited better performance in terms of plant height, LAI, dry weight, cob length (13.67 cm), number of kernels cob^{-1} (304.31) and test weight (19.87 g), culminating in the highest kernel yield (44.87 q ha^{-1}) and stover yield (59.14 q ha^{-1}). On a relative basis, kernel yield at 70 × 25 cm and under ridge sowing was about 6.2 and 3.2% higher, respectively, than at 70 × 15 cm and under flat drilling, while the harvest index remained within a narrow range of about 42-43% across all treatments. The study highlights the importance of optimizing plant geometry and sowing techniques to enhance resource-use efficiency and maximize yield potential. These findings offer actionable insights for maize cultivation strategies under mid-Himalayan agro-climatic conditions.

Key words: Agro-climatic, Flat drilling, Geometry, Kernel yield, Knee height, Ridge sowing.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most adaptable emerging crops having a wider range of agro-climatic tolerance (Damor *et al.,* 2020). Owing to its high genetic yield potential among the cereals, maize is referred to internationally as the “queen of cereals”. It is cultivated on nearly 190 m ha across about 165 countries spanning a wide diversity of soils, climates, biodiversity and management practices and contributes 39% of global grain production (Abdulraheem and Charles, 2013). In India, maize is the third most important cereal crop after rice and wheat, occupying an area of 10.74 million hectares and producing 43.4 million tonnes of grain (2024-25).

Planting technique plays a major role in increasing maize yield (Singh, 2003). Indian farmers generally use the traditional broadcast method of sowing, which has several disadvantages, *i.e.* uneven distribution of seeds and sowing depth and seeds lying scattered on the surface where they are picked up by birds. Improved planting techniques could enhance maize production and help the country become self-sufficient in both food and feed (Kumar *et al.,* 2015). Planting technique not only ensures proper plant arrangement and an optimum plant population in the field but also enables the plants to utilize land and other input resources more efficiently for growth and development. Establishing an adequate plant density is critical for the efficient utilization of available growth factors such as water, light, nutrients and carbon dioxide and for maximizing grain yield. Low crop yields have been partly attributed to inappropriate plant density, planting time and pest pressure (weeds, diseases and insect pests) (Gobeze *et al.,* 2012). Determining the optimum plant population, adapted varieties and appropriate agronomic practices are important components of a maize production package for maximizing productivity (Kandil, 2014). The present study was therefore undertaken to assess the effect of sowing methods and spacing on the growth, yield and yield attributes of maize.

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MATERIALS AND METHODS

The present investigation was carried out during the *Kharif* season of 2025 at the Agricultural Research Farm of the Doon School of Modern Agriculture and Forestry, DBS Global

University, Dehradun. The experimental site lies between latitude 30°22′N and longitude 77°51′E, at an elevation of 600 m above mean sea level. The cultivar VL Maize 57 was used for the experiment. The treatments comprised three spacings, *i.e.* 70 × 15 cm, 70 × 20 cm and 70 × 25 cm and two sowing methods, *viz.* drilling (flat) and ridge sowing, laid out in a randomized block design with three replications.

All recommended agronomic practices were followed. Growth parameters, namely plant height (cm), leaf area index, dry weight and days to reach phenological stages, were recorded at the knee-high, tasseling, silking and maturity stages of the crop from the penultimate rows of each plot. Data on the various yield attributes, *i.e.* cob length (cm), cobs plant^{-1}, kernels cob^{-1}, cob diameter (cm), rows cob^{-1} and test weight were recorded from randomly selected plants in each plot. The kernel yield from each plot was recorded in kg plot^{-1} after sun-drying and then converted to q ha^{-1}. Stover yield (q ha^{-1}) was recorded after the removal of cobs from stalks in each plot.

The data recorded for various parameters were statistically analyzed by the method described by (Cochran and Cox, 1957). In addition, the harvest index was computed as the ratio of kernel yield to biological (kernel plus stover) yield, expressed as a percentage; treatment responses were expressed as percentage changes relative to the narrowest spacing (70 × 15 cm) and to flat drilling and the results were presented graphically with the standard error of the mean.

RESULTS AND DISCUSSION

Growth attributes

Data presented in Table 1 indicate that plant height at the different growth stages increased significantly with wider spacing. The maximum plant height at the knee stage (53.58 cm), tasseling (146.66 cm), silking (153.57 cm) and maturity (160.43 cm) was recorded in S_3 (70 × 25 cm) followed by S_2 (70 × 20 cm), in which the plants attained heights of 51.27 cm at the knee stage, 141.82 cm at tasseling, 146.62 cm at silking and 152.65 cm at maturity. The minimum plant height was recorded under the narrowest spacing, S_1 (70 × 15 cm). A possible reason for the increase in plant height is the reduced competition for moisture and nutrients, which leads to higher nutrient uptake and greater growth. Ezung *et al.* (2019) also reported the same findings where improved plant height was recorded with increasing spacing. Sowing methods also significantly affected the plant height. The maximum plant height at knee stage (54.39 cm), tasseling (148.93 cm), silking (155.42 cm) and at maturity (163.36 cm) was recorded in SM_2 (ridge sowing). Better plant height in ridge sowing might be due to its facilitation in providing loose soil with more aeration and moisture availability. Khan *et al.* (2012) also concluded that improved soil environment helps in better nutrient uptake resulting in more plant height. Gul *et al.* (2015) also reported significant improvement in ridge sowing than other sowing methods.

Table 1: Growth attributes of maize at different growth stages as affected by spacings and sowing methods.

Treatments	Plant height (cm)				Leaf area index				Dry weight (g)			
	Knee high	Tasseling	Silking	Maturity	Knee high	Tasseling	Silking	Maturity	Knee high	Tasseling	Silking	Maturity
S_1 (70×15)	48.14	137.63	140.87	146.71	1.16	1.78	1.51	1.14	5.48	37.98	64.85	96.47
S_2 (70×20)	51.27	141.82	146.62	152.65	1.28	2.12	1.84	1.57	6.51	39.56	70.21	101.54
S_3 (70×25)	53.58	146.66	153.57	160.43	1.65	3.01	2.68	2.51	7.75	43.12	73.47	112.65
SEm (±)	0.67	0.74	0.91	0.94	0.05	0.12	0.07	0.07	0.45	1.13	1.14	1.27
CD 5%	1.63	2.11	2.31	2.47	0.9	1.61	1.53	1.24	1.21	2.47	2.64	3.14
SM_1(Drilling)	51.68	140.21	151.37	156.48	1.23	1.69	1.57	1.25	5.36	35.95	68.27	100.65
SM_2 (Ridge)	54.39	148.93	155.42	163.36	1.31	2.23	1.98	1.47	8.61	44.36	77.36	113.47
SE(m) ±	0.69	0.78	0.98	1.17	0.07	0.15	0.11	0.12	0.48	0.51	0.78	1.04
CD 5%	1.97	2.34	2.87	3.1	0.17	1.14	1.12	0.98	1.27	1.74	1.89	2.65

Leaf area index (LAI) was significantly affected by both spacing and sowing method. LAI increased significantly with wider spacing at all growth stages. The maximum LAI at the knee stage (1.65), tasseling stage (3.01), silking stage (2.68) and maturity stage (2.51) was recorded in the treatment S_3 (70 × 25 cm). LAI was also significantly affected by sowing method; the maximum LAI at the knee stage (1.31), tasseling stage (2.23), silking stage (1.98) and maturity stage (1.47) was recorded under ridge sowing. Hamid *et al.* (2022) also reported that LAI increased with increasing inter and intra-row spacing due to more availability of growth factors and better penetration of light. Comparable improvements in maize canopy development and light interception under favourable planting systems have also been documented by Singh *et al.* (2025).

Dry-matter accumulation was significantly affected by both factors, *i.e*. spacing and sowing method. The maximum dry weight was recorded in treatment S_3 (70 × 25 cm). Dry-matter accumulation increased progressively at successive growth stages. The maximum dry weight at maturity (112.65 g) was recorded in S_3 (70 × 25 cm) and SM_2 (ridge sowing) (113.47 g), followed by S_2 (70 × 20 cm) and SM_1 (drilling), which accumulated 101.54 g and 100.65 g, respectively.

Yield and yield attributes

The experiment revealed that the yield attributes, namely cob length, cob diameter, kernels cob^{-1} and test weight were significantly affected by spacing and sowing methods (Table 2). All the yield attributes except cobs plant^{-1} and number of rows cob^{-1} were significantly increased with wider spacing. The maximum cob length (13.67 cm), cob diameter (2.25 cm), number of rows cob^{-1} (17.21), kernels cob^{-1} (304.31) and test weight (19.87 g) was recorded in S_3 (70 × 25 cm) followed by S_2 (70 × 20 cm) and the least in S_1 (70 × 15 cm). Kumar *et al.* (2015) also concluded that yield attributes improved with wider spacing, which reduces competition for various important factors. A similar finding was reported by Reddy *et al.* (2018), where a higher number of grains per cob was recorded at 60 × 25 cm compared with 60 × 10 cm, 60 × 15 cm and 60 × 20 cm. Wahengbam *et al.* (2025) similarly observed that wider spacing patterns improved the yield attributes and grain yield of maize hybrids under irrigated conditions, while Sangtam *et al.* (2017) recorded better growth and yield with an optimum plant geometry in rainfed maize.

Kernel and stover yields were also significantly affected by spacing and sowing method. The maximum kernel yield (44.87 q ha^{-1}) and stover yield (59.14 q ha^{-1}) was recorded in S_3 (70 × 25 cm). Although the absolute differences among the spacing treatments were modest, the increase in kernel yield with wider spacing (from 42.26 q ha^{-1} at 70 × 15 cm to 44.87 q ha^{-1} at 70 × 25 cm) exceeded the critical difference (CD at 5% = 0.86) and was therefore statistically significant; likewise, the higher kernel yield under ridge sowing than under flat drilling (44.51 vs 43.14 q ha^{-1}) exceeded the corresponding critical difference (CD = 0.91). Sabo *et al.* (2016) also reported that a 25 cm intra-row spacing resulted in the highest grain yield compared with 20 cm and 30 cm. Ridge sowing performed better than flat drilling in the present investigation. The maximum cob length (12.97 cm), cob diameter (2.41 cm), number of rows cob^{-1} (16.25), kernels cob^{-1} (299.82) and test weight (19.52 g) were recorded under ridge sowing. Singh *et al.* (2018) considered ridge sowing the best method for maize cultivation during both the monsoon and winter seasons, under both excess and limited water availability.

Ridge sowing also performed well for kernel yield (44.51 q ha^{-1}). Ridge sowing produced significantly more stover yield than flat sowing. This was probably due to the more favourable below-ground conditions created by ridges. Similar findings were also reported by Raymond *et al.* (2009).

The results of this investigation showed that growth, yield attributes and yield were significantly affected by the manipulation of spacing and sowing methods. The ridge planting method produced better yield and yield attributes, namely cob length, cob diameter, number of rows cob^{-1}, kernels cob^{-1}, test weight and kernel and stover yields, at a spacing of 70 × 25 cm. In ridge sowing, fertilizer and pesticide application was easier and reduced losses, with relatively better weed control. These single-season results therefore suggest that ridge sowing combined with 70 × 25 cm spacing performed best for the VL Maize 57 cultivar under Dehradun conditions; this combination merits confirmation

Table 2: Yield attributes and yield of maize as affected by spacings and sowing methods.

Treatments	Cob length (cm)	Cobs plant^{-1}	Cob diameter (cm)	Number of row cob^{-1}	kernels cob^{-1}	Test weight (g)	Kernel yield (q ha^{-1})	Stover yield (q ha^{-1})
S_1 (70×15)	11.07	1.1	1.87	13.58	279.87	16.57	42.26	57.68
S_2 (70×20)	12.14	1.11	2.14	16.57	296.57	18.69	43.38	58.96
S_3 (70×25)	13.67	1.12	2.25	17.21	304.31	19.87	44.87	59.14
SE (m)	0.14	0.01	0.24	1.04	2.14	0.35	0.19	0.45
CD 5%	1.07	NS	1.67	NS	5.68	1.07	0.86	0.93
SM_1(Drilling)	11.24	1.11	1.98	14.47	280.71	17.68	43.14	58.14
SM_2 (Ridge)	12.97	1.11	2.47	16.25	299.82	19.52	44.51	60.14
SE (m) (±)	0.26	0.01	0.21	0.26	1.68	0.31	0.17	0.47
CD 5%	1.04	NS	1.27	1.61	5.18	0.97	0.91	1.03

over additional seasons before it is recommended for general adoption.

The present study clearly demonstrates that plant spacing and sowing method significantly influence the morphological development, yield attributes and overall productivity of maize. Ridge sowing method provided a more favorable soil environment, characterized by improved aeration, root proliferation and better access to soil nutrients and moisture. This in turn led to enhanced growth parameters such as plant height, leaf area index and biomass accumulation.

Among the spacing treatments, wider spacing of 70 × 25 cm was found to be agronomically optimal, allowing for reduced intra-specific competition and improved physiological performance. This spacing facilitated better development of reproductive structures, reflected in longer cobs, increased kernel number per cob and higher test weight-all contributing to superior grain and stover yields. The interaction between ridge sowing and wider spacing (70 × 25 cm) emerged as the most effective combination, significantly improving productivity without compromising plant health or soil quality. These results underline the importance of adopting precision agronomic practices for maximizing yield potential in maize cultivation, particularly in the Dehradun region and similar agro-ecological zones. The findings are relevant for researchers, extension workers and progressive farmers aiming to enhance maize production sustainably through resource-efficient and location-specific technologies.

To quantify the magnitude of these responses, the treatment means were further expressed on a percentage basis. Widening the spacing from 70 × 15 cm to 70 × 25 cm increased plant height at maturity by about 9.4%, the peak (tasseling) leaf area index by about 69.1% and dry-matter accumulation at maturity by about 16.8%; these gains carried through to a 6.2% higher kernel yield and a 2.5% higher stover yield. Relative to flat drilling, ridge sowing raised the corresponding values by about 4.4% (plant height), 32.0% (peak leaf area index) and 12.7% (dry matter) and by 3.2% and 3.4% for kernel and stover yield, respectively. The kernel-yield differences among all three spacings and between the two sowing methods, exceeded their respective critical differences and were therefore statistically significant.

The harvest index, computed as the ratio of kernel yield to biological (kernel plus stover) yield, remained within a narrow range of about 42-43% across treatments (Table 3). It increased modestly with wider spacing (42.3%, 42.4% and 43.1% at 70 × 15, 70 × 20 and 70 × 25 cm, respectively), indicating that the additional biomass produced at the widest spacing was partitioned slightly more towards grain. Between the sowing methods the harvest index was practically unchanged (42.6% under flat drilling and 42.5% under ridge sowing) as ridge sowing increased kernel and stover yields in similar proportion. This relative stability of the harvest index suggests that the yield advantage of ridge sowing and wider spacing arose mainly from greater total biomass production rather than from a marked shift in dry-matter partitioning.

Table 3: Harvest index of maize as influenced by spacing and sowing methods.

Treatment	Biological yield (q ha^{-1})	Harvest index (%)
S_1 (70×15)	99.94	42.29
S_2 (70×20)	102.34	42.39
S_3 (70×25)	104.01	43.14
SM_1 (Drilling)	101.28	42.59
SM_2 (Ridge)	104.65	42.53

CONCLUSION

The study clearly demonstrates that both sowing method and plant spacing play a crucial role in determining the growth, yield attributes and overall productivity of maize under mid-Himalayan agro-climatic conditions. Ridge sowing proved superior to flat sowing in enhancing physiological parameters and yield performance. Among the different plant geometries, a spacing of 70 × 25 cm emerged as the most effective, resulting in improved plant growth, better yield attributes and higher kernel and stover yields.

Thus, on the basis of this single-season investigation, the combination of ridge sowing with wider spacing (70 × 25 cm) appears to be a promising agronomic practice for enhancing maize productivity. Subject to confirmation over additional seasons and locations, its adoption could improve resource-use efficiency and contribute to sustainable maize cultivation in similar agro-ecological regions.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

This study was conducted on maize, a field crop and did not involve any human participants or animals. Hence, ethical approval and informed consent were not applicable to this research.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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