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Impact of Crop Establishment Methods on the Growth and Yield Performance of Maize Varieties in the *Kharif* Season

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field trial was carried out in Pantnagar, Uttarakhand, India, during the *Kharif* season to evaluate the performance of maize varieties using various planting methods. The study included five distinct planting techniques: Flat, Bed, Ridgetop, Ridge mid-slope and Broad Ridge mid-slope both sides. Two maize varieties were tested: the composite PSM-1 and the hybrid DKC 9144. Results showed that the Broad Ridge mid-slope on both sides method led to the highest growth parameters, including; plant height, stem girth and dry matter accumulation per plant. During both the years, the Broad Ridge mid-slope planting method led to notable increase in plant height (7% and 6.1%), stem girth (5.25 & 4.67 cm) and dry matter accumulation (13.6% & 20.7%) respectively when compared to the flat planting method. Among the varieties, the hybrid DKC 9144 exhibited greater

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height, stem girth, more dry matter accumulation, grain and stover yields compared to the composite PSM-1. The findings suggest that the broad ridge mid-slope planting method, and hybrid variety DKC 9144, was the most effective and viable strategy for *Kharif* maize production in *tarai* region.

Keywords: Planting methods; varieties; growth and yield parameter.

1. INTRODUCTION

Maize (*Zea mays* L.), recognized as one of the world's most vital cereal crops following wheat and rice, is often called the 'Miracle crop' or 'Queen of the Cereals' due to its remarkable productivity potential within the Gramineae family. This versatile crop serves as a foundational raw material for a multitude of industrial products, including alcoholic beverages, pharmaceuticals, food sweeteners, cosmetics, textiles, gum, and paper. In India, approximately 28% of maize is utilized for food purposes, 11% for livestock feed, 12% in the wet milling industry, 48% as poultry feed, and 1% as seed.

Climate change has become a reality, impacting agricultural practices, including maize cultivation. Adapting suitable establishment methods is crucial to sustain maize productivity from emergence to maturity under changing climatic conditions. One prominent feature of climate change is heavy downpours, leading to increased rainfall intensity followed by long dry spells. This results in fluctuating moisture levels, with crops experiencing both excess moisture and moisture shortage during the rainy season. It is essential to develop planting patterns that can mitigate the effects of excessive moisture during heavy rains and conserve moisture during dry spells.

In Northern India, flat sowing is a popular method for planting maize, but it poses challenges during the monsoon season. Heavy rainfall after sowing can lead to soil crusting, which hampers seedling emergence. Additionally, repeated rains compact the soil, reducing root zone activity due to increased bulk density. These factors can lead to reduced crop yields. Ridge planting and bed planting offer advantages over flat sowing by raising the land level. While bed planting accommodates two rows per bed and includes small furrows for drainage, heavy rainfall can still pose challenges, potentially affecting crop growth due to limited drainage capacity. Ridge planting has been favored over flat sowing under rainfed conditions due to better moisture retention. However, traditional ridge planting methods still face challenges such as lodging and moisture shortage, particularly on ridge tops where moisture loss is high. Placing seeds in the middle portion of ridges, instead of on top, offers several advantages. This method provides better anchoring for the plants and reduces moisture loss during heavy rains. Additionally, applying urea on ridge tops ensures better nitrogen availability to the plant roots. Ridge mid-slope planting, whether on one or both sides, requires large ridges for easy planting. With a broad ridge, maize spacing is optimized, enhancing urea interception and water drainage, crucial for managing heavy rains and conserving moisture during dry spells.

Rainfed maize faces challenges under changing climates, requiring suitable cultivars alongside improved planting methods and nutrient balance [1]. Hybrids excel in biotic and abiotic stress resilience, yielding substantially higher than composites [2]. Despite higher seed costs, hybrids' adaptability offsets expenses, offering superior germination stability. Hence, the current investigation was proposed and carried out to evaluate the Impact of Crop Establishment Methods on the Growth and Yield Performance of Maize Varieties.

2. MATERIALS AND METHODS

A field investigation was carried out at GB Pant University of Agriculture & Technology in Pantnagar, Uttarakhand, India, during the *Kharif* seasons of 2022 and 2023. The center is situated at 29° N latitude and 79.3° E longitudes and an altitude of 243.84 m above mean sea level. The treatments comprised of five different planting techniques *viz.,* Flat, Bed (dimension 90:30 cm), Ridgetop, Ridge mid-slope, and Broad Ridge mid-slope on both sides (70:50 cm). Two maize varieties were tested: composite PSM 1 and hybrid DKC 9144. The research trial was performed in a split-plot design (SPD). The planting methods were kept in the main plot and maize varieties were placed in a subplot with 3 replications. The plant-to-plant spacing was 18±2 cm and row-to-row spacing was 60 cm x20 cm.

The growth parameters *viz.,* plant height, no. of leaves, stem girth, dry matter accumulation at harvest, and grain and stover yield were recorded. The plant height at harvest was measured at harvest recorded from the ground surface to the base of the tassel. For dry matter accumulation measurement, two plants were selected randomly in each plot and carefully uprooted which were oven-dried at 65±5°C to attain constant weight and further weighed. The stem girth was measured from the mid-height of the stem at the maturity stage. All the cobs falling in the net plot were plucked after removing the husk and kept for sun drying for 4-5 days. With the help of a maize Sheller, the grains were removed and their weight was recorded expressed in t/ha at 14% moisture. After harvesting the cobs, the plants of the net plot were cut just above the ground level and sun-dried for 4-5 days. The stover produced by each net plot was weighed and expressed as t/ha. The data were analyzed with a computer-based program (CVSTAT statistical programme) and the treatment comparisons were made at a 5 percent level of significance.

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

In Table 1, it was clear that, at harvest in 2022, the Broad Ridge mid-slope planting method resulted in the tallest plants at 190.9 cm, similar to the ridgetop and ridge mid-slope methods. The flat planting method produced the shortest plants at 178.4 cm. In both 2022 and 2023, the Broad Ridge mid-slope method increased plant height by 7% and 6.1% compared to the flat method. However, in 2023, differences in plant height among the planting methods were not statistically significant. This was due to the presence of loose fertile soil having more aeration and moisture availability, along with better uptake of nutrients which might provide a better environment for maize crop resulting in improved plant height. These results confirmed with Singh [3] and [4]. But in 2022 and 2023, a significant plant height was achieved with DKC 9144 compared to the PSM 1 variety at the harvest stage. In the case of varieties, the hybrid DKC 9144 increased the plant height to the percent of 8.2% and 6.5% compared to the composite PSM 1, respectively during the first and second years of the study. At harvest, the crop exhibited significant variation in stem girth during 2022 and did not vary significantly in 2023 due to different planting methods. In the first year of study, the Broad Ridge mid-slope on both sides of the planting method (5.25 cm) was significantly superior to the remaining treatments. The lowest stem girth (4.67 cm) was observed in the flat planting method. Though it was non-significant in 2023, the stem girth varied from 4.67 to 4.33 cm among the different planting methods.

At harvest time, the Broad Ridge mid-slope planting method exhibited significantly higher dry matter accumulation, recording values of 112.2 g/plant. This outperformed other planting techniques in 2022. In contrast, the flat planting method resulted in the lowest dry matter accumulation, with figures of 98.8 g/plant during the first year of study. In 2023, Broad Ridge mid-slope on both sides of the planting method recorded significantly a higher dry matter accumulation (105.8 g/plant) which was followed by the Ridge mid-slope (94.8 g/plant) planting method compared to other planting methods. The lowest dry matter accumulation (83.9 g/plant) was exhibited by the flat planting method. The accumulation of dry matter is a good index, to express the photosynthetic efficiency of the plants, noticeably higher total dry matter including leaves, cob, and stem was recorded with the ridge planting method which could be due to higher plant height and functional leaves under ridge planting techniques. These results are also in agreement with Gul et al. [5] and also supported by Devendra and Sharad [6] Yadav et al. [7]. But in 2022 and 2023, a significant plant height (189.4 and 170.0 cm), stem girth (5.02 and 4.66 cm) and dry matter accumulation (114.6 and 106.8 g/plant) were achieved with DKC 9144 compared to the PSM 1 (183.3 and 165.8 cm), (4.80 and 4.31 cm) and (97.7 and 106.8 g/plant) variety at the harvest stage, respectively. This could be due to the varietal variation of crops and also environmental conditions that prevailed during stem elongation and growth of plants [8] and [9]. In the first year, ridge-mid-slope planting yielded the highest grain output (7.82 t/ha), closely followed by Broad Ridge mid-slope on both sides (7.79 t/ha). In 2023, Broad Ridge mid-slope both sides produced the highest yield (6.34 t/ha), outperforming other methods, particularly flat planting. Overall, Broad Ridge mid-slope both sides showed consistent stability across both years, especially under varying rainfall conditions. In 2022, the crop season had 738.2 mm of rainfall spread over 39 days, leading to higher grain yields due to better distribution. In contrast, 2023 saw 807.4 mm of rainfall concentrated in 32 days. A heavy downpour

Table 1. Growth parameters at harvest and yield of maize under different planting methods and varieties

Treatment	Plant height (cm)		Stem girth (cm)		Dry matter accumulation (g/plant)		Grain yield (t/ha)		Stover yield (t/ha)	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
Planting method										
Flat	178.4	164.9	4.67	4.33	98.8	83.9	6.54	5.11	8.84	7.58
Bed	183.5	165.7	4.84	4.46	102.7	93.3	7.13	5.76	9.36	8.14
Ridgetop	190.4	165.5	4.93	4.36	108.8	85.3	7.46	5.09	10.23	8.30
Ridge mid-slope	189.1	168.6	4.88	4.61	108.2	94.8	7.82	5.65	10.51	8.76
Broad ridge mid-slope on both sides	190.9	175.0	5.25	4.67	112.2	105.8	7.79	6.34	10.46	9.22
SEm±	2.6	3.4	0.10	0.12	2.5	3.1	0.17	0.24	0.37	0.30
CD at 5%	8.5	NS	0.33	NS	8.0	10.2	0.56	0.80	1.23	0.98
Variety										
PSM 1	183.3	165.8	4.80	4.31	97.7	78.5	6.54	4.59	9.33	8.14
DKC 9144	189.4	170.0	5.02	4.66	114.6	106.8	8.16	6.59	10.45	8.66
SEm±	2.7	2.1	0.06	0.07	1.5	1.3	0.17	0.11	0.18	0.20
CD at 5%	NS	NS	0.19	0.20	4.9	4.0	0.54	0.36	0.56	NS

of 150 mm in just two days in September 2023, combined with strong winds, caused crop lodging, particularly affecting the ridge top planting method, which led to reduced grain yields that year. The hybrid variety DKC 9144 outperformed the composite PSM 1, with a greater yield difference in 2023 due to its superior stability and root growth. Elevated planting methods like ridges and beds consistently resulted in higher grain yields compared to flat planting. Higher grain yield under ridge and bed planting over flat planting conform with the findings of Tanveer et al. [10], Singh and Vashist [11], Kumar and Chawla [12] and Goshel and Bedaso [13]. The planting methods significantly influenced stover yield across both years. In 2022, ridge mid-slope planting yielded the highest stover (10.51 t/ha), while in 2023, Broad Ridge mid-slope on both sides led with 9.22 t/ha. The stover yield differences between these methods were minimal, and most methods performed similarly, except for flat planting, which consistently lagged. Elevated planting methods, such as ridge and Broad Ridge mid-slope, improved stover yield due to better soil conditions like aeration and root growth. The hybrid variety DKC 9144 outperformed the composite PSM 1 in stover yield during both years, with a 12% higher yield in 2022. This superior performance of the hybrid is attributed to its greater stability and uniformity in plant growth. Singh (2011) observed a similar trend for stover yield among planting methods. Higher stover yield with hybrids over the composites aligns with the findings of Joshi and Chandrashekar [14].

4. CONCLUSION

- Broad ridge mid slope both sides planting and Ridge mid-slope planting showed superior performance in terms of growth and yield of *Kharif* maize compared to the flat planting method. The gain in grain yield with broad ridge mid slope both side planting over the flat planting was 19.1% in 2022 and 24.1% in 2023.
- From the findings of present study it can be inferred that during the rainy season, maize should be planted on the broad ridge (ridge: furrow 50: 70 cm) mid-slope both sides planting for better growth and yield stability. Maize hybrid DKC 9144 can be used for achieving better establishment, growth stability, and yield. In regions experiencing changing rainfall patterns, planting maize during the rainy season at mid slopes of ridges using a hybrid variety is recommended, particularly in northern plains of India. The study underscores the importance of adapting crop establishment methods to optimize productivity in response to evolving environmental conditions.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

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

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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