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ORIGINAL RESEARCH ARTICLE

Effect of sowing methods and spacings on growth and yield attributes of spring maize (*Zea mays* L.) in Parbat, Nepal

Padmawati Tiwari[1*] iD **, Rubina Karki**[1] iD **, Susan Tiwari**[1] iD **, Namuna Khatri**[1] iD **and Anusha Subedi**[1] iD

[1]College of Natural Resource Management, Faculty of Agriculture, Agriculture and Forestry University, Kapilakot, Sindhuli, Nepal
*Corresponding author's E-mail: padmatiwari15@gmail.com

ABSTRACT

The study was conducted in Phalewas Municipality, Parbat district, Nepal to assess the effect of two sowing methods (ridge bed and raised bed) and four plant spacings (60×15 cm, 60×20 cm, 60×25 cm and 60×30 cm) on growth and yield characteristics of spring maize for improving the maize yield. This experiment aimed to identify adequate sowing method and optimum spacing using a randomized complete block design with three replications. Results of this study showed that yield attributing characteristics per plant was significantly (p<0.05) impacted with decrement in plant spacing up to 60×15 cm. Likewise, number of cobs per plant, ear length, ear circumference, number of kernels per row, grains per cob was found significantly at par up to 60×20 cm spacing but significantly (p<0.05) higher than 60×15 cm. 60×20 cm spacing was found to have the highest impact on biometrical as well as yield attributes. The grain yield (6.53 Mt/ha) was significantly (p<0.05) higher at 60×20 cm than at 60×25 cm and 60×30 cm but at par with 60×15 cm. There was no discernible effect of the sowing method on the metrics of grain yield between ridge bed and raised bed sowing. However, both bed sowing methods significantly (p<0.05) improved the grain yield of maize (5.78 Mt/ha), compared to the farmer's practice in Parbat district. Therefore, this study suggested that farmers of Parbat can combine 60×20 cm plant spacing with bed sowing methods to maximize the production of maize.

INTRODUCTION

Maize (*Zea mays* L.), a member of the Poaceae, is the second-most significant primary cereal crop after rice in terms of area and production in Nepal. Widely regarded as the "Queen of Cereals" due to its great genetic yield potential and versatile characteristics, including higher adaptability that thrives in diverse agro-climatic conditions (Mahajan *et al.*, 2012). Maize having diverse multipurpose uses, commands primary calorie and protein intake for both human consumption and poultry feed, and industrial purposes such as production of biofuels, starch, and oil (Timsina *et al.*, 2016). Nepal has per capita maize consumption of 98g per day in southeast Asia (Ranum *et al.*, 2014). Maize accounts for 6.64 % of Agricultural Gross Domestic Prod-

uct (AGDP) of Nepal in the fiscal year 2022/23 (MoALD, 2024). The overall area of production of maize is 940,256 ha with total production of 2,976,490 Mt, and productivity of 3.17 Mt/ha (MoALD, 2024). The farm-level yield of maize (2.45 Mt/ha) is insufficient when compared to the attainable yield (5.7 Mt/ha) and on-station experimental yield (6.7 Mt/ha) in Nepal (KC *et al.*, 2015). The productivity of the Parbat district (2.59 Mt/Ha) lags behind the national average (3.17 Mt/Ha) (MoALD, 2024). Maize is a major cereal crop and grown throughout the year in mid-hill, contributing 72.85 % of overall maize production (MoALD, 2024). Maize is grown in both irrigated lowland and rainfed sloping land in the mid-hill. The yield of maize is greatly impacted by sowing method and plant density chosen by the farmers. In Nepal, farmer practices a common sowing method of

broadcasting; only progressive farmers and experts maintain optimum plant density using line sowing. Broadcasting allows seeds to scatter without specific arrangement. It necessitates higher seed rate and thinning operations that hinders to maintain optimum plant population at harvest (KC *et al.*, 2015), and promotes inter and intra-plant competition for nutrition water, and light and thus reduces maize yield (Bagula *et al.*, 2022). Economic yield is reduced by both thicker and thinner plant densities than optimum plant density for production system (Djaman *et al.*, 2022). The optimum spacing allows the plants to make full use of the available conditions at their disposal (Malik *et al.*, 1993). Closer spacing increases competition for incident photon flux density, soil nutrients, and soil water and thus reduces the final yield due to hormonally accounted apical dominance contributing to barrenness and less kernel set per ear (Sangoi, 2001). Wider spacing leads to excessive vegetative growth and proliferating weed population due to greater feeding space (Temesgen, 2019). Existing studies often focus on final yield per hectare or are limited to particular regions, leaving a gap in understanding the broader implications. The research aimed to address this gap by conducting systematic evaluation of performance per plant under different spacings across (mid-hill conditions) Parbat, Nepal.

The selection of improved sowing technique is crucial for spring maize grown under less soil moisture conditions. These techniques, finely attuned to local soil, climate and insect, pest conditions enhancing production and productivity. Water stress is the primary abiotic element that hinders maize growth and development (Khalili *et al.*, 2013). Conventional flat sowing includes decreased water use efficiency and nutrient loss (Bagula *et al.*, 2022). Appropriate planting method provides better aeration, moisture retention, enhance nutrient uptake and root development of maize (Khan *et al.*, 2012). This experiment focused on assessing the performance of spring maize under improved sowing technique which is lacking in the environment of Parbat (mid-hill region), Nepal, to provide valuable recommendations and to designate optimum spacing and adequate planting method for maximization of maize yield.

MATERIALS AND METHODS

Description of study area

The study was conducted in a farmer's field in Sirsuwa, Phalebas municipality (83°40′45″E 28°13′06″N), Parbat district, Gandaki province, Nepal during from March to July 2024. Geographically, Phalewas is at an elevation of 1146 masl. Clay loamy textured soil with uniform fertility status was present in the field that followed rice-fallow-maize cropping sequence for two years (2022 and 2023) before the experiment. The experimental plant material was Arun-2, an open-pollinated variety of maize, recommended for terai and mid-hill. Open-pollinated varieties yield more than local maize cultivars, which are poor in transporting assimilates to the ear sink (Worku & Zelleke, 2007). The climate data of the experimental site during research period is presented in Figure 1.

Experimental design and treatment factors

The experiment was conducted in double double-factorized (sowing methods, spacings) Randomized Complete Block Design (RCBD) with eight treatments and three replications. The combination of different sowing methods (A_1: Raised bed sowing, A_2: Ridge bed sowing) and spacing's (S_1: 60×15cm, S_2: 60×20 cm, S_3: 60×25 cm and S_4: 60×30 cm) were used as treatments.

T1: A1S1 (Raised bed + 60×15 cm)
T2: A1S2 (Raised bed + 60×20 cm)
T3: A1S3 (Raised bed + 60×25 cm)
T4: A1S4 (Raised bed + 60×30 cm)
T5: A2S1 (Ridge bed + 60×15 cm)
T6: A2S2 (Ridge bed + 60×20 cm)
T7: A2S3 (Ridge bed + 60×25 cm)
T8: A2S4 (Ridge bed + 60×30 cm)

Each plot size was 3 m × 1.5 m, with total of 24 plots. Spacing between each replication was 1m and spacing between plots was 0.5 m.

Agronomical practices

The land was ploughed, harrowed, cleared of weeds and crop residues, and levelled. Well-decomposed FYM @ 10 tons' ha^{-1}, which is calculated as 4.5 kg per 4.5m^2 plot, was mixed properly during field preparation 15 days before sowing. Urea, DAP and MOP were applied as the source of NPK 120:60:40 kg/ha with three split doses of Nitrogen under band placement method. The raised and ridge beds were prepared with row-to-row spacing of 60 cm and different inter-row plant spacings of 15 cm, 20 cm, 25 cm and 30 cm were made. seeds were dibbled 5 cm deep in line. First irrigation was given after 8 days of sowing for uniform germination. Subsequent 2 irrigations were given at knee high (35 DAS) stage and before tasselling stage (55 DAS) of maize. Manual hand hoeing was carried out at 25 DAS followed by hand weeding 45 DAS, tailored to the prevailing weed infestation levels, root aeration and specific weeding requirements. G-sunami (50% Chlorpyrifos and 5% cypermethrin EC) to control cutworm and King-star (Emamectin benzoate 5% SG) to control armyworm infestation were applied as per requirement. Cobs were harvested when the leaves near the husk were dried and a black layer was formed on grains indicating the maturity of cobs at 95 DAS. The biomass yield of the harvested crop was measured, cobs were de-husked and grain yield attributes were subsequently taken from manually shelled maize grains.
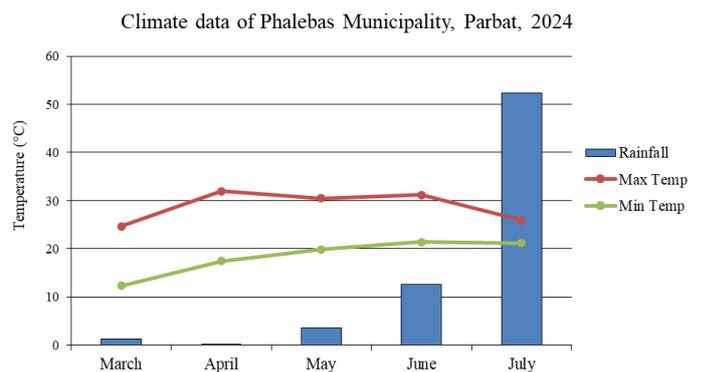

Figure 1. *Climate data of experimental site during the research period (Source: NASA POWER).*

Observations

Eight plants were carefully chosen and tagged from the interior rows, excluding the border rows for assessing plant height, number of leaves, stem diameter at various stages of growth. The data of the selected plants were recorded 30 days after sowing, and this measurement process were repeated three times more at regular 15-day intervals. Days of tasselling and silking were recorded after 50% of the plants in each plot had been tasseled and silked exposing 1 cm from topmost ear (Tollenaar *et al.*, 2004). The number of cobs per plant was recorded from the sampled plant of each plot. The length from the base up to the top of each ear was measured as cob length and circumference of ear was measured from the middle position of the cob, and the average value was worked out. The number of rows per ear, number of kernels per ear were counted from selected cobs of sampled plant. Biomass yield and grain yield were taken at harvest from net plot area.

$$\text{Grain Yield (t/ha)} = \frac{FWT\left(\frac{kg}{plot}\right) \times (100 - HMP) \times SCF \times 1000}{(100 - DMP) \times NPA \times 1000}$$

Where, FWT = Fresh weight of ear in kg per plot at harvest; HMP = Grain moisture percentage at harvest; DMP = Desired moisture percentage, i.e. 15%; NPA = Net harvest plot area, m^2; SCF = Shelling coefficient, i.e. 0.8; This formula was also adopted by Paudel & Thapa (2024) adjusting the grain yield (kg/ha) at 15% moisture content.

Statistical analysis

Data was systematically arranged based on various observed parameters. R-STUDIO version 4.4.1 and MS Excel was used to analyse the data. Microsoft Excel was used for entering data. Analysis of variance (ANOVA), Duncan's Multiple Range Test (DMRT), and LSD were employed to determine the significant differences between the mean values at 5% significance level using R-STUDIO.

RESULTS AND DISCUSSION

Phenological observation

Effect on days to 50% tasselling: Effects of sowing methods and spacings on days to 50% tasseling are shown in Table 1. The number of days to 50% tasselling was found significantly ($p<0.05$) affected by the sowing method. The maximum number of days to tasseling was found in the ridge bed sowing method (64.58 days) than raised bed sowing method (63.33 days). This may be due to optimal moisture and nutrients availability in ridges. These results are supported by Bakht *et al.* (2011) who explored more days to tasseling in ridge planting. The plant spacing was not found significant to the number of days to 50% tasseling. This result coincided with the findings of Gaire *et al.* (2020). Increasing the plant density up to 15 cm spacing, it took slightly higher days to tasseling (64.33 days) than at spacing 30 cm (63.83 days). Dikr (2023), Sharifi & Namvar (2016) observed more days to tasseling and silking in plots with higher density. They also proposed that higher plant density might have enhanced photosynthesis rate while delaying phenological traits like tasseling.

Effect on days to 50% silking: Effects of sowing methods and spacings on days to 50% silking are shown in Table 1. The number of days to 50% silking was found significantly ($p<0.05$) influenced by sowing method. The highest number of days to silking was recorded in ridge bed sowing (68.41 days) than raised bed sowing (67.08 days). These results are supported by Bakht *et al.* (2011) and Tanveer *et al.* (2014). Regarding plant spacing, no significant effects were observed on days to 50% silking. This result aligns with the finding of Gaire *et al.* (2020), Ghimire *et al.* (2023) who reported the effects of sowing methods and spacings on silking in maize.

Table 1. Effect of sowing methods and spacings on days to 50% tasselling and days to 50% silking of maize (*Z. mays*).

Treatments	Phenological observations	
	Days to 50% tasseling	Days to 50% silking
Sowing method (Factor A)		
Raised bed	63.33b	67.08b
Ridge bed	64.58a	68.41a
SEm(±)	0.32	0.39
LSD(α=0.05)	0.98	1.17
CV%	1.76	1.98
F statistics	*	*
Spacing (Factor B)		
60×15 cm	64.33	68.33
60×20 cm	64.00	67.83
60×25 cm	63.67	67.33
60×30 cm	63.83	67.50
SEm(±)	0.56	0.67
LSD(α=0.05)	1.39	1.66
CV%	1.76	1.98
F statistics	ns	ns
Grand Mean	63.96	67.75

Note: Means followed by or sharing the same letter(s) within a column are not significantly different at 5% level of significance; DAS: days after sowing, CV: coefficient of variation, LSD: least significant difference at 5%, *: significant at 5% level of significance, **: significant at 1% level of significance, ***: significant at 0.1% level of significance, ns: non-significant.

Growth attributes

Number of leaves per plant: Effects of sowing methods and spacings on number of leaves of different growth stage are shown in Table 2. The number of leaves per plant was found significantly influenced by the sowing method at 30 and 45 DAS whereas, no disparities in number of leaves at later stages. Significantly highest number of leaves was observed on ridge bed sowing at 30 DAS (4.94) and at 45 DAS (7.19) as compared to raised bed sowing (4.46) at 30 DAS and (6.56) at 45 DAS. Gul *et al.* (2015) observed greater green canopy of maize under ridge sowing due to well established root system in ridges, improving water and nutrient availability. Better uptake of nutrients and water availability due to enhancement in rhizosphere properties in ridge bed, resulting in a maximum number of leaves per plant. Regarding different spacing, no significant difference was observed in number of leaves per plant. The data shows the maximum number of leaves per plant on 25 cm spacing at 30 and 75 DAS. At 45 DAS and 60 DAS, 20 cm plant spacing had recorded highest number of leaves per plant. Decreased plant spacing resulted in a greater leaf per unit area occupied by plants and better utilization of available resources. This is consistent with the findings of Akpan *et al.* (2021) who reported denser plant population increased the need for sunlight, nutrients, and water absorption for optimal growth, which resulted in higher plant growth and the formation of new leaves.

Plant height: Effect of sowing methods and spacing's on plant height of different growth stage are shown in Table 3. The plant height of maize was found significantly affected by the sowing method during the vegetative phase recorded at 45 days of sowing while found to insignificantly differ after the plant had

Table 2. Effect of sowing methods and spacings on the number of leaves per plant maize (*Z. mays*) in Parbat, Nepal, 2024.

Treatments	Number of Leaves per Plant			
	30 DAS	45 DAS	60 DAS	75 DAS
Sowing method (Factor A)				
Raised bed	4.46^b	6.56^b	10.89	12.69
Ridge bed	4.94^a	7.19^a	11.35	12.75
SEm(±)	0.14	0.12	0.25	0.20
LSD(α=0.05)	0.43	0.36	0.76	0.611
CV%	10.38	5.90	7.82	5.49
F statistics	0.03*	0.002**	0.21ns	0.86ns
Spacing (Factor B)				
60×15 cm	4.69	6.88	10.71	12.06
60×20 cm	4.71	7.08	11.75	12.93
60×25 cm	4.90	6.69	11.31	12.94
60×30 cm	4.50	6.84	10.71	12.95
SEm(±)	0.24	0.20	0.43	0.35
LSD(α=0.05)	0.60	0.71	1.08	0.87
CV%	10.38	5.90	7.82	5.49
F statistics	0.57ns	0.44ns	0.15ns	0.11ns
Grand Mean	4.70	6.87	11.12	12.72

Note: Means followed by or sharing the same letter(s) within a column are non-significantly different at 5% level of significance. DAS: days after sowing, CV: coefficient of variation, LSD: least significant difference, *: significant at 5% level of significance, **: significant at 1% level of significance, ns: non-significant.

Table 3. Effect of sowing methods and spacings on plant height of maize (*Z. mays*) in Parbat, Nepal, 2024.

Treatments	Plant Height (cm)			
	30 DAS	45 DAS	60 DAS	75 DAS
Sowing method (Factor A)				
Raised bed	33.13	91.48b	189.08	217.79
Ridge bed	36.58	99.51a	189.40	218.29
SEm(±)	1.28	1.99	1.99	2.06
LSD(α=0.05)	3.88	5.67	6.04	7.89
CV%	12.71	6.05	3.65	4.13
F statistics	ns	*	ns	ns
Spacing (Factor B)				
60×15 cm	36.35	97.43	192.75	219.35
60×20 cm	35.17	98.56	191.50	218.33
60×25 cm	35.82	92.41	187.30	218.28
60×30 cm	32.07	92.58	185.40	216.18
SEm(±)	2.21	3.45	3.45	4.50
LSD(α=0.05)	5.48	8.56	8.54	10.94
CV%	12.71	7.24	3.65	4.13
F statistics	ns	ns	ns	ns
Grand Mean	34.85	95.50	189.24	219.88

Note: Means followed by or sharing the same letter(s) within a column are non-significantly different at 5% level of significance. DAS: days after sowing, CV: coefficient of variation, LSD: least significant difference, *: significant at 5% level of significance, ns: non-significant.

entered the generative phase recorded at 60 days of sowing and 75 days of sowing. The data recorded in 30 DAS was found non-significantly different in plant height, while maximum plant height was found upon ridge bed sowing (36.58 cm) as compared to raised bed sowing (33.13 cm). The plant height was found significantly highest in ridge sowing (99.51 cm) as compared to raised bed sowing (91.48 cm) at 45 days of sowing. This aligns with findings of Khan *et al.* (2012), suggesting ridge beds improve root aeration and water management, leading to better early growth in maize plants. Plant height was found non-significantly influenced by different spacing. While maximum plant height was observed in 20 cm spacing (98.56cm) and the minimum was obtained from 25 cm spacing (92.41 cm) at 45 DAS. Maize upon 20 cm intra-row spacing were taller possibly because of increased competition for space, sunlight, and available nutrients. This is in line with the findings of Akpan *et al.* (2021) and Mua'zu (2020). The findings also supported by the findings of Al Rudha & Al Younis (1978). Plant height at a later growth stage, the spacing effects became non-significant. This aligns with previous studies that show maize plants often compensate for crowding through other growth mechanisms, such as increasing leaf area or biomass per plant (Sangoi, 2001). The equidistant distribution of crop plants led to enhanced light interception and early canopy closure of crops grown in narrow rows (Widdicombe & Thelen, 2002).

Stem girth: Effect of sowing methods and spacing's on stem diameter of different growth stages are shown in Table 4. Stem girth was found non-significantly influenced by the sowing method at 30 DAS and 45 DAS. However, the ridge bed sowing resulted significantly higher stem diameter at 60 DAS (8.29 cm), whereas raised bed resulted in 7.47 cm at 60 DAS. This result is consistent with Manzoor *et al.* (2019). Ridge planting provides well aerated soil conditions promoting deep root penetration and nutrient uptake led to thicker stems. Sangoi (2001), reported ridge sowing improves root aeration, soil structure, and water

drainage, which supports better growth. The effect of spacing on maize stem girth was observed non-significant at 30 DAS and 45 DAS, whereas significantly highest stem diameter was observed at 60 DAS upon 30 cm spacing (8.59 cm) followed by 20 cm (8.09 cm) and 25 cm (8.02 cm) which were statistically at par, and minimum stem girth was found in 15 cm spacing. At 75 DAS, the significantly highest stem girth was observed in 30 cm spacing and significantly lower in stem girth in 15 cm (7.17 cm) which was followed by 20 cm spacing (7.46 cm) and 25 cm spacing (7.48 cm) which were statistically at par. Wider spacing allows plants for better light penetration, more soil moisture, and nutrients than narrower-spaced counterpart plants. This is consistent with the findings of Enujeke (2013).

Yield attributing characteristics

Number of cobs per plant: Effects of sowing methods and spacings on yield attributing characteristics are shown in Table 5. The effect of sowing methods on number of cobs per plant was found non-significant at level of 5% significance among ridge bed sowing and raised bed sowing. The effect of plant spacing on number of cobs per plant was found significant. Plants with spacing of 60x30 cm had led the significantly highest number of cobs per plant (1.88) followed by 25 cm spacing (1.69) and 20 cm spacing (1.65), which were statistically at par. The significantly lowest number of cobs per plant were found upon 15cm spacing (1.29). This is similar to the findings of Temesgen (2019), who reported greater number of cobs per plant in wider spacing due to better availability of growth resources. The intra-specific competition among plants in narrow spacing resulted in a reduced supply of growth resources to the growing cob Kebede (2019). There was no significant difference in the number of cobs per plant among ridge bed sowing and raised bed sowing. This result is consistent with the finding of Kaur & Kumar (2018).

Table 4. Effect of sowing methods and spacings on stem girth of maize (*Z. mays*) in Parbat, Nepal, 2024.

Treatments	Stem Girth (cm)			
	30 DAS	45 DAS	60 DAS	75 DAS
Sowing method (Factor A)				
Raised bed	3.71	7.56	7.87a	7.47
Ridge bed	3.71	7.90	8.29b	7.53
SEm(±)	0.10	0.18	0.11	0.09
LSD(α=0.05)	0.30	0.56	0.35	0.28
CV%	9.15	8.22	4.88	4.20
F statistics	ns	ns	*	ns
Spacing (Factor B)				
60×15 cm	3.63	7.39	7.70b	7.17 b
60×20 cm	3.79	7.84	8.09ab	7.46 b
60×25 cm	3.77	7.72	8.02ab	7.48b
60×30 cm	3.80	7.97	8.53a	7.88a
SEm(±)	0.17	0.32	0.19	0.16
LSD(α=0.051)	0.42	0.79	0.49	0.39
CV%	9.15	8.22	4.87	4.20
F statistics	ns	ns	*	*
Grand Mean	3.75	7.72	8.08	7.50

Note: Means followed by or sharing the same letter(s) within a column are non-significantly different at 5% level of significance. DAS: days after sowing, CV: coefficient of variation, LSD: least significant difference, *: significant at 5% level of significance, ns: non-significant.

Table 5. Effect of sowing methods and spacings on yield attributing parameters of maize (*Z. mays*) in Parbat, Nepal, 2024.

Treatments	Cobs per Plant	Cob Length (cm)	Cob Circumference (cm)	Kernels per Row	Grains per Cob
Sowing method (Factor A)					
Raised bed	1.62	18.99	15.27	33.01	401.16
Ridge bed	1.64	19.00	15.28	33.80	415.90
SEm(±)	0.05	0.29	0.13	0.54	10.33
LSD(α=0.05)	0.16	0.87	0.39	1.62	31.34
CV%	11.06	5.25	2.98	5.65	8.76
F statistics	0.78 ns	0.98 ns	0.93 ns	0.32 ns	0.33 ns
Spacing (Factor B)					
60×15 cm	1.29b	18.13b	14.79b	31.28b	374.12b
60×20 cm	1.65a	18.83ab	15.38a	33.97a	421.47a
60×25 cm	1.69a	19.03ab	15.18ab	33.19ab	402.22ab
60×30 cm	1.88a	19.99a	15.75a	35.18a	436.32a
SEm(±)	0.09	0.49	0.23	0.94	17.90
LSD(α=0.05)	0.22	1.23	0.56	2.33	44.33
CV%	11.06	5.25	2.98	5.65	8.76
F statistics	0.001***	0.04*	0.018*	0.02*	0.048*
Grand mean	1.63	18.99	15.27	33.40	408.53

Note: Means followed by or sharing the same letter(s) within a column are non-significantly different at 5% level of significance. CV: coefficient of variation, LSD: least significant difference, *: Significant at 5% level of significance, **: Significant at 1% level of significance, ***: Significant at 0.1% level of significance, ns: non-significant.

Cob length (cm) and Cob diameter: The effect of plant spacing of maize was found significant on cob length and diameter. Cob length was found significantly highest from 30 cm spacing (19.99 cm) which was statistically at par with 25cm spacing (19.03 cm) and 20 cm spacing (18.83 cm), and significantly shortest cob length was recorded from 15 cm spacing (18.13 cm). The significantly highest cob diameter (15.75cm) was observed from plant spacing of 30cm, which was significantly at par with 20cm spacing (15.38cm) and 25cm spacing (15.18cm). The significantly lowest cob circumference was resulted from 15cm spacing (14.79cm). The cob length and diameter decreased with reducing the plant spacing and increment in plant density possibly due to need for more growth resources like nutrients, soil moisture, and sunlight for crops became larger. This result is in accordance with the findings of Ghimire *et al.* (2023) and Koirala *et al.* (2020). The intraspecific competition among plants in narrow spacing resulted in a reduced supply of growth resources to the growing cob (Kebede, 2019).

Number of kernels per row: The number of kernels per row was not influenced significantly by the method of sowing. In the ridge bed, the maximum number of grains per row (33.80) was obtained as compared to raised bed sowing of maize (33.01). The treatment with 30 cm plant spacing resulted higher number of kernels per row (35.18) followed by 20 cm spacing (33.97) and 25 cm spacing (33.19) which were statistically similar to each other and statistically lower number of kernels was found in plant spacing of 15cm (31.28). The number of kernels per row increases with increasing plant spacing. This result is similar to the findings of Haarhoff & Swanepoel (2022) who reported that row spacing affects the growth and yield of rainfed maize in semi-arid environments.

Number of grains per cob: The number of grains per cob was not significantly influenced by the sowing method while the more number of grains per cob were obtained in ridge sowing (415.90)

than raised bed sowing (401.16). Plant spacing of 30 cm (436.32) and 20 cm (421.47) had resulted significantly higher number of grains per cob followed by 25 cm (402.22), which were statistically similar at par. This result is similar to the findings of Haarhoff & Swanepoel (2022). The number of kernels per cob was found higher in wider intra-row spacing and decreases with increment of plant density might be due to the reduced supply of growth resources, sunlight, and space.

Grain yield (t/ha): Effects of sowing methods and spacings on yield parameters are shown in Table 6. Grain yield per hectare was not found to be significantly influenced by the methods of sowing among ridge bed and raised bed. However, the maximum grain yield (5.89 t/ha) was found in ridge bed compared to grain yield (5.66 t/ha) in raised bed. The grain yield obtained from both ridge bed sowing and raised bed sowing of maize was statistically similar. This result aligns with the findings of Tanveer *et al.* (2014). The effect of plant spacing was observed highly significant on grain yield per hectare. The plant spacing of 15 cm resulted in 6.60 t/ha and plant spacing of 20 cm resulted 6.53 t/ha which were statistically similar at par but significantly higher than in plant spacing of 25 cm (5.00 t/ha) and spacing of 30 cm (4.97 t/ha). The increase in grain yield with decreased spacing could be attributed to efficient usage of available resources like nutrient, water, and sunlight (Begizew, 2018). The higher grain yield obtained at close spacing could be due to more number of cobs harvested under denser plant population (Akpan *et al.*, 2021). Increasing the plant population per unit area up to an optimum level of spacing increases grain yield per hectare by optimizing root distribution, biomass assimilation, and partitioning (Gao *et al.*, 2021).

Fresh stover yield (t/ha): Stover yield was found to be significantly influenced by the method of sowing. The stover yield was found significantly higher in ridge bed sowing (16.67 t/ha) as compared to raised bed sowing (14.17 t/ha). These results are in

Table 6. Effect of sowing methods and spacings on yield parameters of maize (*Z. mays*) in Parbat, Nepal, 2024.

Treatments	Grain Yield (mt/ha)	Stover Yield (mt/ha)
Sowing method (Factor A)		
Raised bed	5.66	14.174b
Ridge bed	5.89	16.67a
SEm(±)	0.23	0.56
LSD(α=0.05)	0.71	1.72
CV%	13.98	12.78
F statistics	0.486ns	0.007**
Spacing (Factor B)		
60×15 cm	6.60a	19.17a
60×20 cm	6.53 a	16.60b
60×25 cm	5.00b	13.25c
60×30 cm	4.97b	12.67c
SEm(±)	0.40	0.98
LSD(α=0.05)	1.00	2.44
CV%	13.98	12.78
F statistics	0.002**	0.0001***
Grand mean	5.78	15.42

Note: Means followed by or sharing the same letter(s) within a column are non-significantly different at 5% level of significance. CV: coefficient of variation, LSD: least significant difference, *: Significant at 5% level of significance, **: Significant at 1% level of significance, ***: Significant at 0.1% level of significance, ns: non-significant.

accordance with the findings of Gul *et al.* (2015), who recorded higher stover yield in ridges might due to better soil conditions, larger assimilatory system, leading to higher dry matter accumulation. The effect of plant spacing was found very highly significant to the stover yield per hectare. Plant spacing of 15 cm resulted in significantly highest (19.17 t/ha) stover yield per hectare than in 20 cm (16.60 t/ha). The plant spacing of 20 cm (16.60 t/ha) was significantly highest than stover yield per ha in plant spacing of 25 cm (13.25 t/ha) and plant spacing of 30 cm (12.67 t/ha). Plants grown at close spacing efficiently utilize available nutrients, resulting in greater storage of dry matter. Begizew (2018) also explored closer spacing resulting in increased dry matter accumulation as a result of efficient nutrient uptake, which allows plants to store photosynthates efficiently.

Conclusion

The analysis of different sowing methods and plant spacings at Parbat provided valuable insights into growth and yield attributes. Studying a two-factorial Randomized Complete Block Design with ridge bed and raised bed sowing, alongside different plant spacings of 60×15 cm, 60×20 cm, 60×25 cm, and 60×30 cm, provided greater understanding of maize performance. Results showed no discernible effect on maize plants sown in lines upon ridge bed (5.89 Mt/Ha) and raised bed (5.66 Mt/Ha) on the metrics of grain yield. However, both bed sowing methods were found to have significantly improved the grain yield of maize compared to farmer's practice in Parbat district (2.59Mt/Ha). Likewise, number of cobs per plant, ear length, ear circumference, number of kernels per row, grains per cob were found significantly at par up to 60×20 cm spacing but significantly higher than 60×15 cm. 60×20 cm spacing recorded superior performance regarding biometrical as well as yield attributes with grain yield (6.53 Mt/ha), which was significantly higher than at 60×25 cm and 60×30 cm but at par with 60×15 cm. This study enriches farmers of Parbat (mid-hill region) with cultivation strategy to combine 60×20 cm plant spacing with bed sowing methods to maximize the production and productivity of maize.

DECLARATIONS

Author contribution statement
Conceptualization: P.T.; Methodology: P.T. and S.T.; Software and validation: P.T.; Formal analysis and investigation: P.T.; Resources: P.T., R.K. and S.T.; Data curation: P.T.; Writing—original draft preparation: P.T.; Writing—review and editing: P.T. and N.K.; Visualization: P.T., A.S. and N.K.; Supervision: P.T.; Project administration: P.T. All authors have read and agreed to the published version of the manuscript.

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