



## Productivity and Land Use Efficiency of Maize Varieties under Different Row Spacings in a Maize–Finger Millet Relay Cropping System of the Mid-Hills of Nepal

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Received: May 15, 2025  
Revised: June 11, 2025  
Published: December 31, 2025

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Publisher: Agronomy Society of Nepal (ASoN)



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### ABSTRACT

Relay cropping of maize with finger millet (maize/finger millet) is the predominant cropping system for sustaining food security situation in the hilly regions of Nepal. Two-year field experiments (2023–2024) were conducted at research field of National Agronomy Research Centre, Khumaltar, Lalitpur, Nepal to evaluate the effects of maize varieties and maize row spacing on growth, yield, and land use efficiency in a maize–finger millet relay cropping system. The study used a split-plot design with three replications. Three maize row spacings (75, 100, and 150 cm) were used as main plots and four maize varieties (BGBYPOP, Arun-2, Manakamana-4, BISCO 940 NEW) as subplots. Finger millet seedlings were transplanted under standing maize 28–35 days after sowing. Data on growth, yield, and land equivalent ratio (LER) were recorded and analyzed over two seasons. Results showed that maize variety significantly ( $P < 0.05$ ) influenced system productivity, whereas row spacing had limited effect on LER. BGBYPOP produced the highest LER (1.65), followed by BISCO 940 NEW (1.62), indicating superior land use efficiency, while narrow row spacing (75 cm) produced 7.42tha<sup>-1</sup> maize yield. Maize varieties Arun-2 and Manakamana-4 gave higher finger millet grain yield (4.19–4.23 t ha<sup>-1</sup>) by reducing inter-crop competition. Maize-finger millet relay cropping with promising maize varieties should be done continuously to recommend maize variety for relay cropping system.

**Keywords:** Maize, Finger millet, Relay cropping, Variety, Row spacing, Land equivalent ratio

### How to cite this article:

Chaulagain B, RK Bhattarai, HP Timalsina, R Neupane, S Kaduwal. 2025. Productivity and Land Use Efficiency of Maize Varieties under Different Row Spacings in a Maize–Finger Millet Relay Cropping System of the Mid-Hills of Nepal. *Agronomy Journal of Nepal* 9(1): 172-179. DOI: <https://doi.org/10.3126/aj.n.v9i1.91446>

### INTRODUCTION

Maize (*Zea mays* L.) and finger millet (*Eleusine coracana*) is the second and fourth important cereal crops of Nepal in terms of area and production. The total production of maize is 3,193,869 t from 916,044 ha and finger millet is 300,732 t from 224,935 ha and productivity is 3.48 t ha<sup>-1</sup> and 1.34 t ha<sup>-1</sup> respectively (MoAD 2025). Maize and finger millet are main staple crops of farmers in hilly areas.

Finger millet is mostly relayed with maize and rarely mono cropped which is also unique example of cereal-cereal relay cropping. Maize-millet systems are advantageous to farmers because of reduced land preparation and more efficient utilization of moisture, nutrient, and labour resources (Subedi 2001). The primary reason for intercropping dominance in hill farming is for high and stable yield as well as income and also to manage weeds because enough area of ground is covered by crops which suppress weed growth (Maitra et al 2020). Nepal is a small land belt country but more yield is expected so, relay intercropping enhances the per unit productivity of the land from the same small parcel (Paudel, 2016). Relay transplanting of finger millet under standing spring-sown maize is a traditional cropping pattern in the hills between 1100 and 1700 m above sea level (asl) and more than 85% of finger millet is grown in combination with maize under this system (Sherchand, 1986). The time of transplanting of finger millet varies from the knee-high stage of maize at sites around 1700 masl to the 50% silking stage at sites around 1100 m so that the overlap period and competition between the two crops increases with altitude. Maize and finger millet inter cropping is a dominant system (Upreti 2001, Paudyal et al 2001, Acharya et al 2001, Shrestha et al 2001) in hill areas of the country. Finger millet has the potential to improve nutritional and health security of growing population especially to the marginalized, small holder farmers but it is considered as underutilized, minor and neglected crop (Gairhe et al 2021). Intercropping of

maize and finger millet has greater scope to utilize land, and other resources to maximum intent. Both, maize and finger-millet are summer crops which can provide dietary requirement along with fodder supply for long term.

Despite its importance, limited research has been conducted to optimize maize variety selection and row spacing in relay systems with finger millet. Existing studies have mostly focused on monocropping or maize–legume intercropping, leaving a knowledge gap on variety-specific performance and plant spacing effects on maize growth, yield, and system productivity under relay cropping. Furthermore, competition for light, nutrients, and moisture between maize and finger millet can affect finger millet establishment and yield, yet variety-specific interactions and land equivalent ratio (LER) in these systems remain poorly quantified.

This study was therefore designed to address these limitations by evaluating four maize varieties with different maturity periods and morphologies under three row spacings in a relay cropping system with finger millet. The research aimed to identify the most suitable maize variety and row spacing combination for maximizing growth, yield, and land use efficiency of the maize–finger millet relay system. The study aimed to: (i) assess the effects of maize varieties and row spacing on growth and yield of both maize and finger millet, (ii) determine the land equivalent ratio (LER) of different relay cropping combinations, and (iii) identify the most suitable maize variety and row spacing for optimizing system productivity in hilly regions of Nepal.

## MATERIALS AND METHODS

### Experimental site

The experiment was carried out at research farm of National Agronomy Research Centre, Khumaltar, Lalitpur, Nepal. The dominant cropping pattern of the region was rice-wheat. The soil of research site was silty clay loam (Sand: 17.3%, Silt: 57.1%, Clay: 25.6%) with acidic (5.98 pH) in reaction, low in organic matter (2.01%), medium in total nitrogen (0.14%) and high in  $P_2O_5$  (478.8 kg ha<sup>-1</sup>) and medium in  $K_2O$  (160.5 kg ha<sup>-1</sup>). Khumaltar lies at 1360 masl with coordinates of 27°39' N latitude and 85°10' E longitude. The total precipitation during the crop growing season was 1012 mm (97 days) in 2023 and 1694 mm (95 days) in 2024.

### Experimental set up

The experiments were laid out in split plot design with row spacing as main factor and maize varieties as sub factor with three replications. Four maize varieties viz. BGBYPOP, Arun-2, Manakamana-4 and BISCO 940 NEW. These varieties are adapted to the hilly regions of Nepal (1100–1700 m asl) where relay cropping with finger millet is common. Using locally adapted varieties ensures the results are relevant to farmers in the target agroecology. Finger millet variety Kabhre Kodo-1 was transplanted as relay crop beneath standing maize to evaluate performance of different maize varieties with finger millet in maize/finger millet relay cropping at Khumaltar in summer season of 2023 and 2024 (May–December) Three different row spacing i.e., 75cm, 100cm and 150cm were used for maize sowing, plant to plant spacing was 25 cm whereas finger millet was transplanted in 10×10 cm spacing. The plot size was 4 m × 3 m. Maize was sown on 8 May 2023 and 9 May 2024. Two seeds per hill were sown, thinned to one plant per hill 25 days after sowing. Fertilizer was applied in maize and finger millet separately. In maize, chemical fertilizer applied was 120:60:40  $NP_2O_5K_2O$  kg ha<sup>-1</sup> and in finger millet was 60:40:25  $NP_2O_5K_2O$  kg ha<sup>-1</sup>. Half dose of nitrogen, full dose of phosphorus and potash were applied as basal dose in maize and remaining half dose of nitrogen was split into two and applied before earthing up (35 DAS) and tasseling stage (60 DAS). The nursery bed for finger millet was established on 15 June 2023. On 20 July, 35 days old seedling were transplanted in maize plot after simple hoeing and applying basal dose of fertilizer for finger millet (30:40:25  $NP_2O_5K_2O$  kg ha<sup>-1</sup>). Similarly, in 2024, finger millet bed established on 15 July and on 12 August, 28 days old seedling were transplanted under standing maize crop giving basal dose of fertilizer for finger millet. Maize was harvested after maturing and finger millet was left to mature. Maize was harvested from third week of August to second week of September in both years because of different maturity time of maize varieties. Ten plants were randomly selected for measuring plant height, ear height, fingers per head at physiological maturity stage. Top dressing in finger millet with 30:0:0  $NP_2O_5K_2O$  kg ha<sup>-1</sup> was done after maize harvesting on 10 September 2023 and 13 September 2024 respectively. Finger millet was harvested on 11 November 2023 (149 DAS) and 10 December 2024 (148 DAS).

### Data Collection

Maize growth and yield parameters recorded included days to 50% tasseling and silking, anthesis–silking interval (ASI), days to 90% maturity, plant height, ear height, total cobs per plot, thousand-grain weight (TGW), grain yield, and land equivalent ratio (LER). Grain yield was estimated using following formula

$$\text{Grain yield} \left( \frac{\text{t}}{\text{ha}} \right) = \frac{\text{F.W.} \left( \frac{\text{kg}}{\text{plot}} \right) \times (100 - \text{HMP}) \times \text{S} \times 10}{(100 - \text{DMP}) \times \text{NPA}} \dots\dots\dots\text{Eq.1}$$

F.W. = the fresh weight of ears per plot (kg) at harvest;  
HMP = moisture percentage of grain at harvest  
DMP = desired moisture percentage, i.e., 14%  
NPA = the area of the net harvest plot, m<sup>2</sup>  
S = shelling coefficient, i.e., 0.8

$$\text{LER} = \frac{\text{Yield of maize in intercropping (g)} + \text{Yield of finger millet in intercropping (g)}}{\text{Yield of maize in sole cropping (g)} \quad \text{Yield of finger millet in sole cropping (g)}} \dots\dots\dots\text{Eq.2}$$

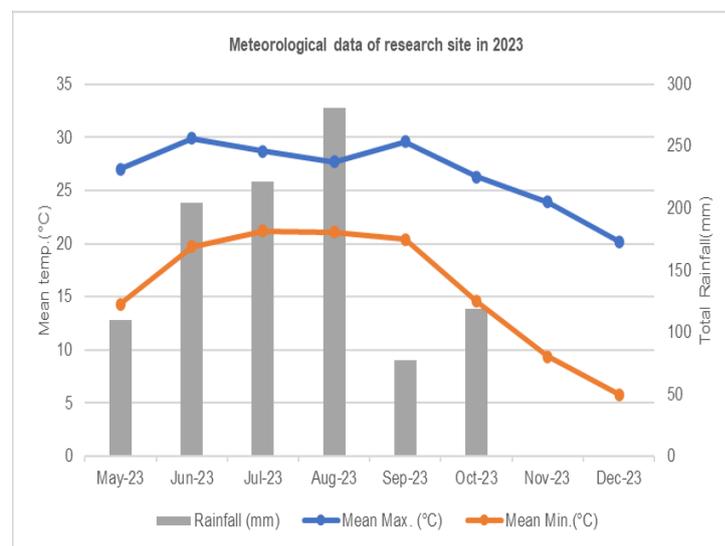
Finger millet parameters included days to 50% heading, 90% maturity, plant height, fingers per head, plant stand, bearing heads per m<sup>2</sup>, straw yield, TGW, grain yield, and harvest index (HI). Maize and finger millet yields were adjusted to 14% and 10% moisture content, respectively.

**Statistical Analysis**

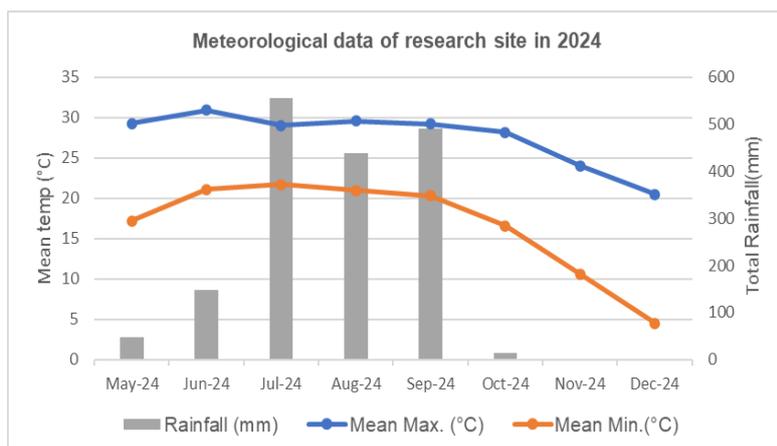
Data were analysed using GenStat 15th Edition with two-way ANOVA, and means were compared using LSD at 5% probability. Two years combined analysis was performed to account for year-to-year variation. Graphs were prepared using Excel Office 2019.

**Argo-meteorological data of research years**

In 2023, Khumaltar experienced a typical monsoonal climate characterized by warm temperatures and concentrated rainfall during June–September. Mean maximum temperatures remained around 27–30°C during the monsoon and declined to about 20°C by December, while mean minimum temperatures decreased from about 21°C in July–August to around 6°C in December. Rainfall peaked in August (over 300 mm) and sharply declined after September. In 2024, a similar seasonal temperature trend was observed, with slightly higher maximum temperatures in early summer (about 31°C in June). However, rainfall was much heavier and more concentrated, particularly in July (over 500 mm), indicating a stronger monsoon compared to 2023. Overall, both years showed favorable thermal conditions for crop growth, but 2024 experienced substantially higher monsoon rainfall, which may have influenced crop performance differently between the two seasons.



**Figure 1: Climatic data during study at Khumaltar in 2023**



**Figure 2: Climatic data during study at Khumaltar in 2024**

## RESULTS AND DISCUSSION

### Maize growth and yield

Ear height was significantly affected by row spacing and variety. Narrower spacing (75×25 cm) had higher ears (136.5 cm), while wider spacing (150×25 cm) had lower ears (123.3 cm), reflecting competition effects (Aslam et al 2021, Liu et al 2025). Among varieties, BISCO 940 NEW had the tallest ear (138.6 cm), whereas BGBY POP had the shortest (123.1 cm). Year had no significant effect. Plant height was not-significant for both row spacing and variety. Plant height was found significant for year only. Plant height was genetically controlled, showing no significant differences among row spacing or varieties (Tesfa and Tilahun 2025).

Combined analysis revealed that row spacing did not significantly affect the days to 50% tasseling and days to 50% silking, while maize variety and year had significant effects (Table 1) These findings were similar to those findings as reported by previous researchers (Koirala et al 2020, Liu et al 2025). Among varieties, Arun-2 was found earlier for days to 50% tasseling (62.6 days), followed by Manakamana-4 (64.9 days). Similarly, the days to 50% silking was earliest in Arun-2 (68.1 days). These results were similar to results founded by Edmeades et al (1997) and Araus et al (2012). Interaction effects among spacing × variety × year were nonsignificant for days to 50% tasseling and days to 50% silking. Anthesis silking interval (ASI) varied significantly with row spacing and variety. Wider spacing (150×25 cm) produced a lower ASI (4.6 days) than 75×25 cm (5.3 days), promoting better synchrony between male and female flowering (Bolanos and Edmeades 1996, Sher et al 2018). BISCO 940 NEW had the lowest ASI (4.3 days), suggesting improved reproductive efficiency (Valkova and Vulchinkov, 2026). Year effects were nonsignificant for ASI. Days to 90% maturity were influenced by variety and year but not by row spacing. Arun-2 matured earliest (97.8 days), while BISCO 940 NEW matured latest (112.4 days), consistent with varietal differences in flowering duration (Edmeades et al 1997). This is due to the fact that Arun-2 takes the shortest days to flower its tassel. Year was also found significant.

The number of cob number per plot and grain yield were significantly influenced by row spacing, variety, and year. Narrower spacing (75×25 cm) produced the highest number of cobs (71.8), while wider spacing (150×25 cm) produced the lowest (44.3), consistent with optimal plant density effects (Koirala et al 2020, Smith and Jones, 2025). Among varieties, BISCO 940 NEW had the highest number of cobs (64.4). Cob numbers were higher in 2023/24 (60.2) than in 2024/25 (56.9). Thousand grain weight (TGW) was influenced by row spacing, variety, and year. The 100×25 cm spacing produced the highest TGW (324.8 g), and Manakamana-4 produced the highest TGW among varieties (339.7 g), while Arun-2 had the lowest (302.5 g) (Fuksa et al 2023). TGW was higher in 2023/24 (341.6 g) than in 2024/25 (301.2 g).

Grain yield followed a similar trend: the narrowest spacing (75×25 cm) produced the highest yield (7.42 t ha<sup>-1</sup>, while 150 ×25 cm gave the lowest (4.72 t ha<sup>-1</sup>). Among varieties, BISCO940 NEW yielded highest (8.19 t ha<sup>-1</sup>) and Arun2 lowest (4.96 t ha<sup>-1</sup>) (Liu et al 2025, Tesfa and Tilahun 2025). Year effects were significant reflecting environmental variation (Singh et al 2022). The combined analysis over years showed that BGBYPOP was found best performing among four tested varieties producing 65% more yield than sole cropping which was followed BISCO 940 NEW yielding 62% more yield than sole cropping in relay cropping. Arun-2 and Manakamana-4 produced only 44% more yield than sole cropping in relay cropping. During first year, land equivalent ratio was 1.45 representing 45% more yield than sole cropping while in second year, land equivalent ratio was 1.67 depicting 67% more yield in maize/finger millet relay than sole cropping of maize and finger millet.

**Table 1. Combined effects of maize row spacing and maize variety on growth and yield of maize under maize–finger millet relay cropping at Khumaltar, Nepal (2023–2024)**

Treatment	50% TAS (days)	50% SLK (days)	ASI	90% MAT (days)	EH (cm)	PH (cm)	Total No. of cobs	TGW	GY (tha <sup>-1</sup> )	LER
<b>Spacing (S)</b>										
75×25 cm	64.7	70	5.3 <sup>b</sup>	106	136.5 <sup>b</sup>	276.3	71.8 <sup>c</sup>	322.0 <sup>ab</sup>	7.42 <sup>c</sup>	2.06
100×25 cm	64.8	69.7	4.8 <sup>ab</sup>	106	133.1 <sup>b</sup>	276.1	59.5 <sup>b</sup>	324.8 <sup>b</sup>	6.37 <sup>b</sup>	NA
150×25 cm	65.3	69.9	4.6 <sup>a</sup>	106	123.3 <sup>a</sup>	288	44.3 <sup>a</sup>	317.5 <sup>a</sup>	4.72 <sup>a</sup>	NA
<b>LSD (0.05)</b>	NS	NS	0.5	NS	6.63	NS	4.64	5.34	0.23	
<b>Variety (V)</b>										
BGBY POP	65.7 <sup>bc</sup>	70.7 <sup>bc</sup>	4.9 <sup>ab</sup>	109.3 <sup>c</sup>	123.1 <sup>a</sup>	253.1	55.8 <sup>a</sup>	322.2 <sup>b</sup>	6.09 <sup>b</sup>	1.65
Arun-2	62.6 <sup>a</sup>	68.1 <sup>a</sup>	5.4 <sup>b</sup>	97.8 <sup>a</sup>	128.4 <sup>ab</sup>	301.9	59.0 <sup>a</sup>	306.5 <sup>a</sup>	4.96 <sup>a</sup>	1.44
Manakamana-4	64.9 <sup>b</sup>	69.8 <sup>b</sup>	4.8 <sup>ab</sup>	104.5 <sup>b</sup>	133.9 <sup>bc</sup>	291.4	55.1 <sup>a</sup>	339.7 <sup>c</sup>	5.43 <sup>a</sup>	1.44
BISCO 940	66.6 <sup>c</sup>	70.9 <sup>c</sup>	4.3 <sup>a</sup>	112.4 <sup>d</sup>	138.6 <sup>c</sup>	274	64.4 <sup>b</sup>	317.2 <sup>b</sup>	8.19 <sup>c</sup>	1.62
NEW										
<b>LSD (0.05)</b>	1.2	1	0.8	2.8	7.17	NS	4.03	7.62	0.56	
<b>Year (Y)</b>										
2023	63 <sup>a</sup>	67.5 <sup>a</sup>	4	104	131.6	315.8 <sup>b</sup>	60.2 <sup>b</sup>	341.6 <sup>b</sup>	7.45 <sup>b</sup>	1.45
2024	67 <sup>b</sup>	72.0 <sup>b</sup>	5	108	130.4	244.4 <sup>a</sup>	56.9 <sup>a</sup>	301.2 <sup>a</sup>	4.89 <sup>a</sup>	1.67
<b>LSD (0.05)</b>	1	1.5	NS	3.1	NS	28.2	3.13	8.61	0.47	
S×V	NS	NS	NS	NS	NS	NS	NS	NS	NS	
V×Y	NS	NS	NS	NS	9.91	NS	5.81	14.01	NS	
S×Y	NS	NS	NS	NS	NS	NS	NS	NS	NS	
S×V×Y	NS	NS	NS	NS	NS	NS	NS	NS	NS	
<b>CV%</b>	0.9	0.7	4.9	0.3	2.2	8.1	3.5	NS	1.7	
<b>Grand Mean</b>	65	69.9	4.9	106	131	280.1	58.6	321.4	6.17	

TAS=days to 50% tasseling, SLK=days to 50% silking, ASI= anthesis–silking interval, MAT= days to 90% maturity, EH= ear height, PH= plant height, TGW= thousand grain weight, GY= grain yield, LER= land equivalent ratio. Values are means of two years (2023–2024). Means followed by different lowercase letters within a column differ significantly at  $P \leq 0.05$  according to LSD test. NS = not significant; NA = not applicable.

ER was significantly affected by maize variety but not by row spacing (Table 1). BGBY POP intercrop achieved the highest LER (1.65), followed by BISCO 940 NEW (1.62), indicating 65% and 62% higher productivity than sole cropping (Mead and Willey 1980, Deb et al 2024). Arun-2 and Manakamana-4 gave LER of 1.44 .

### Finger Millet Growth and Yield

The combined analysis, showed that the days to 50% heading in finger millet was found not-significant for row spacing and maize varieties but significant for year. Days to 50% heading averaged 103.8 days. Fingers per head increased from 5.3 in 2023/24 to 6.2 in 2024/25. Plant height of finger millet was not significantly affected by maize row spacing, maize variety, or year, indicating that this trait was largely governed by genetic constitution rather than relay cropping treatments. The overall mean plant height was 120.4 cm.

Fingers per head were not significantly influenced by row spacing or maize varieties; however, a significant year effect was observed. Fingers per head increased from 5.3 in the first year to 6.2 in the second year, representing a significant improvement of nearly one additional finger per head. The grand mean was 5.9 fingers per head. Plant stand per square meter was not significantly affected by row spacing, maize varieties, or year, with an overall mean of 78.7 plants m<sup>-2</sup>. Similarly, bearing heads per square meter were not influenced by row spacing or maize varieties but differed significantly between years. The first year recorded 97 bearing heads m<sup>-2</sup>, which was significantly higher than 72 heads m<sup>-2</sup> in the second year. The overall mean was 80.9 heads m<sup>-2</sup>.

Straw yield of finger millet was not significantly influenced by row spacing, maize varieties, or year, with a mean value of 8.33 t ha<sup>-1</sup>. Thousand grain weight (TGW) was not affected by row spacing or maize varieties but showed a significant year effect. The second year produced significantly heavier grains (2.78 g) compared to the first year (2.68 g), with a mean TGW of 2.73 g.

Finger millet grain yield was not significantly influenced by maize row spacing, although numerically the narrower spacing (75 × 25 cm) produced the highest yield (4.18 t ha<sup>-1</sup>) and the wider spacing (150 × 25 cm) the lowest (3.89 t ha<sup>-1</sup>). Grain yield was significantly affected by maize variety. Plots associated with early-maturing maize varieties, Arun-2 (4.19 t ha<sup>-1</sup>) and Manakamana-4 (4.23 t ha<sup>-1</sup>), produced significantly higher finger millet yields than those with BGBY POP (3.87 t ha<sup>-1</sup>). The improved performance under early-maturing maize varieties may be attributed to reduced interspecific competition and greater availability of light, nutrients,

and moisture during the critical growth stages of finger millet. Year also had a significant effect on grain yield. Finger millet produced 3.29 t ha<sup>-1</sup> in the first year and 4.85 t ha<sup>-1</sup> in the second year, indicating a substantial yield advantage in the latter season. August transplanting of finger millet in the second year likely reduced competition with maize and facilitated efficient utilization of residual nutrients and favorable rainfall during reproductive stages, thereby enhancing productivity. The overall mean grain yield was 4.07 t ha<sup>-1</sup>. Harvest index was not significantly influenced by row spacing or maize varieties but varied significantly between years. It increased from 0.28 in the first year to 0.37 in the second year, with an overall mean of 0.32, reflecting improved assimilate partitioning toward grain in the second season.

**Table 2. Combined effects of maize row spacing and maize variety on growth, yield, and harvest index of finger millet under maize–finger millet relay cropping at Khumaltar, Nepal (2023–2024)**

Treatment	50% HEAD (days)	90% MAT (days)	PH (cm)	FPH	Plant Stand (m <sup>2</sup> )	Bearing Head (m <sup>2</sup> )	Straw Yield (t ha <sup>-1</sup> )	TGW (g)	GY (t ha <sup>-1</sup> )	HI
<b>Spacing(S)</b>										
75×25cm	103.8	140	119.9	5.7	81.2	86.7	8.08	2.74	4.18	0.34
100×25cm	103.7	140	121.9	5.8	77.9	84.0	8.35	2.77	4.15	0.33
150×25cm	103.9	140	119.4	5.7	76.7	82.6	8.57	2.68	3.89	0.31
<b>LSD (0.05)</b>	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
<b>Variety(V)</b>										
BGBY POP	103.7	140	117.5	5.5	80.8	82	8.33	2.72	3.87 <sup>a</sup>	0.31
Arun-2	103.7	140	121.9	5.9	74.3	85	8.14	2.68	4.19 <sup>b</sup>	0.34
Manakamana-4	103.6	140	123.2	5.9	85.8	93	9.01	2.78	4.23 <sup>b</sup>	0.32
BISCO940	104.1	140	118.9	5.8	73.4	78	7.85	2.73	3.98 <sup>ab</sup>	0.33
NEW										
<b>LSD (0.05)</b>	NS	NS	NS	NS	NS	NS	NS	NS	0.308	NS
<b>Year(Y)</b>										
<b>2023</b>	108.5	140	119.2	5.3 <sup>a</sup>	77	97 <sup>b</sup>	8.36	2.68 <sup>a</sup>	3.29 <sup>a</sup>	0.28 <sup>a</sup>
<b>2024</b>	99.0	140	121.5	6.2 <sup>b</sup>	80	72 <sup>a</sup>	8.31	2.78 <sup>b</sup>	4.85 <sup>b</sup>	0.37 <sup>b</sup>
<b>LSD (0.05)</b>	0.675	NS	NS	0.27	NS	9.0	NS	0.089	0.273	0.016
S×V	NS	NS	NS	0.61	NS	NS	NS	0.072	0.524	NS
V×Y	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
S×Y	NS	NS	NS	NS	NS	NS	NS	0.153	NS	0.032
S×V×Y	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
<b>CV%</b>	0.3	0.0	3.3	4.1	8.9	3.0	4.4	2.2	3.7	4.1
<b>Grand Mean</b>	103.8	140	120.4	5.9	78.7	80.9	8.33	2.73	4.07	0.32

HEAD= days to 50% heading, MAT= days to 90% maturity, PH= plant height, FPH= fingers per head, TGW=thousand grain weight, GY=grain yield, HI= harvest index. Values are means of two years (2023–2024). Means followed by different lowercase letters within a column differ significantly at P ≤ 0.05 according to LSD test. NS = not significant.

From two years analysis, anthesis-silking interval was found to be significant for row spacing as wider spacing had low ASI value which is desirable trait in breeding purpose and drought stress condition as it took longer duration than other spacing for tasseling and silking but the difference minimum. Similarly, ear height was significantly low in wider spacing because of easy availability of resources. Total cob per plot was significant as plant population was significant because plant population decreases by 25% and 50% when compared with standard row spacing of 75×25cm to 100×25cm and 150×25cm.

Grain yield of finger millet was influenced by maize variety and year. Manakamana-4 and Arun-2 intercrops gave higher yields (4.23 and 4.19 t ha<sup>-1</sup>, respectively) than BGBY POP and BISCO 940 NEW. This findings was similar to findings reported by Tesfa and Tilahun (2025). Grain yield increased in 2024/25 (4.85 t ha<sup>-1</sup>) compared to 2023/24 (3.29 t ha<sup>-1</sup>), due to better residual soil nutrients and favorable weather (Xu et al 2023). Harvest index followed a similar trend, increasing from 0.28 to 0.37 in the second year. The thousand grain weight was significant for row spacing, highest value was found in 100×25cm. For maize varieties, Arun-2 was significantly early in days to 50% tasseling, 50% silking and 90% maturity as Arun-2 is early maturing variety than other varieties however BISCO 940 NEW had shortest ASI interval. Ear height was found significant between BGBYPOP and BISCO 940 NEW however plant height was not significant for varieties. BISCO 940 NEW had significantly more cobs than other varieties. Thousand grain weight was significant in Manakamana-4

compared to other varieties. Similarly, grain yield of maize was also significant for varieties. BISCO 940 NEW had significantly higher yield than BGBYPOP, Manakamana-4 and Arun-2.

Land equivalent ratio (LER) varied among maize varieties in relay combination with finger millet. The highest LER was recorded in the BGBY POP/finger millet system (1.65), followed by BISCO 940 NEW/finger millet (1.62). In contrast, Arun-2/finger millet and Manakamana-4/finger millet produced equal LER values (1.44). As all LER values exceeded unity, relay cropping was advantageous over sole cropping; however, the BGBY POP–finger millet combination showed the greatest biological efficiency and overall land use advantage.

For maize, year effects were significant for key phenological and yield traits. Days to 50% tasseling and 50% silking were significantly higher in the second year, indicating relatively delayed flowering. Plant height was significantly greater in the first year (315.8 cm) compared to the second year (244.4 cm). Similarly, number of cobs per unit area, thousand grain weight (341.6 g), and grain yield ( $7.45 \text{ t ha}^{-1}$ ) were significantly higher in the first year, demonstrating more favourable growing conditions for maize during that season.

In finger millet, most growth and yield traits were not significantly influenced by maize row spacing or maize variety. However, grain yield was significantly affected by maize variety. Finger millet grown in plots of Arun-2 and Manakamana-4 produced significantly higher yields than those under BGBY POP and BISCO 940 NEW, suggesting varietal differences in compatibility and competitive interactions within the relay system. Year effects were also pronounced in finger millet. Days to 50% heading and bearing heads per square meter were significantly higher in the first year, whereas fingers per head, thousand grain weight, grain yield, and harvest index were significantly higher in the second year. The improved performance in the second year can be attributed to timely nursery establishment in July, transplanting in August, and more favorable weather conditions during reproductive growth, which enhanced grain filling, biomass partitioning, and overall productivity.

## CONCLUSION

The two-year study conducted at Khumaltar verified that maize–finger millet relay cropping is an effective method of increasing land productivity in Nepal's mid-hills, with maize variety having greater effects on system performance than row spacing. The best maize variety for relay cropping was BGBYPOP, which had the highest land equivalent ratio (1.65) of the evaluated varieties. This indicates better biological efficiency, and it is followed by BISCO 940 NEW (1.62). Row spacing did not significantly alter land-use efficiency, indicating flexibility in spacing adoption, even if it boosted maize output. By decreasing intercrop competition, early-maturing maize varieties like Arun-2 and Manakamana-4 increased finger millet grain production. In order to maximize system productivity, BGBYPOP is advised for maize–finger millet relay cropping; however, early-maturing varieties might be favored in situations.

## ACKNOWLEDGEMENTS

The authors would like to thank Nepal Agricultural Research Council (NARC) for allowing fund for this project. Also, thanks to the principal scientist, senior scientists, scientists, technicians, field technician, and management team of the National Agronomy Research Centre for successfully carrying out this field research activity and recording data during the research period.

## AUTHORS' CONTRIBUTION

Bhimsen Chaulagain: Conceptualization, Methodology development, Data collection, Formal analysis, Data curation, and Visualization, Writing - original draft

Rajendra Kumar Bhattarai: Conceptualization, Writing - review and editing,

Himal Prasad Timalisina: Conceptualization, Field coordination, Formal analysis, Data curation and writing – review and editing.

Reshama Neupane: Data collection, field experimentation, data curation, and writing – review and editing.

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## CONFLICT OF INTEREST

The authors have no any conflict of interest to disclose.

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