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Research article

Evaluation and Preference Ranking of Multinational Companies' Maize Hybrids in Sundarbazar, Lamjung, Nepal

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To evaluate the performance of ten multinational maize hybrids in comparison with nationally developed hybrid maize varieties, a field experiment was conducted during the summer season of 2022 using a randomized complete block design at Sundarbazar, Lamjung. The assessment of farmers' preferences and the agronomic performance of crops in specific agroecological zones plays a crucial role in improving the productivity of any crop. This study aimed to identify superior genotypes, assess farmer preferences, and promote the adoption of high-yielding maize varieties. A total of 12 maize hybrids were evaluated with three replications at a farmer's field in Sundarbazar, Lamjung, Nepal, from March to July 2022. Rampur Hybrid-10 and Khumal Hybrid Maize-2 were standard checks. Analysis of variance revealed significant differences among the genotypes for most quantitative traits, including plant height, ear height, days to physiological maturity, ear weight, ear length, and grain yield. Compared to the check variety Rampur Hybrid-10, all other hybrids produced lower grain yields. However, their yields were statistically similar to that of Khumal Hybrid Maize-2. Farmer participation in the selection process helped identify superior varieties through preference ranking based on desirable ear characteristics. Among the multinational hybrids, TX-369 and CP-808 were the most preferred by farmers. Therefore, these varieties are recommended for cultivation in the Sundarbazar region.

Introduction

In Nepal, maize is the second most important staple crop after rice, covering an area 940,256 of hectares and production of 2,976,490 metric tons, with a productivity rate of 3.17 metric tons per hectare (MOALD 2024). Hybrid maize is successfully cultivated across various regions of Nepal, from the Terai and inner Terai to valleys, foothills, and mid-hill areas. Of the total maize-growing area, hybrid varieties account for 80% in the Terai and 10% in the hills (Kandel 2021). These hybrids can be 25–30% more productive than the best open-pollinated varieties when provided with higher inputs (Belton and Fang 2022). Their popularity among farmers is due to desirable traits such as high yield potential, insensitivity to photoperiod, responsiveness to fertilizers, resistance to lodging, and suitability for green cob production and high-density planting (Dawadi 2015).

To date, the Government of Nepal has released over 27 maize varieties and registered 59 multinational company maize hybrids. There are ten hybrid maize varieties released by the National Maize Research Programme (NMRP). Among these, Khumal Hybrid Maize-2 is recommended for the mid-hill region as a main season crop and as winter maize for the Terai region and Rampur Hybrid-2 for the Terai region, while the other hybrids are suggested for the Terai and inner Terai (SQCC 2021). However, the seed production of national hybrids is unsatisfactory due to issues like mismatched

flowering times of parent plants, lack of essential seed production research information, and poor coordination between private and government sectors in hybrid maize seed production. Approximately 80% of the total maize seed requirement has been imported leading to an annual trade deficit of about 12 billion rupees (USD 109.18 million) in the fiscal year 2017–2018 (Joshi and Gautam 2021). The reliance on imported hybrid maize seeds stems from the limited availability of desirable hybrid cultivars within the country. Consequently, numerous hybrid maize seeds released by multinational companies have been registered with the National Seed Board of Nepal. Although the hybrid maize market is expanding annually in Nepal, and the area under hybrid seeds is increasing, national maize yield remains considerably lower than in developed countries (Kandel and Shrestha 2020). This may be attributed to the diverse agroecological zones and the lack of location-specific maize hybrids in the country (Thapa 2021). A thorough evaluation of different multinational hybrid maize cultivars is lacking in Nepal's mid-hill region (Neupane et al. 2020). Due to porous borders with India and weak monitoring mechanisms, uncertified and unauthorized hybrids have entered the market, causing issues like barren cobs and pest and disease infestations (Gairhe et al. 2025). Additionally, the top-performing varieties have not been fully utilized for their unique genetic traits in various economic aspects. A wealth of genetic resources could be harnessed from this genetic material, thereby enhancing breeding programs (Prasanna 2012). This situation underscores the importance of identifying maize hybrid varieties best suited to the country's diverse agroecological regions.

Another contributing factor to the reduced yield of hybrid maize in Nepal is the limited adoption of improved, high-yielding varieties (Thapa 2021). As highlighted by Tarekegne et al. (2019), the high-yielding varieties do not always correspond to the ones that farmers choose. Therefore, it is crucial to evaluate improved varieties of any food crop for their adoption based on farmers' preferences rather than issuing a blanket recommendation. The participatory variety selection (PVS) method was utilized to assist farmers in identifying their preferred crop varieties and to facilitate the adoption of the most suitable ones (Vasal 2019). This strategy aids in reducing the yield gap caused by insufficient or poor access, as participatory variety selection and evaluation address issues that may be overlooked by the formal breeding system. This method involves assessing released or nearly released genotypes to enhance the success rate in the final stage of the plant breeding process (Bucheyeki et al. 2011, Abebe 2005). Thus, the objective of the study is to select highly adaptive and high-performing international hybrid maize varieties based on farmers' preferences and agronomic yield data.

Materials and Methods

Experimental site: The research was carried out in a farmer's field in Sundar Bazar municipality, Lamjung, Nepal from March to July 2022. Geographically, the experimental location is in the low hills of Gandaki province of Nepal at 28.124783°N latitude, 84.415027°E longitude, at 610 m above sea level.

Experimental materials: Two maize cultivars released in Nepal, Khumal Hybrid Maize-2 and Rampur Hybrid-10, which are recommended for the Terai and mid-hills regions, were used as a local standard check (Table 1). They were collected from the National Plant Breeding and Genetics Research Centre (NPBGRC), Khumaltar, and the NMRP, Rampur, Chitwan, respectively. Ten varieties were the most popular multinational hybrids grown in the Sundarbazar area and collected from the local agrovets.

Table 1. List of twelve maize hybrid varieties used in the study

Genotype name	Yield, mt/ha	Maturity, days	Recommended domain
All-Rounder	7-10	120-160	Terai
Bioseed-9681	6.5-8	90-110	Mid hill, East Terai
Bisco-940	7.13	135-140	Terai, Hill
CP-808	9.95	110-120	Terai
Dekalb Double	6.79	118	Terai, Inner Terai
Suvarna	7.63	150-160	East Terai, Inner Terai
JK-502	7.09	115	Terai, Inner Terai up to 700 m asl
Khumal Hybrid Maize- 2	8.5	152-138	Mid hill, Terai, Inner Terai
TX-369	9	124	Terai, Inner Terai, River basin, Low hill
Rajkumar	8-9	100-110	Terai, Inner Terai, River basin, Low hill
Rampur Hybrid-10	8.05	120-160	Terai, Inner Terai up to 700 m asl
Star-9	8.63	150-160	Terai, Inner Terai

Experimental design and crop management: The experiment was designed in RCBD with three replications with a plot size of $9m^2$ (3m × 3m). A crop geometry of 60 cm × 25 cm (row to row × plant to plant distance) was used. Fertilizer was applied at a rate of 150:60:60 N: P: K kg ha-1 (Urea, Diammonium Phosphate (DAP), and Muriate of Potash (MOP) taking agriculture diary as reference (AITC 2021). Half the dose of nitrogen (N) and the entire dosage of phosphorus (P) along with potassium (K) was applied as a basal dose. Two equal portions of the other half dose of nitrogen were top dressed manually at knee knee-high stage and pre-tasseling / silking stage. At a knee-high stage, earthing up was done. Similarly, optimum irrigation was provided at knee-high, tasseling, and milking stages.

Data collection and observations: Five plants from each experimental plot were selected at random for data collection. The selected plants were examined for phenological traits (days to tasselling, days to silking, and days to physiological maturity), plant growth traits (plant and ear height), and yield and yield attributing traits (ear length, width, and diameter, number of kernels per row, number of kernel rows per cob, 1000 grain weight) following standard evaluation system (IBPGR 1991). Phenological traits such as days to tasselling, days to silking, days to physiological maturity, and anthesis silking interval (ASI) were taken on a whole plot basis. The average value was used for statistical analysis. Grain yield was calculated using the formula of (Carangal et al. 1971)by adjusting the grain moisture at 12.5%. A similar adjustment to grain moisture is also followed by Khanal et al. (2024) and Kandel et al. (2018).

$$\text{Grain yield (tons/ha)} = \frac{\text{FWE} \times (100 - \text{HMP}) \times \text{SCF} \times 10000}{(100 - \text{DMP}) \times \text{NPA} \times 1000}$$

Where, FWE = Fresh weight of ear per plot at harvest (kg), HMP = Percentage of moisture in the grain at the harvest, DMP = Desired moisture percentage, i.e. 12.5%, NPA = Net harvest plot area in sq. m, SCF = Shelling coefficient, i.e. 0.8.

A preference ranking of the maize genotypes was performed where the farmers were allowed to choose the desired varieties from a range of the twelve varieties in an unbiased manner. The ranking criteria used in the preference ranking were set based on the ear and kernel characteristics such as color, and uniformity, and the preference score was obtained as:

$$\text{Preference score} = \frac{\text{Total score obtained by the variety for all traits}}{\text{Total traits studied}}$$

Respondents score the varieties for each trait individually. For a trait like color, the score given by total respondents is averaged, similarly for all the traits. The total score for a variety is divided by the total number of traits and the final score is obtained. The final preference ranking is done as 1st for the highest total score and so on.

Scoring criteria: 1-5 scale where 5 is the highest and 1 is the lowest

Data analysis: All collected data was entered in Microsoft Excel. Subsequently, Analysis of Variance (ANOVA) was performed using the statistical software R version 3.6.1, package Agricolae to determine the mean sum squares (MSS) for each trait. For mean comparison, Duncan's multiple range test was employed to find significant mean differences at a significance level of 0.05

Results and Discussion

Mean performance of genotypes

ANOVA revealed that a cultivar had a significant variation in mean squares ($P<0.001$) for the phenological traits (days to physiological maturity), growth traits (plant height, ear height), and yield and yield-attributing traits (ear length, ear weight, and grain yield). This suggests that there is genetic diversity among these traits, which could be leveraged for screening in future breeding programs (Dhakal et al. 2020).

Phenological traits: Significant variation was observed in the number of days required for physiological maturity (Table 2). The duration to physiological maturity ranged from 105 days for Bioseed-940 to 116 days for Rampur Hybrid-10, with an average of 110 days. Among the multinational hybrid varieties, all-rounder required the longest period to reach maturity at 114 days, followed by Bisco-940 at 112 days, and CP-808 and JK-502, both at 111. Pampana et al. (2009) reported that the extension of the period from silking to physiological maturity is associated with increased nitrogen acquisition from the soil and nitrogen remobilization from vegetative plant parts, leading to higher dry matter accumulation. The interval between physiological maturity and harvest maturity varied from one to three weeks. According to Abendroth et al. (2021), the maturity days for hybrids have decreased, with a median reduction of -0.9 GDD per year. For the hybrids under study, no significant differences were found in the days to 50% anthesis and silking,

and the anthesis-silking interval. The mean value for days to 50% anthesis was 75.06, and for days to 50% silking it was 78. Shrestha et al. (2015) and (Hadi 2021)recorded anthesis and silking days within this range. Anthesis and silking days were shorter in the summer season because of the higher temperatures and prolonged solar radiation. Prior research by Kandel and Shrestha (2020) revealed no variation in ASI among the hybrids. Conditions et al. (2018) reported that ASI was negatively correlated with ear weight, kernel number, and number of ears per plant. As the ASI increases, these yield components tend to decrease, ultimately reducing maize yield. According to Alvi et al. (2003), hybrids with anthesis to silking intervals of less than three days, along with a reduced incidence of diseases and pests, contributed to higher grain output.

Plant growth traits: Significant differences were noted between the two plant growth traits: plant height and ear height as shown in Table (2). (Manjunatha et al. 2018) also identified genotypic variability among hybrids concerning these traits. Khumal Hybrid Maize-2 (226 cm) emerged as the tallest genotype, followed by Rampur Hybrid-10 (219 cm), TX-369 (218 cm), Rajkumar (214 cm), Dekalb Double (214 cm), JK-502 (213 cm), Bisco-940 (204 cm), CP-808 (202 cm), All-Rounder (187 cm), Suvarna (174 cm), and Bioseed-940 (171 cm). Both genetic and environmental factors contribute to variations in plant height among the genotypes (Bishnu Prasad Kandel & Shrestha, 2020b). Factors such as canopy architecture, carbon and nutrient uptake, and weed competition influence plant height. Ear height ranged from 84 cm (Bioseed 940) to 123 cm (Khumal Hybrid Maize-2), with a mean of 99.51 cm. The ear heights of other genotypes, in descending order, are Bisco-940 (113 cm), Rampur Hybrid-10 (106 cm), Rajkumar (101 cm), JK-502 (99 cm), Dekalb Double (96 cm), CP-808 (95 cm), TX-369 (94 cm), All-Rounder (89 cm), and Suvarna (89 cm). Excessive plant height and elevated ear placement significantly increase the center of gravity in maize plants, thereby increasing the risk of lodging and bending (Wang 2023). However, increased plant height is associated with higher dry matter accumulation and yield. Maintaining an appropriate plant height can effectively mitigate lodging, enhance the transfer of assimilates to reproductive organs, and promote a balanced source-sink relationship (Wang 2023). These factors collectively contribute to achieving a high maize yield Rampur Hybrid-10, with moderate plant height and ear height, yielded the highest grain yield. Numerous researchers have documented the architectural characteristics of maize plants within this range, which aligns with the current findings(Thapa et al. 2022, Kandel et al. 2018).

Table 2. Mean performance of phenological and growth attributes of maize hybrid.

Treatment	DTA	DTS	ASI	DTM	PH (cm)	EH (cm)
All-Rounder	72	75	2	114^{ab}	187^{de}	89^{de}
Bioseed-940	74	77	3	105^{e}	171^{e}	84^{e}
Bisco-940	74	76	2	112^{ab}	204^{abcd}	113^{ab}
CP-808	75	77	2	111^{bcd}	202^{bcd}	95^{cde}
Dekalb Double	75	77	2	110^{bcd}	214^{abc}	96^{cde}
Suvarna	77	80	3	107^{de}	174^{e}	89^{de}
JK-502	77	79	3	111^{bcd}	213^{abc}	99^{bcde}
Khumal Hybrid Maize-2	75	78	3	108^{cde}	226^{a}	123^{a}
Rampur Hybrid-10	77	80	3	116^{a}	219^{ab}	106^{bc}
TX-369	73	76	3	108^{cde}	218^{ab}	94^{cde}
Rajkumar	74	77	3	107^{cde}	214^{abc}	101^{bcd}
Rampur Hybrid-10	77	80	3	116^{a}	219^{ab}	106^{bc}
Star-9	75	78	3	111^{bc}	196^{cd}	105^{bc}
LSD	3.47	3.25	1.21	3.60	19.4	13.4
CV (%)	2.73	2.48	29.29	1.93	5.67	7.98
Grand Mean	75.06	77.5	2.44	110.03	203.14	99.51
F-test	NS	NS	NS	***	**	***
SEM±	1.04	0.97	0.35	1.03	6.03	4.15

Means followed by common letters within a column do not differ significantly at the ≤ 5% level of significance; LSD = least significant difference; significant codes *** at $p \leq 0.001$; ** at $p \leq 0.01$; * at $p \leq 0.05$ level and ns = non-significant; SEM = standard error of the mean, CV = coefficient of variation; DTA= days to 50% anthesis, DTS= days to 50% silking, ASI= anthesis-silking interval, DTM= days to physiological maturity, PH= plant height, EH= ear height

Yield attributing traits: Significant variations were observed in traits, such as grain yield, ear weight, and ear length as presented in Table 3. However, other yield-attributing traits, such as the number of kernels per row, number of kernel rows per ear, and thousand-grain weight, were not significantly different. Kandel et al. (2018) also showed no significant difference among these traits in maize hybrids. Ear weight ranged from 0.11 kg (Rajkumar) to 0.28 kg (Bisco-940)

with a mean value of 0.23 kg. A wide gap of 15 cm (Suvarna) – 21 cm (Rampur Hybrid-10), with a mean of 17.82 cm was observed for ear length. Grain yield is one of the fundamental parameters considered when determining elite hybrid genotypes (Koirala et al. 2025). The grain yield had a mean value of 8.56 tons/ha and varied from 5.98 tons/ha (Rajkumar) to 11.94 tons/ha (Rampur Hybrid-10). Koirala et al. (2021) recorded a similar yield for Rampur Hybrid-10 at Sarlahi. Rampur Hybrid-10 being the best performer in terms of yield may be due to the greater ear length.

Table 3 showed that all hybrids other than the Rampur Hybrid-10, including the Khumal Maize Hybrid-2, were not statistically different from each other in terms of yield. The different backgrounds of the parental lines from which the hybrids were created are most likely the cause of variance in yield potential (Kandel and Shrestha 2020). In agreement with our result, Neupane et al. (2020) reported significant genotypic differences in ear length, ear weight, and grain yield. Thapa et al. (2022) revealed a positive significant relationship between grain yield, ear weight, and ear length. Thus, varieties with higher yield, ear weight, and ear length should be recommended to enhance production.

Table 3. Mean performance of yield and yield-attributing traits of maize hybrid.

Treatment	EL, cm	NKPR	NKRPE	EG, cm	EW, kg	TGW, g	GY, mt/ha
All-Rounder	17^{bcd}	37	16	5	0.23^{abcd}	267	6.73^{bc}
Bioseed-940	18^{bc}	42	16	4	0.22^{abcd}	250	7.13^{bc}
Bisco-940	19^{abc}	38	15	5	0.28^{ab}	259	9.39^{bc}
CP-808	17^{bcd}	39	15	5	0.27^{abc}	266	8.51^{bc}
Dekalb Double	17^{bcd}	37	15	5	0.24^{abcd}	255	8.59^{bc}
Suvarna	15^{d}	31	15	5	0.2^{d}	303	7.94^{bc}
JK-502	20^{ab}	40	15	5	0.28^{a}	254	9.49^{b}
Khumal Hybrid Maize-2	16^{cd}	35	14	5	0.20^{cd}	255	7.27^{bc}
TX-369	19^{bc}	38	14	5	0.25^{abcd}	261	9.41^{bc}
Rajkumar	17^{bcd}	35	14	5	0.11^{d}	274	5.98^{c}
Rampur Hybrid-10	21^{a}	39	13	5	0.22^{abcd}	286	11.49^{a}
Star-9	17^{bcd}	35	13	5	0.21^{bcd}	240	7.26^{bc}
LSD	2.5	5.1	1.7	0.34	0.058	48.19	2.41
CV (%)	8.36	8.15	6.80	4.31	14.76	10.78	17.16
Grand Mean	17.82	37.19	14.65	4.47	0.23	263.95	8.29
F-test	**	NS	NS	NS	*	NS	**
SEM±	0.79	1.67	0.50	0.10	0.02	13.87	0.84

Means followed by common letters within a column do not differ significantly at the ≤ 5% level of significance; LSD = least significant difference; significant codes ** at $p \leq 0.01$, * at $p \leq 0.05$ level and ns = non-significant; SEM = standard error of the mean, CV = coefficient of variation; EL= ear length, NKPR= number of kernels per row, NKRPE= number of kernel rows per ear, EG= ear girth, EW= ear weight, TGW=thousand grain weight, GY= grain yield.

Preference ranking of hybrid maize genotypes

Through the participatory varietal selection process, farmers were able to objectively choose their preferred varieties from twelve commercial hybrids. Farmers ranked their preferred traits from most to least desirable, assigning scores from 5 to 1. According to the preference ranking results, Khumal-Hybrid 2 was rated highest among the genotypes, followed by TX-369 and CP-808, while Bioseed-940 was rated lowest (Table 4). Khumal Maize Hybrid-2 was rated highest for grain color (4.42) and TX-369 for grain shape (4.25) and uniformity (4.67). Vasal (2019) reported that varieties with yellow grain color were preferred and ranked highly, despite having fewer kernel rows and poor grain filling. Similarly, Worku et al. (2020) noted that during varietal selection, farmers prioritized maize varieties that were high-yielding, early maturing, and had large ears and a greater number of ears per plant. This study underscores the importance of ear characteristics in varietal selection. However, it did not include preference ranking at the standing crop level, which limits the ability to capture farmers' evaluations of in-field characteristics such as husk cover, lodging resistance, and foliar disease appearance. The preference ranking was conducted only based on cob characteristics, which does not account for all factors influencing farmers' variety choices. Therefore, to confirm the consistency and reliability of these findings, a combination of pre- and post-harvest assessments is recommended.

Table 4. Preferencing ranking and overall ranking based on corn characteristics.

	Ranking criteria						
Genotypes	**Color**	**Length**	**Roundness**	**Grain shape**	**Uniformity**	**Average score**	**Overall rank**
All-Rounder	2.08	4.33	4.00	3.50	3.22	3.43	
Bioseed-940	2.50	3.33	3.67	2.58	2.33	2.88	12
Bisco-940	3.00	2.92	3.58	2.83	2.33	2.93	
CP-808	3.42	3.83	4.17	3.75	4.33	3.90	3
Dekalb Double	3.75	4.00	4.17	3.58	3.89	3.88	4
Suvarna	2.92	3.58	4.42	3.17	3.56	3.53	
JK-502	3.75	3.92	4.00	3.92	3.22	3.76	
Khumal Hybrid Maize-2	4.42	4.25	4.00	4.25	4.00	4.18	1
TX-369	4.33	3.92	3.67	4.25	4.67	4.17	2
Rajkumar	3.25	3.92	3.92	4.17	3.89	3.83	5
Rampur Hybrid-10	2.50	3.33	3.08	3.17	3.00	3.02	
Star-9	3.50	4.33	3.58	3.67	4.22	3.86	

Conclusion

In this study, locally available commercial hybrids were evaluated for key agronomic traits. Significant variation was observed across the evaluated genotypes in plant height, ear height, ear weight, ear length, ear aspect, and grain production. None of the tested hybrids outperformed the standard check variety, Rampur Hybrid-10, which recorded the highest grain yield (11.49 mt/ha), along with a moderate plant height (219 cm), ear height (106 cm), and the longest ear length (39 cm). Given the increasing demand for maize that national production alone cannot satisfy, the Nepalese market relies on multinational hybrids, often lacking location-specific performance assessments. This research identified several multinational maize hybrids JK-502, TX-369, Bisco-940, Dekalb Double, and CP-808 demonstrating comparable yielding potential to the standard check, Khumal Hybrid Maize-2. Considering farmers' variety preferences and rankings, TX-369 and CP-808 were highly favored. Combining the yield performance and farmers' preferences, TX-369 and CP-808 are recommended as promising multinational hybrid varieties suitable for this area. These varieties should be considered in future selection programs to enhance productivity and adaptability.

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Author contributions

Samskriti Subedi and Deepa Sharma contributed equally to the experimental design and field implementation, data analysis, visualization, and manuscript writing. Bishnu Pd. Kandel provided oversight, and critical revisions, and contributed to the discussion and interpretation of results. All authors participated in reviewing and approving the final manuscript.

Conflict of interest declaration

The authors declare that there is no conflict of interest regarding the publication of this paper.

Data availability statement

The dataset includes raw measurements of phenological traits, plant growth traits, yield attributes, and farmer preference scores. Researchers are welcome to contact the corresponding author for any additional information or clarifications.

Declaration on the use of generative AI tools

Generative AI tools (such as ChatGPT by OpenAI) were used solely to improve the grammar and formatting of the manuscript. The content was critically reviewed and edited by the authors to ensure academic accuracy and integrity.

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