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Research Article

Evaluation of maize (*Zea mays* L.) hybrids for growth, yield and yield attributing traits in Rampur, Chitwan, Nepal

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ABSTRACT
Hybrid maize plays a crucial role in enhancing maize productivity in Nepal due to its higher yield potential and superior agronomic performance compared with open-pollinated varieties. The objective of this study was to identify high-yielding maize hybrids suitable for winter planting under the Terai conditions of Nepal. A total of ten maize hybrids were evaluated in a randomized complete block design with three replications during the winter season of 2024-25 at Rampur, Chitwan. The results revealed significant differences ($p<0.01$) among hybrids for growth parameters, including days to 50% anthesis, days to 50% silking, plant height, and ear height. Yield and yield-attributing traits, such as thousand-kernel weight, number of kernel rows per ear, number of kernels per row, cob length, and cob diameter, were also found significantly affected by hybrid differences ($p<0.01$). The highest grain yield was recorded for KWM92/KWM93 (10,076 kg ha^{-1}), followed by KWM91/KWM93 (9,892 kg ha^{-1}), Winner (NMH8352) (9,878 kg ha^{-1}), CML581/CML582 (9,168 kg ha^{-1}), and CML581/CML612 (8,778 kg ha^{-1}). These results indicate that the identified hybrids possess high yield potential and can be promoted as promising candidate hybrids for winter maize production in the Terai region of Nepal.
Keywords: Grain yield, hybrids, winter season, Terai

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INTRODUCTION
Maize is the second most important cereal crop of Nepal, cultivated on approximately 0.98 million ha with a total production of about 3.1 million metric tons (MoALD, 2023). It contributes~7.6% to the agricultural gross domestic product of the country (MoALD, 2023). The national average maize yield is 3.48 t ha^{-1}; which is considerably lower than the global average yield of 5.96 t ha^{-1} (MoALD, 2023). As compared with neighbouring countries, maize productivity in Nepal remains low, largely due to limited adoption of high yielding hybrids.
Maize is one of the most important cereal corps in Nepal, serving as a major source of food, feed and income for smallholder farmers, particularly in Terai and Inner Terai region. The demand of seeds of hybrids has increased because of their higher yield potential (Tripathi *et al.*, 2016). Hybrids can give 25-30% higher grain yield than open pollinated varieties. In Nepal only 17% of farmers grow hybrid maize varieties, while the remaining 83% continue to grow open-pollinated varieties (OPVs), mainly due to limited availability and accessibility of hybrid seed (Gairhe *et al.*, 2021).

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The Nepal Agricultural Research Council (NARC), through the National Maize Research Programme (NMRP), Rampur, Chitwan, has released several maize hybrids for the Terai and inner Terai regions. Previous studies have evaluated the growth and yield performance of maize hybrids under different agro-ecological conditions in Nepal (Adhikari *et al.*, 2024; Bastola *et al.*, 2021; Rai *et al.*, 2022). However, systematic evaluation of nationally developed hybrids remains poor compared to multinational company hybrids.

Nepalese farmers rely heavily on imported hybrid maize seed, many of which do not consistently perform well under local agro-climatic conditions of diverse micro-climatic regions of the country. Therefore, rigorous testing, evaluation and release of maize hybrids specifically adapted to the Terai and inner Terai regions can enhance farmers' confidence to Nepalese hybrids, and help to strengthen the national seed system. Furthermore, demand for maize in this south Asian region is increasing due to the rapid expansion of the poultry and livestock sectors. Therefore, the identification of high-yielding and well-adapted maize hybrids for the Terai and inner Terai region is essential to improve productivity, profitability and national food and feed security.

MATERIALS AND METHODS

This study was carried out during the winter season of 2024-25 at research field of NMRP, Rampur, Chitwan. Its geographical location is at 27°40' north latitude and 84°19' east longitude, 228 meters above sea level. It consists of humid subtropical climate. The field is sandy loam with slightly acidic reaction.

A total of ten hybrids were evaluated in randomized complete block design with three replications. The plot size was 4 rows of 4.2 m long with spacing of 75 × 20 cm. The gap between plots was 0.5 m and gap between replications was 1.0 m. The hybrids KWM91/KWM93, KML5/KYM33, KWM92/KWM93, KML8/KYM33 and Khumal Hybrid-2 were derived from National Plant Breeding and Genetics Research Centre, Khumaltar, Lalitpur, Nepal. CAH1511, CML581/CML612, Rampur Hybrid-10 and CML581/CML582 were sourced NMRP, Rampur, and Winner (NMH8352) was from multinational seed companies.

Seeds were sown at depth of 4-5 cm using two seeds per hill on November 22, 2024 and later they were thinned at 15 DAS to maintain optimum plant population**.** Well-decomposed farmyard manure (FYM) was applied at the rate of 10 t/ha one week prior to seed sowing. The chemical fertilizer was used at the rate of 180:60:40 kg N:P_2O_5:K_2O [nitrogen (N), phosphorus (P), and potassium (K)] per hectare through urea, di-ammonium phosphate (DAP), and muriate of potash (MOP). The full doses of P_2O_5, 20% of N, and full doses of K_2O was applied at the time of field preparation. The remaining N dose (40%) was applied at 45 days after sowing, and another 40% was used before flowering. Weeding, insect pest control and irrigation practices were carried out in accordance with the standard practices applied for maize. Data on plant height (cm), ear height (cm), root lodging (%), shoot lodging (%), plant aspect, ear aspect, days to 50% anthesis, days to 50% silking, cob length, cob diameter, number of kernel rows per cob, number of kernels per row, thousand kernel weight (g) and grain yield (kg $plot^{-1}$) were recorded based on the CIMMYT protocol used by NMRP, Rampur. Plant and ear aspects are scored on 1-5 scale, where 1 = desirable and 5 = undesirable characteristics (CIMMYT, 2025). Grain yield (kg ha^{-1}) was calculated using the given formula (Eq. 1) based on the fresh weight of ears at a moisture content of 12.5%.

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$$\text{Grain yield } \left(\frac{kg}{ha}\right) = \frac{F.W.\left(\frac{kg}{plot}\right) \times (100-HMP) \times S \times 10000}{(100-DMP) \times NPA} \text{ .... Eq. 1}$$

Where,
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., 12.5%; NPA = the area of the net harvest plot, m^2;
S = shelling coefficient, i.e., 0.8

The collected data was subjected to ANOVA analysis using GenStat Discovery Edition 4.10. Treatment means were compared using the least significant difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Plant height, ear height and flowering traits

Plant height, ear height, days to 50% anthesis, days to 50% silking and anthesis-silking interval (ASI) varied significantly (p<0.01) among the hybrids. Plant height varied from 208 cm to 265 cm, ear height from 100 to 153, days to 50% anthesis from 103 to 109 days, days to 50% silking from 104 to 111 days and ASI from 1 to 3 days. Significant variation in plant height, ear height, days to 50% anthesis, days to 50% silking and ASI among the maize hybrids reflect considerable genetic diversity and environmental effect on hybrid performance.

Table 1: Plant height, ear height and flowering traits of hybrids

Hybrids	Plant height (cm)	Ear height (cm)	Days to 50% anthesis	Days to 50% silking	Anthesis-silking interval (ASI)
CAH1511	218[a]	100[a]	104[a]	106[ab]	2[ab]
CML581/CML582	253[cd]	153[d]	108[bc]	111[d]	3[b]
CML581/CML612	233[abc]	133[cd]	107[bc]	108[c]	1[a]
Khumal Hybrid-2	255[cd]	140[d]	108[c]	109[cd]	1[a]
KML5/KYM33	218[a]	108[abc]	104[a]	105[a]	1[a]
KML8/KYM33	208[a]	102[a]	103[a]	104[a]	1[a]
KWM91/KWM93	248[bcd]	130[bcd]	108[bc]	110[cd]	2[ab]
KWM92/KWM93	265[d]	147[d]	109[c]	111[d]	2[ab]
Rampur Hybrid-10	220[a]	105[a]	103[a]	105[a]	2.33[ab]
Winner (NMH8352)	225[ab]	115[abc]	106[b]	108[bc]	1.66[ab]
Mean	234	123.3	106	106	1.7
SEm(±)	8.27	7.27	0.58	0.65	0.45
p-value	0.001	<.001	0.001	<.001	0.01
CV, %	6.1	10.2	1	1	46.3
LSD (0.05)	24.58	21.59	1.73	1.95	1.34

SEm(±)= Standard Error of the mean, LSD= Least Significant Difference, CV= Coefficient of Variation. Treatment means followed by the same letter (s) within a column are not significantly different among each other by DMRT (Duncan Multiple Range Test) at 5 % level of significance.

This variation has important implications for breeding maize for improving yield and adaptation to local agro-climatic conditions. Previous researchers (Adhikari *et al.*, 2024; Mahato *et al.*, 2025) recorded significant variation for plant height and ear height of hybrid maize. Kunwar and Shrestha (2014) noted variations in plant height and ear height among various varieties and came to the conclusion that plant height is influenced by both genetic and environmental factors. Variability in plant height indicates there is genetic difference in vegetative growth and it is due

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to environmental factor. It may interact with water, nutrient and light availability. Taller hybrids provide greater biomass and more prone to lodging under adverse weather conditions. Significant variation in ear height indicates genetic difference in vegetative growth and due to environmental influence. This trait may influence plant architecture and lodging susceptibility.

In this study hybrids significantly varied for flowering traits. This result was consistent with the findings of Bista *et al.* (2021), Kumar *et al.* (2023), Kandel *et al.* (2018) who reported that significant variation was seen in the anthesis-silking interval, days to 50% silking, and days to 50% tasselling in several maize varieties. Such variation in flowering traits is due to combination of genetic and environmental factor. Earliness in anthesis and silking days is associated with improved synchronization and reduced risk of stress at reproductive stage in maize. Shorter ASI and optimal plant height contribute lodging resistance and yield performance as noted by previous researchers (Hussain & Hassan, 2014; Nayaka *et al.*, 2015).

Plant aspect, ear aspect and lodging

The traits namely plant aspect and root lodging varied significantly ($p<0.05$) among the hybrids. Hybrids significantly ($p<0.01$) varied for ear aspect and shoot lodging. Plant aspect ranged from 2.16 to 3.66, ear aspect from 1.5 to 2.66. Similarly, root lodging varied from 0.43% to 12.7%, shoot lodging ranged from 0% to 30.7%. The variation in ear aspect was found by previous researchers (Kandel *et al.*, 2018; Sah & Sharma, 2007).

Table 2: Plant aspect, ear aspect and lodging of hybrids

Hybrids	Plant aspect (1-5)	Ear aspect (1-5)	Root lodging (%)	Shoot lodging (%)
CAH1511	2.16^{a}	2.5^{bde}	3.33^{a}	3.33^{a}
CML581/CML582	3.5^{cd}	1.5^{a}	4.3^{a}	6.2^{a}
CML581/CML612	2.83^{abcd}	1.83^{ab}	8.33^{a}	0.01^{a}
KHUMAL HYBRID 2	3.16^{bcd}	1.83^{abc}	8.63^{a}	18.9^{b}
KML5/KYM33	3.66^{d}	2.66^{e}	11.23^{a}	30.66^{c}
KML8/KYM33	3.16^{bcd}	2.65^{e}	12.7^{a}	5.16^{a}
KWM91/KWM93	2.83^{abcd}	1.66^{a}	0.96^{a}	1.43^{a}
KWM92/KWM93	2.66^{abc}	1.83^{abc}	0.43^{a}	2.13^{a}
Rampur Hybrid-10	2.5^{ab}	2^{abcd}	1.23^{a}	3.03^{a}
Winner (NMH8352)	2.5^{ab}	1.83^{abc}	2.83^{a}	4.9^{a}
Mean	2.9	2.033	5.4	7.58
SEm(±)	0.29	0.20	3.66	2.38
p-value	0.04	0.004	0.02	<.001
CV, %	17.5	17.4	117.5	54.5
LSD (0.05)	0.86	0.59	10.88	7.08

SEm(±)= Standard error of the mean, LSD= Least Significant Difference, CV= Coefficient of Variation. Treatment means followed by the same letter (s) within a column are not significantly different among each other by DMRT (Duncan Multiple Range Test) at 5 % level of significance.

In this study, hybrids showed considerable variation in root and shoot lodging. The evaluation or shoot lodging and root lodging is important for varietal selection in maize. Hybrids having low lodging resistances, superior stalk strength and robust root systems produce agronomically superior performance.

Lodging resistance is strongly associated with root diameter, root number, spatial distribution and anchorage force (Liu *et al.*, 2020; Zhang *et al.*, 2022). Shoot lodging is associated with stalk strength, rind thickness, internode diameter and cell wall composition (Liu *et al.*, 2020; Robertson *et al.*, 2024). In present study, CV of root lodging reached 117.5%. The higher CV, % for root lodging reflects the strong influence of environmental factors such as wind, rainfall and soil condition along with hybrid architecture and stalk strength. CV, % of shoot lodging is

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54.5%. This finding is similar to findings of Hu *et al.* (2022) and Liu *et al.* (2020) who reported 15% to 55% CV for shoot lodging in maize.

Grain yield and yield attributing traits

Grain yield varied significantly (p<0.01) among the evaluated hybrids (Table 3). The yield ranged from 5,702 to 10,076 kg ha^{-1}. The highest grain yield was given by KWM92/KWM93 (10,076 kg ha^{-1}), followed by Winner (9,879 kg ha^{-1}) and KWM91/KWM93 (9,892 kg ha^{-1}). Yield attributing traits were found significant among the hybrids. The cob length varied from 15.3 to 17.8 cm, number of kernel rows per cob from 12.7 to 16.7 and thousand kernel weight from 327 to 446 g. The significant variation found in cob diameter, cob length, number of kernel rows per cob, number of kernels per row, thousand kernel weight is due to combination of genetic factors, heterosis and genotype × environmental interaction. The grain yield and yield attributing traits were found significant for maize genotypes as noted by previous researchers (Maruthi and Rani, 2015; Bastola *et al.*, 2021; Manivannan, 1998; Khan *et al.*, 2019; Sesay *et al.*, 2016; Tripathi *et al.*, 2016, Hussain *et al.*, 2004; Ajala *et al.*, 2020, Elmyhun *et al.*, 2020).

Table 3: grain yield and yield attributing traits of hybrids

Hybrids	Cob length (cm)	Cob diameter (cm)	Number of kernel rows per cob	Number of kernels per row	Thousand kernel weight (g)	Grain yield (kg ha^{-1})
CAH1511	16.0^{ab}	4.43^{a}	13.0^{ab}	28.2^{a}	390^{bc}	7130^{abc}
CML581/CML582	17.4^{bcd}	4.83^{bc}	16.6^{f}	32.7^{bcd}	327^{a}	9169^{ef}
CML581/CML612	17.7^{d}	4.93^{bcd}	14.8^{de}	29.3^{ab}	446^{c}	8778^{def}
Khumal Hybrid-2	17.0^{bcd}	4.83^{bc}	13.3^{abc}	31.0^{abc}	438^{c}	7975^{cde}
KML5/KYM33	17.8^{d}	5.10^{d}	14.3^{cd}	33.5^{cd}	406^{bc}	6007^{ab}
KML8/KYM33	15.3^{a}	4.96^{bcd}	215.5^{e}	29.7^{abc}	349^{ab}	5702^{a}
KWM91/KWM93	16.6^{abcd}	5.10^{d}	14.1^{bcd}	33.1^{bcd}	400^{bc}	9892^{f}
KWM92/KWM93	16.3^{abc}	5.06^{cd}	14.4^{cde}	32.7^{bcd}	423^{c}	10076^{f}
Rampur Hybrid-10	16.8^{bcd}	4.46^{a}	12.6^{a}	31.1^{abc}	429^{c}	7470^{bcd}
Winner (NMH8352)	17.6^{cd}	4.76^{b}	14^{bcd}	35.4^{d}	441^{c}	9879^{f}
Mean	16.9	4.85	14.3	31.1	405	8208
SEm(±)	0.42	0.07	0.5	1.23	17.95	507.9
p-value	0.007	<.001	<.001	0.018	0.002	<.001
CV, %	4.4	2.6	4.3	6.8	7.7	10.7
LSD (0.05)	1.25	0.21	1.06	3.68	53.32	1509

SEm(±)= Standard error of the mean, LSD= Least Significant Difference, CV= Coefficient of Variation. Treatment means followed by the same letter (s) within a column are not significantly different among each other by DMRT (Duncan Multiple Range Test) at 5 % level of significance.

Correlation study

Hybrids showed significant correlations for various traits. There was strong positive correlation between days to 50% anthesis and days to 50% silking (r=0.96), plant height and ear height (r=0.93) and plant height and days to 50% silking day (r=0.94); this indicates that one trait can increase with another traits. There was strong positive correlation between ear aspect and grain yield (r=0.88), grain yield and anthesis-silking interval (r=0.82); indicating indirect selection criteria for improvement of grain yield. There was positive correlation between grain yield and cob length (r=0.30), cob diameter (r=0.18), number of kernels per row (r=0.49), number of kernels per row (r=0.11), thousand kernel weight (r=0.28). The positive correlation between grain yield and yield attributing traits were found by previous researchers (Ogunniyan and Olakaago, 2014; Bhusal *et al.*, 2017; Adhikari *et al.*, 2018; Kandel *et al.*, 2018).

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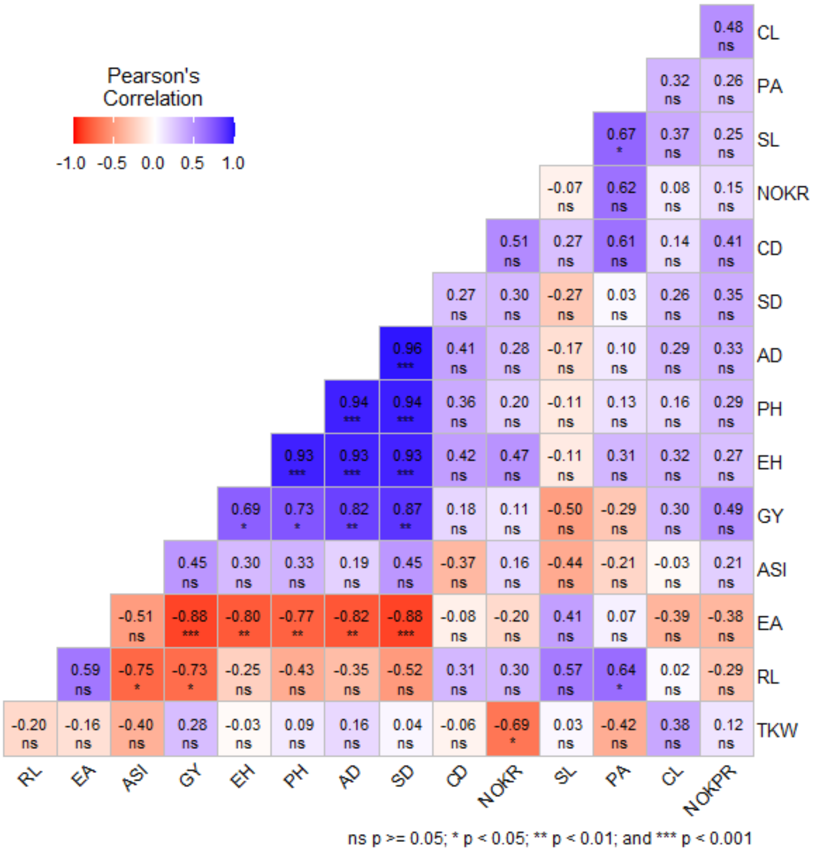

Figure 1: Correlation among the traits in tested hybrids

CONCLUSION

The evaluated hybrids showed the significant variation for growth, yield and yield attributing traits. Yield attributing traits showed positive correlation with grain yield; that indicate that these traits can be prioritized in selection for yield improvement. Three hybrids namely KWM92/KWM93, WINNER and KWM91/KWM93 were identified the top yielding hybrids. Growing these hybrids enhance the maize productivity in Terai region of Nepal. The multilocation and multi-year testing is necessary to strengthen this finding.

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Author's Contribution

Krishna Hari Dhakal conducted this field research, collected and analysed the data. He wrote this manuscript. The final form of the manuscript was approved by the author.

Conflicts of Interest

The author declares no conflict of interest.

Ethics Approval Statement

This field-based study did not involve humans or animals. Experimental activities were in accordance with environmental and biosafety guidelines.

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