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Performance Evaluation of Hybrid Maize in Deukhuri, Dang

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Abstract

The evaluation of hybrid maize in terms of agro-morphology and genetic variability is crucial for hybrid maize development programs. The main purpose of the study was the evaluation of the performance of various hybrid genotypes in terms of production. The study was conducted at the research field of Prithu Technical College, Lamahi Dang. Twelve maize hybrids with three replications were under study in a randomized complete block design (RCBD) during the spring of 2021. Rampur Hybrid-6 and Rampur Hybrid-10 were the standard checks. Each genotype was cultivated in a plot of 3m x 3m resulting in a net plot area of 385 m^2 per block. Analysis of variance showed that all the studied traits were found to be significant except ear length, ear diameter, and the number of kernel rows per ear. Three varieties, RML-98, RML-4, and RL-107, were found to be superior with grain yield values of 11.26, 9.92, and 10.22 tons ha^{-1}, respectively, which were higher than the standard checks Rampur Hybrid-10 (9.24 tons ha^{-1}) and Rampur-Hybrid-6 (8.23 tons ha^{-1}). A positive correlation was found between the number of kernels per row and grain yield. The trait with the highest impact on the grain yield was days to silking. Therefore, these traits are suggested for selection in further breeding improvement programs.

Keywords

Selection, maize, hybrid maize, agronomic traits, grain yield

Introduction

Hybridization results in heterosis vigor. Hybrids can be single-gene or multiple-gene hybrids or single-cross or double-cross hybrids (Narang & Gill, 2004). Hybrid maize results in higher production, although it is vulnerable to biotic and abiotic stresses (Bahtiar *et al*., 2023). To obtain the maximum yield, plants must be provided with adequate fertilizers, pesticides, and irrigation (Belton & Fang, 2022). Hybrid maize can be one of the best alternative

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options for increasing production at the farmer level (Chim *et al.*, 2012). In Nepal, approximately 10% of farmland growing maize was occupied by hybrid maize in 2020 (Kandel, 2020). Nearly 20% of maize seeds are imported every year (Adhikari, 2014) with India being the major exporter of hybrid maize to Nepal (Gurung *et al.*, 2011). Terai and inner-terai in particular have a better potential for hybrid maize production in the spring and winter (Dawadi & Shah, 2012). The major yield-reducing factors in maize are a lower plant density and a lack of nutrient management practices. Having excess moisture stress levels during the period of the early vegetative phase also adversely affects the growth of plants (Zaidi *et al.*, 2004). The most common worldwide problems that can decrease maize crop productivity are heat and drought stresses (Ali *et al.*, 2015). To address the issues related to stress tolerance in maize, breeders should prioritize the development of stress-tolerant inbred lines and the evaluation of pipeline hybrids and landraces at both molecular and phenotypic levels (Kandel, 2021). The two most important elements for growing a plant population are water and fertilizers, mainly nitrogen, in increased proportions (Dawadi & Sah, 2012). A digital adoption index (DAI) value of 63% has been observed in the hilly areas of Nepal growing maize. This indicates that there is potential for increasing maize yields by implementing recommended cultural practices in conjunction with high-yielding varieties (Lamichhane *et al.*, 2015). Farmers began to produce hybrid maize in Nepal in the 1980s by importing seeds from India (Thapa, 2013). Farmers started to prefer improved maize varieties after the initiation of community-based seed production (CBSP) in the hilly areas under the Hill Maize Research Project in 2000 (KC *et al.*, 2013). The number of hybrid seeds imported has increased as a result of the nation's research system producing fewer and less competitive hybrids. Due to the lower yields of released varieties, seed availability is inadequate for expansion. Despite the increasing number of hybrid seeds, the national yield is still reported to be considerably lower (2.59 tons ha^{-1}) when compared to developed nations (6-10 tons ha^{-1}) (Kandel & Shrestha 2020). The unchecked distribution of imported hybrid seeds without undertaking proper performance trials could be the possible reason for lower yields.

In the past, the National Maize Research Programme (NMRP) focused on open-pollinated varieties (OPVs). However, at present, its focus has shifted to hybrid maize research and development. The NMRP has so far released 34 maize varieties, among which 29 are open-pollinated and five are hybrids. Four hybrids were recommended for cultivation in Terai, inner valleys, and river basins. One was suggested for the mid-hills. Gaurav, Rampur Hybrid 2, Khumal Hybrid 2, Rampur Hybrid 4, and Rampur Hybrid 6 are single cross yellow maize hybrids. Additionally, the NMRP has been evaluating and documenting the hybrid maize developed by international organizations. Fifty-three hybrids produced by multinational companies have been registered in Nepal for marketing. These hybrids are reported to have significantly higher yields than domestic ones (Kandel, 2021). More than 27 varieties of maize and 58 hybrids are registered while 14 are designated (Gairhe *et al.*, 2021). RH-8, RH-10, RH-12, RH-14, and RH-16 are recently released varieties by the NMRP (Personal Communication, BP Kandel 2022). The non-synchronization of male and female parents is responsible for hindrance in F1 seed production and there is a lack of suitability for cultivation of developed hybrids due to diverse climatic and environmental conditions (Tripathi *et al.*, 2016). Only 10 hybrid varieties have been developed that are not location-specific except the Khumal Hybrid for the Terai region. Therefore, area-specific performance trials should be carried out before suggesting hybrid maize for that area. This practice is significantly important in order to choose the best varieties for a particular area to get the highest levels of grain yield of various maize hybrids. The main objective of this research was to evaluate the production performance of different genotypes of hybrid maize in comparison to two standard checks, Rampur Hybrid-6 and Rampur Hybrid-10.

Materials and Methods

Study area

The experimental site was Lamahi, Dang, Nepal. The research site was provided by Prithu Technical College, which is located at an elevation of 581m above sea level at the coordinates 28º N latitude and 82.25º E longitude. The experimental site is situated in the eastern inner plains of Province-5 of Nepal. This area has humid weather with cold winters and extreme summers.

Climate and cropping history of the experimental sites

The experimental site has a warm sub-tropical climate. The average temperature ranges from 25℃ to 31.27℃ with an average of 28.13℃. The average temperature in April is 25.7℃, and in June the average temperature is 31.17℃. The average rainfall is 938.1mm. The driest month is November, with an average of 0.11mm of rain per day. The month of July experiences the most precipitation, averaging 9.66mm per day. The cropping history of the experimental field was a maize-mustard- fallow sequence.

Experimental materials (Table 1)

Experimental design and cultural practices

The experiment was conducted in a randomized complete block design (RCBD) with three replications of the 12 maize hybrids (**Table 1**) during the spring of 2021. Out of the 12, Rampur Hybrid-6 and Rampur Hybrid-10 were used as standard checks. The maize was sown in the first week of February 2021. Each genotype was grown in a 3m × 3m plot with a net plot area of 385 m^2 per block. Seed sowing was performed at the rate of two seeds per hill with a crop geometry of 75 × 25 cm^2 (RR × PP). Each plot contained four rows with 12 plants in each row for a total of 48 plants per plot. Farmyard manure was applied at the time of land preparation. Fertilizer was applied at the rate of 150:60:40 NPK kg ha^{-1} (urea, diammonium phosphate (DAP), and muriate of potash (MoP)). A half dose of N and full doses of P_2O_5 and K_2O were applied as a basal dose. The remaining half of the N was applied in two splits at the knee-high and pre-tasseling/silking stages.

Data collection and observation

All agro-morphological, yield, and yield-attributing traits were obtained from the sample row except the phenological traits, namely days to 50% anthesis (AD), days to silking (SD), and harvesting date (HD). When at least half of the plants in a plot had extruded the first anther (beginning of pollen shedding), the plot was recorded as having reached 50% anthesis, and when the first silk was visible on at least half of the plants in the plot, the plot was recorded as having reached 50% silking (Zaidi *et al*., 2016). Data collection and observations were taken on five randomly selected sample plants from each experimental plot excluding the border plants in the parimeters. These observations were plant height (PH, cm), ear height (EH, cm), ear length (EL, cm), ear diameter (ED, cm), number of kernels per row (NKPR), number of kernel rows per ear (NKRPE), ear weight (EW, kg), thousand kernel weight (TGW, kg), and grain yield (GY, tons ha^{-1}). PH was measured from the base of the plant to the node of the tassel. The measurement of EH was made from the soil's surface to the ear's base, or the node that bore the topmost ear (Zaidi *et al*., 2016). A steel measuring tape was used to measure PH, EH, and EL. ED was measured with a Vernier caliper. NKPR was measured by counting the total number of kernels in each row and NKRPE was measured by counting the kernel rows per ear. EW and TGW were measured with an electronic balance after shelling ears. The ear aspect was assessed based on the visual evaluation of the appearance of corn ears and maize kernels. The grain yield (tons ha^{-1}) was obtained by retaining the moisture percentage at 12.5% and by applying the formula used by MacRobert *et al*. (2014):

$$\text{Grain yield (ton ha}^{-1}\text{)} = \frac{\text{F.E.W} \times (100 - \text{GMC}) \times \text{S} \times 10000}{(100 - \text{DMP}) \times \text{NHA} \times 1000}$$

where, F.E.W is the fresh ears weight (kg/plot), GMC is the grain moisture content at harvest (%), S is the shelling percentage (80%), DMP is the desired moisture percentage (12.5%), and NHA is the net harvested area (m^2).

Table 1. List of the 12 treatments of hybrid maize genotypes

S.N.	Treatments	S.N.	Treatments
1.	RL-94/RL-101	7.	RML-94/RML-17
2.	RL-272	8.	Rampur Hybrid-6
3.	RL-107	9.	Rampur Hybrid-10
4.	RML-88	10.	RML-98
5.	RML-108	11.	RL-241
6.	RML-150	12.	RML-4

Source: NMRP Status (All pipelines hybrids released by single cross mating design), All the hybrid maize genotypes were selected randomly and were obtained from the NMRP.

Statistical analysis

For data entry, MS Excel was used. The mean, coefficient of variation, and analysis of variance were computed by using the statistical package R version 3.6.1. Character variance was examined using the randomized complete block design method described by Gomez and Gomez (1984) and Panse and Sukhatme (1954). SPSS version 25 was used to calculate the correlation coefficient by utilizing the equation given by Weber and Moorthy (1952). Path analysis modelling was generated from MS Excel. For determining the direct path coefficient, regression analysis on a set of standardized variables was conducted (Akintunde, 2012).

Results and Discussion

Analysis of variance in maize performance

The results in **Table 2** show significant differences among the hybrids for phenological traits, growth traits, yield, and yield components. The distinct backgrounds of the paternal lines were likely the cause of the characteristics' significant differences (Muchie & Fentie, 2016). However, there were no significant differences observed in ear length, ear diameter, number of kernel rows per ear, or ear aspect.

Phenological traits

The maize plants were grown for nearly four months from February 8 to June 21. The hybrids exhibited intermediate values for the phenological traits. The flowering characteristics, such as days to anthesis and days to silking, demonstrated highly significant differences, whereas the anthesis-silking interval (ASI) showed moderately significant differences. According to **Table 2**, the days to anthesis ranged from 79-86. Particularly, RL-272 and RML-108 displayed earlier days to anthesis and silking periods, while RML-98, RL-241, and Rampur Hybrid-10 demonstrated later days to anthesis and silking, flowering after the average values of anthesis and silking, 83 and 84, respectively. The genetic makeup of RL-272 and RML-108, the environment, flowering time difference, and the large ASI could be responsible for their early tasseling and silking. Studies by Manjunatha *et al*. (2018) and Kandel and Shrestha (2020) also reported similar results. Previous findings have also reported significant differences for days to anthesis and silking (Manjunatha *et al*., 2018; Kandel and Shrestha, 2020; Koirala *et al*., 2020).

Growth traits

Table 2 indicates that there were substantial and noteworthy variations ($P \leq 0.05$) in the heights of plants among the different hybrid maize genotypes. The maximum plant height (PH) (200.66 cm) was observed in Rampur Hybrid-10 (standard check) and the minimum (177.33) was observed in RL-107. RL-107 and RL-94/RML-17 were found to be inferior to Rampur Hybrid-6. RML-108, RML-150, and RL-94/RML-17 were statistically similar to Rampur Hybrid-6. The highest PH values were recorded in RL-94/RL-101, RL-272, RML-88, Rampur Hybrid-10, RML-98, and RL-241, which had values greater than the mean value of 187.16cm. Earlier reports by Koirala *et al*. (2013), Hussain and Hassan (2014), Ghimire and Timsina (2015), and Kandel and Shrestha (2020) also showed highly significant differences in PHs in various hybrid maize genotypes.

Both genetic and environmental factors contribute to the variation in PH among different genotypes. The height of a plant can be affected by a variety of factors such as competition, density, variety, light absorption, uptake of nutrients and carbon, and competition with weeds. In this research, highly significant variations in ear height (cm) were found due to divergent maize genotypes. The ears were between 104.33cm and 85.3cm above the soil line. The Rampur Hybrid-6 genotype, with an ear height of 104.33cm, remained significantly superior among the 12 maize genotypes and was followed by the second standard check, Rampur Hybrid-10, with an ear height of 101cm. These results get sufficient validation from the findings of Koirala *et al*. (2013), Hussain and Hassan (2014), and Kandel and Shrestha (2020).

Yield and yield components

Table 2 reveals ear weight to be highly significant in the results. This aligns with the results of Ghimire and Timsina (2015), Aung *et al*. (2016), Kandel *et al*. (2018), Manjunatha *et al*. (2018), and Kandel and Shrestha (2020). Similarly, the thousand-grain weight and number of kernels per row also had highly significant outcomes, which were analogous to the reports of Ghimire and Timsina (2015), Aung *et al*. (2016), and Kandel *et al*. (2018). The genotypes' varied ancestries may have contributed to their outstanding performances in terms of grain yield and agro-morphological features. The performances of these hybrids may also reflect the variability in the testing site's environmental factors and soil type. Likewise, temperature, radiation, photoperiod, and water availability also influence the growth and development of crops (Tsimba *et al*., 2013).

When comparing grain yield among different varieties, significant results were achieved by Aung *et al*. (2016) and Koirala *et al*. (2020), which is consistent with our results. The ultimate objective of any research is to achieve a high grain yield, which is determined by a combination of genetic potential and environmental interactions. The highest grain yield (11.3 tons ha^{-1}) was observed in RML-98, which may be the manifestation of the highest ear weight (14.75kg). This finding is supported by Manjunatha *et al*. (2018). According to our research, RML-98 has a higher degree of adaptability and is ideal for growing in the Lamahi region because it produces the most grain. The highest thousand-grain weight was observed in RML-150. RML-150 was found to be statistically similar and superior to Rampur hybrid-10. Statistics showed that Rampur Hybrid-6, RML-4, RL-94/RML-17, RML-88, RML-98, and RL-94/RL-101 were equivalent to one another. Whereas Rampur Hybrid-6 was determined to be inferior to RL-241 and RL-272. RL-94/RML-17 had the most kernels per row. Hence, for a subsequent breeding effort to produce a large yield, the variety with the greatest number of kernels per row must be chosen.

Correlation of grain yield with yield components

The relationship between grain yield and traits that contribute to yield must be determined in order to comprehend how different parameters affect grain yield. As shown in **Figure 1**, there were positive highly significant associations between grain yield and the sample ear weight, ear diameter, and ear height, whereas a negative non-significant association between ear aspect and grain yield was observed. Analogous results from Wannows *et al*. (2010), Matin *et al*. (2017), Kandel *et al*. (2018), and Kandel and Shrestha (2020) also found in that ear weight, ear diameter, and ear height were all positively connected with yield. According to **Table 2**, the hybrids with the highest grain yield also had the highest number of kernels per row. The positive and statistically significant correlations of grain yield with ear weight, ear diameter, and ear height indicate that selecting hybrids with these traits are crucial for improving the overall grain yield of hybrid maize. The negative non-significant association between ear aspect and grain yield indicates that as ear aspect increases (i.e. more damaged cobs), yield reduces. Such findings might aid breeders in selecting this feature to produce high grain yields.

Path analysis

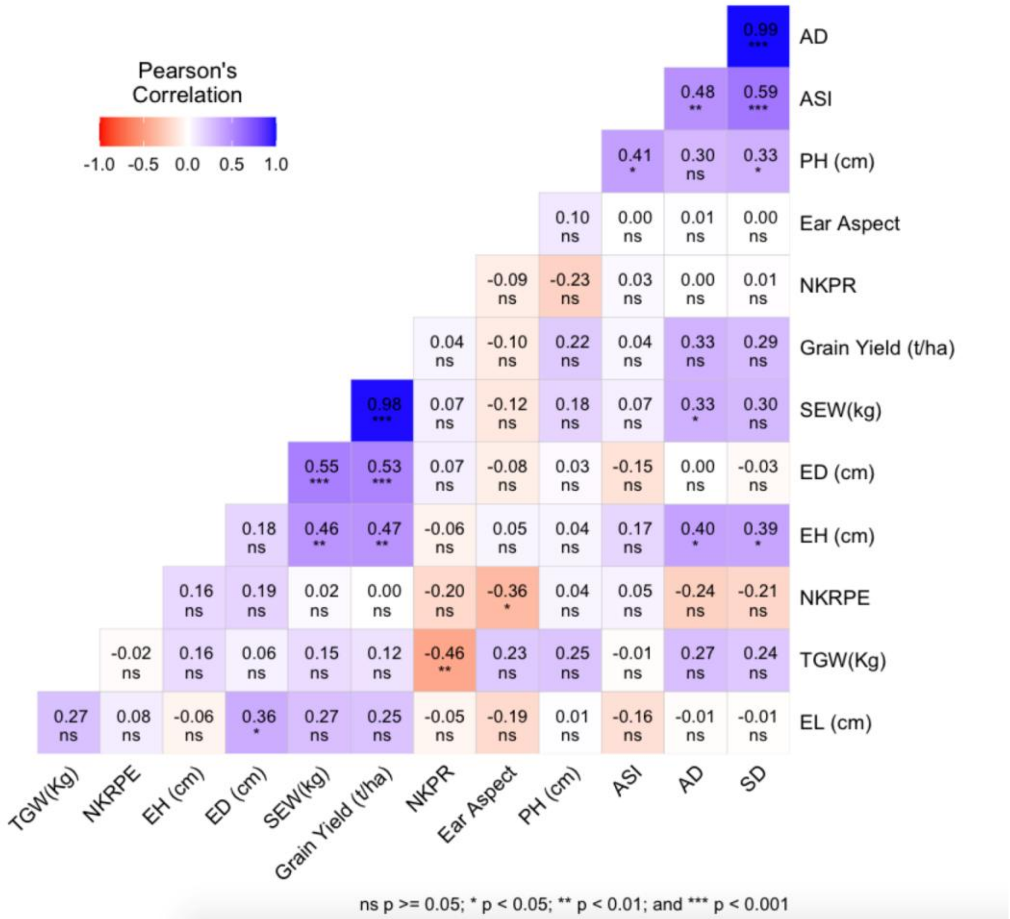
The data indicated that days to silking had the most positive direct effect on yield, followed by plant height, number of kernels per row, ear diameter, ear height, and number of kernel rows per ear. Kinfe *et al*. (2015), Begum *et al*. (2016), Matin *et al*. (2017), Kandel *et al*. (2018), and Shikha *et al*. (2020) obtained similar results. Grain yield is a very sensitive parameter and any changes in other growth traits can result in drastic changes in grain yield in maize. Based on the results, the strong correlations between grain yield and various traits (such as phenological traits, growth, yield, and yield attributes) were primarily influenced by the direct effects of these traits. This suggests that selecting these traits directly would be a productive strategy to improve grain yield. Days to anthesis exhibited the highest negative effect on grain yield followed by the anthesis-silking interval, ear length, and thousand-grain weight. Analogous results were obtained by Raghu *et al*. (2011), Wali *et al*. (2012), Nataraj *et al*. (2014), and Kandel *et al*. (2018). Accordingly, selection for these traits results in lower grain yields.

Table 2. Mean performance of the hybrid maize varieties grown in Lamahi, Dang

Genotypes	AD	SD	ASI	PH (cm)	EH (cm)	EW (kg)	EL (cm)	ED (cm)	NKRPE	NKPR	TGW (kg)	GY (tons ha^{-1})
RL-94/RL-101	80^{cd}	82de	2^{ab}	194.66^{b}	94.66^{de}	12.39^{cd}	20.15^{a}	4.52^{ab}	13.99^{b}	35.33^{cde}	0.36^{cde}	9.05^{c}
RL-272	79^{d}	80^{e}	1^{b}	188^{c}	98.33^{bc}	11.57^{de}	21.22^{a}	4.92^{a}	16.66^{a}	33.77^{e}	0.41^{b}	8.36^{de}
RL-107	82^{bc}	83^{cd}	1^{ab}	177.33^{d}	98.33^{bc}	13.73^{b}	20.34^{a}	4.71^{ab}	13.55^{b}	39.33^{ab}	0.36^{de}	10.22^{b}
RML-88	84^{ab}	86^{ab}	2^{a}	188.33^{c}	97.0^{cde}	12.43^{c}	19.33^{a}	4.65^{ab}	14.44^{b}	37.55^{bc}	0.36^{cde}	8.75^{cd}
RML-108	79^{d}	80^{e}	1^{b}	181.33^{d}	94^{e}	11.84^{cd}	20.25^{a}	4.72^{ab}	13.99^{b}	35.22^{de}	0.34^{e}	8.38^{de}
RML-150	83^{abc}	84^{bcd}	1^{b}	181.33^{d}	95de	10.85^{c}	20.89^{a}	4.56^{ab}	13.33^{b}	33.77^{e}	0.46^{a}	7.99^{e}
RL-94/RML-17	80^{cd}	81de	1^{b}	179.66^{d}	96^{cde}	12.39^{cd}	20.13^{a}	4.76^{ab}	13.55^{b}	40.66^{a}	0.37^{cd}	9.02^{c}
RML-4	83^{ab}	85^{abc}	2^{ab}	187^{c}	97.33^{cd}	13.95^{b}	20.39^{a}	4.87^{ab}	14.22^{b}	37.44^{bcd}	0.38^{cd}	9.92^{b}
Rampur Hybrid-6	85^{a}	86^{ab}	1^{ab}	181.33^{d}	104.33^{a}	11.73^{cd}	20.15^{a}	4.69^{ab}	14.07^{b}	35.33^{cde}	0.38^{cd}	8.23^{de}
Rampur Hybrid-10	85^{a}	86^{ab}	1^{ab}	200.66^{a}	101^{a}	12.42^{c}	20.65^{a}	4.72^{ab}	14.10^{b}	35.77^{cde}	0.44^{a}	9.24^{c}
RML-98	86^{a}	87^{a}	1^{ab}	197.33^{ab}	98.33^{bc}	14.75^{a}	20.26^{a}	4.85	13.55^{b}	36.87^{cd}	0.38^{c}	11.26^{a}
RL-241	85^{a}	87^{a}	2^{a}	189^{c}	85.33^{abc}	9.29^{f}	21.14^{a}	4.69^{ab}	13.32^{b}	34.22^{e}	0.41^{b}	6.98^{f}
Grand mean	83	84	1.44	187.16	97.58	12.24	20.48	14.06	4.72	36.27	0.38	8.95
SEM	0.92	0.97	0.24	1.47	0.90	0.26	0.88	0.12	0.51	0.79	0.008	0.19
F-test	***	***	*	***	***	***	ns	ns	ns	***	***	***
LSD	2.67	2.80	0.68	4.18	3.05	0.76	2.50	1.49	0.38	0.02	0.03	0.56
CV(%)	1.92	1.98	28.26	1.32	1.85	3.75	7.25	6.30	4.80	3.97	3.97	3.73

*Note: 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 ≤ 0.001; ** at p ≤ 0.01; * at p ≤ 0.05 level, ns = non-significant;*

SEM = standard error of the mean, CV = coefficient of variation, AD = days to 50% anthesis , SD = days to 50% silking, ASI = anthesis-silking interval, PH = plant height, EH = ear height, EW = ear weight, EL = ear length, ED = ear diameter, NKRPE = number of kernel rows per ear, NKPR = number of kernels per row, TGW = 1000 grain weight, and GY = grain yield.



*Note: ** Highly significant (P <0.01), *Significant (P <0.05), AD = days to 50% anthesis, SD = days to 50% silking, ASI = anthesis-silking interval, PH = plant height, EH = ear height, EL = ear length, ED = ear diameter, SEW = sample ear weight, NKRPE = number of kernel rows per ear, NKPR = number of kernels per row, TGW = 1000 grain weight, and GY = grain yield.*

Figure 1. Correlation analysis for measuring traits

Table 4. Path analysis of different traits of the hybrids *(Bold numbers: Direct effects)*

	AD	SD	ASI	PH (cm)	EH (cm)	EL (cm)	ED (cm)	EW (kg)	NKRPE	NKPR	TGW (kg)
AD	**-2.55**	-2.52	-1.21	-0.77	-1.02	0.03	0.007	-0.85	0.60	0	-0.69
SD	2.80	**2.83**	1.67	0.94	1.09	-0.03	-0.08	0.85	-0.59	0.03	0.66
ASI	-0.33	-0.42	**-0.71**	-0.29	-0.12	0.11	0.10	-0.04	-0.03	-0.02	0.01
PH (cm)	0.15	0.16	0.20	**0.49**	0.02	0.007	0.01	0.09	0.02	-0.11	0.12
EH (cm)	0.02	0.02	0.009	0.002	**0.05**	-0.003	0.01	0.02	0.009	-0.003	0.008
EL (cm)	0.004	0.003	0.04	-0.004	0.01	**-0.29**	-0.1	-0.07	-0.02	0.01	-0.07
ED (cm)	-0.0002	-0.002	-0.01	0.002	0.01	0.03	**0.08**	0.04	0.01	0.006	0.005
EW (kg)	0.05	0.05	0.01	0.03	0.07	0.04	0.09	**0.1**	0.003	0.01	0.02
NKRPE	-0.0006	-0.0006	0.0001	0.0001	0.0004	0.0002	0.0005	6.04E	**0.002**	-0.0005	-6E-05
NKPR	0	0.005	0.012	-0.1	-0.02	-0.02	0.03	0.03	-0.09	**0.4**	-0.2
TGW (Kg)	-0.05	-0.05	0.003	-0.05	-0.03	-0.05	-0.01	-0.03	0.004	0.09	**-0.2**

Note: AD = days to 50% anthesis, SD = days to 50% silking, ASI = anthesis-silking interval, PH = plant height, EH = ear height, EL = ear length, ED = ear diameter, EW = ear weight, NKRPE = number of kernel rows per ear, NKPR = number of kernels per row, and TGW = 1000 grain weight.

Conclusions

For a hybrid maize program to succeed, it is crucial to evaluate hybrids in specific locations. The hybrids that consistently yield high results are considered superior and should be selected for further development. Among the 12 genotypes tested, there were significant variations in the agro-morphological traits. In terms of plant height, ear height, ear weight, number of kernels per row, thousand-grain weight, and grain production, there were considerable variations. For the traits of yield and ear weight, with values of 11.26 tons ha^{-1} and 14.75kg, respectively, the genotype RML-98 beat other cultivars in the experiment. However, it was shown that RL-107 and RML-4 were also superior to the two standard checks. The positive links between grain yield and ear weight, ear diameter, and ear height suggest that these factors should be considered when making selections. The strong correlations between yield and its components provide valuable insights for breeders in developing high-yielding maize varieties. Both genetic and environmental factors play a role in the performance of maize hybrids. These findings highlight the importance of selecting hybrids with favorable phenological and growth traits. We conclude that these hybrids should be recommended for further selection to enhance the production and productivity of maize.

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