Research article

Varietal evaluation of hybrid maize in the summer and winter seasons in terai region of Nepal

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ABSTRACT

Comparing hybrid maize to open-pollinated varieties, the former is widely recognized for its higher producing capacity. However, the production potential of hybrids varies depending on the region and the season. In order to find the high yielding stable genotypes throughout both settings, this experiment was carried out in the summer of 2021 and the winter of 2021–2022, using a Randomized Complete Block Design with 11 genotypes and 3 replications. The tallest genotypes among those evaluated were CP 808 and G-25 in the winter and summer, respectively. Both P3553 in the winter and CP 808 in the summer reported earlier days to anthesis. Grain yield showed a substantial and positive links with cob characteristics and a negative correlation with reproductive traits, according to correlation analysis. When compared to the yield of both seasons, P3355 and Bisco gold 941 showed highest yield in both environments. Thus, genotypes P3355 and Bisco gold 941 are recommended for cultivation in study area over other available hybrids in the market.

1. Introduction

Maize is the major cereal of Nepal both in terms of production and use ranking second in production after rice and being widely used for human consumption and for agro-industries (feed industry for poultry, fish and cow) [1]. Its cultivation is diverse, ranging from Terai and Inner-Terai to the hilly regions of the country. Hills practice rainfed farming whereas irrigated conditions prevail in the Terai and Inner-Terai regions of Nepal. Mainly maize is sown in spring season [2] after harvesting of wheat in mid-hills and both in spring and summer in Terai region of Nepal [3, 4].

The use of Open Pollinated variety (OPV) is high in mid-hills but in Terai region, hybrid maize tends to be dominating with increase in yield per hectare. There are several maize varieties available in Nepal’s seed market from different international corporations, some of which are registered and some of which are not. This leads to a variety of issues in Nepal, from barren cob to a high disease incidence and low plant stand [5]. Hybrid maize has potential of giving 20–30% more grain yield in comparison to other cultivated maize varieties. In rice-wheat based farming system with irrigation facility, hybrid maize is best option for catch crop in mid hill and Terai [5].

The study of genotypes in different seasons is desired as a genotype suitable for summer cultivation may not be suitable for winter and vice versa and some can perform optimally with stable production in both seasons [3, 4, 6]. The variation in yield and yield attributing traits of maize has also been associated with variation in agro-climatic conditions [7, 8] and cropping domain [2, 5].

Though there are 45 registered commercial maize hybrids in Nepal, the hybrids that performs better with stable grain yield in individual and across the season is not studied. Kandel and Shrestha [2] reported that Shresta and P3396 were best yielding genotype in two year when sown in winter season.

Due to fragmentation, the majority of farmers in developing nations have extremely limited access to land, and the hybrid maize seed that is available is rarely used entirely in a single cropping season. Therefore, small landholder farmers may find it advantageous to adopt high yielding maize cultivars in both seasons, improving the productivity of the crop, if we were able to identify high yielding and stable varieties/hybrids for both the summer and winter seasons. The demand of hybrid seeds of maize is almost dependent on India with very few national hybrids (Released by National Maize Research Program (NMRP), Chitwan) under cultivation, among which Rampur hybrid-10 is one of the most promising heat resilient maize hybrid [2, 5]. Due to open border with India, hybrid seeds enter Nepalese market and farmers field without any certification [9] and registration procedure which have caused huge difficulty in relation to...
production, incidence of disease and pest and crop failure at early stage [10]. Nowadays, NMRP is conducting multi location, multi environment and multi-year trials to identify the stable, high yielding and promising maize genotypes [11]. Followingly, it is also conducting performance trial of various multinational companies and their registration for Nepalese market [11]. Large number of genotypes were suggested for cultivation but they donot perform optimally in all environment [2, 5]. Thus, genotypes are recommended for diverse ecological condition rather than specific ecological condition. Thus, this study was conducted as per farmers demand in Sunsari district with an objectives identify the high yielding maize for cultivation in both the seasons to study genetic variability, correlation and AMMI analysis for yield and yield related traits that would aid in crop improvement programs.

2. Materials and methods

2.1. Experimental location details

The experiment was conducted in the farmers field of Itahari sub-municipality (26°39′47″N 87°16′28″E). The study area lies in the terai region of Nepal located at 110 masl that has humid weather with cold winters and very hot summers. The climatic details of the experimental site are presented in Figure 1. The soil type present in study area was clay loam soil. Experiment was conducted in the same field for both the seasons.

2.2. Design of experiment and experiment details

The experiment was conducted in Completely Randomized Block design (RCBD) with 11 genotypes and 3 replications in both the seasons (Summer 2021 and Winter 2021/2022). The genotypes used in the study were collected from local agrovets of Itahari and Biratnagar in their original sachet of 2kg quantity and all of them were commercial maize hybrids developed by various multinational companies. A total of nine multinational company hybrids, RH-10 (developed by NMRP, Chitwan used as a standard check) and Arun 2 (open pollinated variety) as local check was used in the experiment. The details of the genotypes used has been presented in Table 1.

The experimental field was laid out plot size of 4 m × 3 m with row to row and plant to plant spacing of 0.75m and 0.2m, respectively. Every genotype was sown in four consecutive rows. The plot to plot distance was 0.75m and block to block distance was 1m. In summer, sowing was done on 25th of April and harvested from 21st of August to 23rd of August. In winter, sowing was done on 15th of November and was harvested from April 18-April 25 when physiological maturity has been attained.

2.3. Plant management practices

Field preparation was done by ploughing two times followed by leveling and ensuring optimal moisture for germination. Farm yard manure was applied at the rate of 15 t/ha. Chemical fertilizers were applied at the rate of 180:60:40 kg ha⁻¹ of N:P₂O₅:K₂O in the form of Urea, Diammonium Phosphate and Muriate of potash respectively [7]. Planting was done on last week of April, 2021 for summer environment and for winter, on second week of November by line sowing along the row. Phosphorus and Potassium were applied in basal dose and half portion of Nitrogen were applied at the time of sowing respectively. Remaining Nitrogen was applied in two equal splits (25%-25%) after first and second weeding. Two weedings were carried out at 30 DAS and 45 DAS. Thinning out was done during first weeding to ensure single plant per hill and earthing up was done during second weeding.

2.4. Data collection

Data collection was done on five randomly selected plants from all plot in both the seasons. Except for reproductive traits, all the traits were recorded after the crop has attained physiological maturity and harvesting. Reproductive traits include day to 50% tasseling (anthesis days), days to 50% silking (silking days) and Anthesis silking interval (ASI). Plant height and ear height was measured at physiological maturity from five randomly selected plants.

| Treatment code | Genotype name       | Company                                      |
|----------------|---------------------|----------------------------------------------|
| 1              | Arun 2              | Local Agrovet                                |
| 2              | BS9220              | Bio seed research India pvt. ltd.            |
| 3              | CAH 153 (RH-10)     | NMRP, Rampur                                 |
| 4              | CP 808              | Charoen Popkhand Seeds pvt. ltd.             |
| 5              | P3553               | Du pont pioneer                              |
| 6              | Bisco gold 941      | Bisco Bio Sciences Private Limited           |
| 7              | P3355               | Du pont pioneer                              |
| 8              | P3396               | Du pont pioneer                              |
| 9              | G-25                | Geneva Hybrid seeds                          |
| 10             | Rajkumar            | Bio seed research India pvt. ltd.            |
| 11             | TX 369              | Bio seed research India pvt. ltd.            |

Table 1. Details of genotypes used in study.

In winter, sowing was done on 15th of November and was harvested from April 18-April 25 when physiological maturity has been attained.

Figure 1. Agro-climatic condition during study period.
plants as suggested by Badu-Apraku et al. [12]. After harvesting all the ears from each plot was collected, ear count was taken and later converted in hectare (Equation 1) as suggested by Badu-Apraku et al. [12] which was also followed by others [7, 8, 13, 14, 15, 16] in maize breeding program. Ears from tagged plants were taken and used for recording cob characteristics like Cob length (CL), Cob diameter (CD), Number of grains per row (NOGPR), and Number of rows per cob (NORPC). Grain yield (Equation 2) was calculated after weighing the total harvested ears per plot (Field weight) and grain moisture content in field using the formula as suggested by Badu-Apraku et al. [12]. Thousand kernel weight (Equation 3) was also recorded and later converted into 12.5% moisture content as reference.

\[
\text{NOEPH} = \frac{\text{No. of ears per plot} \times 10000}{\text{Plot size} (m^2)} \quad (\text{Equation 1})
\]

\[
\text{Grain yield} = \frac{\text{Field weight (kg)} \times 0.8 \times (100 - \text{Moisture content})}{\text{Plot size} (m^2) \times 87.5} \times 10 \quad (\text{Equation 2})
\]

\[
1000 - \text{kernel weight} = \frac{\text{Kernel weight} \times (100 - \text{moisture } \%)}{100 - 12.5} \quad (\text{Equation 3})
\]

2.5. Statistical analysis

Data was entered in MS-Excel 2016 and was analyzed using R-studio 4.0.1 and SPSS v.20. Estimation of genetic parameters was done by using R-studio v.4.0.1 and SPSS v.20. Correlation coefficient was computed by the formula Eq. (1), given by Webster and Moorty and also used by several researchers [17, 18, 19, 20, 21, 22, 23, 24].

\[
\text{rp}(xy) = \frac{\text{cov } p(\text{xy})}{\sigma^2 \text{g}(x) \times \sigma^2 \text{p}(y)} \quad (1)
\]

Where.

\[
\text{rp}(xy) \text{ is phenotypic correlation, cov } p(\text{xy}) \text{ is covariance due to phenotype of xy, and } \sigma^2 \text{g}(x) \text{ and } \sigma^2 \text{p}(y) \text{ are the genotypic and phenotypic standard deviation of x and y.}
\]

As recommended by Singh and Chaudary [25], the phenotypic coefficient of variation as in Eq. (2) and genotypic coefficient of variation (Equation 3) have been determined. Eqs. (4) and (5) measure heritability in broad sense and genetic advance as percentage of mean as suggested by Johnson [26] and Robinson et al. [27], respectively.

\[
\text{PCV} = \sqrt{\frac{\delta^2_p \times 100}{x}} \quad (2)
\]

\[
\text{GCV} = \sqrt{\frac{\delta^2_g \times 100}{x}} \quad (3)
\]

\[
\text{Heritability (h}^2 \text{bs)} = \frac{\delta^2_g}{\delta^2_p} \quad (4)
\]

\[
\text{Genetic advance (GA)} = K(\delta^2_p)/(h^2 \text{bs}) \quad (5)
\]

Where, \( K = \) selection differential that varies depending up on the selection intensity and stands at 2.056 for selecting 5% of the genotypes.

2.6. Analysis of variance and AMMI analysis

Data were subjected to analysis of variance across the environments (season) using ADEL-R version 2.0. Additive Main Effect and Multiplicative Interaction (AMMI) model was used for the mean of the yield of the 11 genotype of maize from both the environments using GEA-R software. The AMMI model equation is:

\[
Yij = \mu + ai + bj + n \sum_{n=0}^{N} \delta_{jn} yjn + \theta ij + eij
\]

Where: \( Yij = \) the mean yield of elite line i in environment j, \( \mu = \) the grand mean of the yield, \( ai = \) the deviation of the elite lines mean from the grand mean, \( bj = \) the deviation of the environment mean from the grand mean, \( \delta_{jn} = \) the singular value for the PCA; n, N = the number of PCA axis retained in the model, \( yjn = \) the PCA score of an elite line for PCA axis n, \( \theta ij = \) the AMMI residual and \( eij = \) the error term

3. Results and discussion

3.1. Analysis of variance and mean performance

3.1.1. Plant architectural trait

Analysis of variance revealed that the plant height differed significantly in both the seasons and ear height differed significantly in winter season and was not significantly different in summer season (Table 2). Plants in summer season were comparatively taller than winter season and ear height also showed a similar trend and was also supported by earlier findings of Tripathi et al. [7]. Temperature and solar radiation have direct effect on photosynthesis and inter-node elongation [28, 29, 30, 31]; optimum temperature and sunlight hours are reported in summer season were comparatively taller than winter season leading to positive effect on plant architectural traits (Figure 1, Table 2). Genotype and environment interaction reveal that there was significant difference in performance of genotypes in two seasons.

CP 808 (255.3cm) was the tallest genotype in winter season followed by Bisco gold 941 (236.6cm), G-25 (236.67cm), and P3355 (235.3cm) (Table 2). In summer season, G-25 (308.3cm) was the tallest genotype followed by CAH 153 (296cm), TX369 (290.67cm) and B9220 (290.3cm). Highest ear height was reported in CP 808 (133cm) in winter season and G-25 (202cm) in summer season. Plant height and ear height

| Genotype       | Plant height (cm) | Ear height (cm) |
|----------------|-------------------|-----------------|
|                | Winter | Summer | Winter | Summer |
| Arun2          | 205.3d | 282.33bcd | 107.67d | 138.67b |
| B99220         | 211.33d | 290.3bc | 99.76de | 150.32b |
| CAH153         | 208.33d | 296ab | 97.3de | 164.2ab |
| cp808          | 255.33a | 286.66bc | 133a | 144.33b |
| Bisco gold 941 | 236.43d | 288bc | 125.33ab | 161ab |
| G-25           | 236.67b | 308.33a | 127.33a | 202a |
| P3355          | 235.23b | 257.33f | 92.3e | 136b |
| P3359          | 233.38bc | 275cde | 114b | 138.33b |
| P3353          | 211.28d | 256ef | 105.41cd | 139.33b |
| Rajkumar       | 219cd | 268.33def | 102de | 140b |
| TX369          | 210.3d | 290.67bc | 97de | 138b |
| grand mean     | 223.87 | 282.61 | 199.23 | 143.17 |
| CV             | 4.22 | 3.35 | 6.09 | 18.31 |
| LSD            | 16.11 | 16.17 | 11.66 | 46.85 |
| Genotype       | *** | *** | *** | Ns |
| Environment    | *** | *** | *** | |
| G x E          | *** | *** | Ns | |
are important traits in maize as they are two main traits for selection in maize architecture because optimal plant height and ear height are critical for improving plant density to maximize fertilizer utilization, water use and incident photosynthetically active radiation [32, 33, 34, 35]. The plant height in the study ranged from 205.33cm-255.3cm in winter season and 257.3-308.3cm in summer season. The ear height ranged from 92-127cm and 136-164cm in winter and summer season respectively. Several researchers [7, 13, 14, 15, 36] reported plant architectural traits of maize within this range which supports current finding.

3.1.2. Reproductive traits

Analysis of variance revealed that the reproductive traits anthesis days, silking days and anthesis silking interval showed highly significant differences (P ≤ 0.0001) in both the seasons, between the genotypes (Table 5). The anthesis and silking days are significantly higher in winter season than that of summer however the required Growing Degree Days (GDD) was constant in both the seasons [6]. The spring maize are earlier than winter maize for reproductive traits [37] where the average length varies from 100-111 day in anthesis and 102-113 day in silking in winter season (Table 3). Genotypes P3355 and P3553 were early for days to anthesis and BS9220 took longer time to anthesis in winter season and in summer CP 808 was early for tasseling. Minimum difference in anthesis silking interval was reported in BS9220 and TX369 in winter season and TX-369 in the summer season. In summer season genotypes CAH 153, CP 808 and P 3396 had ASI of one day. The maximum difference was recorded in P3355 in winter season and P3553 in summer season. In winter season genotypes TX-369 in the summer season. In summer season genotypes CAH 153, CP 808 and P 3396 had ASI of one day. The maximum difference was reported in P3355 (6 days) in winter and G-25 in summer season (4.6 days). Anthesis silking interval between 2-4 days are found to have a positive effect on grain yield of maize i.e. ASI is negatively correlated to yield and Anthesis silking interval between 2-4 days are found to have a positive effect on grain yield of maize i.e. ASI is negatively correlated to yield and P3355 and Bisco gold 941 can be suggested for cultivation in both the seasons. Comparing yield of both the seasons, genotype P3355 was high yielding followed by P3353 and BS9220 and Arun 2 being the lowest yielding genotype. In summer season, P3553 being the highest yielding genotype followed by P3355 and Bisco gold 941, and Arun 2 being the lowest performing genotype. Comparing yield of both the seasons, genotype P3355 and Bisco gold 941 can be suggested for cultivation in both the seasons for tetal domain. There was significant difference among the genotypes for 1000-kernel weight during winter season and they were nonsignificant in summer season. Highest 1000-kernel weight was reported in P3355 in winter season and P3353 in summer season.

3.1.3. Cob characteristics

Number of rows per cob (NORPC), Number of grains per row (NOGPR) and Cob length (CL) are significantly different in both the seasons. Cob diameter and number of ears per hectare (NOEPH) showed significantly different performance in summer and nonsignificant performance in winter season. The details of the cob characteristics have been presented in Table 4. There were significant differences in performance of genotypes in both seasons for number of rows per cob and number of grains per row but Genotype × Environment interaction was non-significant. This might be due to the reason that the trait might be under the genetic control and has low influence on variation in environmental condition [43] and similar finding has also been reported by Dhakal et al. [8] in three-way cross hybrid maize. A significant difference between the genotypes and nonsignificant difference in Genotype × Environment interaction was also reported by Tripathi et al. [7]. The mentioned cob characteristics are the yield attributing traits and are found to be positively correlated with yield i.e. increase in any of the cob characteristics increases the yield [7, 8].

3.1.4. Yield and thousand kernels weight

Analysis of variance revealed that the grain yield differed significantly in both the seasons, However the average grain yield was higher in the summer season. Similar finding was also reported by Dhakal et al. [6] where the yield of top performing variety is 8.36 t/ha in winter and 9.76 t/ha in summer season. Researchers suggest that the grain yield of maize is higher in summer season as compared to spring due to long sunshine hours [28, 29], hot and humid climate and low susceptibility to low temperature and highly responsive to nitrogenous fertilizer during summer and spring seasons. The average grain yield of top-performing genotypes is higher in both the seasons in our study as compared to [8]. In winter season, genotype P3355 was high yielding followed by Bisco gold 941, and P3396 and Arun 2 being the lowest producing variety (Table 5). In summer season, P3553 being the highest yielding genotype followed by P3355 and Bisco gold 941, and Arun 2 being the lowest performing genotype. Comparing yield of both the seasons, genotype P3355 and Bisco gold 941 can be suggested for cultivation in both the seasons for tetal domain. There was significant difference among the genotypes for 1000-kernel weight during winter season and they were nonsignificant in summer season. Highest 1000-kernel weight was reported in P3355 in winter season and P3353 in summer season.

3.2. Estimation of genetic parameters

3.2.1. Genetic variability

Genetic parameters differed significantly in both the summer and winter seasons. PCV was larger than GCV in both the seasons in terms of

| Genotype     | Anthesis days | Silking days | Anthesis silking interval |
|--------------|---------------|--------------|---------------------------|
|              | Winter | Summer | Winter | Summer | Winter | Summer |
| Arun2        | 103.33bc | 56a    | 111.33a | 57.33ab | 5ab   | 1.3def |
| BS9220       | 109.67a  | 58.33a | 108.33ab | 60.66a | 1.7f  | 2.33bc |
| CAH153       | 101c     | 55.33a | 104.33c | 56.33abc | 3.3e | 1ef |
| CP 808       | 95d      | 47b    | 99d     | 48d    | 4bcd  | 1ef |
| Bisco gold 941 | 97d   | 49.33b | 100d    | 52.33cd | 2.67def | 3b |
| G-25         | 95.6de   | 48.66b | 100.67d | 53.33bc | 5ab   | 4.6a |
| P3355        | 87.67f   | 58.33a | 90f     | 60a    | 2ef   | 1.67def |
| P3353        | 94.33e   | 57a    | 98.67d  | 58a    | 4.33bc | 1ef |
| Rajkumar     | 88f      | 58a    | 94e     | 59.33a | 6a    | 1.33def |
| TX369        | 104.3b   | 57.66a | 107.33bc | 59.67a | 3cdef | 2cd |
| Grand mean   | 98.27    | 54.72  | 101.81  | 56.54 | 3.54  | 1.82 |
| CV           | 1.77     | 4.6    | 1.69    | 4.75  | 24.6  | 22.85 |
| LSD          | 2.96     | 4.29   | 3.32    | 4.57  | 1.48  | 0.7 |
| Genotype     | ***      | ***    | ***     | ***   | ***   | *** |
| Environment  | ***      | ***    | ***     | ***   | ***   | *** |
| G x E        | ***      | ***    | ***     | ***   | ***   | *** |
Similar finding was also reported by several researchers [24, 44, 45]. The PCV and GCV was found highest in terms of ASI during winter season and summer season among all the genetic parameters. Though, GCV indicates greater variation in PCV and GCV in traits reveal that the expression of trait is heavily influenced by environmental factors [24]. Overall highest GCV was observed in ASI during winter season and summer season among all the genetic parameters. Though, GCV indicates a high level of genetic diversity, but heritability estimates and genetic gain are used to determine the amount of heritable variation in traits [24, 45].

**3.2.2. Heritability and genetic advance**

In winter season, the highest heritability was reported in anthesis days (0.9407) followed by silking days (0.9131), number of grains per row (0.9004), thousand kernel weight (0.8621), cob length (0.86070), ear height (0.7892), anthesis silking interval (0.7402), plant height (0.7230) and grain yield (0.7205). The least heritable trait was cob diameter (0.0959). The highest heritability during summer season was reported in anthesis silking interval (0.8832) followed by number of grains per row (0.8677), cob diameter (0.7367), anthesis days (0.7131), number of grains per row (0.7060) and plant height (0.6827). The least heritable trait was cob length (0.0679), number of rows per cob (0.6621), cob length (0.6377) and silking days (0.6339). Thousand kernel weight and ear height were low heritable traits and number of ears per hectare was moderately heritable. This study reported that, in both the seasons, heritability of trait was low (<30%), moderate (30–60%) and highly heritable (>60%) (Table 7) as proposed by Johnson et al. [26] and

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**Table 4. Comparison of cob characteristics of studied genotypes in both seasons.**

| Genotype | NORPC | NOGPR | Cob diameter (cm) | Cob length (cm) | NOEPH |
|----------|-------|-------|-------------------|----------------|-------|
|          | Winter | Summer | Winter | Summer | Winter | Summer |
| Arun2    | 14cd  | 14.33de | 27de  | 25.66c | 4.13bc | 4.17d |
| BSH220   | 14cd  | 14.33de | 27de  | 25.66c | 4.13bc | 4.17d |
| CAH153   | 14.67bde | 13.78e | 25.67de | 28.4e | 4.15bhe | 4.50cde |
| cp808    | 14cd  | 16abc  | 24.7e  | 26.89c | 3.83c | 3.32e |
| Bisco gold 941 | 13.67d | 14.89cde | 25.3e  | 25.56c | 4.37abc | 4.29d |
| G-25     | 13.66d | 15.56bde | 28.6cd | 32.67b | 4.43bc | 4.75bc |
| F3355    | 17a   | 16.73ab | 38a   | 41.67a | 4.34abc | 5.42a |
| F3396    | 15.3bc | 17.07a  | 37.67a | 41.86a | 4.72a | 5.19b |
| F3553    | 14.67bde | 16.93a | 38a   | 41.67a | 4.39b | 5.26a |
| Rajkumar | 14.67bde | 16.74de | 31bc  | 32.67b | 4.9bc | 4.2d |
| TX369    | 15.67ab | 15.33cde | 32.67b | 33.78b | 4.53ab | 4.13d |
| Grand mean | 14.66 | 15.42a  | 30.3a  | 32.58a | 4.25 | 4.61 |

**Table 5. Yield comparison and thousand kernel weight in both seasons.**

| Genotype | Grain yield (t/ha) | Thousand kernel weight |
|----------|--------------------|------------------------|
|          | Winter | Summer | Winter | Summer |
| P 3355   | 9.94a  | 11.94a | 327.33a | 297.23a |
| Arun 2   | 4.13d  | 5.93e  | 248ef   | 279.6abc |
| BSH220   | 7.76bc | 8.66cde | 268.71cde | 273.67abcd |
| CAH153   | 7.8bc  | 10.139abc | 270.67cde | 296.37cabc |
| CP 808   | 4.21d  | 7.18de | 235f    | 229.6abc |
| F3355    | 8.59abc | 12.21a | 284.33bc | 332.67a |
| Bisco gold 941 | 8.87ab | 11.42ab | 302.67b | 287.38abc |
| P 3396   | 8.71ab | 10.38bc | 284.04bc | 268.54abc |
| G-25     | 8.52abc | 10.59abc | 249.47def | 266.44bc |
| Rajkumar | 7.86bc | 9.26cd | 246.34f | 229.6abc |
| TX369    | 6.79c  | 8.68cd | 212.21g | 229.6abc |
| Grand mean | 7.56  | 9.67  | 266.25c | 274.54 |
| CV       | 14.3  | 13.25a | 4.71   | 13.84 |
| LSD      | 1.65  | 1.28a  | 3.05   | 4.16a |
| Genotype |       |       | 0.20   | 0.69 |
|         |       |       | 0.45   | 2.29a |
|         |       |       | 2.97   | 8261.17 |
|         |       |       | 6281.7 |     |

**Table 6. Estimate of Genetic variability.**

| Traits under study | Winter | Summer |
|--------------------|--------|--------|
|                    | GCV    | PCV    | GCV    | PCV    |
| Plant height       | 6.82   | 8.03   | 4.92   | 5.96   |
| Ear height         | 12.13  | 13.66  | 7.74   | 19.88  |
| ASI                | 38.03  | 45.31  | 62.85  | 66.88  |
| SD                 | 6.21   | 6.5    | 6.28   | 7.89   |
| NORPC              | 5.72   | 8.77   | 6.83   | 8.39   |
| NOGPR              | 17.81  | 18.77  | 19.23  | 20.64  |
| CL                 | 17.04  | 18.37  | 10.86  | 13.60  |
| CD                 | 3.11   | 10.05  | 7.97   | 11.38  |
| NOEPH              | 6.48   | 11.02  | 6.93   | 9.51   |
| TKW                | 11.93  | 12.85  | 8.04   | 16.01  |
| GY                 | 23.08  | 27.19  | 18.8   | 23.01  |

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all genetic parameters, i.e. environment influenced in expression of traits. Similar finding was also reported by several researchers [24, 44, 45]. The PCV and GCV was found highest in terms of ASI with 45.31 and 38.03 respectively in winter season; also, highest PCV and GCV for ASI 66.88 and 62.85 respectively was recorded in summer season (Table 6). Moderate PCV and GCV was found in traits like NOGPR, CL and GY with 20.64 and 19.23, 23.01 and 18.8 was observed in winter season. Low PCV and GCV was found in terms of PH, EH, AD, SD, NORPC, CD, NOEPH and TKW with 8.03 and 6.82, 13.66 and 12.13, 7.28 and 7.06, 6.5 and 6.21, 8.77 and 5.72, 10.05 and 3.11, 11.02 and 6.48, 12.85 and 11.93 respectively was observed in winter season. Low PCV and GCV was found in terms of PH, AD, SD, NORPC, CL, CD and NOEPH with 5.96 and 4.92, 8.62 and 7.29, 7.89 and 6.28, 8.39 and 6.83, 13.60 and 10.86, 11.38 and 9.77, 9.51 and 6.93, respectively in winter season. While in summer season, moderately high PCV was found in terms of EH and TKW with 19.88 and 16.01 respectively; low GCV was found in terms of EH and TKW with 7.74 and 8.04 respectively. The greater variation in PCV and GCV in traits reveal that the expression of trait is heavily influenced by environmental factors [24]. Overall highest GCV was observed in ASI during winter season and summer season among all the genetic parameters. Though, GCV indicates a high level of genetic diversity, but heritability estimates and genetic gain are used to determine the amount of heritable variation in traits [24, 45].
reported by several authors [7, 24, 44, 45, 46, 47, 48, 49, 50, 51] in trait study of maize.

Genetic advance as a percentage of mean ranged from 1.7% in cob diameter to 65.74% in anthesis silking interval in winter season and 6.21% in ear height to 81.68% in anthesis silking interval in summer season. Greater estimates of GAM were reported in anthesis silking interval (65.74) followed by grain yield (40.36), number of grains per row (34.82), cob length (32.57), 1000-kernel weight (22.31), and ear height (22.21) in winter season and in summer season higher estimate of GAM was reported in anthesis silking interval (81.68) followed by number of grains per row (36.9) and grain yield (31.66). Based on heritability and genetic advance of different traits in both season anthesis silking interval, number of grains per row and grain yield are under genetic control governed by additive genes. Mohana Krishna et al. [43] reported that high heritability coupled with high GAM is due to additive effect of genes governed by additive genes. The AMMI graph of PC1 and traits under study has been presented in (Supplementary figure).

3.3. Correlation analysis

Correlation analysis showed that grain yield is positively and significantly correlated with thousand kernel weight (TKW) (r = 0.597), anthesis silking interval (r = 0.446), plant height (r = 0.381), ear height (r = 0.384), number of grains per row (r = 0.446), number of rows per cob (r = 0.375), cob diameter (r = 0.431), cob length (r = 0.461) and number of ears per hectare (r = 0.499). Reproductive trait like anthesis days (r = -0.487) and silking days (r = -0.466) are negatively and significantly correlated with grain yield i.e. earlier tasseling and silking days are related with high grain yield in maize (Table 8). Similar finding was reported by several authors that grain yield is positively correlated with cob characteristics and negatively related with reproductive traits like silking days and anthesis days [2, 7, 22, 23, 24, 44, 45, 52, 53, 54, 55].

The correlation between the traits has been presented in Table 8. The selection of these traits would suggest an indirect selection of genotypes for grain yield if there is a positive and strong correlation between them [24]. The findings of Thapa et al. [24] suggest that if ASI is longer in crop, it facilitates vegetative growth thus causing lower yield which contradicts our finding as it is positively correlated with grain yield. This finding also contradicts with finding of few researchers [2, 47, 56].

3.4. AMMI analysis of grain yield and yield attributing traits in maize

AMMI analysis was done for all the traits under study and it is observed that the trait viz. anthesis silking interval, anthesis days, silking days, plant height, number of ear per hectare, cob diameter, number of rows per cob showed significant variations (p < 0.05) for both the main (genotypes and environment) and interaction effects revealing the presence of considerable variability among the studied genotypes, environment, and their interaction. Genotype was not significantly different for Cob length, number of ears per hectare, ear height, grain yield, number of grains per row and for environment showed a significant variation. Thousand kernel weight showed significant variation between genotypes whereas environment and interaction effects were not significantly different.

In our study, AMMI analysis revealed that maximum part of total variance was attributed to environment followed by genotype and interaction for the traits anthesis days, silking days, anthesis silking interval, ear height, and plant height. Similar finding was reported by Zaid et al. [57]. Maximum part of total variation was attributed to genotype followed by interaction and environment in the traits cob diameter, number of rows per cob, thousand kernel weight. Maximum part of total variation was attributed to genotype followed by environment then interaction has been reported for traits grain yield, number of ears per hectare, cob length, and number of grains per row. Only one Principal component was generated by AMMI analysis and it explained 100% variation of all traits. While comparing maize grain yield under two contrasting seasons on single location Dhakal et al. [8] reported that only one principal component was generated i.e. 100% variation in yield was explained by PC1. Also 100% variation in PC1 in AMMI analysis has also been reported by [58] in comparing yield of wheat in terminal heat stress. The AMMI graph of PC1 and traits under study has been presented in (Supplementary figure).
4. Conclusion

Hybrid maize is well known for its remarkable contribution to food security as it out yielded OPV's by more than double their production. However, the hybrids that performed superior in one environment do not perform similarly in other locations and environments. In this study, locally available for sale commercial hybrids were used for evaluation and they reported a significant variation in both the seasons for yield and yield attributing traits. Correlation coefficient revealed that cob characteristics have a significant and positive association with grain yield. The field experiment over two seasons revealed that genotype P3355 and Bisco gold 941 showed promising yield when cultivated in winter and summer seasons under optimum conditions. Farmers direct evaluation for grain yield and yield attributing traits of two recommended hybrids (P3355 and Bisco Gold 941) under various planting geometry and nutrient content is suggested for optimal production and increased profitability.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Declarations

Author contribution statement
Sandesh Thapa; Sandhya Adhikari: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.
Sara Rawal: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data will be made available on request.

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The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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