Research Article

Comparative Assessment of the Agronomic Traits of White Maize Hybrids with National and Multinational Hybrids

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Abstract | A field trial was conducted for the comparative study of the 34 maize hybrids (CHT-I to CHT-34) along with two control lines i.e., Azam (Check-I) and Pioneer 30-K08 (Check-II). The seeds were sown in a randomized complete block design with two replications. Different agronomic features were observed including plant height, ear height, grain yield, days to 50% pollen shedding, days to 50% silking, and ear population per hectare. The analysis of variance revealed that the plant height, ear height, and grain yield indicated significant differences, while ear population per hectare, days to 50 % pollen shedding, and 50% silking showed non-significant differences. The least significant difference (LSD) means values revealed that maize hybrid CHT-3 produced the tallest plants (212.5 cm) and had a maximum ear height (111.7 cm) against other hybrids including both controls. The three maize hybrids ranked in the grain yield are CHT-17 (12.533 tonnes ha^{-1}) followed by CHT-23 (11.861 tonnes ha^{-1}) and CHT-6 (11.259 tonnes ha^{-1}). The highest grain yield per hectare indicates their superior performance over all entries and both controls. The present study showed that maize hybrids that outperformed all other genotypes and controls in terms of plant height, ear height, and grain yield could be considered potential maize hybrids for approval after completing their adaptability studies and large-scale multi-location trials.

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Introduction

Maize (*Zea mays* L.) is a member of the family Poaceae, which used to be cultivated more than 9,000 years earlier in southern Mexico/Meso (Erenstein *et al*., 2022). *Zea mays* L. utilization for direct human consumption in Pakistan is decreasing, however its usage is increasing rapidly in the feed and wet milling industry than expected (Tahir and Habib, 2013). It is an adjustable crop, which can be planted across a series of agroclimatic regions i.e., humid, subtropical, and moderate (Khan *et al*., 2017). Maize is grown in two seasons (spring and autumn) in Pakistan. It is Pakistan's third major grain crop next to wheat and rice and is taken as a food and feed (Saeed *et al*., 2018). In Pakistan, maize is grown on an area of 2.3 million hectares with 8,465 tonnes of production and an average yield of 5,970 Kg ha^{-1}, while in Khyber Pakhtunkhwa maize covers an area of 0.2 million hectares with a 904.5 tonnes production and 1933 Kg per hectare yield (Saleem *et al*., 2024). Its turnout improved by 6% during 2019-2020 (Khan *et al*., 2021).

The presence of maize as one of the top-yielding grain crops on the earth holds considerable significance for countries like Pakistan, where rapid population growth at present has exceeded the existing nutrition resources. Demand for maize on a worldwide level is steadily rising due to population growth, dietary shifts, demand for industrial supplies, and the need for biofuel. To fulfill this growing demand and ensure food security, it is important to enhance maize yields and associated traits. Maize grain consists of an important source of protein (10.4%), starch (71.8%), fat (4.5%), and other essential nutrients such as calcium, phosphorous, and sulfur (Imran *et al*., 2016). To ensure environmental sustainability along with agriculture production, accurate application of production inputs plays a vital role in effective maize production. Being a warm-weather cereal grass, maize cultivation is not carried out in zones where the mean daily temperature falls below 19 ºC or where the mean summer temperature is less than 23 ºC (Du Plessis, 2003).

The maize crop is highly domesticated with limited capability to propagate in the wild. Maize is grown mainly due to its ability to provide abundant yield, ease of cultivation and storage, and high starch content, which can be metabolized promptly into useful energy (Eckhoff and Paulsen, 1996). Nearly every province of the country grows maize crops however Punjab and KP are the main regions of production. In Pakistan, maize is grown throughout the spring (February to March) and fall (July to August) seasons. Approximately 97 % of the total maize production in Pakistan comes from the Punjab and KP provinces (Khan *et al*., 2017).

Improved genotypes stimulate healthy plant growth and improve the maize crop to yield more grain along with their resistance to unfavorable environmental factors (Khan *et al*., 2019; Rauf *et al*., 2023). Since plants' breeders have added genetic advancements in maize yield over time, plant-breeding programs work as the foundation for maize output improvement (Tollenaar and Lee, 2002; Rauf *et al*., 2023). For better agriculture yield and profitability, improvement in the agronomic traits of maize genotypes and management practices are necessary. The selection of hybrids, considering soil, climatic, and biological measures at several phases of growth and development is important for effective management of corn seed productivity (Shahini et al., 2023).

Genetic studies of hybrids serve as the basis for understanding the basic mechanisms to control yield and yield-related traits (Rauf *et al*., 2023). This study not only contributes to our understanding of maize genetics but holds significant implications for crop development and sustainable agriculture as well. Breeders can make refined judgments to create high-yielding varieties that are well adapted to a variety of environmental conditions by analyzing the genetic basis of these qualities in both national and international maize hybrids. Adoption of hybrid seeds by advanced agronomists during spring and some shifts by small farmers in the fall has led to an increase in per hectors yield of maize. Some international organizations sell and import most hybrid seeds currently accessible on the market at high prices. The farming community, which relies on local maize hybrids, could not afford commercial hybrids with expensive prices. Furthermore, in most parts of the country, the production of maize is not ideal due to the growing low-yielding open-pollinated varieties (OPVs) with heavy weed infestation (Khan *et al*., 2017). The demand for maize inevitably rises with population growth and everyday gains in the poultry and animal industries. Farmers are drawn to grow hybrids because they have a higher yield advantage than open-pollinated varieties (OPVs) (Tripathi and Shrestha, 2016). The current study was conducted to compare the agronomic traits of local versus commercial maize hybrids by confirming the superior maize hybrids for yield and yield-related parameters as well as their adaptability to the agro-climatic conditions of Khyber Pakhtunkhwa.

Materials and Methods

The current study was carried out at the Cereal Crops Research Institute (CCRI) Pirsabak, Nowshera, Pakistan in 2023. Thirty-four candidate white maize hybrids (CHT-1 to CHT-34) were developed during spring, 2023 through controlled hand pollination (Table 1). These hybrids including two check entries i.e., Azam (White grain, approved open pollinated variety) and Pioneer30-K08 (Single cross white grain maize hybrid of the multinational company) were evaluated in autumn, 2023. A randomized Complete Block Design (RCBD) with two replications was selected for the experiment conduction. Each hybrid entry was sown in two rows each 05 meters long with a row-row gap of 75 cm and the plant-plant gap of 25 cm. Non-experimental lines were sown at the start and end of each block to avoid the border effect. Plot size 02 ×05 ×0.75m = (7.5 m^2) was kept in the experiment for both replications. All the standard agronomic practices were followed throughout the experiment.

Table 1: *List of different maize genotypes used in the study at CCRI, Pirsabak.*

Entry No	Genotypes names	Entry No	Genotypes names
1	CHT-1	19	CHT-19
2	CHT-2	20	CHT-20
3	CHT-3	21	CHT-21
4	CHT-4	22	CHT-22
5	CHT-5	23	CHT-23
6	CHT-6	24	CHT-24
7	CHT-7	25	CHT-25
8	CHT-8	26	CHT-26
9	CHT-9	27	CHT-27
10	CHT-10	28	CHT-28
11	CHT-11	29	CHT-29
12	CHT-12	30	CHT-30
13	CHT-13	31	CHT-31
14	CHT-14	32	CHT-32
15	CHT-15	33	CHT-33
16	CHT-16	34	CHT-34
17	CHT-17	35	P30-K08(Check-I) Hybrid
18	CHT-18	36	Azam (Check-II) OPV

Data collection

Data were taken with a standard procedure using five plants randomly in each experimental plot on days to 50% pollen shedding, days to 50% silk emergence, plant height, ear height, number of ears per hectare, and grain yield (tonnes ha^{-1}).

Statistical analysis

The recorded data was gathered on an Excel Sheet, after which it was subjected to computer software Genstat 12 for further detailed analysis. Analysis of variance was carried out where significant and non-significant differences were noted from the LSD test.

Results and Discussion

Days to 50% pollen shedding (Number)

Mean values regarding days to 50% pollen shedding are shown in (Table 2). Data presented in the table revealed that maize hybrids did not differ significantly for days to 50% pollen shedding. Pollen shedding ranged from 58 to 64 days across entries (Figure 1). Minimum days to 50% pollen shedding (58 days) were noted for CHT-15, CHT-24, and CHT-26 followed by CHT-6 and CHT-7 (59 days). The coefficient of variation calculated was 3.0% (Table 2), indicating consistency across entries such as entries CHT-1, CHT-2, CHT-11, CHT-27, CHT-30, and P30-k08 (Check-I) all have a pollen shed count of 62 indicating similar reproductive vigor. Both checks (P30-K08 and Azam) demonstrated similar timing for pollen shedding in line with the other studied hybrids. Ige *et al*. (2019) also discussed that maize genotypes do not differ significantly for days to 50% pollen shedding. Early pollen shedding not only promotes successful pollination before adverse conditions arise but also lowers the risk of pests and diseases associated with prolonged growing seasons.

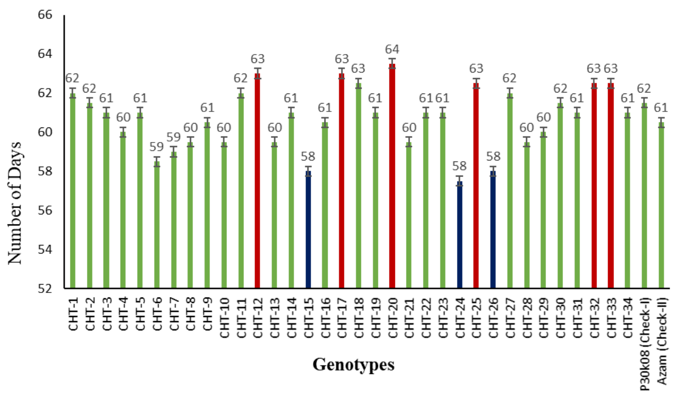

Figure 1: *Graph showing 50% pollen shedding of different maize genotypes. The maize genotypes including CHT-15, CHT-24, and CHT-26 showed the least days to 50% pollen shedding, the genotypes (CHT-12, CHT-17, CHT-20, CHT-25, CHT-32, and CHT-33) with the maximum number, while the remaining genotypes with an average number.*

The maize genotypes including CHT-15, CHT-24, and CHT-26 showed the least days to 50% pollen shedding, the genotypes (CHT-12, CHT-17, CHT-20, CHT-25, CHT-32, and CHT-33) with the maximum number, while the remaining genotypes with an average number.

Table 2: *Detail of the mean performance, LSD values, and CV of the 34 maize hybrids along with 02 controls. Data of the different maize genotypes are shown for days to 50% pollen shedding, days to 50% silk emergence, and plant height.*

S. No.	Hybrids candidates	Days to 50% pollen shedding (days)	Days to 50% silk emergence (days)	Plant height (cm)
1	CHT-1	62	65	164.2
2	CHT-2	62	65	143.3
3	CHT-3	61	64	212.5
4	CHT-4	60	63	159.2
5	CHT-5	61	64	163.3
6	CHT-6	59	61	181.7
7	CHT-7	59	62	170.0
8	CHT-8	60	63	183.3
9	CHT-9	61	63	186.7
10	CHT-10	60	63	175.8
11	CHT-11	62	65	162.5
12	CHT-12	63	66	188.3
13	CHT-13	60	62	159.2
14	CHT-14	61	64	149.2
15	CHT-15	58	61	181.7
16	CHT-16	61	64	177.5
17	CHT-17	63	67	190.8
18	CHT-18	63	66	183.3
19	CHT-19	61	65	162.5
20	CHT-20	64	67	190.0
21	CHT-21	60	63	168.3
22	CHT-22	61	64	184.2
23	CHT-23	61	66	191.7
24	CHT-24	58	62	175.8
25	CHT-25	63	66	155.0
26	CHT-26	58	62	171.7
27	CHT-27	62	65	154.2
28	CHT-28	60	63	149.2
29	CHT-29	60	63	174.2
30	CHT-30	62	65	177.5
31	CHT-31	61	66	155.0
32	CHT-32	63	67	140.8
33	CHT-33	63	67	165.8
34	CHT-34	61	64	180.0
35	P30-K08 (Check-I)	62	66	199.2
36	Azam (Check-II)	61	64	151.7
CV%		3.0	3.2	5.6
LSD (0.05)		NS	NS	19.61

Days to 50% silk emergence (Number)

The emergence of silk was earlier (61 days) for maize hybrids CHT-6 and CHT-15, followed by hybrids CHT-7, CHT-13, CHT-24, and CHT-26 which took (62 days) in days to 50% silk emergence against other hybrids, and both check varieties (Figure 2). Non-significant differences for days to 50% silking were noticed across different maize hybrids. The CV values for days to 50% silking were 3.2% (Table 2), indicating less difference among tested hybrids. The low coefficient of variation (3.2%) suggested consistent performance across entries. Azam (Check-II) took (64) days regarding days to 50% silk emergence and outperformed 15 maize hybrids, while the Check-I (P30-K08) variety demonstrated poor performance in days to 50% silking at (67days) in contrast to many studied maize hybrids. The results are those reported by Ige *et al*. (2019) who noticed non-significant differences amongst maize hybrids. Hybrids that took a minimum of days to 50% silking like CHT-6 and CHT-15 could be better options to grow in regions where early harvesting and double cropping are required, where the risk of late season stresses is high, and where the weather patterns are unpredictable, ultimately resulting in the delayed maturity.

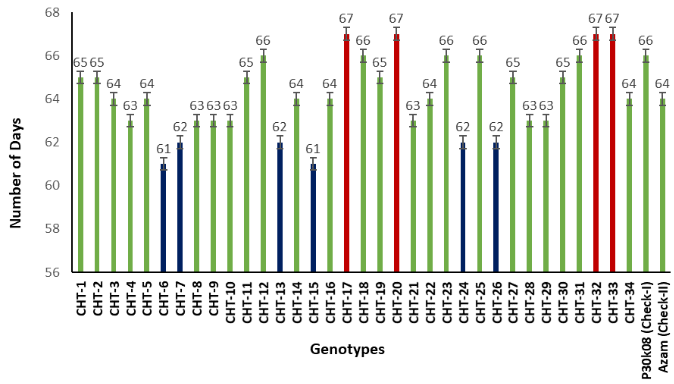

Figure 2: *Graph representing days to 50% silking. The maize genotypes (CHT-6, CHT-7, CHT-13, CHT-15, CHT-24, and CHT-26) with the least number of days taken in 50% silking, genotypes (CHT-17, CHT-20, CHT-32, and CHT-33) with a maximum number of days, and all the remaining genotypes with an average day before the emergence of silks.*

The maize genotypes (CHT-6, CHT-7, CHT-13, CHT-15, CHT-24, and CHT-26) with the least number of days taken in 50% silking, genotypes (CHT-17, CHT-20, CHT-32, and CHT-33) with a maximum number of days, and all the remaining genotypes with an average day before the emergence of silks.

Plant height (cm)

Mean values for plant height across various maize hybrids exhibited considerable variation, ranging from 140.8 cm to 212.5 cm with a coefficient of variation noticed at 5.6 % (Table 2). The present result revealed that various maize hybrids from different genetic backgrounds had affected plant height significantly. The tallest plants were produced by hybrid CHT-3, measuring (212.5 cm) followed by check-I (P30-K08) with a plant height of (199.2 cm). Other candidates like CHT-23 and CHT-17 also showed good performance with plant heights of (191.7 cm) and (190.8 cm), respectively, (Figure 3). Similarly, significant variability regarding plant height was also observed by Nazeer et al. (2010), Salami *et al.* (2007), and Malik *et al.* (2010). In checks, Azam (Check II) with a plant height of (151.7 cm) demonstrated poor performance against many maize genotypes, while check I (P30-K08) with its excellent performance competed well against all maize genotypes except the CHT-3 candidate. Growers need to ensure the strength of root and stalk, availability of sufficient nutrients and water supply, and less risk of lodging when growing crops with maximum plant height. Growing maize hybrids CHT-3, CHT-23, and CHT-17 with their maximum plant height could be a viable option for farmers aiming to grow maize for dual purposes.

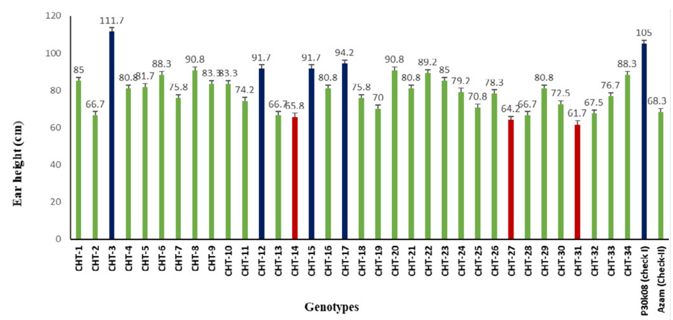

Figure 3: *Graph showing mean performance of hybrids plant height. In the given graph, the bars in blue represent maize genotypes (CHT-3, CHT-17, CHT-23, and (Check-1) P30-K08 with the maximum plant height, in red, represent genotypes (CHT-2, CHT-14, CHT-28, and CHT-32) with a minimum plant height, and in green represent genotypes with an average plant height.*

In the given graph, the bars in blue represent maize genotypes (CHT-3, CHT-17, CHT-23, and (Check-1) P30-K08 with the maximum plant height, in red, represent genotypes (CHT-2, CHT-14, CHT-28, and CHT-32) with a minimum plant height, and in green represent genotypes with an average plant height.

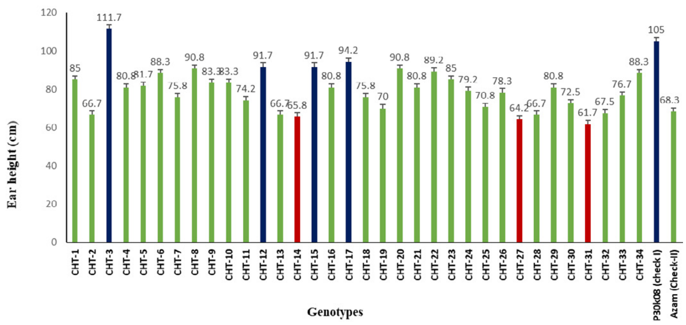

Figure 4: *Graph showing mean performance of hybrids for ear height (cm). The bars represent maize genotypes (CHT-3, CHT-12, CHT-15, CHT-17, and (Check-I) P30-K08) with a maximum ear height, genotypes (CHT-14, CHT-27, and CHT-31) with the smallest ear height, while other genotypes with an average ear height.*

Ear height (cm)

In the present study, variation in ear height (cm) was found to be significantly different due to various maize hybrids. Maize hybrid CHT-3 demonstrated superior performance, having an ear height of approximately, (117.5 cm) followed by check I (P30-K08) measuring, (105 cm) of ear height, maize hybrid CHT-17 (94.2 cm), CHT-12 and CHT-15 (91.7 cm) respectively (Figure 4). Similar significant differences in ear height were also indicated in the results of Radu and Dodocioiu (2020), Salami *et al.* (2007), and Mekasha *et al.* (2020). The above-mentioned hybrids with their maximum ear heights have created a balanced ratio to their plant's height and have decreased the risk of lodging which is a common challenge in maize crop production. In checks, P30-dK08 (Check-I) showed excellent performance against all studied hybrids excluding the CHT-3 maize candidate while the Azam (Check-I) variety demonstrated poor ear height data (68.3 cm), ranked 29th in the ear height parameter. The selection of hybrids with maximum ear height can lead to the development of high-yielding maize varieties, show resistance to environmental stresses, and are easy to manage during harvesting. Based on the findings of this experiment, farmers can select hybrids like CHT-3, CHT-17, CHT-12, and CHT-15 to have better performance in overall maize production.

The bars represent maize genotypes (CHT-3, CHT-12, CHT-15, CHT-17, and (Check- I) P30-K08) with a maximum ear height, genotypes (CHT-14, CHT-27, and CHT-31) with the smallest ear height, while other genotypes with an average ear height.

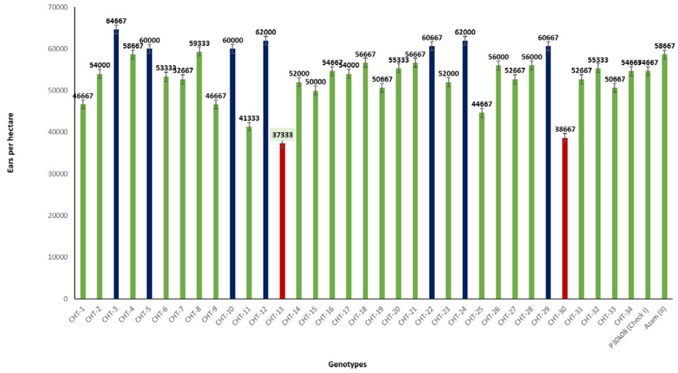

Figure 5: *Graph representing the number of ears per hectare. The maize genotypes (CHT-3, CHT-5, CHT-10, CHT-12, CHT-22, CHT-24, and CHT-29) with the highest number of ears per hectare, genotypes (CHT-13 and CHT-30) with lowest ears ha^{-1} and remaining with an average number of ears per hectare values.*

Number of ears per hectare (ha^{-1})

Data indicated that ear per hectare values varied across the tested hybrids, ranging from (37,333 ha^{-1}) to (64,666 ha^{-1}) (Figure 6). Hybrid CHT-3 exhibited the highest E/ha value of (64,667 ha^{-1}) against all maize hybrids and check varieties, followed by CHT-12 and CHT-24 hybrids at (62,000 ha^{-1}), CHT-22 and CHT-29 at (60,667ha^{-1}), CHT-5 and CHT-10 with (60,000 ha^{-1}). Check-II (Azam) with the number of ears (58,667 ha^{-1}) outperformed 26 new maize hybrids in contrast to Check-I (P30-K08) that exhibited lower ears per hectare data (54,667 ha^{-1}) against many maize genotypes. ANOVA revealed CV values of 15.1% for this parameter (Table 3), indicating moderate change among the tested maize hybrids in terms of ear production. Despite this, LSD values indicated that the differences in ear-per-hectare values among the hybrids were non-significant. Similarly, the results reported by Ben *et al*. (2017) also showed non-significant differences among maize genotypes. The lack of significant differences shows that under the experimental condition hybrids displayed similar productivity in terms of ear production per hectare. Based on our findings, the high number of ears per hectare values have made hybrids CHT-3, CHT-12, and CHT-24 better choices for growers aiming for profitability and productivity in maize crop cultivation.

The maize genotypes (CHT-3, CHT-5, CHT-10, CHT-12, CHT-22, CHT-24, and CHT-29) with the highest number of ears per hectare, genotypes (CHT-13 and CHT-30) with lowest ears ha^{-1} and remaining with an average number of ears per hectare values.

Table 3: *Mean performance, LSD, and CV of the 34 maize hybrids along with 02 controls for ear height, ear population, and grain yield (Tonnes ha^{-1}).*

S. No.	Hybrids	Ear height (cm)	Ear population per hectare (Number)	Grain yield (Tonnes ha^{-1})
1	CHT-1	85.0	46667	9.901
2	CHT-2	66.7	54000	7.228
3	CHT-3	111.7	64667	9.561
4	CHT-4	80.8	58667	9.282
5	CHT-5	81.7	60000	9.287
6	CHT-6	88.3	53333	11.259
7	CHT-7	75.8	52667	7.991
8	CHT-8	90.8	59333	10.064
9	CHT-9	83.3	46667	7.567
10	CHT-10	83.3	60000	9.168
11	CHT-11	74.2	41333	7.407
12	CHT-12	91.7	62000	10.330
13	CHT-13	66.7	37333	7.701
14	CHT-14	65.8	52000	8.879
15	CHT-15	91.7	50000	10.581
16	CHT-16	80.8	54667	9.668
17	CHT-17	94.2	54000	12.533
18	CHT-18	75.8	56667	11.083
19	CHT-19	70.0	50667	9.851
20	CHT-20	90.8	55333	11.089
21	CHT-21	80.8	56667	10.080
22	CHT-22	89.2	60667	10.684
23	CHT-23	85.0	52000	11.861
24	CHT-24	79.2	62000	10.796
25	CHT-25	70.8	44667	8.565
26	CHT-26	78.3	56000	9.259
27	CHT-27	64.2	52667	8.352
28	CHT-28	66.7	56000	7.670
29	CHT-29	80.8	60667	9.650
30	CHT-30	72.5	38667	10.069
31	CHT-31	61.7	52667	8.160
32	CHT-32	67.5	55333	7.690
33	CHT-33	76.7	50667	7.750
34	CHT-34	88.3	54667	9.287
35	P30-K08 (Check-I)	105.0	54667	9.361
36	Azam (Check-II)	68.3	58667	6.322
CV%		10.3	15.1	16.6
LSD (0.05)		16.7	NS	3.15

Grain yield (Tonnes ha^{-1})

Analysis of variance (Table 3) revealed that maize hybrids differed significantly for grain yield parameters. Grain yield (Tonnes ha^{-1}) values ranged from 6.322 tonnes ha^{-1} to 12.533 tonnes per hectare (Figure 6). Maize hybrid (CHT-17) the top performing hybrid achieved the highest grain yield per hectare of (12.533 tonnes ha^{-1}) among all maize hybrids followed by maize candidates CHT-23 with (11.861 tonnes ha^{-1}), CHT-6 (11.259 tonnes ha^{-1}), CHT-20 (11.089 tonnes ha^{-1}) and CHT-18 (11.083 tonnes ha^{-1}) respectively. In checks, Check-I (P30-K08) completed many maize hybrids yielding (9.361 tonnes ha^{-1}) and ranked 18th, while Check-II (Azam) showed the lowest grain yield tonnes per hectare data, yielding (6.322 tonnes ha^{-1}) and ranked last in number of grain production thus, showing the advancements of newly maize hybrids. The coefficient variation of 16.6% (Table 3) indicated moderate to high variability among the tested hybrids in terms of grain yield tonnes per hectare data. The present study's result indicated that maize hybrids differ significantly for grain yield parameters showing consistency with the reports of Maqbool *et al.* (2019) and Mekasha *et al.* (2020). Based on the findings of this study, by adopting high-yielding maize hybrids including CHT-17, CHT-23 CHT-6, CHT-20, and CHT-18, farmers can optimize grain yield and contribute to increased food production.

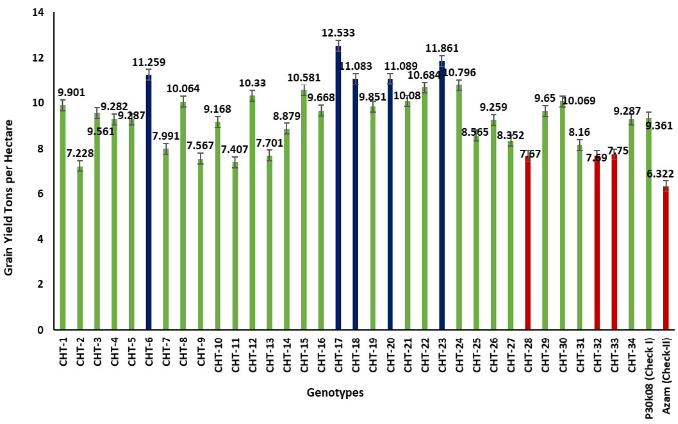

Figure 6: *Graph showing mean performance of grain yield per hectare in tonnes. Bars representing maize genotypes (CHT-17, CHT-23, CHT-6, CHT-20, and CHT-18) with the highest grain yield in tonnes ha^{-1}, Azam (Check II), CHT-28, CHT-32, and CHT-33 genotypes with the lowest grain yield, while all other genotypes with an average grain yield in tonnes per hectare.*

Bars representing maize genotypes (CHT-17, CHT-23, CHT-6, CHT-20, and CHT-18) with the highest grain yield in tonnes ha^{-1}, Azam (Check II), CHT-28, CHT-32, and CHT-33 genotypes with the lowest grain yield, while all other genotypes with an average grain yield in tonnes per hectare.

Conclusions and Recommendations

It is concluded that maize hybrid CHT-17, followed by CHT-23 and CHT-6 remained superior in terms of grain yield, while CHT-3 remained superior regarding plant height parameters by evaluation of the 34 white maize hybrids in comparison with National and Multinational hybrids (Check-I P30-K08 and Check-II Azam) for their yields and other agronomic traits. For gaining sustainability and profitability in maize crop production, these hybrids with better performance can be considered good options for the agro-climatic conditions of Khyber Pakhtunkhwa. In addition, these findings also suggest that farmers who are cultivating OPVs can achieve maximum yields by adopting these hybrids, which is obvious from the yield of Check-II (Azam) vs the yield of top-ranking hybrids in the experiment.

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Novelty Statement

Out of 36 hybrid maize (CHT-I to CHT-34 and two control lines i.e. Azam and Pioneer 30-K08), three experimental lines produced the maximum grain yield i.e. CHT-17 (12.533 tonnes ha^{-1}), CHT-23 (11.861 tonnes ha^{-1}) and CHT-6 (11.259 tonnes ha^{-1}).

Author's Contribution

Syeda Khshnood: Research Experiment Executed/ MS drafting.
Muhammad Yasir Khan: Research Supervision.
Muhammad Qayash, Farooq Jan, Muhammad Qayash, Saman Yaqoob and Nasir Shah: Proofreading.
Kashmala Jabbar, Iqra Ambreen and Guleena Khan: Data analysis.
Ikramullah Khan: Proofreading/Data analysis.
Abdur Rauf: Research Supervision/MS drafting and proofreading.

Conflict of interest
The authors have declared no conflict of interest.

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