Comparative Performance of Thirteen Grain Corn Commercial Hybrid Varieties in the Serdang Environment

ABSTRACT

Selecting and evaluating hybrid varieties based on environmental suitability could enhance both growth performance and yield of grain corn cultivation, thereby improving the profitability of grain corn economic gains. This study aimed to compare the performance of thirteen commercial grain corn hybrid varieties from local and foreign sources in the MARDI Serdang, Malaysia environment. The experiment used a randomized complete block design with three replications for two planting seasons (July-November 2020 and February-June 2021). Seven agronomic and yield parameters were recorded and analyzed using ANOVA and DMRT analysis. The results revealed a significant interaction between planting seasons and hybrids for days to 50% pollen shed, plant height and Cut Cutting Test (CCT) yield. Season 2 produced higher component yield traits but not significantly different for CCT yield. Considering overall individual performance, the best performing varieties were DK9979C, GWG5005, and P4554, which showed the best yield and were consistent over seasons, especially in fluctuated environment factors. In contrast, the varieties GWG888 and DK9950C produced the least, with yields of 4279.2 kg/ha and 4051.2 kg/ha, respectively, marking a decline of over 50.0% in the second season compared to the first season. This result shows that season influenced the yield and performance of some tested hybrids. This study provides useful information for grain corn farmers and breeders in selecting good adaptability hybrid varieties suitable for the Serdang environment

Keywords: evaluation, genotypes, planting season, adaptability, yield

1. INTRODUCTION

The grain corn (*Zea mays* L.) is a cereal crop that has important roles in the feeding industry, especially for poultry. The grain is preferably used in poultry feeding formulation. Malaysia is currently highly dependent on imports for this commodity to fulfil the industry demand with an estimated 4 million tons annually, which is about RM 3.1 billion (Mohammad and Chan, 2019). This situation has a negative impact on the industry due to the increase in production costs. Therefore, the production of grain corn from local farmers is the main objective in dealing with the importation issue while reducing the cost of poultry production.

However, Malaysia has limited resources of grain corn varieties to be grown commercially to support the industry. In short terms approach, introducing commercial varieties with good yield and high adaptability to the climate is necessary to ensure the profitability of grain corn production successfully grown by Malaysian farmer. Hybrid varieties are mostly preferred and widely used by farmers due to their superior characteristics, high yield, pest and disease resistance, and adaptability to various climates. Most genotypes respond differently to environmental conditions such as temperature, total rainfall and water storage in the soil. Simon et al. (2023) reported that the yield potential of hybrids and the yield quality are correlated and strongly influenced by environmental factors.

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Maize growth is significantly influenced by climate factors such as temperature, rainfall and sunlight. Abnormalities of these conditions, such as imbalance in water availability and abnormal temperatures, may affect maize growth differently (Zang et al., 2022). Bonea and Urechean (2020) reported a strong positive correlation between rainfall and corn yield in Oltenia. Statistical studies have indicated that daily maximum temperatures above approximately 30°C limit maize yields (Lobell et al., 2011). Understanding the relationship of climatic changes at specific plant growing stages in grain corn is important for the best practice of good production in the specific region. Thus, this study aimed to identify a superior and stable hybrid for yield and adaptation to the MARDI Serdang environment.

2. MATERIAL AND METHODS

2.1 Planting material

This study utilized 13 commercial grain corn hybrids from four seed companies (Table 1). All these genotypes were selected for their high-yield characteristics, which were imported from Thailand, except for GWG888 and GWG5005, which were procured from a local grain corn seed company. The hybrid P4546 was employed as a check variety due to its superior yield and adaptability, as demonstrated in a previous study (Ghaffar, 2019). The remaining twelve hybrids were chosen based on the recommendations provided by the seed companies.

Table 1. List of tested grain corn commercial hybrids and their origin

No.	Hybrid lines	Country of origin	Seed producer
V1	P4546	Thailand	Pioneer
V2	P3875	Thailand	Pioneer
V3	P3582	Thailand	Pioneer
V4	P4554	Thailand	Pioneer
V5	P3537	Thailand	Pioneer
V6	P3136	Thailand	Pioneer
V7	GWG888	Malaysia	Green World Genetic Sdn. Bhd.
V8	GWG5005	Malaysia	Green World Genetic Sdn. Bhd.
V9	GT709	Thailand	Golconda
V10	GT722	Thailand	Golconda
V11	GT822	Thailand	Golconda
V12	DK9979C	Thailand	Mosanto
V13	DK9950C	Thailand	Mosanto

2.2 Experimental site

The field evaluation was conducted at Industrial Crop Research Centre plot, located within the Malaysian Agriculture Research and Development Institute (MARDI) in Serdang, Selangor, with coordinates 2.926361 and 101.696445. The assessment spanned two planting seasons: the first from July to November 2020 (Season 1) and the second from February to June 2021 (Season 2). Climate parameters for each season were retrieved by climate website Open-Meteo.com as presented in Table 2. The mean temperature for both seasons was within the normal range for Malaysia, at 23.2°C to 32.4°C. The recorded relative humidity ranges from 72.0-79.0%. Season 1 experienced higher rainfall with a total amount of 1514.3 mm, while season 2 recorded a lesser total amount of 1110.9 mm during the growing season. The data pattern is illustrated in Figure 1.

Table 2. Climatic data of two growing seasons for thirteen evaluated grain corn hybrids

Planting season	Planting period (Month)	Minimum temperature (°C)	Maximum Temperature (°C)	Relative Humidity (%)	Total rainfall (mm)
Season 1 (Year 2020)	July	23.3	29.9	77	401.1
	August	23.6	30.5	75	173.3
	September	23.4	29.9	73	305.5
	October	23.7	30.1	78	211.6
	November	23.4	29.3	79	422.8
Season 2 (Year 2021)	February	23.2	32.4	72	61.1
	March	23.3	31.5	73	251.8
	April	23.5	30.6	78	262.1
	May	23.9	30.3	79	291.2
	June	23.5	30.2	78	244.7

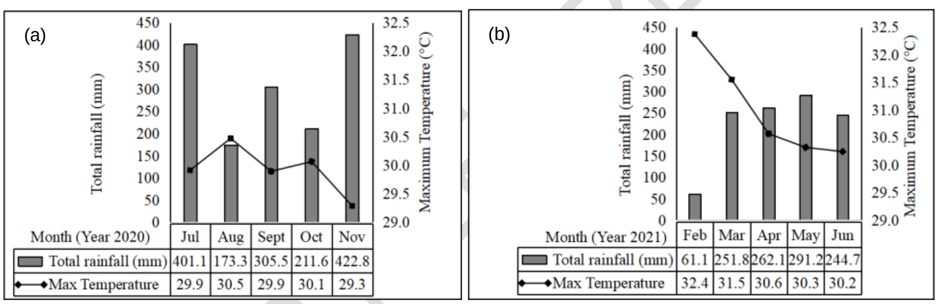

Figure 1. Total rainfall and maximum temperature pattern during (a) Season 1 (July-November 2020) and (b) Season 2 (February-June 2021)

2.3 Agronomic practices

The hybrids were evaluated using a Randomized Complete Block Design (RCBD) with three replicates. Each block consisted of seven rows, each row consists of 5.0 m long, and a 1.0 m gap between blocks. The plants were arranged with a plant distance of 75 cm between rows and 20 cm between individual plants. All agronomic practices were performed following MARDI's recommendations. A compound fertilizer NPK (15:15:15) was applied at 400kg/ha, and UREA was used for top dressing at 120 kg/ha at 30 days after sowing (DAS). Chemical spraying was employed to control pests and diseases in the affected plot areas. The cobs were harvested when the average moisture content dropped below 25% at 110-120 DAS.

2.4 Data collection

Collection data on agronomic traits were collected from a sample comprising five central rows in each plot, a strategy designed to minimize the impact of border effects. The recorded morphology parameters included the days to 50% pollen shed and plant height at maturity.

The duration of 50% pollen shed was calculated as the number of days from planting to the point at which half of the plants in a plot began tasselling. Data on yield components were also recorded from a sample of four plants chosen from each triangle of the plot. Parameters such as cob length (cm), cob girth (cm), weight of thousand kernel (g), and grain moisture (%) were measured. The Crop Cutting Test (CCT) method was employed to estimate the yield per hectare at 14% moisture content (MC) using the formula provided below:

CCT yield at (14% MC) kg/ha = [Total cob weight without husk (kg) x 1 ha]/CCT area (m^2)
which,
CCT area (sample size) = 2 m x 3.75 m (5 rows) = 7.5 m^2

2.5 Data analysis

All the data obtained were analysed using SAS Software Version 9.4 (SAS Institute Inc, 2016) for analysis of variance (ANOVA), and the means were separated using Duncan's Multiple Range Test (DMRT) analysis at a significant level of 1% and 5%.

3. RESULTS AND DISCUSSION

3.1 Effects of seasons and hybrids

The results of the combined analysis of variance (ANOVA) for thirteen evaluated hybrids in two planting seasons are summarized in table 3. The result shows that season was a significant factor affecting the performance of the evaluated hybrid, except for plant height and CCT yield traits. This indicates that the hybrids' flowering, cob and grain growth were influenced by the variability of the seasons. The different between tested hybrids were also observed significant differences in plant height, cob girth, thousand kernel weight, and CCT yield. This indicates that the hybrids evaluated considerably varied in morphological and yield performance across different seasons. Comparison hybrids however are depending on interaction between hybrids and seasons. In this study, significant interaction was identified for character the number of days to 50% pollen shed, plant height, and CCT yield. Therefore, comparing hybrids performance will be carried out in each season separately. Detail explanations will be presented in subtopic later.

Table 3. Analysis of variance (ANOVA) of seven traits for thirteen grain corn hybrids across two planting seasons

Source	d.f	Days to 50% pollen shed	Plant height (m)	Cob length (cm)	Cob girth (cm)	Thousand kernel weight (g)	Grain moisture (%)	CCT yield (kg/ha)
Season (S)	1	2208.0**	66.5ns	582.7**	0.6**	63469.6**	304.1**	53349.2ns
Hybrid (V)	2	4.3ns	1520.2**	6.8ns	0.1*	6808.0**	1.5ns	13741265.7**
S*V	12	7.9**	716.5*	6.4ns	0.1ns	1977.8ns	4.6ns	13050597.0**
Average		55.68	215.29	22.71	4.84	384.42	24.92	9722.02
CV%		3.04	8.26	8.92	4.51	11.23	6.55	17.99

Notes: ns = not significant; *significant at 0.05 probability level; **significant at 0.01 probability level

From the table, all genotypes performed with an average of 55.68 days after sowing to tasselling, achieved an average height of 215.29 m, 22.71 cm of cob length, 4.84 cm of cob girth, 384.42 g weight of thousand kernel, 24.92 % of grain moisture and 9,722.02 kg/ha of CCT yield. This result is approximately similar with result reported by Adham et. al (2022), plant achieved a mean plant height of 220.0 cm, 56.6 days of tasselling and approximately 9,000 kg/ha of yield across the different environments. All parameters showed a minimal CV value as below 20% which the selection process will be more accurate because external factors were minimal in influencing the data.

3.2 Comparison of plant performance among planting seasons

Table 4 shows the average morphology traits and yield performance of all the hybrids in each planting season. Hybrids in season 2 shed 50% of their pollen at 61.0 days which was later than in season 1 at 50.4 days after sowing. Environmental factors such as dry or sunny seasons could play a major role in influencing this delay flowering character. Zhong-Yang~~, C.~~ et al. (2024) discovered planting maize in hot subtropical monsoon regions exposes the plants to higher temperatures, which accelerates both vegetative and reproductive growth. However, it prolongs the vegetative-to-reproductive transition and reduces yield by decreasing grain number and/or weight. Shao et al. (2021) also found similar pattern that high treatment heat on maize before flowering damaged the anther structure caused the delaying of pollen shedding and was shortened the duration. Our meteorological data collected shown in Figure 1 has support this claimed. Hybrids planted in season 2 was found has a higher temperature and lower total amount of rainfall compared to season 1.

At 110 days after sowing, which was during the harvesting date, grain moisture content for season 1 was 22.94 %, which was lower than in season 2, with grain moisture content of 26.89%. Higher moisture content in season 2 describes a higher thousand kernel weight since the cob was harvested during the rainy season. The moisture might have contributed to the kernel weight at harvesting. However, hybrids in season 2 revealed a higher thousand kernel weight of 412.95 g compared to season 1 with the weight of 355.9 g. This result describes that those traits of hybrids were affected by the climatic factor over the season. However, the final CCT yield showed that there was no significant difference between season 1 and season 2 after drying to 14% of grain moisture.

Table 4. Comparison of means between planting seasons of five characters of thirteen hybrid grain corn genotypes

Season	Days to 50% pollen shed	Cob length (cm)	Cob girth (cm)	Thousand kernel weight (g)	Grain moisture (%)	CCT yield (kg/ha)
Season 1	50.4a	25.45a	4.93a	355.90b	22.94b	9719.7a
Season 2	61.0b	19.98b	4.75b	412.95a	26.89a	9724.3a

Means within a column followed by the same letters is not significantly different from one another (based on DNMRT at *P≤0.05*)

3.3 Hybrids performance over planting season

The mean of trait performances of the thirteen hybrids in comparison for both combined planting seasons are shown in Table 3. Cob girth among the hybrids varied between 4.67 cm to 5.08 cm. Hybrid P3582 was the biggest cob, and GWG888 was the smallest. Cob diameter is an important trait that contributes to grain corn yield. Big cob diameter responds to a higher thousand kernel weight. DK9979C hybrid achieved the highest CCT yield among the thirteen hybrids, with a yield of 11,829.00 kg/ha, big cob size, and high grain weight. Small cobs of hybrid GWG888 responded to low thousand grains weight. Thus, resulting this GWG888 hybrid for the lowest CCT yield among the hybrids tested. It also was proved from the Table 7 that cob diameter was significant positively associated with CCT yield for both planting seasons. It was similar performance of the same pattern result revealed by Azam et al. (2014) that cob diameter was significantly positively correlated with grain yield/plant.

Table 5. Mean comparison values of four characters for thirteen hybrid genotypes across two planting seasons

Hybrid	Cob girth (cm)	Thousand kernel weight (g)	CCT yield at 14% MC (kg/ha)
P4546	4.85a-d	380.67b-d	10450.00a-c
P3875	5.02a-c	369.50b-d	9942.16a-c
P3582	5.08a	393.33bc	8432.30c-e
P4554	5.03ab	388.67bc	10495.00a-c
P3537	4.81a-d	328.00d	10064.00a-c
P3136	4.72c-d	352.00cd	9478.02b-d
GWG888	4.67d	357.33cd	6480.55e
GWG5005	4.75b-d	403.33bc	11594.00ab
GT709	4.81a-d	390.67bc	10746.00ab
GT722	4.75b-d	360.67b-d	9712.25a-c
GT822	4.80a-d	462.67a	9760.94a-c
DK9979C	4.91a-d	392.00bc	11829.00a
DK9950C	4.76b-d	418.67ab	7402.56de

Means within a column followed by the same letters are not significantly different from one another (based on DNMRT at $p \leq 0.05$)

3.5 Comparison performance with the interaction between genotype and planting season

From Table 3, three traits, including days to 50% pollen shed, plant height, and CCT yield, show significant differences in the analysis of variance for the interaction between hybrids and planting seasons. Therefore, the mean between hybrids must be compared in each planting season separately.

For the trait days to 50% pollen shed, significant differences between hybrids were observed in planting season 2 but not in season 1. P3537 was found to be the earliest hybrid, which took only 49.6 days and 59.0 days to produce 50% pollen shed in both seasons, season 1 and season 2, respectively. This variety can be classified as an early flowering type if compared to variety check P4546, which took longer to produce 50% pollen shed.

Table 6. Mean comparison value of performance among thirteen grain corn hybrids

Hybrids	Days to 50% pollen shed		Plant height (m)		CCT yield (kg/ha)	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
P4546	50.00a	61.67a-c	226.00a	231.50ab	10086.0a	10814.0a-c

P3875	51.33a	60.00bc	213.92a-c	244.33a	8781.0a	11104.0ab
P3582	50.00a	63.00ab	233.50a	201.5b-d	9452.0a	7412.4c
P4554	50.00a	59.00c	220.92ab	226.92ab	9540.0a	11450.0ab
P3537	49.67a	59.00c	221.17ab	229.50ab	8745.0a	11383.0ab
P3136	49.67a	63.00ab	240.00a	230.92ab	9796.0a	9160.1bc
GWG888	49.67a	63.00ab	213.58a-c	192.92cd	8682.0a	4279.2d
GWG5005	49.67a	60.33a-c	185.25bc	215.17a-c	10591.0a	12596.0ab
GT709	52.00a	61.33a-c	179.08c	181.42d	11226.0a	8212.0ab
GT722	53.33a	59.00c	211.75a-c	204.50b-d	9026.0a	10266.0a-c
GT822	49.67a	60.33a-c	207.75a-c	204.42b-d	9628.0a	9894.1bc
DK9979C	49.67a	60.00bc	226.75a	238.25a	10049.0a	13609.0a
DK9950C	50.00a	63.33a	231.17a	185.50cd	10754.0a	4051.2d

Means within a column followed by the same letters are not significantly different from one another (based on DNMRT at $p \leq 0.05$)

For the plant height, most of the evaluated hybrids showed significant differences for each season, with an average height of 214.37 cm in season 1 and 216.22 cm in season 2. DK997C showed among the highest hybrids with a height of 226.75 cm in season 1 and 238.25 cm in season 2. However, GT709 was recorded as the shortest hybrid for both seasons, with a height of 181.42 cm in season 2 and 179.08 cm in season 1. Liu, W. et al. (2021) mentioned that maize height characteristics including plant height, ear height, and ear–plant height ratio were important in improving maize lodging resistance and increasing grain yields. However, the height of different hybrids in season 1 did not significantly impact the yield as in Table 7. Even the shortest hybrid, GT709, had a chance to gain the high CCT yield in season 1. It might be due to the suitable planting distance applied encouraging GT709 to have enough sun exposure interception suit with its height for undergoing the photosynthesis process, resulting in high yield.

For yield performance, only season 2 shows a significant difference in mean comparison for all hybrids. Interestingly, all hybrids performed with a similar yield performance in season 1. Hybrid DK9979C resulted in the highest CCT yield in season 2 with 13,609.00 kg/ha. However, there were no significant differences with other hybrids except P3136, P3582, DK9950C, and GWG888. This could be caused by climatic factors such as rain and temperature. This result proved that tested genotype response to climatic factors. DK9950C and GWG888 were the two hybrids not recommended to be planted during season 2 due to their low yield of 4,051.23 kg/ha and 4,279.20 kg/ha, respectively. Both hybrids showed more than a 50% decrease in yield in season 2 compared to season 1. From the table, most hybrids performed a higher yield during season 1, and the best hybrids recommended to be planted in the Serdang environment were DK9979C, GWG5005, P4554, P4546 and P3875.

Table 7. Genotypic correlations for agronomic and yield distributing characters in 13 grain corn genotypes during season 1 in July until November 2020 (above diagonal) and second season 2 in February until June 2021 (below diagonal)

Characters	Days to 50% pollen shed	Plant height (m)	Cob girth (cm)	Grain Weight (g)	Thousand kernel weight (g)	CCT yield (kg/ha)
Days to 50% pollen shed	1	-0.131	-0.219	-0.135	-0.032	-0.143
Plant Height (m)	-0.323*	1	0.373*	0.344*	0.090	0.100
Cob diameter (cm)	-0.348*	0.341**	1	0.694**	0.376*	0.414**
Grain Weight (g)	-0.453**	0.152	0.640**	1	0.612**	0.512**
Thousand kernel weight (g)	-0.008	-0.222	0.287	0.360*	1	0.390**
CCT yield (kg/ha)	-0.656**	0.630**	0.455**	0.537**	-0.006	1

* and ** significant at 0.05 and 0.01 probability level, respectively

Correlations among the five agronomic characters obtained from the field experiments in season 1 (above diagonal) and season 2 (below diagonal) are shown in Table 7. In the two seasons, a positive and highly significant correlation was found between CCT yield with cob diameter and grain weight. Other traits were also found to have significant correlation with CCT yield in season 1 was thousand kernel weight and plant height in season 2. In season 1, the correlation coefficient of grain weight with CCT yield were the highest (0.512**) followed by the association of cob girth and thousand kernel weight with CCT yield having r values of 0.414** and 0.390** respectively. Meanwhile in season 2, the correlation between plant height with CCT yield was the highest with r value of 0.630** followed by the association of grain weight and cob girth with CCT yield with 0.537** and 0.455** respectively.

4. CONCLUSION

Both planting seasons gave similar potential yields for overall hybrids tested, with an average yield of 9,719.7 kg/ha in season 1 and 9,724.3 kg/ha in season 2. However, the result revealed significant interaction between seasons and varieties for days to 50% pollen shed, plant height, and CCT yield describe which season affected the performance of some hybrids tested. Among the thirteen hybrid varieties, DK9979C, GWG5005, and P4554 were the most promising hybrids, which showed the best yield and were consistent over seasons, especially in fluctuated environment factors in the Serdang environment.

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