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Short communication

Evaluation of Yield Performance and Variation on its Adaptation-Related Traits of Hybrid Maize to Local Environment in Terengganu, Malaysia

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Abstract

The study evaluates the yield performance and adaptation-related traits of 16 hybrid maize to the local environment in Terengganu Malaysia. The seeds of 15 hybrid maize were supplied by CIMMYT (International Maize and Wheat Improvement Centre), Mexico and one commercial local hybrid maize (Sweet King) was used as a control. The soil type at the experimental area is BRIS Soil of Merchang series which represent most of the soil types in Terengganu Malaysia. Data recorded was time taken for the plant to produce male and female flower; plant and ear height; straw, ear, shell and grain dry weight; ear number; and ear length. Time taken to produce male and female flowers, plant and ear height, and ear length are significantly different among tested plants. Other plant traits and yield performance shows no significant different among tested plants. Overall, the local hybrid maize shows the best performance in term of time taken to produce male and female flowers and plant growth compared to other hybrid maize tested in this experiment. However, the traits and performance of hybrid maize A13 is comparable to the local hybrid. The correlation between plant traits are also varies. It can be concluded that hybrid maize A13 shows good performance at local environment and have a potential as commercial hybrid maize for cultivation in Terengganu, Malaysia.

***Keywords**: Hybrid maize, plant genotype, plant traits, yield performance.*

1. Introduction

Maize or corn (*Zea mays* L.) is cultivated globally, being one of the most important cereal crops used as a food for human nutrients and one of a basic element in animal feed [1]. Maize is also important as a raw material for fuel and manufacture of many industrial products [1]. Maize is the most important cereal crop worldwide followed by rice and wheat, based on a production amount of over 1.03 billion metric tons in 2017/2018 [2]. Malaysia currently imports 99% of its maize requirement as there is no commercial maize production for feed in Malaysia. In 2016/17, Malaysia imported 3.8 million tons of maize due to positive acceptance of U.S. maize among Malaysian feed millers [3]. Most of the maize variety planted in Malaysia is sweet maize and were only used as a human consumption. A small amount is cultivated for dry grain for own consumption as human food or for animal feed by rural population. In Malaysia, maize was considered as an instant cash crop and usually planted in rotation with other plants such as banana, sweet potatoes, pineapple and watermelon to complement farmer income. Based on data by Malaysia Department of Agriculture, cost of production for maize in Malaysia was US$84.00 per ton in 2012 [3]. Demand for maize has increased globally, and the outlook concerning whether future supply can meet the demand is uncertain. In Malaysia there is much concern over the steep increase in the price of imported grain maize. At present, with increasing industrial demand, it is necessary for the government to encourage farmers in maximizing the maize production.

Maize with desirable traits are a major contributing factor in grain yield per unit area and it's become the prime objective in the most breeding program. The traits such as grain yield, time taken to tasselling and to silking, tassel branches, plant height, ear height, leaf length, leaf width, leaf area, ear weight, grain moisture, kernel rows and kernel weight are important to consider in selecting the best genotype of maize for cultivation [4]. The hybrid maize with high yield production and short growth duration is considered as the best hybrid to cultivate. Hybrid maize was created by crossing, or breeding, two different inbred parent lines with desired characteristics to combine into a hybrid. To develop stellar seed performers is not an easy task. Researcher need to evaluate multiple generations of inbreeds and use computer networks and other technologies to help them select the best-performing plants. When an inbred exhibits genetic purity and consistently delivers high yield, it is identified as a potential parent. Tens of thousands of hybrid maize crosses are made every season, however, less than one percent of these hybrids will meet the requirements to be a commercial hybrid.

Maize requires abundant of readily available plant nutrients and soil reaction between 5.5 and 8.0 pH for best production. However, the type of the soil at most of the coastal area in Terengganu (67, 582.61 ha) is identified as BRIS soil (Beach Ridges Interspersed with Swales) [5], which is not really suitable for agriculture plantation. The suitability of soil is usually determined by the robust success of plant cultivated in the study area [6]. BRIS soil is a problematic soil and as such should be handle traditionally in terms of the physical capability classification, knowing very well the constraints like, limited ability to support crop growth, poorly

structured, low water retention, this is as a results of excessive accumulation of sediments and sand from undulating sea during the monsoon seasons that carries along coarse sand particles [6].
Hence, this study was initiated with the objectives of investigating the adaptability, variation of adaptation-related traits and correlation of yield and yield related traits of hybrid maize at the local environment of Terengganu. The result obtain can be used as a guide for the 'maize producer' to improve their maize hybrid for supply to the local farmer in Malaysia especially in BRIS soil area.

2. Materials and method

2.1. Hybrid Maize

Fifteen hybrids maize seeds supplied by International Maize and Wheat Improvement Center (CIMMYT), Mexico and one local hybrid maize (Sweet King) were used in the experiment (Table 1). The hybrids maize is given their special coding (Table 1) by CIMMYT and their parents are not known.

2.2. Experimental Design

Experiment was carried out in September 2013 and completed in January 2014 at the Universiti Sultan Zainal Abidin (UniSZA) Farm in Gong Badak Campus (5°24'07.9"N 103°05'00.5"E). The soils at the UniSZA farm classified as BRIS soil of Merchang series. The local temperature approximately 30°C with 70-80% humidity. The local maize hybrid (Sweet King) was used as a control in the experiment. Experiment was set up as Randomized Complete Block Design (RCBD). Plants were planted in three blocks with three replicates per maize genotype per block. Maize seeds were planted in planting holes made on beds with the distance between plants were 5 inches apart. Plants were watered daily, and weeding was done manually at each month interval. Fertilizer used was NPK Blue Special with the ratio of 12:12:17. Five grams of the fertilizer per plant were placed at the first month of planting, and second application was given two months after planting. The data obtained were (1) time taken for the plant to produce male flowers, (2) time taken for the plant to produce female flower, (3) plant height, (4) ear height, (5) ear weight, (6) ear length, (7) ear number and (8) total dry grain weight. All data on dependent variables were collected and recorded after four months of planting.

Table 1: List and specific code for hybrid maize used in the experiment.

Genotype	Specific Code
A1	(CLQ-RCYQ44/CLQ-RCYQ40)//(CLQ-S89YQ06/CML161)
A2	(CLQS89YQ06/CLQRCYQ58)//(CLQ-RCYQ44/CLQ-RCYQ40)
A3	(CLQRCYQ60/CLQRCYQ63)//(CLQ-RCYQ44/CLQ-RCYQ40)
A4	(CLQS89YQ06/CLQRCYQ58)//(CLQ-RCYQ49/CML165)
A5	(CLQRCYQ60/CLQRCYQ63)//(CLQ-RCYQ49/CML165)
A6	(CLRCY044/CLRCY038)//(CLRCY041/CL02450)
A7	(CLRCY044/CLRCY040)//(CLRCY041/CL02450)
A8	(CLQRCYQ49/CLQRCYQ59)//CL02450Q
A9	(CLQRCYQ49/CLQG2508)//CML165
A10	(CLQS89YQ06/CLQRCYQ58)//CML161
A11	(CLQS89YQ06/CLQRCYQ44)//CML161
A12	(CLQRCYQ60/CLQRCYQ63)//CML161
A13	(CLRCY041/CL02450)//CML451
A14	(CLRCY044/CLRCY038)//CL02450
A15	(CLRCY044/CLRCY040)//CL02450
A16	Sweet King (Local genotype)

To determine the best hybrid maize, we only gave the scores to the traits that shows significant different for all hybrid maize tested. The hybrid maize with the highest score were considered as the best maize genotype. The score given based on the sequence from the best to poorest according to the mean value of parameters measured. The best genotype in respective criteria were rate as 16 (as there are 16 type of hybrid seeds used in this experiment) and the poorest were rate as 1. Same score was given to the maize genotypes that have the similar mean value of the parameters. The scores for the all the dependent variables are shown in Table 3.

2.3. Statistical Analysis

Data was analysed using Unbalanced Incomplete Block Design as some replicates were gone due to the environmental stress. All independent variables were run by One-Way Analysis of Variance (ANOVA), except ear number in R Statistical Software [7]. The ear number was run by using Kruskal Wallis, a non-parametric method.

3. Results and Discussion

Result obtained shows the time taken by the maize plants to produce male flower was significantly difference among maize plant genotypes ($F = 7.275$, $P = 0.0001$) (Table 2). The first genotype that produce male flower is local sweet maize (46 days) followed by A13 (52 days); A12, A5, A1, A7, A3, A4, A6 (55 days); A14 and A15 (56 days); A10 (57 days); A9 and A11 (58 days). Genotype A2 was the last maize genotype to produce male flower (67 days) compared to another genotype. Similar to the production of male flower, the time taken by the maize plants to produce female flower also shows significant different among plant genotypes ($F = 5.958$, $P = 0.0001$) (Table 2). The local sweet maize was the first plant genotype to produce female flower (51 days) followed by A13 (57 days); A12 (58 days); A1, A7, A3, A4, A5 and A6 (59 days); A14 (60 days); A9 and A11 (62 days); and A8 (64 days). Genotypes A2 was the last to produce female flowers (71 days) compared to other genotypes.
The height of the maize plants was significantly difference among maize genotypes ($F = 6.361$, $P = 0.0001$) (Table 2). Plant of genotype A4 was the tallest (240 cm ± 0.50) compared to other genotypes, while the shortest was local maize genotype (151 cm ± 3.20). Further investigation revealed that the height of local maize plant (genotype A21) was significantly differed compared to at least half of the plant genotype tested (A9, A11, A12, A15, A3, A4 and A6). Similar to the plant height, there is also significant different among genotypes for maize ear height ($F = 9.929$ $P = 0.0001$) (Table 2). Genotype A4 has the highest ear (78.5 cm ± 7.5), while the lowest was shown by genotype A16 (37.6 cm ± 1.00). As the height of the maize ear is correlated to the plant height [8], we expected the height of maize ear for genotype A16 will also differ compared to other genotypes. Our result showed maize plant genotype A16 was significantly differed compared to genotypes A11, A12, A14, A15, A2, A3, A4, A6.
Contrary to the maize ear height, there is no significant different on the number of maize ear (chi-sq. = 14.6, $P = 0.621$) and maize ear weight ($F = 0.915$, $P = 0.555$) (Table 2) for all maize plant genotypes. However, at the end of experiment, genotype A11 produced more maize ear (1.75 maize ears per plant) and the least is genotype A5 (1.25 maize ears per plant). Genotype A1 has the highest ear weight (356.25 g ± 30.10) and the lowest ear weight was genotype A8 (220.66 g ± 25.43). There is significant different among genotype for the ear length ($F = 2.315$, $P = 0.007$) (Table 2). Genotype A7 has the highest ear length (23.05 cm ± 1.18). The shortest length was shown by genotype A8 (15.66 cm ± 1.10).
The grain dry weight produced by all plant genotypes shows no significant different ($F = 1.392$, $P = 0.164$) (Table 2). However, genotype A4 produced more grain (99.00 g ± 25.00) compared to other genotypes, while the genotype A8 (31.33 g ± 9.33) produced the least. Similar with above, the maize shell weight was not significant different among maize genotypes ($F = 1.397$, $P = 0.162$) (Table 2). Genotype A4 has the highest shell weight (132.00 gm ±

8.00). The lowest shell weight shown by genotype A11 (60.25 g ± 4.09).

The model genetic organisms are typically selected for their short generation time, small size, large number of progeny, and inexpensive maintenance [9]. In this study, our definition on the quality of plant was the faster the plant to produce flower, the better the genotype [9]. In this experiment, we found the local hybrid maize have produced both male (46 days) and female flowers (51 days) earlier than another hybrid maize. It's then followed by the hybrid maize genotype A13 at 51 days and 56 days respectively. The faster the plant to produce flowers, the quicker for the plant to reach their reproductive maturity, thus the time taken for the farmers to harvest the yield will be shorten. Plant that have rapid development to produce yield is the best since farmer don't need to wait longer to harvest the yield, thus they can grow the crops two or three times in a year. Farmers also can save a lot of money in pest and disease management since the shorter lifetime for the plants means the ability of these threat to achieve the minimum level of injury is reduce.

Plant height adaptations are essential to plant fitness and agricultural performance as they are intrinsic to the evolutionary history, standing diversity, and genetic architecture of a population, and impact the velocity of its evolution and response to breeders' selection pressures [10]. In our experiment, we classified the shorter the plant height as the better the plant genotype. This is because the height adaptations of the plant influenced the partition of carbon and nutrients between grain and nongrain biomass, and enhance fertilizer, pesticide, and water use efficiency [11]. In addition, the height of the plant may influence the attachment of the plant roots to the soil. Terengganu is located at the east coast of Malaysia where most of the soil is BRIS soil. The location of this state may expose the plants to the strong wind. The shorter the plant means the possibility of plant to fell off during the bad weather such as stormy or windy day will be reduced as plant roots attachment at the BRIS soil is not as good as laterite soil. In our experiment, we found the local hybrid maize (151.33 cm ± 3.20) is the shortest plant followed by hybrid maize genotype A13 (152.00 cm ± 4.72). The height of the local hybrid maize was classified as acceptable and is suitable for the cultivated maize.

Table 2: Summary of the effect of hybrid maize genotype differences on the plant traits.

Dependent Variables		Df	Sum sq	Mean sq	F value	Pr (>F)
Time taken to produce male flower (Day)	Genotype	15	1590	106.00	7.275	0.0001
	Residual	87	1268	14.57		
Time taken to produce female flower (Day)	Genotype	15	1411	94.05	5.958	0.0001
	Residual	87	1373	15.78		
Plant height (cm)	Genotype	15	42451	2830.0	6.361	0.0001
	Residual	87	38710	444.9		
Ear height (cm)	Genotype	15	15857	1057.1	9.929	0.0001
	Residual	87	9263	106.5		
Dry straw weight (g)	Genotype	15	25210	1681	1.175	0.307
	Residual	87	124492	1431		
Ear weight (g)	Genotype	15	122805	8187	0.9179	0.484
	Residual	87	727523	8362		
Ear length (cm)	Genotype	15	229.2	15.28	2.315	0.007
	Residual	87	574.2	6.60		
Grain dry weight (g)	Genotype	15	14156	943.8	1.446	0.145
	Residual	87	56797	652.8		
Shell weight (g)	Genotype	15	34308	2287	1.472	0.134
	Residual	87	135201	1554		

The higher the ear height is better and shorter ear heights are generally not desirable [12]. This is because the problem of crowded canopy, aeration and low transmission of sun light to the lower parts may result in drastic reduction in yield [13]. However, the ear placement at a greater height from the ground level is also undesirable since it may exerts pressure on plants during grain filling and physiological maturity and may cause lodging, which could ultimately affect the final yield [14]. In this study, the maximum height of ear placement is at 78.5 cm which can be considered as acceptable and at the good height, while the lowest was at 37.6 cm which is too low.

The heavier the plant straw weight mean the healthier the plant. The growth of the maize plant is influenced by the nutrient uptake that is available in the soil [15]. BRIS soil is always considered practically worthless for agricultural purposes [16] as this type of soil has less nutrient content [6]. As a result, it will affect the plant growth and development. Our result shows there is no significant difference in term of straw weight between hybrid maize tested in this study. We also found there is no significant difference on the ear length and shell weight of the hybrid maize tested. The longer the ear length and the heavier the shell, the better the plant. Both plant trait influenced the yield of maize [17]. The most important characteristic evaluated in this study is the grain weight as it is the important traits in choosing the best hybrid maize for cultivation. The heavier the grain weight per plant means the better the plant genotype as more yield can be harvested from the plant. The result obtained in this study shows there is no significant difference on the grain weight among hybrid maize tested. This result shows that the hybrid maize genotypes supplied by the CMIYYT can produce the yield as similar as the local hybrid.

Our calculation on the plant scores (Table 3) found that the local hybrid maize (A16) shows the best performance in the local environment. However, hybrid maize genotype A13 has a potential to replace the local hybrid maize as the scores obtained are comparable to local hybrid maize. The least is hybrid maize A8, where it shows the lowest scores compared to other hybrid maize.

Table 3: Scores of plant traits.

Genotype	Time taken to produce male flower (Day)	Time taken to produce female flower (Day)	Plant height (cm)	Ear height (cm)	Total scores
A1	10	11	10	6	37
A2	1	1	11	9	22
A3	8	8	2	13	31
A4	12	13	1	16	42
A5	14	11	13	5	43
A6	9	10	5	14	38
A7	11	8	9	15	43
A8	2	2	14	2	20
A9	3	3	4	12	22
A10	5	5	8	7	25
A11	4	4	6	10	24
A12	13	14	3	4	34
A13	15	15	15	3	48
A14	6	7	12	8	33
A15	7	6	7	11	31
A16	16	16	16	1	49

Result obtained showed time taken for the plant to produce male flower is strongly correlated to the time taken for the plant in producing female flower (Table 4). While correlation of these two variables with other variables are low (<0.40). Correlation of plant height are moderate (0.40 – 0.70) with straw dry weight and grain dry weight. There was strong positive correlation between plant height and ear height. This finding is in line with work of Yusuf [18] in which plant height is highly correlated with ear height, but contradictory to Sorsa and Kassa [19] research, where they found that plant and ear height showed negative correlation which is believed might be due to the stress condition (low rain fall). Correlation of ear height with other variables follows similar trend with plant height. There was low correlation of straw dry weight with total dry grain weight and shell weight.

Table 4: Correlation between parameters recorded.

No.	Dependent Variables	1	2	3	4	5	6	7	8	9	10
1	Time taken to produce male flower (day)										
2	Time taken to produce female flower (day)										
3	Plant height (cm)										
4	Ear height (cm)										
5	Shell weight (gm)										
6	Straw dry weight (gm)										
7	Ear number										
8	Ear weight (gm)										
9	Ear length (cm)										
10	Grain dry weight										

Note:

= Strong positive correlation where $r \geq 0.7$.

= Medium positive correlation where $0.4 \leq r < 0.7$.

= Low correlation where $-0.4 < r < 0.4$.

There was strong correlation between ear number and ear weight and medium correlation with grain dry weight and shell weight. There was low correlation of the former with other variables. For total ear weight, there was medium correlation with straw dry weight and maximum ear length. Low correlation was shown for the former with time taken for the plant to produce male and female flower, plant height and ear height. There was strong correlation of ear weight with grain dry weight and shell weight. For ear length, there was similar trend with the ear weight except medium correlation with ear weight and grain dry weight, and low correlation with ear number and shell weight. There was strong correlation between grain dry weight with ear weight, medium correlation with plant height, ear height, ear number, ear length and shell weight. There was low correlation with time taken for the plant to produce male and female flower and straw dry weight. For shell weight, low correlation was observed for time taken by the plant to produce male and female flower, plant height, ear height and total ear weight, while medium correlation was observed for ear number and grain dry weight.

4. Conclusion

This experiment was conducted to screen the suitable maize hybrid genotype supplied by CIMMYT that can be cultivated in Malaysia, particularly in the state of Terengganu. The plant was grown at the BRIS soil area in order to evaluate the performance and adaptability of those hybrid maize at the unfertile area. From the foregoing results and discussion of the experiment, hybrid maize genotype A13 was identified as the best hybrid maize genotype supplied by CIMMYT, that can be cultivated in Terengganu. This new hybrid maize can be planted by farmers to gain extra income, especially since these hybrids maize genotype is of grain type which can be used for animal feed.

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Table 4: Correlation between parameter recorded

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7	Ear number										
8	Ear weight (gm)										
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