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Performance, Heritability and Correlation Studies on Varieties and Population Cross of Sweet Corn

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Abstract: A breeding programme was initiated at University Putra Malaysia (UPM), aimed at combining good qualities from both genetic materials. Mains Madu, Hybrid SSC 240 and Hybrid 368 were first evaluated and compared for general performance. Fresh car yields of the three varieties were comparable (12304, 9733 and 9641 kg ha^{-1} for Manis Madu, Hybrid 240 and Hybrid 368, respectively), but plants of Manis Madu were significantly taller (169.5 cm) and tasseling (53.7 days) than the hybrid varieties. Broad-sense heritability estimates for traits measured on the varieties were moderate to high. Based on performance, Mains Madu and Hybrid Ssc 240 were selected as source populations for the succeeding study and were subsequently crossed. The resulting population was advanced by one generation of intermating and its performance was compared with those of the parental populations. The inermated population was highest for car height (67%) as opposed to those for other traits (between-11.1 to 39.7%). All the traits studied in the population cross were positively correlated with each other, with the highest being between plant height and number of leaves at 21 days after planting. The distribution of the individual plants in the population showed the tendency of values skewed towards the hybrid parent, SSC 240, for all traits except ear height, which showed a mid-way distribution between the two parents. It was suggested that more generations of intermating should be carried out on the population to allow free gene flow within the crossed population, before selection for superior individuals could be employed, for population improvement.

Key words: Performance, heritability, population improvement, sweet corn

Introduction

Sweet corn (*Zea mays* L. saccharata) cultivation in Malaysia utilizes both local open-pollinated composite varieties such as Mas Madu, Mains Madu, Thai Supersweet and Bakti-1, as well as imported hybrid varieties. Yields obtained from these composite varieties are however, moderate and of lower quality (Rahman *et al.,* 1987), while the imported hybrid necessary, to produce sweet corn varieties that are high yielding, possessing high eating quality and suitable for growing in the local environmental conditions. Sweet corn started to gain popularity in Malaysia since the early sixties with the introduction of the variety Chinta. Thereafter, many composite varieties of sweet corn had been introduced, developed and selected for local utilization (Rahman *et al.*, 1987).

As a further advancement in genetic improvement, a breeding programme as initiated at University Putra Malaysia aimed at combining the good qualities from both the local as well as imported sweet corn genetic materials, to produce high yielding varieties that possess good eating qualities and adaptable to the local environmental conditions (Saleh *et al.*, 1998).

This study was a part of the above-mentioned programme, conducted to identify potential foreign materials that can be utilized in the improvement programme of the local sweet corn varieties. All possible crosses among the varieties studied were made for further improvement strategies. In experiment 1, performance of the two imported hybrid varieties, Hybrid SSC 240 and Hybrid 368 was compared to that of a local composite variety. Manis Madu. Furthermore, the genetic variance components, broad-sense heritability and simple phenotypic correlations among the plant traits in the varieties studied were also investigated. Experiment 2 was conducted to compare the general performance of the intermated F_2 population of the cross with its two parental populations, Manis Madu and Hybrid SSC 240. Heritability of important traits, correlations among them within the populations and distribution of individual plants representing the three populations were also investigated.

Materials and Methods

The plant materials used in the experiments were one local open-pollinated composite variety, Manis Madu, two imported sweet corn F_1 hybrid varieties, Hybrid SSC 240 and Hybrid 368 and the intermated F_2 population derived from the cross between Manis Madu and Hybrid SSC 240. Experiment 1 was conducted in the period from July to September 1998, while experiment 2 from August to November 1999, both at field 2, University Putra Malaysia, in a randomized complete block design (RCBD). The replications were used in experiment 1, while four for were used in experiment 2. The planting density used was 0.75x0.25 m^2. Plot size was 4.00x3.75 m^2 in experiment 1 and 8.75x3.75 m^2 in experiment 2, each consisting of five rows of plants. Standard cultural practices were applied uniformly to all experimental plots. Hand pollination procedure described by Singh (1987) was used in making crosses and their reciprocals among the varieties involved in the study. Crosses between the local sweet corn composite variety, Manis Madu and the imported hybrid variety, SSC 240 were made to generate the base population for selection as the initial step in the breeding programme.

Data collected in experiment 1 include ear yield, plant height, ear height, number of ears ha^{-1}, days to tasseling, fresh ear weight, car length, ear diameter, number of kernels row^{-1} total soluble soils (TSS). In experiment 2, data collected were plant height at 21 days after planting, number of fully expanded leaves at 21 days after planting, ear height and length. Plant height and number of fully expended leaves at 21 days after planting, which were mainly used as indicators of plant vigour, were utilized as criteria in forming the base populations before selection was employed.

Data were analyzed using the SAS computer package (SAS Institute Inc., 1990). The analysis of variance (ANOVA) was used to determine the significance of variation among genotypes and among plants within genotypes. The Duncan's new multiple range test (DNMRT) was used to compare performance among genotypes.

In experiment 1, broad-sense heritability (h^2_B) values for various important plant traits in the varieties were estimated based on the variance components in ANOVA table using the formula described by both Singh and Chaudhary (1977) and Beeker (1984).

The h^2_B estimates in experiment 2 were calculated following the formula described by simmonds (1979) for data obtained from the intermated population cross as follows:

$$h^2_B = \frac{\text{Phenotypic variance-Environmental variance}}{\text{Phenotypic variance}}$$

$$h^2_B = \frac{V_{PC}-V_{SSC}\ 240}{V_{PC}}$$

where:

h^2_B = broad-sense heritability,

V_{PC} = variance within the intermated population cross and

V_{SSC} = variance within the parent, Hybrid SSC 240.

Hybrid SSC 240 was used to estimate the environmental variance because as an F_1 single cross hybrid, any variation among plants would be due to environmental effects.

Simple phenotypic correlations among the traits investigated were analyzed using the formula described by Gomez and Gomez (1984).

Results

Experiment 1: Performance of varieties: Mean squares from ANOVA showed that, the varieties evaluated were significantly different for plant height, ear height (both at $P \leq 0.05$). Mean squares of plants within varieties for the individual plant traits, viz. plant height, ear height, length, ear diameter and number of kernels row^{-1}, are presented in Table 1. Cutting across varieties, variation among plants within varieties was not significant for all traits, except ear diameter.

General performance of the local composite variety, Mains Madu and the two imported hybrid varieties, Hybrid SSC 240 and Hybrid 368 were showed that the ear yield, number of ears ha^{-1} and ear diameters of all the three varieties were comparable, as no significant difference among them, for these traits (Table 2). Ear yields revealed were 12304, 9733 and 9641 kg ha^{-1} for Manis Madu, Hybrid SSC 240 and Hybrid 368, respectively.

Manis Madu had plants significantly taller (169.5 cm) than did Hybrid SSC 240 (93.9 cm) and Hybrid 368 (92.3 cm). It also had plants with higher ear placement (92.2 cm), than did Hybrid SSC 240 (34.4 cm) and Hybrid 368 (34.9 cm). For ear length, Manis Madu gave significantly higher value 24.5 cm than Hybrid 368 21.3 cm, but not significantly higher than Hybrid SSC 240 23.2 cm (Table 2). Manis Madu had an average of 34.6 kernels row^{-1}, significantly higher than 29.6 and 29.0 revealed by Hybrid SSC 240 and Hybrid 368, respectively (Table 2).

The two hybrid varieties were significantly different from each other for days to tasseling, ear length and number of kernel rows ear^{-1}. Hybrid 368 was significantly earlier in tasseling, after 40.0 days compared with 45.3 days for Hybrid SSC 240. Both hybrid varieties also tasseled significantly earlier than Manis Madu, which tasseled after 53.7 days (Table 2).

Broad-sense heritability estimates were generally moderate to high for all traits. The highest estimate was shown by ear height (99.8%), while the lowest was revealed by ear diameter (61.9%). Fresh ear yield showed a comparatively lower estimate (77.9%) (Table 3).

Experiment 2: Performance of population cross: From results of ANOVA in experiment 2, significant effects of populations were found for ear height, ear length (both at

Table 1: Mean squares from ANOVA for plant traits measured on individual plant samples, on three sweet corn varieties

		Mean squares				
Source of variation	d.f.	Plant height	Ear height	Ear length	Ear diameter	Number of kernels row^{-1}
Blocks	2	237.78	148.92	1.60	17.53	7.14
Varieties	2	58289.60**	33133.89**	77.59	10.34	289.57*
Block x varieties (Experimental error)	4	226.91	60.77	6.07	3.95	24.03
Plants/variety)	27	137.63	81.18	3.37	1.31*	15.34
Sampling error	54	175.10	116.07	5.33	6.09	16.91
c.v. (%)		11.2	20.0	10.1	6.0	13.2

Table 2: Mean values for yield and plant traits measured on three sweet corn varieties

	Mean				
Variety	Ear yield (kg ha^{-1})	Plant height (cm)	Ear height (cm)	Number of ears ha^{-1}	Days to tasseling (days)
Manis Madu	12304a	169.5a	92.2a	54815a	53.7a
Hybrid SSC 240	9733a	93.9b	34.4b	53333a	45.3b
Hybrid 368	9641a	92.3b	34.9b	53333a	40.0c
Mean	10559	118.6	53.8	53827	46.3
c.v. (%)	11.7	4.0	4.6	1.4	1.8
	Ear weight (g)	Ear length (cm)	Ear diameter (mm)	Number of kernels row^{-1}	Kernel total soluble solids (%)
Manis Madu	224.4a	24.5a	41.7a	34.6a	18.8a
Hybrid SSC 240	182.5a	23.2a	40.7a	29.6b	17.7a
Hybrid 368	180.8a	21.3b	41.8a	29.0b	17.1a
Mean	195.9	23.0	41.4	31.1	17.9
c.v. (%)	11.3	3.4	1.5	5.0	4.6

Table 3: Genotypic and phenotypic variances and broad-sense heritability estimates for yield and plant traits measured on three sweet corn varieties

	Variance		
Trait	Genotypic	Phenotypic	Broad-sense heritability
Fresh ear yield	1779741.80	284461.26	77.9
Plant height	1935.42	1942.99	99.6
Ear height	1102.44	1104.46	99.8
Number ears ha^{-1}	548700.69	2284461.26	77.9
Days to tasseling	47.22	47.44	99.6
Ear weight	445.99	609.23	73.2
Ear length	2.38	2.59	92.2
Ear diameter	0.21	0.35	61.9
Number of kernels row^{-1}	8.85	9.65	91.7
Total soluble solids (TSS)	0.53	0.76	69.8

Table 4: Mean squares from ANOVA for plant traits measured on the intermated population and its parents, Manis Madu and Hybrid SSC 240

		Mean squares			
Source of variation	d.f.	Plant height[1]	Number of levels[1]	Ear height	Ear length
Replications	3	139.31	8.20	5166.75**	387.50
Populations	2	1373.76	65.68*	278348.04**	2617.06**
Replications x populations	6	284.38**	11.90**	1792.80**	11.49
Error	#	7.26	0.64	168.26	11.49
c.v. (%)		3.14	17.4	25.1	14.7

[1]Measured at 21 days after planting

\# due to unequal sample size, error degree of freedom for plant height at 21 days after planting=1428; and for ear length and ear height =1279

**,* Significant at p≤0.05, respectively

Table 5: Mean values for plant traits measured on the intermated population and its parents, Manis Madu and Hybrid SSC 240

Plant trait	Plant height[1]	Number of levels[1]	Ear height	Ear length
Intermediate population	7.4c	4.4b	46.2b	21.7b
Manis Madu	10.5a	5.0a	79.0a	25.9a
Hybrid SSC 240	7.9a	4.4b	29.8c	21.6b
Mean	8.6	4.6	51.7	23.1

[1]Measured at 21 days after planting

Mean values followed by the same letter in the same column are not significantly different at p≤0.05 based on DNMRT

Table 6: Phenotypic variances (Variances within intermated population), environmental variances (variances within Hybrid SSC 240) and broad sense heritability estimates for plants traits measured in the study

	Variance		
Plant trait	Intermated population	Hybrid SSC 240	Broad-sense heratability (%)
Plant height[1]	8.24	5.90	28.4
Number of levels[1]	0.72	0.80	-11.1
Ear height	184.76	60.34	67.3
Ear length	13.74	9.66	29.7

Table 7: Simple phenotypic correlation coefficients among plants traits measured on the intermated population

Plant trait	Plant height[1]	Number of leaves[1]	Ear height
Number of leaves[1]	0.71**		
Ear height	0.44**	0.32**	
Ear length	0.23**	0.16**	0.40**

[1]Measured at 21 days after planting

** Significant at p≤0.01

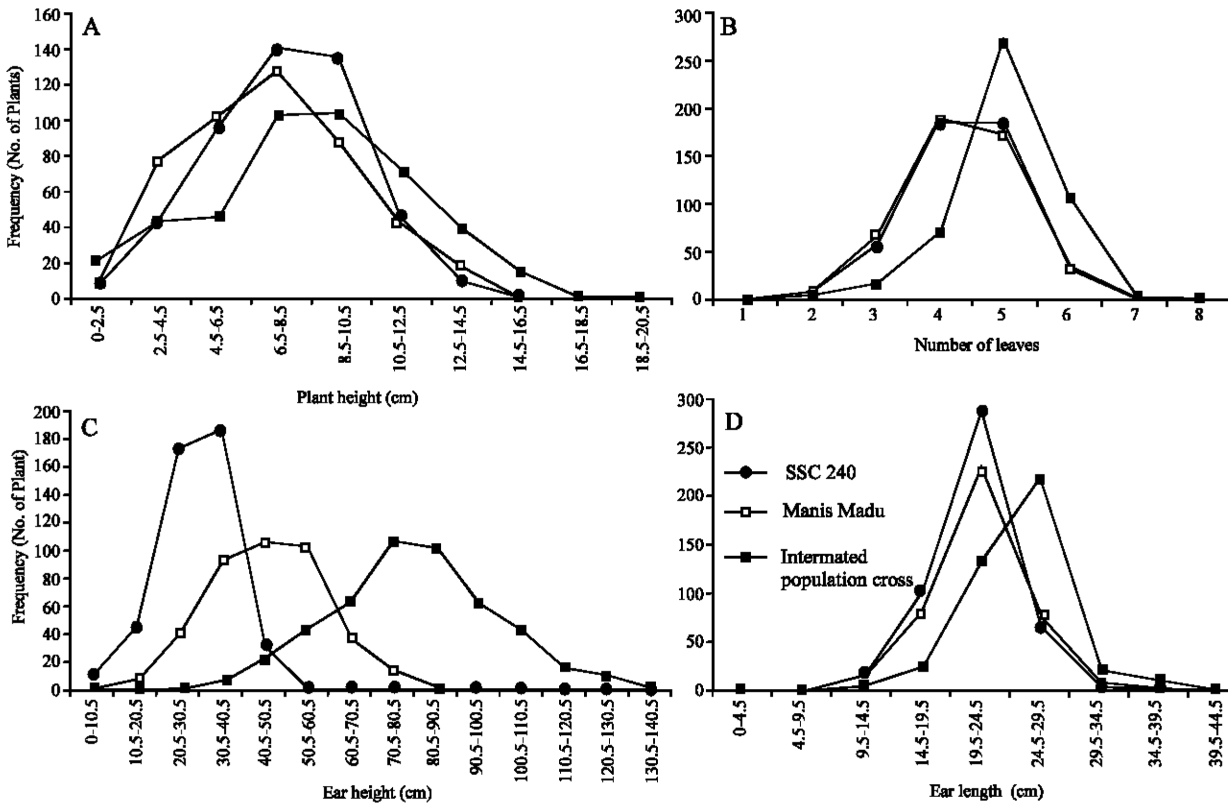

Fig. 1: Distribution of individual plant performance for plant height at 21 days after planting (A), number of fully expanded leaves at 21 days after planting (B), ear length (D), measured on intermated population cross and its parents, Mains Madu and Hybrid SSC-240

P≤ 0.01) and number of fully expanded leaves P ≤ 0.05), but no significant effect was observed for plant height at 21 days after planting (Table 4).

Comparing mean values for plant traits (Table 5), the population cross was found to have plant height at 21 days after planting (7.4 cm) lower than both parents, Manis Madu (10.5 cm) and SSC 240 (7.9 cm). The mean values for number of leaves and ear length between the population cross and Hybrid SSC 240, were similar, with both measuring 4.4 for number of leaves and 21.7 and 21.6 cm, respectively for ear length. For ear height, the population cross showed an intermediate value (46.2 cm) between the parents, Manis Madu (79.0 cm) and SSC 240 (29.8 cm). For all traits, Manis Madu produced highest mean values.

The ear height was found to reveal the highest broad-sense heritability estimate (67.3%) in the intermated population, whereas plant height at 21 days after planting and ear length showed moderate heritability estimates (28.4 and 39.7%, respectively). The number of fully expended leaves at 21 days after planting revealed a negative broad-sense heritability estimate (-11.1%) and thus, considered zero (Table 6).

Simple phenotypic correlation coefficients among the four traits showed significant positive correlations with each other (Table 7). Plant height at 21 days after planting in the intermated population cross gave the highest correlation with number of fully expanded leaves at 21 days after planting (r=0.71). The lowest correlation was seen between the number of fully expanded leaves at 21 days after planting and ear length (r= 0.16) (Table 7).

The distribution of individual plant values for the four traits studied within the population cross and the two parents separately is shown in Fig. 1. The population cross showed distribution of individual plant values intermediate between the two parents only for ear height (Fig. 1C), while for the other three traits, the distribution was shewed more towards the values of the hybrid parents. Hybrid SSC 240.

Discussion

Performance of varieties: Results of ANOVA in experiment 1 indicated that the individual varieties had plants that were quite uniform in plant height, ear height, ear length and number of kernel row^{-1}, but less uniform for measurements of ear diameter.

Fresh ear yields, revealed by the two imported hybrid varieties were comparable to that reflects their high potential to be exploited further in the breeding programme of local sweet corn. This could also justify for their use as germplasm sources in crosses made between them and the local composite variety, Mains Madu, to combine the good qualities from both materials.

Among varieties, taller plants were generally later flowering, while shorter ones were associated with early flowering. This was observed in comparing Manis Madu with the two imported hybrid varieties.

As the significant difference shown in ear length between the two hybrid varieties was not reflected in the number of kernels row^{-1}, Hybrid SSC 240 could be said to have longer blank tips than Hybrid 368. Furthermore, the fact that Hybrid SSC 240 had higher number of kernel rows ear^{-1} than Hybrid 368 but not for ear diameter, could be attributed to Hybrid 368 possessing thicker huck or comparatively bigger kernels, if the empty cob diameter remained the same for both hybrid varieties.

Plant traits studied showed moderate to high broad-sense heritability estimates, indicating that expression of these traits were sufficiently heritable. The broad-sense heritability estimates revealed in this study were in agreement with those obtained by Rafii *et al.* (1994) and Saleh *et al.* (2003), where yield and its components showed lower h^2_B than other growth characters like plant height, ear height and flowering traits.

Performance of population cross: Results of mean comparisons in experiment 2 reflect that, heterosis for plant height was not maintained in the population cross, as its mean value was significantly lower than those of both parents. Ear height measured on the population cross revealed complete co-dominant gene segregation for the trait. Traits with moderate to high broad-sense heritability in the population cross include plant height, ear height and ear length, indication that these traits were highly influenced by environmental factors. Results also showed that traits measured in the intermated population cross were significantly positively correlated and were in agreement with those reported by Saleh *et al.* (2002).

In the distribution of individual plant values for the traits investigated within the population cross and its two parents, Manis Madu and Hybrid SSC 240, the population cross had revealed an intermediate trend between the two parents only for ear height, while for other traits, the distribution was skewed towards valued of the hybrid parent SSC 240. This might have been due to the effects of linkage between the alleles responsible for the expression of these characters with alleles responsible for traits possessed by Hybrid SSC 240, or due to more dominant genes associated with the traits are possessed by Hybrid SSC 240.

Although the two imported hybrid varieties, Hybrid SSC 240 and Hybrid 368 were less adaptable to the local conditions, they have exhibited promising yield and yield components, comparable to those of the local well adapted composite variety, Manis Madu. This gives an indication that they possessed many additive and non-additive genes that can be further exploited in the local improvement programmes. They were found suitable to be used as genetic sources for breeding efforts to be undertaken, particularly for establishing base populations after recombination with the local population, Manis Madu. Special features of the hybrid varieties that could be exploited are earliness and shortness of the plants. As the population cross showed more resemblance to the hybrid parent, more generations of intermating would be required to break any linkage blocks associated with genes possessed by the hybrid parent, in order to give a better chance for gene recombinations in further improvement procedures planned.

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