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Performance, Correlation and Heritability Studies on Selected Sweet Corn Synthetic Populations

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Abstract: Nine advanced selected synthetic populations and a check variety of sweet corn were used to compare the performance among populations, to determine correlations between important traits in the populations, and to estimate a broad-sense heritability of the traits. The populations showed a wide range of performance in fresh ear yield and other traits and yield components measured. The potential of two populations, MMX368NS and P368 was revealed, and could be short-listed for further testing and selection before release as new varieties. Population MMX368NS, in particular possessed high ear yield of 8750 kg/ha, high number of ears per hectare, moderate plant height, moderate maturity, superior ear measurements as yield components and moderate brix content. Number of ears per hectare, ear weight, ear length and number of kernels per ear row were found to be most correlated with ear yield, while plant height, days to tasseling and ear length were the traits found to be most heritable in these populations of sweet corn. This information would be greatly useful to help breeders in making appropriate selection in genetic improvement of tropical sweet corn populations.

Key words: Sweet corn, *Zea mays* L., breeding, performance, correlations, heritability

Introduction

Sweet corn (*Zea mays* L) is a popular crop in Malaysia, planted for fresh consumption and canning. It has a stable market and consistent demand in the country. However, due to low productivity and yielding capability of the available varieties, the local production of sweet corn does not meet the market demand, and as a result, a significant amount is still imported, particularly from Taiwan, Thailand and Australia (Khairool, 1992).

The local sweet corn production has recently increased, due to the utilization of superior imported hybrid varieties. The production figures have increased from 44,521 m. ton in 1995, to 50,247 m. ton in 1996, and to 56,807 m. ton in 1997. The local growing of sweet corn is greatly dependent on the use of imported hybrid varieties as seed sources because the local open-pollinated composite varieties, such as Manis Madu, have low eating quality. The use of imported hybrid varieties have resulted in high import bills for the seeds. Unlike the local composites, the imported varieties are however very sensitive to environmental stress, and their yields were found to have been badly affected by even slight environmental limitations like soil factors, water stress and pest and disease conditions (Saleh, 1998a). It is therefore essential to develop local hybrid or synthetic varieties that are not only uniform and high yielding, but also posses high eating quality and able to tolerate local environmental stresses on local growth conditions (Saleh, 1998b). The exploitation of heterosis in local maize breeding has been widely documented (Saleh et al., 1994; Saleh and Sujiprihati, 1997), although not much in sweet corn.

An extensive sweet corn breeding programme is currently on-going at University Putra Malaysia, aimed at producing local superior hybrid and synthetic varieties. Advanced breeding populations have been developed from sources obtained locally as well as imported germplasm. A series of improved selected populations have resulted, where further testing for performance is required to aid in subsequent selection programmes. The present study is part of the ongoing programme of testing of the developed advanced populations. The aim of the study were to compare performance of a series of nine advanced populations developed from the local breeding programme and a local open-pollinated composite as control, to estimate heritability of some of the important plant traits in the populations, and to determine correlations among those traits.

Materials and Methods

Location of study: The study was conducted at the University Research Park's Research Plot, University Putra Malaysia in the year 2000 and 2001.

Plant materials: This study was an advanced stage of a long-term sweet corn hybrid and synthetic variety development programme conducted at University Putra Malaysia, Serdang, where a series of advanced populations have been developed and selected. Based on the previous evaluations, the nine best performing synthetic populations involving various genetic backgrounds and a local open-pollinated composite variety, Manis Madu, were used as plant materials in this study. The populations were P368, P240, PA1, HY18, 368I2, 240I2, 368X240, MMX240S, MMX368NS and variety Manis Madu as control.

Experimental design and plot arrangements: The evaluation was carried out in a randomized complete block design, with three replications. Each replicate consisted of 10 plots, each represented by a population. Each plot measured 5.0 x 3m². The planting density used was 0.75 x 0.25m². Every plot consisted of four plant rows, each five metres in length, giving a total of 20 plants per row, and 80 plants per plot.

Cultivation practices: Before planting, the soil was ploughed twice to a depth of 15 to 30 cm, followed by rotorvation. The soil pH was raised from 5.5 to 6.5 by applying Ground Magnesium Limestone before rotorvation. Planting was done manually, at the rate of two seeds per point, and plants were later thinned to just one per point at 10 days after planting. Fertilizer at the rate of 160 kg/ha N, 100 kg/ha P_2O_5 and 100 kg/ha K_2O was given in split applications, where the balanced compound fertiliser (15:15:15) was used at seven days after planting, followed by Urea (46% N) at 20 and 35 days after planting. Weeds were controlled manually using a pre-emergence herbicide, 'Lasso' (2-chloro-2'-6'-diethyl-N-methoxymethyl) and a post-emergence contact herbicide, 'Gramoxone' (1,1, dimethyl-dimethyl-4, 4'-bipyridinium). A sprinkler irrigation system was used to supply water to the plants when necessary.

Harvest and data collection: Data collected involved pre-harvest data including plant height at flowering, days to tasselling and silking, and harvest data including fresh ear yield, and yield components including number of ears per hectare, ear weight, ear length, ear diameter, kernel brix content, number of kernel rows per ear and number of kernels per ear row.

Fresh ears were harvested from each plot separately, at 21 days after plant tasselling. Two middle rows of each plot measuring four metres long, giving an area of 6.0 m², were used as the harvest area for yield and number of ears per hectare estimations. Among the plants in the harvest area, 12 plants were used as samples for the measurements of individual plant and ear data. In

cases where more than one ear were present on a plant, the largest ear was used.

Data analyses: Data were subjected to the analysis of variance (ANOVA) to determine the effects of the populations evaluated. The Duncan's New Multiple Range Test was used to compare mean performances among populations.

Relationships among all traits were computed using simple phenotypic correlation coefficients based on the formula:

$$r_{xy} = \frac{\sum [(x_i - \bar{x})(y_i - \bar{y})]}{\sqrt{[\sum (x_i - \bar{x})^2 \times \sum (y_i - \bar{y})^2]}}$$

where:

r_{xy} = correlation between the traits x and y,
x_i = variance of x_i, and
y_i = variance of y_i.

The SAS statistical computer package (SAS Institute Inc., 1990) was used for ANOVA and the correlation analyses.

Broad-sense heritability for the traits were estimated using the ANOVA components of variance procedure suggested by Singh and Chaudhary (1977), as follows:

$$h^2_B = \frac{\sigma^2_G}{\sigma^2_P}$$

where:

$$\sigma^2_G = \frac{(r\sigma^2_G + \sigma^2_e) - \sigma^2_e}{r}$$

$$= \frac{MS_G - MSe}{r}$$

$$\sigma^2_P = \sigma^2_G + \sigma^2_e$$

h^2_B : broad-sense heritability,
σ^2_G : genotypic variance,
σ^2_P : phenotypic variance,
σ^2_e : environmental variance,
r : number of replications,
MS_G : mean squares for populations,
MSe : mean squares for error.

Results and Discussion

Results from ANOVA showed that the populations differed significantly for fresh ear yield and all other traits measured, except ear diameter. This indicates that the populations evaluated varied substantially in many aspects, and these differences could be exploited for specific purpose in breeding programmes.

From separation of mean values indicated by DNMRT (Table 1), highest fresh ear yields were revealed by populations MMX368NS and P368, with yields of 8750 kg/ha and 7333 kg/ha, respectively, compared to just 5806 kg/ha produced by the control local open-pollinated variety, Manis Madu. The superiority of populations MMX368NS and P368 was also revealed by the high number of productive ears per hectare they produced, amounting to 43,889 and 41,111 ears per hectare, respectively, far higher than those produced by the control variety, Manis Madu (30,000 ears per hectare). There is therefore, a strong indication of the potential of these two populations for their utilisation towards production of a new variety, if further trials involving them in the future prove their consistent superiority for yield.

All tested populations were found to have plants significantly shorter than those of the control variety Manis Madu, which measured 177.3 cm (Table 1), although they also varied greatly with each other. This was a good indication of the outcome of the

breeding programme previously conducted on them, as shorter plants are preferred because they have low incidence of lodging. However, caution has to be addressed on this point because plants that were too short had low yields, as seen in the case of populations 368I2 and 240I2 (91.7 and 88.0 cm, respectively). This was also emphasized by Vera and Crane (1970), who reported that shorter plants had the tendency to produce smaller ears. The high yielding populations, MMX368NS and P368 were moderate and low in plant height, respectively, measuring 154.3 and 108.7 cm.

All the tested populations were also generally earlier in tasselling and silking, compared to the control variety, Manis Madu (51.3 and 55.3 days to tasselling and silking, respectively) (Table 1). The earliest in flowering was population HY18 (35.7 days to tasselling and 42.7 days to silking). The earliest flowering populations were however, were not the superior yielding populations, giving the indication that too early flowering varieties did not allow adequate amount of assimilate accumulation in the plants before they were turned into energy for yield production and grains filling. This was clearly seen on the two superior populations MMX368NS and P368 which were moderate in earliness of tasselling and flowering. Days to tasselling and silking were 42.0 and 48.0 days, respectively for MMX368NS, and 36.3 and 43.3 days, respectively for P368.

For yield components, the populations differed significantly for fresh ear weight and effective ear length, but not for ear diameter (Table 1). The high yielding population MMX368NS was found to have produced heaviest and longest ears, with average ear 203.4 g in weight and 17.0 cm in length, compared to 192.1 g and 15.5 cm respectively for the control variety, Manis Madu. The low yielding populations were seen to have lighter and shorter ears. This result indicates the importance of ear weight and ear length as yield components contributing to ear yield. The measurements for ear weight and ear length for the other high yielding population P368 were however, moderate.

The brix percentage, taken as a measurement of percentage of total soluble solids, indicating sweetness of the endosperm of the kernels, were found to greatly varied with populations (Table 1). The percent brix for population MMX368NS (14.0%) was comparable to that of Manis Madu (15.4%) the control variety which also gave the highest brix content, together with other populations such as MMX240S (15.0%) and 368X240 (14.0%). The brix for kernels produced by P368 was low (11.6%). These results have shown that brix content is an independent trait specific to populations, and not associated with the yield traits.

Results on simple correlation analysis among ear yield and other traits are presented in Table 2. Fresh ear yield was found to be highly positively correlated with number of ears per hectare, plant height, ear weight and ear length (with correlation coefficients of 0.80, 0.57, 0.83 and 0.81, respectively). This indicates that high measurements of these traits had direct positive contribution to ear yield, as clearly seen in the case of the superior high yielding population, MMX368NS which revealed high measurements for these traits as discussed earlier in Table 1. The indirect contribution of number of kernels per ear row to yield by increasing ear length is obvious, from the positive significant correlation of this trait with ear yield (r = 0.85). This was confirmed by the highly positive correlation of r = 0.90 between ear length and number of kernels per ear row. However, the correlation between ear yield with number of kernel rows per ear was also significant (r = 0.59), although ear diameter, the trait contributed by number of kernel rows per ear was found not significantly different among the populations as revealed in Table 1 earlier. Days to tasselling, days to silking, ear diameter and brix percentage in the populations were not correlated with ear yield. In a recent study on hybrid maize populations, Saleh *et al.* (2002) revealed similar positive correlations between ear yield and plant height. However, they reported contrasting result of negative correlations between ear yield and days to flowering and maturity. This difference was due to different populations used in the studies.

Table 1: Mean values for yield and other traits measured on 10 sweet corn populations

Population	Mean value								
	Ear yield (kg/ha)	Number of ears/ha	Plant height (cm)	Days to tasseling	Days to silking	Ear weight (g)	Ear length (cm)	Ear diameter (mm)	Brix (%)
P368	7333 ab	41111 ab	108.7 d	36.3 e	43.3 de	178.2 abc	15.8 abc	42.6 a	11.6 c
P240	6361 bc	36111 abc	106.7 d	39.0 cde	44.7 de	177.0 abc	16.6 ab	42.1 a	13.5 abc
PA1	3733 de	25000 e	101.3 d	39.0 cde	45.3 de	150.0 bcd	15.0 bc	40.5 a	12.2 bc
HY18	4917 cd	26666 de	106.0 d	35.7 e	42.7 e	185.8 ab	14.1 cd	38.7 a	13.0 abc
368I2	2528 e	27222 de	91.7 e	37.7 de	48.3 bcd	89.9 e	11.9 e	44.3 a	13.0 abc
240I2	2333 e	22500 e	88.0 e	43.5 bc	51.0 abc	104.0 de	12.4 de	32.2 a	13.9 abc
368X240	4417 cde	34444 bcd	102.7 d	40.7 cde	47.0 cde	128.1 cde	13.9 cd	38.2 a	14.0 ab
MMX240S	6139 bc	37222 abc	144.0 c	47.7 ab	53.0 ab	165.0 abc	15.6 abc	39.9 a	15.0 a
MMX368NS	8750 a	43889 a	154.3 b	42.0 cd	48.0 cd	203.4 a	17.0 a	44.5 a	14.0 ab
Manis Madu	5806 bcd	30000 cde	177.3 a	51.3 a	55.3 a	192.1 ab	15.5 abc	41.2 a	15.4 a
Overall Mean	5330	32758	119.1	41.2	47.8	159.2	14.9	40.7	13.5

Mean values followed by the same letter in the same column are not significantly different at p= 0.05, following DNMRT.

Table 2: Simple correlation coefficients among traits measured on 10 sweet corn populations

Traits	Ear yield	Number of ears/ha	Plant height	Days to tasseling	Days to silking	Ear weight	Ear length	Ear diameter	Brix	Number of kernel rows/ear
Number of ears/ha	0.80**									
Plant height	0.57**	0.35ns								
Days to tasseling	0.05ns	0.05ns	0.67**							
Days to silking	-0.14ns	-0.06ns	0.53**	0.94**						
Ear weight	0.83**	0.36ns	0.58**	0.05ns	-0.18ns					
Ear length	0.81**	0.60**	0.52**	0.12ns	-0.09ns	0.78**				
Ear diameter	0.35ns	0.34ns	0.10ns	-0.14ns	-0.20ns	0.30ns	0.40*			
Brix	0.15ns	-0.02ns	0.55**	0.61**	0.55**	0.22ns	0.05ns	-0.12ns		
Number of kernel rows/ear	0.59**	0.45*	0.46**	0.37ns	0.20ns	0.52**	0.52**	0.12ns	0.47**	
Number of kernels per ear row	0.85**	0.59**	0.74**	0.34ns	0.10ns	0.84**	0.90**	0.24ns	0.32ns	0.63**

**, *, ns : significant at *p*= 0.01, *p*= 0.05, and non-significant, respectively.

Table 3: Genotypic and phenotypic variances, and estimates of broad-sense heritability for yield and other traits measured on 10 sweet corn populations

Trait	Genotypic variance	Phenotypic variance	Broad-sense heritability (%)
Ear yield	3456681.00	4780908.00	72.3
Number of ears/ha	40907914.00	62646452.00	65.3
Plant height	842.83	871.24	96.7
Days to tasseling	22.82	29.51	77.3
Days to silking	14.82	21.62	68.5
Ear weight	1150.16	1818.86	63.2
Ear length	2.36	3.26	72.4
Ear diameter	-0.83	32.20	-2.6
Brix	0.88	2.31	38.1

Besides being associated with higher ear yield, populations with higher number of ears per unit area tended to be also associated with producing longer ears, as indicated by the significant correlation between number of ears per hectare and ear length (r = 0.60), and also number of kernels per ear row (r = 0.59). Number of ears per hectare was also found correlated with number of kernel rows per ear (r = 0.45). Other traits were found not to be associated with number of ears per hectare. Plant height was found to be highly positively correlated with ear yield all other traits except number of ears per hectare and ear diameter, indicating that plant height is a good trait to maintain in sweet corn breeding programmes, if not too extreme to an extent where lodging would result. This was seen on populations MMX368NS and P368, the two promising population, which possessed moderate plant height.

Days to tasselling and days to silking which were highly correlated with each other (r = 0.94), did not seem to be associated with yield or any other trait except plant height and percent brix. The highly significant positive correlation between these flowering traits with plant height and percent brix, indicates that populations with tall plants flowered and matured late to allow longer time for accumulation of total soluble solids which confers sweetness of the kernels. It is therefore, advantageous to have slightly late flowering and maturing populations as long as they could still capitalize on the optimum time for harvest. Higher brix content was also found correlated with ears having higher number of kernel rows, which could have some genetic bearing on the populations.

Populations with plants possessing heavier ears were generally those which produced plants with longer ears (r = 0.78), but not those with higher ear diameters (not correlated). Ear length was however correlated with ear diameter (r = 0.40). Both ear weight and ear length were significantly associated with number of kernel rows per ear and number of kernels per ear row. Ear diameter was surprisingly not correlated with number of kernels rows per ear, which could have been due to the fact that populations with higher number of kernel rows on the ears had smaller kernels, thus not contributing to any increase in ear diameter. As a possible genetic trait associated with populations, populations with ears having higher number of kernel rows were also those with higher number of kernels per ear row (r = 0.63).

Table 3 shows the broad-sense heritability estimates for the important traits measured from the populations. Plant height was found to be the most heritable trait in the population, with heritability estimate of 96.7%, followed by days to tasselling (77.3%) and ear length (72.4%). This indicates that selection for these traits in these populations would be most effective for the expression of these traits in the succeeding generations. However, from the previous discussion, among these three traits, only plant height and ear length were found significantly correlated with ear yield, the economic trait. The high heritability of ear length, added with high correlation with ear yield (r = 0.81) (Table 2) should be exploited in breeding and selection programmes for improvement of ear yield. Furthermore, the marketable products of fresh sweet

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corn are actually the fresh ears, and varieties with long ears are normally preferred and express quality of the product. This point was confirmed by the superior ear lengths possessed by MMX368NS and P368 (Table 1), the two promising populations identified earlier. Hallauer and Filho(1981) suggested that selection may be exerted on yield components indirectly, but however, such selection would be effective if the character used possesses high heritability compared with the primary one. In addition, the correlation between them has to be substantial.

Ear yield, number of ears per hectare, days to silking and ear weight had moderate heritability estimates (ranging from 63.2 to 72.3%), indicating that they were sufficiently heritable in populations. Brix percentage, as a quality trait which involves complicated genetic control involving various oligigenes, was found not to be an easy trait if selection for the trait is to be employed, as the heritability estimates revealed was low (only 38.1%). Therefore, strict caution should be applied if selection is to be done on this trait. This was even made more complicated by the absence of correlation between brix percentage and ear yield and other important traits in the populations, as discussed earlier (Table 2). On the extreme, ear diameter was found to be a non-heritable trait in the populations.

Rafii *et al.* (1994) in their estimation on the selfed populations of local sweet corn using the same ANOVA method, reported moderate broad-sense heritability values ranging from 42.6 to 65.7% for traits including ear weight, days to tasselling, ear diameter and plant height. Using the same method of estimation, but involving progenies of diallel crosses of sweet corn, Daniel and Batjay (1975) reported high heritability values of 83% for ear length and 81% for plant height. The variation in the results was due to different populations involved in the studies. In a recent study on local maize hybrids Saleh *et al.* (2002) reported generally low estimates of broad-sense heritability for most traits measured. The study has clearly revealed the potential of at least two of the advanced populations evaluated, MMX368NS and P368, for further testing, evaluation and selection before they could be released as new varieties. Population MMX368NS, in particular possessed high ear yield of 8750 kg/ha, high number of ears per hectare, moderate plant height, moderate maturity, superior ear measurements as yield components and moderate brix content. The superiority of this population might have been through the accumulation of desirable, highly heritable genes for traits directly correlated with its ear yield, such as ear length.

Number of ears per hectare, ear weight, ear length and number of kernels per ear row were found to be most correlated with ear yield, while plant height, days to tasselling and ear length were the traits found to be the most heritable in these populations of sweet corn. These information would be greatly useful to aid breeders in making appropriate selection in tropical sweet corn populations.

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