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Heterosis and combining abilities of 10 supersweet corn lines adapted to the humid tropics

(Heterosis dan keupayaan bergabung bagi 10 titisan jagung manis yang disesuaikan dengan kawasan tropika lembap)

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Key words: supersweet corn, standard heterosis, specific combining ability, general combining ability

Abstrak

Kacukan dialel 10 titisan induk jagung manis Thai Supersweet (TSS), tidak termasuk kacukan salingan dan induk, telah dianalisis bagi hasil tongkol basah, daun kulit pembalut, kadar penyakit, ketinggian pokok dan tongkol serta aspek tongkol. Perbezaan yang sangat ketara didapati dalam keupayaan bergabung am (GCA) dan keupayaan bergabung khusus (SCA) untuk daun kulit pembalut, kadar penyakit serta ketinggian pokok dan tongkol. Keupayaan bergabung am juga sangatlah ketara bagi aspek tongkol, manakala kesan SCA juga sangat ketara untuk hasil tongkol basah. Perbandingan nilai relatif kesan GCA dan kesan SCA menunjukkan nisbah nilai jumlah ganda dua GCA/SCA yang tinggi bagi kebanyakan ciri yang diselidiki melainkan hasil tongkol basah. Ini menunjukkan pentingnya gen tambah bagi kebanyakan ciri ini. Tambahan pula, enam gabungan hibrid F_1 menunjukkan kesan SCA yang amat ketara untuk hasil. Oleh yang demikian, gabungan ini merupakan gabungan yang terbaik untuk memajukan hibrid antara titisan.

Abstract

A 10-parent diallel cross, excluding reciprocals and parents, of sweet corn Thai Supersweet (TSS) lines, was analysed for fresh cob yield, husk cover, disease rating, plant and ear heights as well as ear aspect. Highly significant differences were observed among the F_1 hybrids in both general combining ability (GCA) and specific combining ability (SCA) effects for husk cover, disease rating as well as plant and ear heights. The GCA effect was also highly significant for ear aspect while the SCA effect was also highly significant for fresh cob yield. A comparison of the relative magnitudes of GCA and SCA effects showed high GCA/SCA sum of square ratios for most of the characters investigated, except fresh cob yield, suggesting the importance of additive genes for most of the traits. In addition, six F_1 combinations showed very highly significant SCA effects for fresh cob yield, thus representing the best combinations for developing interline hybrids.

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Introduction

Thai Supersweet (TSS) was the earliest, widely grown supersweet (with *shrunken-2* gene) corn grown in Malaysia since its introduction in 1980 (Lee et al. 1983). However, this supersweet corn variety is heterogenous for grain type, in particular kernel colour (Lee et al. 1986) . It has the sweetness and taste that is wanted, but its kernel colour varies from light yellow to orange. Ears with light yellow and soft-textured kernels are usually preferred by consumers. To obtain a supersweet corn variety acceptable to farmers and consumers, five cycles of mass selection for colour purification in Thai Supersweet had resulted in a superior yellow-kernelled supersweet population called Manis Madu (Lee et al. 1986). Subsequently, also with the purpose of developing more homogenous populations for kernel colour, an inbreeding programme was initiated. By 1989, through selection and elimination of unwanted lines, 26 S_7 inbred lines of TSS remained from the more than 300 S_0 lines originally selected. These 26 selected TSS lines were evaluated for their combining abilities in topcrosses against three top sweet corn varieties, namely Manis Madu, Masmadu and MS111C2. The evaluation resulted in the identification of 10 lines having high general combining ability values. This paper reports on the evaluation of these lines in crosses among themselves, as hybrids could be formed from inbred lines derived from the same population.

Materials and methods

Ten selected inbred lines, i.e. TSS 2, TSS 6, TSS 9, TSS 10, TSS 11, TSS 13, TSS 15, TSS 19, TSS 23 and TSS 28, were crossed among themselves in all combinations but without reciprocal crossing. The crosses were made in late 1991, and evaluated in early 1992. A 7 x 7 simple lattice design formed a replicate, and two replications were used in this study. Parental lines were not included as it would be more meaningful to compare the performance of the crosses to the base population from which the lines were extracted, i.e. Thai Supersweet composite, and the population developed locally from the latter, i.e. Manis Madu. In addition, Masmadu and MS111C2 were also included in the planting to fill up the two vacant plots of each replicate. The experimental plots were provided with supplementary irrigation throughout the experiment.

Each plot comprised two rows of 5 m long spaced 75 cm apart. The plants were spaced 50 cm apart within rows, and two seeds were sown per point. Hand weeding was carried out periodically to eliminate competition from weeds.

Data were recorded on plant and ear heights, effectiveness of husk cover rating (husks tightly covering the tip of ears are given a value of 1 while a badly exposed ear tip a value of 5 and intermediate values proportionally inbetween these two extreme ranges), ear aspect rating (a well-formed and fully filled ear is given a value of 1 while badly filled and deformed ear a value of 5), disease rating (generally free from diseases is given a value of 1 while badly infected with fungal and bacterial diseases a value of 5), and fresh cob yield (with husk removed).

For analytical purposes, data on the above plant characteristics are usually normally or nearly normally distributed around a mean, whether they are measured as continuous (plant and ear heights, and fresh cob yield) or as ranked continuous data (ear aspect, husk cover and disease rating). Thus, the data could be analysed by parametric analytical methods. Estimates of GCA (general combining ability) and SCA (specific combining ability) were calculated by Griffing's (1956) Method 4 (Model 1). The significance of the GCA and SCA effects was determined by an F-ratio of the respective estimates divided by the appropriate mean square error.

Results and discussion

Standard heterosis

In this experiment, heterosis is expressed as the percentage of improvement over either one of the two check varieties (standard heterosis as defined by Virmani et al. 1982). Fresh cob yields of the F_1 crosses varied from 3 872 to 10 831 kg/ha with a mean of 8 074 kg/ha. The results, as seen in *Table 1*, revealed that 49% of the F_1 crosses showed heterosis over either one or both of the check varieties and only 17% were clearly superior over both. With respect to Thai Supersweet composite, the F_1 crosses gave yields ranging from a decrease of 61.2% to an increase of 10.5%. Only six F_1 crosses were superior to this check variety. They were TSS 6 x TSS 10, TSS 9 x TSS 10, TSS 11 x TSS 28, TSS 13 x TSS 15, TSS 13 x TSS 23 and TSS 15 x TSS 19. Compared with the other check, Manis Madu, the F_1 crosses gave yields ranging from a decrease of 52.5% to an increase of 35.4%, where 20 crosses showed positive values in the comparison.

Combining ability analysis

Genetic analysis for fresh cob yield revealed SCA effects were highly significant but not GCA *(Table 2)*. Hence, non-additive genes were more important than additive genes in the genetic control of yield among the 10 lines. It can thus be inferred that these lines may not be useful for producing synthetic varieties, but there is certainly scope for producing hybrids which are dependent on non-additive genes for heterotic expression.

For the character, ear aspect, the GCA effect was highly significant but not SCA. As for the other characters, i.e. husk cover, disease rating, plant height and ear height, both the GCA and SCA effects were highly significant. A comparison of the relative magnitudes of GCA and SCA effects indicated that GCA was more important than SCA for all the traits except cob yield. The

Table 1. Performance of F_1 crosses expressed as percentage of increase or decrease of their yields over Thai Supersweet and Manis Madu for fresh cob yield

	TSS 6	TSS 9	TSS 10	TSS 11	TSS 13	TSS 15	TSS 19	TSS 23	TSS 28
TSS 2	–28.51[t] –12.39[*]	–27.03 –10.57	–40.45 –27.02	–19.18 –0.95	–24.71 –7.73	–20.49 –2.56	–1.05 21.26	–8.69 11.91	–0.01 22.45
TSS 6		–27.72 –11.42	9.34 34.00	–11.91 7.95	–25.99 –9.30	–54.28 –43.97	–24.03 –6.90	–23.71 –6.51	–10.51 9.68
TSS 9			6.81 30.90	–43.35 –30.58	–19.68 –1.56	–23.54 –6.30	–25.66 –8.89	–11.75 8.16	–38.68 –24.85
TSS 10				–47.47 –35.63	–36.14 –21.74	–12.55 7.17	–17.50 1.11	–1.48 20.73	–21.52 –3.82
TSS 11					–33.48 –18.47	–26.66 –10.12	–11.48 8.48	–10.38 9.83	2.13 25.16
TSS 13						6.50 30.52	–34.72 –20.00	8.43 32.89	–18.57 –0.20
TSS 15							10.50 35.42	–32.63 –17.44	–14.18 5.18
TSS 19								–15.74 3.26	–3.09 18.77
TSS 23									–61.21 –52.46

[t]top line, yield as percentage of Thai supersweet
[*]bottom line, yield as percentage of Manis Madu

Table 2. General combining ability and specific combining ability mean squares for fresh cob yield, husk cover, disease rating, plant height, ear height and ear aspect

Source	d.f.	Fresh cob yield	Husk cover	Disease rating	Plant height	Ear height	Ear aspect
GCA	9	519 512.89	0.465**	0.52**	579.41**	170.71**	0.677**
SCA	44	1 848 982.49	0.259**	0.32**	80.53**	50.28**	0.256
Error	36	596 557.02	0.108	0.15	33.03	20.39	0.226

*significant at the 0.05 level of probability
**significant at the 0.01 level of probability

Table 3. Estimates of general combining ability effects for fresh cob yield, husk cover, disease rating, plant height, ear height and ear aspect

Parent	Fresh cob yield	Husk cover	Disease rating	Plant height	Ear height	Ear aspect
TSS 2	36.97	0.075	–0.172	9.215*	6.315*	–0.063
TSS 6	–295.38	–0.113	0.319**	–3.361	–2.648	0.445*
TSS 9	–457.98	–0.425	0.774**	2.823	–4.372	0.335*
TSS 10	150.15	–0.175	–0.329	7.391*	3.918*	0.148
TSS 11	–349.96	0.013	–0.173	–4.879	–5.618	–0.489
TSS 13	–62.76	0.388**	0.075	–9.923	–1.054	–0.289
TSS 15	72.09	–0.238	–0.006	3.811*	5.515*	0.202
TSS 19	617.95	0.075	–0.296	6.571*	4.865*	0.003
TSS 23	196.79	0.200	0.041	5.248*	–3.422	–0.243
TSS 28	92.13	0.200	0.463**	–16.895	–3.498	–0.048
SE ($\hat{g}$i)	510.37	0.111	0.131	1.928	1.515	0.160

*significantly different from zero at the 0.05 level of probability

results emphasise the importance of additive genes in the genetic control of these characters, and this was also reported earlier by Yap and Tan (1973). Plant height, ear height and ear aspect displayed particularly high GCA/SCA ratios, suggesting that these traits might be effectively improved by recurrent selection methods.

The GCA estimates of the individual parental lines for yield and other traits are shown in *Table 3*. None of the parental lines gave a significant estimate of GCA effect for yield, reemphasising the relative unimportance of additive genes in yield determination. For characters other than yield, the GCA effects of a few parents were significantly different from zero. For husk cover, the GCA effect was significant only in TSS 13. For disease rating, the GCA effect was only significant in TSS 6, TSS 9 and TSS 28; for plant height in TSS 2, TSS 10, TSS 15, TSS 19 and TSS 23; and for ear height in TSS 2, TSS 10, TSS 15 and TSS 19. Lastly, for ear aspect, the GCA effect was only significant in TSS 6 and TSS 9.

The estimates of SCA effects for fresh cob yield, plant height and ear height are presented in *Table 4.* Referring to fresh cob yield, the SCA effects were significant in TSS 6 x TSS 10, TSS 9 x TSS 10, TSS 11 x TSS 28, TSS 13 x TSS 15, TSS 13 x TSS 23 and TSS 15 x TSS 19. As stated earlier, these F_1 hybrids gave yields comparable with the best composite variety, i.e. unimproved Thai Supersweet in small plot trials. Other characters of these crosses are

Table 4. Estimates of specific combining ability effects for fresh cob yield, plant height and ear height

	TSS 6	TSS 9	TSS 10	TSS 11	TSS 13	TSS 15	TSS 19	TSS 23	TSS 28
	–649.8[t]	–341.9	–2 265.7	319.9	–509.5	–231.1	1 128.2	801.2	1 748.7
TSS 2	17.3*	–3.3	–5.1	–6.5	–12.3	10.6*	3.5	3.5	–13.8
	11.6*	–9.5	–8.8	–3.4	–4.9	14.5*	–1.8	9.0*	–6.8
		–77.1	2 947.4*	1 364.0	–302.8	–3 210.8	–791.6	–339.2	1 060.0
TSS 6		–6.6	10.5*	–3.9	4.3	–7.3	1.7	–17.5	1.5
		–1.9	5.0	–4.3	–6.8	3.5	–8.8	–2.0	
			2 862.0*	–1 554.9	478.3	–35.0	–788.5	996.2	–1 539.1
TSS 9			–7.4	–7.4	21.3*	8.6	6.2	–5.4	–6.0
			1.3	–10.6	12.0*	6.8	9.7*	–6.9	–0.7
				–2 567.0	–1 743.2	434.3	–597.0	1 394.0	–464.8
TSS 10				1.6	–2.3	2.4	–2.9	9.5	–6.3
				1.2	–1.6	–2.2	–3.2	8.5	–0.2
					–981.3	–449.1	492.8	1 022.4	2 353.1*
TSS 11					–3.6	–6.7	2.6	8.1	9.8
					8.9*	–5.0	5.2	–1.0	9.1*
						2 514.3*	–2 072.1	2 579.1*	37.2
TSS 13						–9.3	–5.2	6.8	0.3
						–6.3	–1.9	–0.8	1.4
							2 225.7*	–1 580.7	332.6
TSS 15							0.3	–3.6	4.9
							1.3	–7.1	–5.3
								–471.4	873.9
TSS 19								–8.6	2.4
								0.5	–0.9
									–4 401.6
TSS 23									7.2
									–0.1

Standard error	Fresh cob yield	Plant height	Ear height
SE (Sij)	900.21	5.069	3.983
SE (Sij – Sik)	1 350.31	7.603	5.974
SE (Sij – Skl)	1 250.15	7.039	5.531

[t]top line, fresh cob yield, middle line, plant height, bottom line, ear height
*significantly different from zero at the 0.05 level of probability

also within acceptable levels *(Table 5)*. These six combinations, therefore, represent the best for developing interline hybrids, and their potential in larger plots is being investigated. Additionally, these lines could be used for developing hybrids by crossing with distantly related inbreds currently being developed. Initial observations showed that these potential hybrids have good qualities, i.e. light yellow kernel colour, high sugar content and good kernel texture, all of which are constantly searched for in new breeding materials. Accordingly, these quality characteristics will be reconfirmed in future large-scale evaluations.

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Table 5. Yield and some agronomic characteristics of Thai supersweet interline hybrids

Entry	Yield (kg/ha)	Plant ht. (cm)	Ear ht. (cm)	Ear aspect	Husk cover	Disease rating
TSS 6 x TSS 2	7 600	206.7	115.5	2.44	1.50	2.83
TSS 9 x TSS 2	8 200	192.3	92.6	2.25	1.51	2.66
TSS 9 x TSS 6	7 167	176.4	91.2	2.59	1.50	2.66
TSS 10 x TSS 2	6 587	195.1	101.6	2.50	1.01	1.83
TSS 10 x TSS 6	11 067	198.1	106.5	2.50	2.01	1.95
TSS 10 x TSS 9	10 067	186.3	101.0	2.13	1.00	1.89
TSS 11 x TSS 2	7 667	187.4	98.4	0.84	1.00	1.43
TSS 11 x TSS 6	9 080	171.3	87.6	1.72	1.50	3.28
TSS 11 x TSS 9	6 160	174.1	79.5	2.41	1.49	2.60
TSS 11 x TSS 10	6 120	187.6	99.7	1.53	2.49	1.72
TSS 13 x TSS 2	7 760	170.5	100.5	1.85	2.50	2.00
TSS 13 x TSS 6	7 027	174.6	89.7	2.06	2.00	2.11
TSS 13 x TSS 9	8 053	197.7	106.7	2.47	1.51	2.07
TSS 13 x TSS 10	6 374	178.7	101.5	2.09	1.51	2.28
TSS 13 x TSS 11	6 294	165.1	102.4	1.94	2.99	2.22
TSS 15 x TSS 2	8 000	207.2	126.5	1.91	1.99	1.22
TSS 15 x TSS 6	5 387	176.7	106.5	3.16	0.99	2.43
TSS 15 x TSS 9	6 134	198.8	108.1	2.84	1.00	1.89
TSS 15 x TSS 10	8 400	197.2	107.4	1.81	1.49	2.33
TSS 15 x TSS 11	7 454	175.8	95.0	1.53	1.51	2.05
TSS 15 x TSS 13	10 707	168.0	98.3	1.13	1.49	1.50
TSS 19 x TSS 2	9 613	202.8	109.6	1.53	2.01	1.45
TSS 19 x TSS 6	8 560	188.4	93.6	3.13	2.01	1.95
TSS 19 x TSS 9	7 814	199.1	110.3	2.06	0.99	1.54
TSS 19 x TSS 10	7 160	194.6	105.7	2.31	1.00	0.89
TSS 19 x TSS 11	8 774	187.8	104.6	1.59	1.49	0.57
SSS 19 x TSS 13	7 134	175.0	102.1	1.63	1.99	3.00
TSS 19 x TSS 15	10 400	194.2	111.9	2.37	1.99	1.78
TSS 23 x TSS 2	9 160	201.5	112.2	1.82	1.50	2.07
TSS 23 x TSS 6	7 707	167.9	92.1	2.31	1.99	1.71
TSS 23 x TSS 9	7 640	186.2	85.4	2.34	1.00	2.00
TSS 23 x TSS 10	9 600	205.7	109.2	2.06	2.01	1.35
TSS 23 x TSS 11	8 200	192.0	90.1	0.84	1.51	2.07
TSS 23 x TSS 13	9 960	185.7	94.9	0.87	2.01	1.67
TSS 23 x TSS 15	6 960	189.0	95.1	1.53	1.99	2.61
TSS 23 x TSS 19	7 733	186.7	102.1	1.31	2.50	2.27
TSS 28 x TSS 2	9 040	162.0	96.2	2.13	3.00	2.78
TSS 28 x TSS 6	7 907	164.8	97.6	1.41	0.99	2.28
TSS 28 x TSS 9	5 827	163.4	91.6	1.34	2.01	2.95
TSS 28 x TSS 10	8 027	167.7	100.3	2.00	1.50	1.78
TSS 28 x TSS 11	10 134	171.6	100.1	1.44	1.49	1.33
TSS 28 x TSS 13	7 467	154.1	97.0	1.41	2.50	2.39
TSS 28 x TSS 15	8 094	175.4	96.9	3.09	1.00	2.78
TSS 28 x TSS 19	8 893	175.6	100.7	1.84	1.99	2.83
TSS 28 x TSS 23	4 680	179.1	93.1	2.72	2.51	3.23
Thai Supersweet	9 640	220.2	116.7	1.44	1.00	1.39

(cont.)

Table 5. (*Cont.*)

Entry	Yield (kg/ha)	Plant ht. (cm)	Ear ht. (cm)	Ear aspect	Husk cover	Disease rating
Manis Madu	7 600	200.0	108.9	1.53	2.50	2.67
Masmadu	11 253	189.4	98.7	0.87	2.01	1.57
MS111C2	9 333	205.2	105.7	1.37	1.99	2.16
Overall mean	8 073	185.20	100.80	1.92	1.72	2.06
SE/plot	1 444	8.10	6.40	0.67	0.47	0.55
C.V.(%)	17.88	4.39	6.34	35.06	26.98	26.87

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