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Combining Abilities and Heterosis of Five Maize Cultivars for Industrial Baby Corn (*Zea mays* L.)

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Abstract

The maize experiments were carried out at Khon Kaen University on Yasothon soil series during 1990 in the pursuit of better combining abilities and heterosis of five maize cultivars as to obtain new varieties for industrial "baby corns" both fresh and canned food products. The five maize cultivars being used were: KKU#1, R1-KKU SRC6, BC#1 DMR, SW2 and CMB. These maize varieties were used as parental materials. Both direct and reciprocal crosses produced 20 off-springs and the seeds of both direct and reciprocal crosses and parents were sown for progeny test and this was carried out for two seasons i.e. Dry and wet seasons. Both experiments were laid out in a Randomized Complete Block Design with four replications. The data obtained were statistically analyzed with the use of cross diallel-analysis II and analysis III. The results showed that there were some highly significant effects due to sowing season on harvesting age, number of cobs/rai, cob fresh wrights/rai and also some interactions between season and crosses on harvesting age and season and ratio between cob fresh weights and baby corn fresh weights. Dry season hastened harvesting age of baby corns but a delay with wet season. The results on reciprocal analysis revealed that significant effects were found with number of cobs/plant, cob fresh weights/rai, baby corn fresh weights/rai, standard weights of baby corns/rai and out-standard weights of baby corns/rai 1 ha =6.25 rai. The results of reciprocal crosses revealed that there were significant effects on number of cobs/plant, cob fresh weights/rai, baby corn fresh weights/rai, standard baby corns/rai and out-standard baby corns/rai due to maternal effect. With diallel analysis, an excellent general combining abilities was found with harvesting age on direct crosses and number of cobs/plant of reciprocal off-springs but only found with dry season. Gene expression was not freely independent of season. SW2 variety has a short harvesting age while KKU1 and BC#1 DMR (1x3) possessed highly significant effects on GCA and SCA. The best variety for open-pollinated fertilization was BC#1 DMR. There was a highly significant correlation between cob fresh weights and baby corn fresh weights and did between cob fresh weights and out-standard cob fresh weights.

Introduction

Young cobs of maize which is known among growers and consumers in most regions of Thailand as "baby corns" have been widely recognized as an important vegetable. The Thai people normally consume baby corns in the form of fresh vegetable while other temperate countries consume this type of vegetables as canned products which is being exported mostly from tropical countries. The annual producation in Thailand was up to 67 tons during 1974 and leter increased with time up to 28,581 tons during 1997. Up to the present, the need to use baby corns for human consumption is enormous and the products being exported are those of fresh and canned baby corns, hence baby corns cultivation has been widely recognized among growers as one of the important economic cash crops and number of scientists have now paid their attention to this cash crop. Nevertheless, can food industry on baby corns products has not been well established due to some attraction in size and shape of baby corns. This makes it difficult for the factory to classify them into their respective needs. Furthermore, a similar problem has also been tended to marketable fresh baby corns i.e. the young bs being produced are not of similar shape and size. In addition, the taste and colour of cobs must also be improved i.e. the length and width of young cobs should be 4 and 1-1.5 cm, respectively. Therefore, it is of imperative value for plant breeders to consider the problem in order to combine the various genes from maize parents as to produce as much as possible the majority baby corns of a similar shape and size. At the present, it turns out that varieties being used for baby corns production possess variation in shape and size of young cobs largely. Furthermore, the yield of cobs per plant has been relatively low apart from having only some few varieties available. Therefore, the need to produce more varieties with high performance for can food industry is urgently needed so that can food industry of baby corns could be expanded since more people around the globe have now learned to consume this vegetable for their daily diets. The combining ability of maize parents to produce heterosis off-springs should be of an important key to develop foundation populations for hybridization and selection for outstanding characteristics as to pursuit new variety that suits the purpose, hence the objectives of this study were: (1) to investigate the combining ability of different outstanding characteristics, general combining ability, specific combining ability of five varieties of baby corns, (2) to select heterosis characters of hybrid off-springs and (3) to produce correlation coefficients among different characteristics and baby corns yields. Although this job will take a long time to develop new varieties but it would be worthwhile to carry out more experiments, hence a series of experiments has been been carried out at Khon Kaen University.

Materials and Methods

Five varieties of baby corns obtained from the Faculty of Agriculture, Khon Kaen University, Khan Kaen, Thailand were used, they are: KKU#1, R1 -KKU SRC6, BC#1DMR, SW2 and CMB. The five varieties possess a similar harvest period of young cobs i.e.. 45 days after sowing except that of SW2 which possesses harvest period of 47 days after sowing, A few seeds of each variety was sown directly in to the soil (Yasothon soil series; Oxic Paleustults pH 5.8) to the depth of 2-3 cm at the distances between rows and within the rows of 65x25 cm, respectively. Seeds of SW2 variety were sown two days earlier than the rest as to achieve a similar flowering period. Ten days after emergence, surplus seedlings were removed leaving only one plant per hill. For Fl -hybrid plants, the population of each variety consisted of 8 rows and each row has 100 plants. These were the populations for diallel crosses. The experiment was carried out during January-March, 1990 on the Experimental Farm, Khon Keen University. The 8 rows of each variety were arranged from KKU1, R1-KKU SRC6, BC#1 DMR, SW2 and CMB, respectively. The first row of each varieties was used for both direct and reciprocal crosses. Out of the crosses carried out, direct and reciprocal crosses produced 20 off-springs. For further work, seeds of the 20 off-springs were sown again together with seeds of their parents for progeny test and this was carried out for two seasons i.e. dry and wet seasons. The test of progeny was laid out in a .Randomized Complete Block Design with four replications. The plot size used was a 3 x 6.5 m. and each plot consisted of 4 rows, each row has 26 hills and each hill has two plants, hence the number of plots used were 100 plots altogether. Ten days after emergence, the plant seedlings were thinned leaving only two plants per hill. The chemical fertilizer 15-15-15 (NPK) was applied at the rate of 50 kg/rai (one hectare = 6,25 rai) and the applications were carried out twice i.e. 25 kg/rai before sowing and another half was added when the plants reached the age of 28 days after emergence. The addition of urea fertilizer being used as top dress was also applied at the rate of 25 kg/rai when the seedlings reached the age of 14 days after emergence. Weeding was carried out twice at the age of 14 and 28 days after emergence. During the growth period, no insecticide was used due to no insect pests found. Sprinkler irrigation water was given to the plants twice a week during the dry season at the rate of approximately 56.25 m^3/hour/ha for two hours. Sprinkler irrigation water was not needed in wet season. The plant samples were chosen from the two inner rows and the border rows were left out. The harvest of young cobs was carried out when the silks appeared at the length of approximately 2 cm. The sample collections were carried out daily within 14 days from the initial samples. The plant samples were measured for the following parameters: plant heights, initial cob heights, harvesting age (measured when 50% silky), harvesting age of second cob, age of detassel, number of cobs/rai, average cobs/plant, total fresh weights of cobs/rai, fresh weights of baby corns/rai (not including husk), ratio between cob fresh weights and baby corn fresh weights (without husk), numbers and weights of standard cobs/rai and eventually numbers and weights of out-standard cobs/rai. The data obtained were statistically analyzed for the analysis of combining ability, reciprocal and genetic effect with the used of variety cross diallel analysis ll and analysis III (Gardner and Eberhart, 1966).

Results and Discussion

The results on the analysis of variance of the combining analysis showed that there was a significant effect of seasons on harvesting age, number of cobs/rai, fresh weights of cobs/rai. The differences were large and statistically significance (Table 1). The significant differences were also found with the crossing effects in all characteristics tested. There were significant interactions between the effect of seasons and crosses on harvesting age and the ratio between cob fresh weights and baby corn fresh weights while other characteristics were not significantly found. The results suggested that seasons have some large effects on cob weights due to perhaps the differences in the total amount of water received by the plants which may not adequate enough in dry season although the amount of radiant energy may be exceedingly available, hence further application of sprinkler irrigation should be required or perhaps the system in dripping water should be carried out with a shorter duration but once every two days. This may help to supply adequate amount of soil moisture content.

The higher cob fresh weights of wet season than that of dry season could also be attributed to the high amount of soil moisture content as previously discussed. Nevertheless, harvest age was earlier for dry season than wet season. The differences could possibly be due to the differences in total amount of radiant energy which may be greater in dry season than that of wet season. Other possibility should be due to the less amount of soil moisture content in dry season than wet season. This condition may have hastened maturity of the crop plants. As the seasons have much influences on cob development, it is, therefore of interest to carry out further analysis of each season separately. The data showed that the cross effects on harvesting age, ratio between cob fresh weights and baby corn fresh weights were significantly found with both seasons reciprocal crosses analysis, the results snowed tlia were significant effects found on number of cobs plant, cob fresh weights/rai, baby corn fresh weights/rai, standard weights of baby corns/rai and out-standard weights of baby corns/rai. The results implied that these characteristics did not receive equally parental inheritance as a result of

Table 1: Values of variance combine analysis of direct crosses and reciprocal crosses for various characteristics of those none interaction between season and crosses

Characteristics								
	df 1	6	24	10	14	24	144	cv%
	Mean squares							
	Season	Rep/season	Cross	Reciprocal	Residual	Season x Cross	Error	
1.	19.41	453.36	533.94**	17.37	902.93	142.53	120.89	6.39
2.	35.69	440.03	732.46**	27.57	1235.96	84.28	87.87	8.55
3.	1568.00	7.20	15.96**	0.94	26.68	1.96	1.88	3.37
4.	1568.88	3.85	2.66**	0.075	4.50	1.04	1.03	1.89
5.	0.12	0.23	0.13**	0.12**	0.14	0.03	0.02	8.97
6.	0.006	0.013	0.007**	0.006	0.012	0.001	0.001	0.63
7.	11201198.12	447638.83	209972.72**	178410.60*	232517.09	128240.79	88104.93	10.99
8.	62510.47	12902.47	11292.31**	4214.70**	9204.89	1929.06	2734.89	11.58
9.	0.09	0.05	0.14**	0.11**	0.16**	0.01	0.01	5.77
10.	17660.72	14309.34	10883.26	19339.15**	4845.35**	1992.08	1864.69	13.05

1 = Plant heights; 2 = Initial cob heights; 3 = Age of detassel; 4 = Second cob harvesting age; 5 = Number of cobs/plant; 6 = Number of cobs/rai; 7 = Cob fresh weights/rai; 8 = Baby corn fresh weights/rai; 9 = Cob standard weights/rai; 10 = Out-standard cob weights/rai.
* = Significant ($p<0.05$); ** = Highly significant ($p<0.001$)

Table 2: Variance analysis of direct crosses and reciprocal crosses, interaction

	df 3	24	10	14	72
			Mean square		
Characteristics	Replication	Crosses	Reciprocal	Residual	Error
Dry season					
Harvesting age	1.58*	3.36**	0.009*	5.69	0.47
Ratio between cob fresh weights/ baby corn fresh weights	0.93*	0.75	0.013	1.27**	0.09
Wet season					
Harvesting age	5.48**	4.65**	0.28	7.76	0.65
Ratio between cob fresh weights/ baby corn fresh weights	0.43	1.23**	0.12	2.02	0.24

maternal effect. The results agree with the work reported by Rood and Major (1981), Bdliya and Burris (1988) and Pollak *et al*. (1991). With the combining ability, the results from diallel analysis showed that characteristics that possess excellent general combining ability were harvesting age of direct cross and number of cobs/plant of reciprocal off-springs (Table 2). However, harvesting age of direct cross effect was found only with that of the dry season. The results indicated that both characteristics had derived from additive gene action. There was an interaction between season on harvesting age. The results evidently implied that gene expression was not freely independent of season, hence the analysis was separately carried out for each season. For dry season, the results on reciprocal crosses revealed that there was some significant effect found that is both parents could not be equally inherited genes to their off-springs (Table 3). This could be attributed to the effect of maternal inheritance. However, the results on wet season indicated that there were no reciprocal differences found. This may be attributed to the differences in total energy from the sun which was greater in dry season than wet season and perhaps it may also be due to the amount of soil moisture content which was presumably less in dry season. The results on harvesting age found with dry season, revealed that only SW2 variety shown the effect due to variety and CGA, which were the lowest. It is of a common practice that low values on the effect due to variety and CGA are supposed to be discriminated, however, for this work the two items are needed since SW2 possesses short harvesting age, which is considered as an ideal character. For reciprocal off-springs, the results revealed that there were some highly significant differences in the values of SCA and GCA. These two values gave the ratio greater than three folds. The results indicated that SCA manifested a greater effect than CGA. The results implied that the expression on harvesting age of reciprocal off-spring in dry season has its effect from non-additive gene action (Table 4). Therefore, off-springs that suppose to be chosen for breeding purposes were those of KKU1 and BC#1 BMR (1x3).

With number of cobs/plant, the results showed that the effect due to reciprocal test was highly significance. The results indicated that additive gene action has its significant role on number of cobs/plant and the outstanding variety to be chosen is BC#1 DMR. This variety was chosen due to its high values of both GCA and the effect due to variety, hence this variety should be used as an open-pollinated

Table 3: Analysis of variance, Analysis II on different characteristics of baby corns

			df 14	4	10	1	4	5
					MS			
Characteristics	Season	Crosses	Population	Var.	Heterosis	Average	Variety	Specific
Plant heights	-	-	188.68	73.56	149.79	53.20	38.67	335.78**
Initial cob heights	-	-	137.68	349.69**	36.35	10.85	20.94	51.38
Detassel age	-	-	2.22	6.16**	1..32	1.46	0.63	1.85
Harvesting age	Dry	Direct	0.99**	1.72**	14.73**	140.37**	1.42*	0.24
		Reciprocal	1.07*	2..96**	-765.55**	7695.75**	0.82	7..39**
	Wet	-	1.14	0.49	315..93**	-3172.84**	0.32	2.49**
Second cob harvesting age	-	-	0.001	0.003*	-0.015**	0.003	0.003	-0.03**
Cob fresh weights/rai	-	Direct	1529268.00**	823342.00**	2416658.00**	603793.00* *	1148691.00**	3793605.00**
	-	Reciprocal	37800.42	26071.32	146199.50	5907954.00	34367.28	253089.3*
Baby corn fresh weights/rai	-	Direct	1574.67	4271.9	2915.25	3466.66	1091.68	-7397.19**
	-	Reciprocal	1846.09	3158.3	12915.00	2821.34	1254.35	4262.26
Ratio between cob fresh weights/								
	Dry	-	0.271*	0.41**	0.69**	1.09**	0.0.9*	1.08
baby corn fresh weights	Wet	-	0.64	0.59*	1.67**	1.51**	0.36	2.75**
standard cob weights/rai	-	Direct	0.28*	0.059**	0.005	0.08*	0.01	-0.01
	-	Reciprocal	0.019	0.038*	0.055**	0.071*	0.008*	0.089**
Out-standard cob weights/rai	-	Direct	1674.82	5264.03*	-989.99	9.16	428.06	-2323.25
	-	Reciprocal	2147.42	4505.66	165.41	413.45	921.38	488.92

Table 4: Analysis fo variance, Analysis III on different characteristics of baby corns

			df 14	4	1	9	4	5
	Season	Crosses				MS		
Characteristics			Entries	Var.	Var.xCross	Cross	GCA(gi)	SCA(sij)
Plant heights	-	-	73.56	177.30	53.20	56.37	71.15	335.78**
Initial cob heights	-	-	137.68	269.95*	10.85	92.99	103.66	51.38
Detassel age	-	-	2.22	3.34	1.46	1.81	3.45	1.85
Harvesting age	Dry	Direct	0.99*	0.88	140.37	-14.44**	2.27**	0.24
	-	Reciprocal	1.07*	1.27*	-7695.75**	865.18**	2.51**	7.39**
	Wet	-	1.14	1.49	-3172.84**	353.65**	-0.68	2.46**
Second cob harvesting age	-	-	0.34	732.21**	569.29**	-388.19	-460.69	-0.39
Cob number/plant	-	Direct	0.02	0.02	1.18	-0.11**	0.01	-0.05
	-	Reciprocal	0.03	0.04	-19052.90	2117.02**	24.26**	-0.04
Cob numbers/rai	-	-	0.001	0.002	0.0003	0.0008	0.001	-0.03**
Cob fresh weights/rai	-	Direct	1529268.00**	1871594.00**	603793.00**	1479953.00**	100439.00	3793605.00**
	-	Reciprocal	37800.42	16502.84	59079.54	44901.66	43935.7	253089.3*
Baby corn fresh weights/rai	-	Direct	1574.67	2486.94	3466.66	958.99	2876.65	-7397.19*
	-	Reciprocal	1846.09	2591.19	2821.34	1406.57	1821.47	4262.26
Ratio between cob fresh weights/								
baby corn fresh weights	Dry	-	0.27*	0.56**	1.09**	0.048	-0.06	1.08**
	Wet	-	0.64*	1.07**	1.51**	3.36	0.57	2.75**
standard cob weights/rai	-	Direct	0.03*	0.06**	0.005	0.08*	0.01	-0.01
	-	Reciprocal	0.02	0.04*	0.06**	0.07*	0.008**	0.09**
	-	Direct	0.03*	0.05*	0.08*	0.01	0.02	-0.014
Out-standard cob weights/rai	-	Reciprocal	0.02	0.04*	0.07	0.004	0.005	0.09**

Table 5: Type of off-springs, Combining abilities, outstanding crosses and some significant values of the effect due to varieties and excellent values of GCA

Charateristics	Season	Type of off-spring	Combining abilities	Outstanding crosses	variety effected and Excell, GCA values
Plant heights	-	-	SCA	BC#1 DMR x CMB	-
Initial cob heights	-	-	-	-	BC#1 DMR x SW2
Detassel age	-	-	-	-	BC#1 DMR x CMB
Harvesting age	Dry	Direct	GCA	SW2 x CMB	SW2, CMB
		Reciprocal	SCA > GCA	KKU#1 x BC#1 DMR	-
	Wet	-	SCA	KKU#1 x BC#1 DMR	-
Second cob harvesting age	-	-	SCA	BC#1 DMR x SW2	-
Cob numbers/plant	-	Direct	-	-	-
	-	Reciprocal	GCA	BC#1 DMR, CMB	BC#1 DMR, CMB
Cob nurnbers/rai	-	-	SCA	R1-KKU SRC6 x CMB	-
Cob fresh weights/rai	-	Direct	SCA	KKU#1 x KKU#1	-
	-	Reciprocal	SCA	BC#1 x KKU#1	-
					-
Baby corn fresh weights/rai	-	Direct	SCA	R1-KKU SRC x SW2	-
	-	Reciprocal			KKU#1, R1-KKU SRC6
Ratio between cob fresh weights/					
baby corn fresh weights	Dry	-	SCA	R1-KKU SRC6 x SW2	-
	Wet	-	SCA	BC#1 DMR x CMB	-
standard cob weights/rai	-	Direct	-		R1-KKU SRC6 x CMB
	-	Reciprocal	SCA	KKU#1 x CMB	-
Out-standard cob weights/rai	-	Direct	-	-	KKU#1 x SW2
	-	Reciprocal	-	-	SW2, CMB

Table 6: Heterosis off-springs (F1-hybrid) of maize with respect to various characteristics tested

	Heterosis value greater than mid-parents					Heterosis value greater than better parents			
Charateristics	Season	Cros. No.	Perform.	%heterosis	Crosses	Cros. No.	Perform.	%heterosis	Crosses
Plant heights	-	6	Low	-2.45	CMB x KKU#1	9	Low	-6.19	R1-KKU SRC6 x SW2
Initial cob heights	-	6	Low	-6.19	CMB x R1-KKU SRC6	15	Low	-13.08	R1-KKU SRC6 x SW2
Detassel age	-	16	Early	-7.73	BC#1 DMR x CMB	All	Early	-8.72	BC#1 DMR x CMB
Harvesting age	Dry	16	Early	-4.13	BC#1 DMR x CMB	16	Early	-5.29	BC#1DMR x CMB
	Wet	15	Early	-2.84	SW2 x CMB	18	Early	-3.06	SW2 x CMB
Second cob harvesting age	-	17	Early	-100.00	CMB x R1-KKU SRC6	16	Early	-100.00	CMB x R1-KKU SRC6
Cob number/rai	-	15	High	0.93	CMB x R1-KKU SRC6	8	High	0.42	R1-KKU SRC6 x SW2
Cob fresh weights/rai	-	15	High	18.08	KKU#1 x CMB	14	High	16.72	BC#1 DMR x KKU#1
Baby corn fresh weights/rai	-	19	High	16.83	R1-KKU SRC6 x SW2	11	High	8.59	CMB x KKU#1
Ratio bet. cob fresh weights/	-								
Baby corn fresh weights	Dry	13	Low	-8.52	R1-KKU SRC6 x SW2	17	Low	-19.46	SW2 x R1-KKU SRC6
	Wet	6	Low	-17.87	R1-KKU SRC6 x SW2	12	Low	-30.85	R1-KKU SRC6 x SW2
Standard cob fresh weights	-	15	High	15.45	BC#1 DMR x KKU#1	3	High	12.44	KKU#1 x CMB

variety. The results confirm the work reported by Nevado and Cross (1990).

For the effect of specific combining ability (SCA), the results showed that there were highly significant effects on non-additive gene action found on harvesting age and plant height but only found during wet season experiment. At the same time non-additive gene action has also significant effects on number of cobs/rai, cob fresh weights/rai, baby corn fresh weights/rai, ratio between cob fresh weights/baby corn fresh weights, standard baby corn fresh weights/rai. The outstanding off-springs derived for each category were: harvesting age was with KKU#1xBC#1 DMR (1x3), plant height was with BC#1 DMRxCMB (3x5), number of cobs/rai was with R1-KKU SRC6xCMB (2x5), cob fresh weight/rai was with KKU#1xSW2 (1x4) but for direct cross only and KKU#1xBC#1 DMR (1x3) for reciprocal cross, baby corn fresh weights/rai was with R1-KKU SRC6xSW2 (2x4) only with direct cross, ratio between cob fresh weights/baby corn fresh weights was with R1-KKU SRC6xSW2 (2x4) for dry season only and BC#1 DMRxCMB (3x5) for wet season only, standard baby corn fresh weights/rai was with KKU#1xCMB (1x6). The significant effects found with all of these characteristics were due to low values of SCA with respect to harvesting age, plant height and ratio between crop fresh weights and baby corn fresh weights (Table 5). These characteristics were chosen for breeding assets and they were chosen for the reason that plant height must be short with short harvesting age and greater size and weight of baby corns. Therefore, non-additive gene has much influences on these characteristics and these characteristics are needed for further breeding programme while other characteristics gave much higher values of SCA which were recognized as the ideal characteristics needed for further work as to produce an ideal type of hybrid off-springs. This could be attributed to the effect of gene expression i.e. non-additive gene expresses itself as a dominant gene, hence the off-springs produced could possibly be able to retain these outstanding characteristics.

With the effects due to variety, the results showed that variety has much influences on the following parameters; SW2 variety has high effect on height of the initial cob, BC#1 DMR variety has its effect on detassel age, R1-KKU SRC6 variety has much influences on baby corn fresh weights/rai, this result was found only with reciprocal offsprings. R1-KKU SRC6 and CMB varieties have high influences on standard cobs/rai, this was found only with direct crosses. SW2 has significant influences on weights of out-standard cobs both direct crosses and reciprocal crosses. All of these varieties have possessed significant effects due to variety with high values of GCA. The results indicated that all of these outstanding characteristics are the ideal characteristics for further breeding programme as to produce new varieties to suit the purpose of industrial uses

With heterosis off-springs, the results showed that plant height, height of initial cob, detassel age, second cob age and harvesting age of off-springs were negatively found with detassel age and harvesting age while others were positively found when compared with the mean values of mid-parents. The negative results must be attributed to the lower mean values of both detassel and harvesting age. These outstanding features could be of value for further breeding programme since short harvesting age and short detassel age are ideal (Table 6). The results were found with BC#1 DMR x CMB but only with dry season for harvesting age and did with SW2 x CMB with wet season. For detassel age, the crosses between BC#1 DMR x CMB were the best. Other negative values were found with plant height, height of initial cob. The ideal plant height was found with CMB x KKU#1 while height of initial cob was with CMB x R1-KKU SRC6. The other negative values were found with the item of second cob harvesting age i.e. the best heterosis was with CMB x R1 -KKU SRC6. With the comparison between heterosis off-springs and better parents, the results showed that the negative results on harvesting age were found with BC#1 DMR x CMB but only with dry season while wet season the best off-springs were with SW2 x CMB. For detassel, the results revealed that the best off-springs were with BC#1 DMR x CMB while second cob harvesting age was found with CMB x R1-KKU 5R06. Plant height and height of initial cob were with R1-KKU SRC6 x SW2. The results confirm the work reported by Eyherabide and Hallauer *et al*. (1991).

With number of cobs/plant, the results revealed that the majority of off-springs possessed greater values of heterosis than that of mid-parents. These include CMB x R1-KKU SRC6. For a comparison with better parents, the results revealed that the best values were found with R1-KKU SRC6 x 5W2, however, the results of the off-springs were relatively low. The results suggested that the parents being used were of poor performance and should not be used in breeding programme for the improvement of cob numbers/rai.

For cob fresh weights/rai, the results showed that the majority of off-springs possessed heterosis values greater than both mid-parents and better parents as a result of dominant gene. This was found with KKU1 x CMB compared with mid-parents but when compared with better parents, the results revealed that the heterosis of BC#1 DMR x KKU1 was the best. The results agree with the work reported by Beck *et al*. (1991).

With baby corn weights/rai, the results showed that the majority of off-springs possessed better values of heterosis performance than that of mid-parents. This was found with R1-KKU SRC6 x SW2 but when compared with better parents, the CMB x KKU1 was the best. The results agree with the work reported by Crosse and Gardner (1987), Bridges and Gardner (1987), Mungoma and Pollak (1988) and Beck *et al*. (1991).

For the ratio of cob fresh weights and baby corn fresh weights, the results showed that the majority of off-springs manifested low values of heterosis than both mid-parents and better parents for dry season only while wet season, the results showed that the majority of off-springs possessed better performance than mid-parents but not better parents. This was found with R1-KKU SRC6 x SW2 compared with mid-parents in dry season and wet season with R1-KKU SRC6 x SW2. The best off-springs, when compared with better parents, found in dry season were with SW2 x R1-KKU SRC6 while wet season was with R1-(KKU SRC6 x SW2.

For standard cob fresh weights, the results showed that the majority of off-springs possessed greater performance than mid-parents. This was found with BC#1 DMR x KKU#1 while that of better parents, off-springs derived from KKU#1 x CMB were the best. With out-standard cob fresh weights, the majority of off-springs possessed poor heterosis value when compared with both mid-parents and better parents. The results revealed the outstanding features of crosses. Furthermore, the best performance on heterosis value was found with CMB x R1-KKU SRC6 when compared with mid-parents and those of SW2 x BC#1 DMR produced the best heterosis value much better than the rest when compared with better parents. The results implied that genetics factor could not be only a factor dominated the heterosis value of the off-springs yet environmental factor may be one of them contributed to the expression of genes. These findings confirm the work reported by Cross (1977), Pollak *et al*.(1991) and Beck *et al*. (1991). The effect of environmental condition has much influences on baby corn production was stated by Jones *et al*. (1984) and Ouattar *et al*. (1987). They stated that environmental temperature and water supply have enormous effects on baby corn development while that of genetics effect has some effects but with a certain extent.

With correlation coefficients between cob fresh weights and baby corn fresh weights, the results showed that there was a highly significant correlation found while that of cob fresh weights and out-standard cob fresh weights, there was a significant correlation. There was no correlation found between cob fresh weights and ratio between cob fresh weights/baby corn fresh weights and also standard cob fresh weights. The results suggested that cob fresh weights possessed a direct correlation with baby corn fresh weights and out-standard baby corn fresh weights. This could be attributed to the high amount of cob fresh weights resulted in high amount of baby corn fresh weights. These characteristics may not be of ideal for industrial utilization. The results confirm the work of Younes and Andrew (1978). There were highly significant correlation coefficients between baby corn fresh weight and ratio between cob fresh weights/baby corn fresh weights and out-standard baby corn fresh weights while that of ratio between cob fresh weights/baby corn fresh weights and standard baby corn fresh weights and out-standard baby corn fresh weights, these gave highly significant correlation

Table 7: Correlation coefficients among the different characteristics of maiz cultivars grown at Khon Kaen University

	X2	X3	X4	X5	X6	X7	Y1	Y2	Y3	Y4	Y5
Plant heights (X1)	0.815**	0.536**	0.615**	0.300	0.478	0.508**	0.201	0.367	0.219	0.454*	0.004
Initial cob heights (X2)		0.520**	0.658**	0.416*	0.390	0.399	0.145	0.614**	0.603**	0.320	0.321
Detassel age (X3)			0.838**	0.674**	0.727**	0.728**	0.144	0.068	0.000	0.004	0.153
Harvesting age (X4)				0.729**	0.661**	0.636**	0.059	0.305	0.281	0.068	0.108
Second cob harvesting age (X5)					0.602**	0.542**	0.285	0.041	0.079	0.214	0.088
Cob number/rai (X6)						0.977**	0.474*	0.234	0.130	0.068	0.353
Cob number/plant (X7)							0.448*	0.230	0.141	0.038	0.428
Cob fresh weights/rai (Y1)								0.637**	0.124	0.394	0.469*
Baby corn fresh weights/rai (Y2)									0.753**	0.366	0.639**
Ratio between cob fresh weights/baby corn fresh weights (Y3)										1.000**	0.536*
Standard cob weights/rai (Y4)											0.080

and significant correlation, respectively. The results indicated that when the ratio between standard cob fresh weights/baby corn fresh weights increased then there was an increase in both standard and out-standard cob fresh weights. For the correlation between cob fresh weights and number of cobs/rai and also number of cobs/plant, the results revealed that there was a significant correlation among these parametres. There was also a highly significant correlation between baby corn/rai and height of initial cob and did with ratio between cob fresh weights/baby corn fresh weights. Standard baby corn fresh weights manifested highly significant correlation with plant heights (Table 7).

To sum up, this investigation has given some outstanding features of individual varieties and interaction between season and different characteristics tested. There were highly significant effects due to sowing season on harvesting age, number of cobs/rai, cob fresh weights/rai and also some interactions between season and crosses on harvesting age and season and also ratio between cob fresh weights and baby corn fresh weights. Dry season hastened cob maturity age of baby corns but a delay was with wet season. The reciprocal analysis revealed that some significant effects were found with number of cobs/plant, cob fresh weights/rai, baby corn fresh weights/rai, standard weights of baby corns/rai and out-standard weights of baby corns/rai. Diallel analysis indicated that an excellent general combining abilities was with harvesting age on direct crosses and number of cobs/plant of reciprocal offsprings but only with dry season, gene expression was not freely independent of season. SW2 variety possessed short harvesting age while KKU1 and BC#1 DMR (1x3) on GCA and SCA. BC#1 DMR possessed excellent standing for open-pollination variety. There was a highly significant correlation between cob fresh weights and baby corn fresh weights and did between cob fresh weights and out-standard cob fresh weights.

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