International Journal of Biotechnology and Biomedical Sciences
p-ISSN 2454-4582, e-ISSN 2454-7808, Volume 4, Issue 2; July-December, 2018 pp. 45-50

http://www.krishisanskriti.org/Publication.html

Estimation of Heterosis for Quantitative Characters in Maize (*Zea mays* L.)

B. Priya[1], R. Nirmal Raj[2] and J. Gokulakrishnan[3]

[1]P.G. Scholar, Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, Annamalainagar 608 002
[2]P.G. Scholar, Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, Annamalainagar 608 002
[3]Assistant Professor, Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, Annamalainagar 608 002
E-mail: [1]priyabalu96agri@gmail.com, [2]rnimmu37@gmail.com, [3]gokulayamuna@gmail.com

Abstract—*Maize (Zea mays L.) is the world's most widely grown cereal. Farmers are always on the lookout for better maize hybrids in the competitive seed market. Heterosis, heterobeltiosis and standard heterosis for maize yield per plot and yield attributing traits in maize were evaluated in line × tester design involving 7 lines (AU 121, AU 161, AU 183, AU 562, AU 716, AU 720 and AU 523), 3 testers (AMU 23, AMU 44 and AMU 57) and standard check as dragon. Based on per se performance, the lines AU 161, AU 183 and AU 720 and the testers AMU 44 and AMU 57 were adjudged as the best for most of the traits studied. Among the hybrids, AU 720/AMU 44, AU 161/AMU 44 and AU 183/AMU 51 exhibited high per se performance. Among the hybrids AU 161/AMU 44, AU 183/AMU 57 and AU 720/AMU 44 were adjudged as the best since they possessed significant and positive heterosis for all the characters except days to 50 percent silking. The hybrids AU 720/AMU 44, AU 161/AMU 57 and AU 121/AMU 23 showed desirable performance based on per se performance and standard heterosis over best check for most of the economic traits and so those hybrids can be exploited for further improvement.*

1. INTRODUCTION

Maize (*Zea mays* L.) is the world's most widely grown cereal and is the primary staple food in many developing countries [1]. It is a versatile crop with wider genetic variability and able to grow successfully throughout the world covering tropical, subtropical and temperate agro-climatic conditions. It is the key crop for food and food security and income generation for millions of farmers [2]. Farmers are always on the lookout for new varieties and replace their existing hybrids with better ones whenever available in the market. Development of new and better hybrids on continuous basis is a big and difficult challenge [3].

Exploitation of heterosis has been recognized as a practical tool in providing a means of increasing yield and other commercial characters in maize. The greater extent of out crossing facilitates for the development of commercial maize hybrids. Therefore to meet the quantum jump in yield in short term, heterosis breeding has been undertaken to develop and identify the suitable best performing hybrids.

Maize is a highly cross pollinated crop. It is generally protandrous *i.e.,* male spikelets mature earlier than female spikelets. The wind borne nature of the pollen and protandry leads to cross pollination, but there may also be reported 5% self pollination [4]. It offers tremendous scope for the plant breeders for genetic improvement.

It possesses one of the most well studied genetic system among cereals which have motivated a rich history of research into the genetics of various traits in maize [5]. The invention of heterosis phenomenon, the development of hybrid breeding technology and successful commercial exploitation of heterosis in maize are considered to be significant achievements and landmarks in the history of biological sciences during the past century. The scope for the exploitation of hybrid vigour will depend on the magnitude of heterosis, biological feasibility and the type of gene action. Information on different traits of interest especially their genetic control is a prerequisite for planning the genetic improvement strategies.

2. MATERIALS AND METHODS

The Experiment was conducted at Plant Breeding Farm, Annamalai University in two seasons (kharif and rabi). The materials for the current study consisted of seven lines (AU 161, AU 121, AU 183, AU 562, AU 716, AU 720 and AU 523), three testers and crossing was performed in a line × tester fashion to produce twenty one hybrids. The Experiment was laid out in a Randomized Block Design with three replications. Three seeds per hill were dibbled at a spacing of 60 cm with in rows and 10 cm between plants in a row. The selected seven inbreds were grown along with three testers for effecting crosses in a separate crossing block. During Rabi, seven lines, three testers and twenty one hybrids were raised in RBD with three replications. Twenty five plants were maintained in each replication foe each cross and parents. Ten randomly selected plants in each replication were used for recording the biometrical observations on plant height, days to 50 per cent silking, days to maturity, cob weight, ear length, number of grain rows per ear, number of grains per row, hundred grain weight and grain yield per plant. The mean over three replications and for all the hybrids for each of the trait was calculated over mid parent, better parent and standard parent used in the estimation of heterosis as per procedure given by [6].

3. RESULTS AND DISCUSSION

The mean sum of square of ten quantitative characters obtained over pooled analysis of variance are presented in Table 1. The pooled analysis of variance revealed that mean square due to females (lines) differed significantly for all characters. The variance due to hybrids differed significantly for all characters. The mean square due to males (testers) were found non significant for plant height. Thus, suggesting the importance of heterosis breeding for improvement of maize.

Table 1: Pooled analysis of variance for L × T analysis of yield and yield attributing traits in Maize

Source	MSS										
	DF	Plant height	Days to 50% silking	Days to maturity	Cob weight	Ear length	Ear girth	No. of. grain rows per ear	No. of. grains per row	100 grain weight	Grain yield/ plant
Replication	2	274.2580	0.7812	193.4193	193.4193	7.5869	7.5115	3.9887	5.8381	1.11496	3.2762
Hybrid	20	399.6397**	85.7871**	1470.2441**	1470.2441**	15.8576**	44.5207**	30.4432**	95.9873**	24.0216**	1420.1802**
Line	6	256.1101**	114.7025**	1871.9274**	1871.9274**	17.0076**	47.3708**	57.7356**	55.7356**	24.5357**	1629.2587**
Tester	2	189.8392	33.1057**	4540.6360**	4540.6360**	21.3530**	82.1993**	372.4926**	372.4926**	45.8642**	4731.6474**
L × T	12	506.3709**	82.1363**	757.6705**	757.6705**	14.3667**	36.8159**	70.0289**	70.0289**	20.1241**	763.7294**
Error	60	158.5171	1.6857	36.2305	36.2305	0.7085	10.014	8.1942	8.1942	3.4766	27.2126

*Significant at 5 percent level **Significant at 1 percent level **Note:** DF- Degrees of freedom, MSS-Mean sum of square

Among the lines, AU720, AU161, AU183 and AU562 recorded with high *per se* performance for the traits like days to 50 per cent silking, plant height, number of kernel per row, cob length, cob weight, cob girth, number of grain rows per ear, 100 grain weight and grain yield per plant. Among the testers, AMU 44 and AMU 51 recorded with high *per se* values for yield and its component traits like days to 50 percent silking, cob weight, ear length, number of grain rows per ear, 100 grain weight and grain yield per plant (Table 2). Among the hybrids, AU 183/ AMU 51, AU 161/AMU 44 and AU 720/AMU 44 were rated as best hybrids based on mean performance for cob weight, ear length, ear girth, number of grain rows per ear and grain yield per plant (Table 3).

Table 2: Pooled mean performance of parents for quantitative traits in Maize

Source	Plant height (cm)	Days to 50% silking (days)	Days to maturity (days)	Cob weight (g)	Ear length (cm)	Ear girth (cm)	No. of grain row per ear	No. of grains per row	100 grain weight (g)	Grain yield/plant (g)
Lines										
AU121	115.13	63.66	102.41	85.85	20.69**	15.33	12.00	25.67	19.05	95.89*
AU161	124.59	59.66	101.54*	105.25*	14.56**	14.56*	12.27**	39.32*	29.21**	189.96**
AU183	133.88	51.00**	102.43**	120.42*	12.75	12.75	12.97	41.32**	27.97**	71.49*
AU562	104.03	65.00	121.76	84.99	15.43	15.43	12.67	36.32	19.31	71.23
AU716	158.73	66.33	112.33	69.05	12.56	12.56	11.50	34.31	19.62	55.13
AU720	194.77	56.00	104.24*	209.29**	15.33**	19.79**	12.10**	36.66	27.73**	103.99**
AU530	152.12	64.66	102.46	104.18	15.63	15.63	11.53*	32.32	19.45	91.51
Testers										
AMU23	149.69	69.32	110.24	80.25	13.29	13.29	11.87	31.66**	19.78	98.86**
AMU44	161.92*	58.01*	101.23*	111.66**	13.22	12.24*	12.17**	41.32**	22.23*	56.79*
AMU57	138.23	63.32	103.56	53.46	15.36*	14.33*	12.60	36.33	30.14**	68.62*

*Significant at 5 percent level **Significant at 1 percent level

Table 3: Pooled mean performance of hybrids for quantitative traits in Maize

Source	Plant height	Days to 50% silking	Days to maturity	Cob weight	Ear length	Ear girth	No. of grain row per ear	No. of grains per row	100 grain weight	Grain yield/plant
Hybrids										
L1×T1	182.97	64.32	96.58*	180.33	21.20	21.20	13.27	31.33	28.42	181.33*
L1×T2	182.20	66.01	99.83*	193.16	21.90	21.90*	14.97	39.33	30.16	166.92
L1×T3	204.57	66.02	103.83*	153.29	16.32	16.32	14.17	32.01	30.15	128.29
L2×T1	199.02	65.66	109.14	184.66	19.61	19.61	15.57	34.02	27.83	163.29
L2×T2	202.24**	68.32	110.17*	212.33**	23.49**	23.49**	16.30**	35.00	30.62	185.46**
L2×T3	171.59	48.66**	105.58*	197.49	20.55	20.55	13.63*	47.32**	35.11*	178.45
L3×T1	193.51	65.32	102.54*	190.62	20.42	20.42	12.73**	34.32	30.16	166.49
L3×T2	168.25*	59.00	94.83	178.14	21.27	21.27	13.83**	28.66	27.85	155.79
L3×T3	195.00	64.01	105.47**	205.25*	23.91**	27.29**	13.37**	47.32**	36.24**	203.52**
L4×T1	196.69	64.32	105.84	180.29	19.48	19.48	14.43**	35.32	31.09	159.69
L4×T2	201.14	65.32	101.84*	191.99	17.42	23.22**	16.07**	40.66*	33.65	170.55
L4×T3	188.20	63.66	96.87	197.33	22.22**	22.22**	15.93*	35.32	30.73	176.43
L5×T1	191.71	64.66	105.24	201.99	18.45**	18.45	13.70*	31.01	29.84	181.41*
L5×T2	192.65	67.01	94.84*	171.66	20.35**	20.35	14.17**	39.66	33.39	151.02
L5×T3	181.97	65.66	109.52	223.96**	17.99	18.45	14.17**	34.00	29.78	164.44
L6×T1	197.25	67.32	111.13	191.99	19.13	19.13	15.13*	38.00	33.89	170.11
L6×T2	204.67**	48.01**	104.53	263.15**	23.22**	23.91**	15.10	48.00**	36.67**	239.62**
L6×T3	201.60	63.32	102.57*	195.66	25.29**	17.99	15.07*	38.00	32.31	173.85
L7×T1	170.83	64.66	96.68*	182.88	19.62**	19.62	15.07	31.66	27.37	162.16
L7×T2	201.97	64.01	104.00*	173.16	18.53	18.53	16.83**	40.32	28.55	153.99
L7×T3	198.19	63.65	93.45*	181.89	17.62	17.62	15.93	30.32	32.28	161.33

*Significant at 5 percent level **Significant at 1 percent level

Information on the magnitude of heterosis is a pre requisite in the development of hybrids. A good hybrid should manifest high amount of heterosis for commercial exploitation. Relative heterosis is of limited importance because it is only the deviation of F_1 from mid parental value [7]. Heterobeltiosis is a measure of hybrid vigour over the better parent. The need for computing standard heterosis for commercial exploitation of hybrid vigour [8,9]. Hence, for the evaluation of hybrids, standard heterosis is to be given importance. The hybrid AU 720/AMU 44 was identified as the top ranking hybrid since it had significant and positive standard heterosis for all the traits except days to 50 per cent silking, days to maturity. The next best hybrid identified was AU161/AMU44 and AU 720/AMU 44 and AU 183/AMU 51 since it possessed desirable standard heterosis for all the traits except days to 50 per cent silking and days to maturity respectively (Tables 4-8).

Table 4: Percentage of Heterosis for Plant height and Days to 50% silking

Crosses	Plant height			Days to 50% silking		
	MP	BP	SP over dragon	MP	BP	SP over dragon
L1 × T1	9.67	-8.46**	78.80**	-3.21	-7.11	10.73*
L1 × T2	23.92**	-4.63**	86.28**	8.36**	3.61	13.56**
L1 × T3	23.72**	-6.47**	82.69**	3.88	3.61	13.56**
L2 × T1	36.06**	35.36**	78.80**	1.78	-5.21	12.99**
L2 × T2	43.56**	29.02**	70.42**	15.88**	14.29**	17.51**
L2 × T3	44.80**	27.21**	68.04**	-20.53**	22.80**	-15.82**
L3 × T1	40.74**	37.13**	88.97**	9.34**	-5.69	12.43**
L3 × T2	38.48**	22.16**	68.34**	10.91**	3.39	3.39
L3 × T3	42.58**	23.03**	69.53**	12.72**	1.04	10.17*
L4 × T1	67.60**	35.62**	77.31**	-4.16	-7.11	10.73*
L4 × T2	80.74**	59.73**	68.24**	6.13	0.51	12.43**
L4 × T3	101.58**	82.27**	82.27**	-0.77	2.02	9.60*
L5 × T1	48.80**	44.31**	88.67**	-3.90	-6.64	11.30*
L5 × T2	67.13**	55.26**	90.60**	6.91*	1.01	13.56**
L5 × T3	85.89**	68.65**	107.04**	1.53	-0.01	12.43**
L6 × T1	62.39**	49.66**	95.66**	5.76	-4.27	14.12**
L6 × T2	71.62**	67.80**	115.81**	-17.24**	-18.64*	-18.6**
L6 × T3	105.30**	95.77**	84.97**	6.04	-0.01	9.04*
L7 × T1	80.56**	62.23**	112.1**	3.43	-6.64	11.30*

L7 × T2	82.92**	81.93**	91.62**	4.28	-1.02	10.17*
L7 × T3	91.75**	87.89**	95.77**	0.51	-1.52	9.60*

*Significant at 5 percent level **significant at 1 percent level

Table 5: Percentage of Heterosis for Days to maturity and Cob weight

Crosses	Days to maturity			Cob weight		
	MP	BP	SP over dragon	MP	BP	SP over dragon
L1 × T1	-9.16**	12.39**	-4.59**	41.78**	-1.93	283.96**
L1 × T2	-1.95	-2.51**	-1.38	20.37**	-7.71	261.34**
L1 × T3	6.5**	0.26	2.56**	61.62**	1.45	297.19**
L2 × T1	3.06**	9.97**	7.81**	94.42**	71.33	237.33**
L2 × T2	8.34**	8.49**	8.83**	41.34**	37.28**	186.76**
L2 × T3	2.95**	1.95	4.29**	148.87**	87.64**	269.45**
L3 × T1	-3.56**	-6.98**	1.29	130.71**	124.28**	256.59**
L3 × T2	-6.87**	-7.41**	-6.32**	81.17**	59.54**	233.25
L3 × T3	2.40**	1.84	4.18**	166.75**	117.26**	245.44
L4 × T1	-8.75**	13.07**	4.55**	79.69**	49.72**	237.26
L4 × T2	-8.65**	-16.36**	0.60	65.45**	59.44**	259.16**
L4 × T3	-14.01**	-20.44**	-4.30**	126.97**	63.87**	269.13**
L5 × T1	-5.42**	-6.31**	3.96**	-170.58**	151.69	277.86*
L5 × T2	-11.18**	-15.57**	3.96**	89.98**	53.73	221.12**
L5 × T3	1.46	-2.50**	6.31**	265.62**	224.34**	318.95**
L6 × T1	3.47**	0.80	9.77**	131.18**	123.65**	259.16
L6 × T2	1.58	-0.38	3.25**	98.13**	75.23**	392.27
L6 × T3	-1.43	-1.91	1.32	277.81**	206.53**	266.02**
L7 × T1	-9.09**	-12.30**	-4.49**	98.32**	75.55**	242.12**
L7 × T2	2.12*	1.50	2.73**	60.45**	55.08**	223.93**
L7 × T3	-9.28**	-9.76**	-7.68**	130.77**	74.59**	240.25**

*Significant at 5 percent level **significant at 1 percent level

Table 6: Percentage of Heterosis for Ear length and Ear girth

Crosses	Ear length			Ear girth		
	MP	BP	SP over dragon	MP	BP	SP over dragon
L1 × T1	24.79**	2.48	38.02**	-87.94**	-88.37**	-84.32**
L1 × T2	29.17**	5.87	42.58	38.25*	28.73	73.50*
L1 × T3	30.31**	13.54	52.91**	41.01*	22.82	65.53
L2 × T1	40.80**	34.66**	27.65**	31.55	28.14	60.59*
L2 × T2	17.50*	12.11*	6.27	42.46*	40.89	67.43
L2 × T3	37.34**	33.77**	33.77**	57.18**	44.73	71.98*
L3 × T1	56.84**	53.67**	32.96**	39.22*	38.14	73.12
L3 × T2	63.79**	60.88**	38.50**	43.56*	39.38	71.98*
L3 × T3	27.96**	17.10**	17.10**	52.96**	38.46	70.84*
L4 × T1	35.69**	26.30**	26.84**	40.47**	28.75	61.35*
L4 × T2	62.12**	50.54**	51.19	56.60**	48.64	72.74*
L4 × T3	44.37**	44.06**	44.68**	81.98**	76.04**	88.19**
L5 × T1	42.75**	38.83**	20.12**	42.33*	33.90	67.81*
L5 × T2	57.88**	53.92**	32.51**	47.71*	44.07	67.43*
L5 × T3	71.30**	55.69**	55.69**	76.05**	67.70*	85.27**
L6 × T1	33.64**	24.74**	24.52**	53.85**	38.44	73.50*
L6 × T2	29.22	20.33**	20.12**	55.76**	45.05	68.56*
L6 × T3	64.79	64.65**	64.65**	64.96**	64.77*	65.15*
L7 × T1	35.72**	25.58**	27.76**	36.95**	31.48	64.77*
L7 × T2	28.43*	18.56**	20.62**	44.31**	43.74	67.05*
L7 × T3	13.73**	12.76**	14.71**	71.75**	60.36*	84.89**

*Significant at 5 percent level **significant at 1 percent level

Table 7: Percentage of Heterosis for No. of grain rows per ear and No. of grains per row

Crosses	No. of grain rows per ear			No. of grains per row		
	MP	BP	SP over dragon	MP	BP	SP over dragon
L1 × T1	11.17*	10.56*	5.29	9.30	-1.05	-24.19**
L1 × T2	23.86**	23.01**	18.78**	20.40**	-2.42	-2.42
L1 × T3	15.18**	12.43*	12.43**	4.76	-11.61	-20.16**
L2 × T1	19.01**	16.90**	13.54**	-4.23	-13.56*	-17.74**
L2 × T2	13.42**	12.88**	19.37**	-13.22**	20.24**	18.32**
L2 × T3	9.65*	8.20	8.20	23.48**	-15.32**	14.52*
L3 × T1	2.55	-1.80	1.06	-5.94	-16.94**	-16.94**
L3 × T2	10.08*	6.68	9.79*	16.13**	16.13	16.13**
L3 × T3	4.56	3.08	6.08	24.12**	-30.65**	-30.65**
L4 × T1	17.66**	13.95**	14.55**	3.92	-2.75	-14.52*
L4 × T2	19.40**	16.84**	17.01**	4.72	-1.61	-25.00**
L4 × T3	16.12**	15.79**	16.42**	-4.07	-5.36	-4.03
L5 × T1	17.26**	15.45**	8.73	-6.06	-9.71	-17.74*
L5 × T2	19.72**	16.44**	12.43*	4.85	-4.03	-8.06
L5 × T3	17.57**	12.43*	12.43*	-5.12	-8.93	14.44*
L6 × T1	26.29**	25.07**	20.11**	11.22**	3.64	-8.06
L6 × T2	24.45**	24.11**	21.84**	21.37**	14.52**	13.52**
L6 × T3	26.05**	13.54**	13.54**	2.70	1.79	-8.06
L7 × T1	28.77**	20.02**	19.58**	-1.04	-2.06	-23.39**
L7 × T2	24.05*	20.08**	17.60**	9.50*	-2.42	-2.42
L7 × T3	19.04*	19.12**	18.46**	12.92*	-18.75**	-26.61

*Significant at 5 percent level **significant at 1 percent level

Table 8: Percentage of Heterosis for 100 grain weight and Grain yield per plant

Crosses	100 grain weight			Grain yield per plant		
	MP	BP	SP over Dragon	MP	BP	SP over Dragon
L1 × T1	37.68**	27.82**	-5.71	40.25**	-4.54*	83.42**
L1 × T2	21.61**	0.06	0.05	35.29**	-12.13	68.84**
L1 × T3	55.28**	52.43**	0.02	28.43**	-2.37	87.60**
L2 × T1	18.85**	6.66	-1.02	98.51**	70.28*	65.17**
L2 × T2	5.38	1.59	1.58	68.04*	33.78**	29.77**
L2 × T3	51.18**	29.03**	19.74**	83.25**	80.50**	80.50**
L3 × T1	17.29**	3.30	0.05	137.64	132.87**	68.41**
L3 × T2	23.60	21.65**	15.65**	142.87**	117.90**	57.58**
L3 × T3	13.68**	4.86	7.65	93.05**	66.33**	66.33**
L4 × T1	49.66**	39.81**	3.12	85.25**	53.55**	61.53**
L4 × T2	36.08**	11.62*	11.62*	112.15**	64.00	72.52**
L4 × T3	57.21**	55.33**	1.92	73.95**	69.65**	78.46**
L5 × T1	32.98**	25.17**	-7.66	193.18**	164.36**	83.50**
L5 × T2	34.17**	10.76*	10.76*	169.86**	165.91**	52.76**
L5 × T3	51.18**	50.56**	-1.18	164.33**	105.87**	105.87**
L6 × T1	35.69**	22.25**	12.45	143.27**	138.82**	72.07**
L6 × T2	25.22**	20.19**	21.02**	171.59**	144.39**	142.39**
L6 × T3	35.96**	16.47**	7.14	181.76**	142.06**	75.85**
L7 × T1	31.30**	23.10**	-9.21	-102.53**	77.20**	64.03**
L7 × T2	15.12**	-5.29	-5.29	107.67*	68.27**	55.77**
L7 × T3	66.09**	64.71**	8.08	69.48*	63.19**	63.19**

*Significant at 5 percent level **significant at 1 percent level

Hence, from the foregoing discussion it may be concluded that, among the twenty one hybrids, three hybrids *viz.*, AU 720/AMU 44, AU 183/AMU 51 and AU 161/AMU 44 were noted as best hybrids based on the magnitude of heterosis.

REFERENCES

[1] Morries, M.L., Risopoulos, J., and Beck, D., "Genetic changes in farmers recycle maize seed: A review of the evidence", CIMMYT Econ, Working Paper No. 99-07, Mexico, D.F., CIMMYT, 1999, pp. 1.

[2] Prasanna, B.M., "Maize research for development scenario: Challenges and opportunities for Asia", Extended Summaries of 12th Asian Conference, 30 Oct. 1 Nov. 2014, Bangkok, Thailand, pp. 2-10.

[3] Vassal, S.K., "Hybrid maize technology: Challenges and expanding possibilities for research in the next century", Proceeding for the Seventh Asian Regional Maize Workshop Held in Philippines, 1998, pp. 58-65.

[4] Chopra, V.L., Breeding Field Crops. Oxford and IBH Publishing, New Delhi, India, 2001.

[5] Hallauer, A.R., and Miranda, J.B., "Quantitative Genetics in Maize Breeding 2nd ed.", Iowa State University Press Ames USA, 1988, pp. 468.

[6] Turner, J.H., "A Study of Heterosis in Upland Cotton, Combining Ability and Inbreeding Effects. *Agronomy Journal*, 45: 1953, pp. 487-490.

[7] Grakh, S.S., and Chaudhary, M.S., "Heterosis for early maturing and high yield in *Gossypium arboretum*", *Indian J. Agric. Sci.*, 55: 1985, pp. 10-73.

[8] Swaminathan, M.S., Siddiq, E.A., and Sharma, S.D., Outlook for Hybrid Rice in India. *In:* Rice Breeding", Int. Rice Res., Inst., Manila, Philippines, 1972, pp. 609-613.

[9] Bobby, T.P.M., and Natarajan, N., "Heterosis and Combining Ability Studies in Rice Hybrids Involving CMS Lines", *Oryza*, 31: 1994, pp. 5-8.