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ESTIMATION OF HETEROSIS, HETEROBELTIOSIS AND GENETIC EFFECT FOR YIELD AND SOME YIELD RELATED AGRONOMIC CHARACTERS IN CHILLI (*Capsicum annuum* L.)

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ABSTRACT

Twelve locally developed F1 hybrids and their parents (10 parents) were selected to study heterosis, heterobeltiosis and genetic effect for yield and some yield related agronomic characters in chilli (Capsicum annuum L.) In a Randomized Complete Block Design with two replicates. The crosses, GK-1 x CAH 218-1, MICH 3-1 x CAH 218-1, MI 1-1 x MI Waraniya 1-1 which recorded significance heterosis for yield were also heterotic for number of pods per plant, pod length, plant height and canopy width. These crosses can be utilized to extract higher yielding breeding lines to develop pure lines with great vigour through generation advancement. Highest heterobeltiosis was shown in the cross, MICH 3-1 x CAH 218-1 for number of pods per plant, plant height and canopy width. The cross, MI 1 x MI Waraniya 1-1 showed the highest mean performance and significant heterosis for yield, number of pods per plant and plant height indicating close agreement between mean performance and heterosis. This positive relationship can be used as one indicator to isolate this cross as a successful hybrid. Numerical values of dominance effect greater than additive effect for yield, plant height, number of pods per plants and pod length in most of the crosses indicated that the genes of those characters are dispersed between parents resulting more segregates in the next generation of selfing.

Key words: chilli, heterosis, heterobeltiosis, genetic effects

INTRODUCTION

Chilli (*Capsicum annuum* L) is grown worldwide both as a spice and as a vegetable crop. It is one of the major condiments in Sri Lanka. The total extent of green chilli in 2013 was 15,454 ha producing 72,020 mt (DOA, 2013). Since dry chilli production within the country is not sufficient, dry chilli is imported from India and China. Development of open pollinated and hybrid chilli varieties having high productivity and desirable qualities is identified as a key factor to increase the production of chilli within the country.

Exploitation of heterosis has been recognized as a practical tool in providing a means of increasing yield and other economic traits of chilli (Senevirathna and Kannangara, 2004). East and Hays (1912) were the first to advocate heterosis breeding as an alternative crop improvement strategy. In chilli, heterosis was reported by Doshi and Sukula (2000) who observed that heterosis effect is high for number of fruits per plants, fruit length, fruit girth, and fruit shape index and fruit volume. Higher early and total yield, improved chemical composition as well as other morphological features of the fruit are the heterosis effect in chilli (Banga and Banga, 1998). According to Mllawithanachchi *et al.* (2006) high heterobeltiosis was reported for total yield, while heterosis for total number of pods, average pod weight and dry matter percentage was low.

Additive genetic effect and dominant effect are important in genetic analysis. Additive genetic effect is fixable effect and it will not change due to selfing. Dominance effect is an unfixable variation. It will segregate in the next generation on selfing. According to Banga and Banga (1998) both additive and non additive (dominance, overdominance, epistasis) gene effects have been reported to be important with varied extent from character to character. Considering the importance of chilli for Sri Lanka and necessity of developing high yielding open pollinated and hybrid chilli varieties within the country, this study was conducted to study heterosis, heterobeltiosis and genetic effect for yield and some yield related agronomic characters in chilli.

MATERIALS AND METHODS

Location

This experiment was conducted at the Field Crop Research and Development Institute (FCRDI), Sri Lanka. It is located in Mahailluppallama, DL1b agro-ecological region.

Parent material and seed production of F1 hybrids

Ten inbred lines (GK- 1, MICH 3-1, CAH 218-1, HB-1, MI Waraniya 1-1, CAH 36-1, KA 2-1, 985.3-1, MI Hot-1, MI 1-1) developed at the FCRDI were used as parents to incorporate characters related to yield such as number of pods/plant, pod length, pod diameter, pericarp thickness, plant height and canopy width. These inbred lines were developed using the varieties, MI 1, KA 2, MI Hot (Kannangara, 2003) Galkiriyagama (Kannangara, 2012), MICH 03 (Kannangara *et al.*(2013) and breeding lines, CAH 218, Hot Beauty, CAH 36 and 985.3 (Kannangara, 2003) developed at the FCRDI. Selection of germplasm was done on the basis of previous germplasm evaluation under field conditions at the FCRDI. Thirty day old seedlings of these parental lines were planted in clay pots during *Yala* 2013. Fifteen pots from each parent were maintained inside the net house. Plants were grown under good management conditions providing enough amounts of water and fertilizer according to the recommendation of Department of Agriculture (DOA). Crossing program was started with the onset of flowering. The crosses (MICH 3-1 x GK-1 , MICH 3-1 x CAH 218-1 , GK-1 x CAH 218-1 , HB-1 x MI Hot-1 , MI 1-1 x MI Waraniya 1-1 , MI 1-1 x GK-1 , MI 1-1 x MICH 3-1 , CAH 218-1 x CAH 36-1 , MI 1-1 x CAH 218-1 , MI 1-1 x KA 2-1 , MI 1-1 x 985.3-1 , MI 1-1 x MI Hot-1) were made through hand emasculation and pollination. Pollinated flowers were covered using oil paper bags. Ripened pods were harvested. F1seeds were extracted from ripened pods, separately.

Field experiment

F1 seeds of the crosses and their parents were sown in nursery trays and after thirty days they were transplanted in the field during *Maha* 2013/14. Randomized complete block design with two replicates was adopted. Each plot (6.0 m x 1.8 m) consisted of five rows of plants at the spacing of 60 cm x 60 cm and 2 plants per hill. Each plot contained 100 plants. Well decomposed cattle manure was incorporated before planting at the rate of 500g/per planting hole. Chemical fertilizer application was done according to the recommendation of

DOA. Insecticides and fungicides were applied to protect the crop from pests and diseases. Weed control was done manually. Enough water was supplied throughout the cropping period.

Data recording

Agronomic characters were assessed based on the descriptors published by DOA (DOA, 1995). Harvesting was started 70 days after field planting and continued in 10 days intervals. Number of pods and fresh green chilli yield of F1 hybrids and parents were recorded at each harvesting. The yield was measured using electronic balance. Pod diameter, pericarp thickness were recorded on randomly selected 10 pods from 10 plants from each replicate of each treatment using digital vernier caliper. Pod length, was recorded on randomly selected 10 pods from 10 plants from each replicate of each treatment using a ruler. Height and canopy width of the randomly selected 10 plants from each hybrid and parent were measured using a ruler.

Data analysis

Analysis of variance was done to find whether there is significant difference among hybrids and parents for tested characters. Mean separation was done using Duncan Multiple Range Test (DMRT). Heterosis and heterobeltiosis values for yield and other agronomic characters were calculated using the mean values of the yield and yield related agronomic characters as suggested by Chaudhary *et al.* (2013).

Heterosis = (F1 - MP)/MP) x 100

Where, F1 = mean performance of hybrid, MP = average performance of both parents

Heterobeltiosis = (F1 - BP)/BP) x 100

Where, F1 = mean performance of hybrid, BP = mean performance of better parents.

Significance ($p=0.05$) of the heterosis and heterobeltiosis values was tested using the t test explained by Wynne *et al.* (1970).

T test for heterosis values

$T = F1ij\text{-}MPij \,/\, \sqrt{3/8}\ EMS$

Where, Fij = The F1 hybrid value of i^{th} *and* j^{th} *parents, MPij = Mid parent value of* i^{th} *and* j^{th} *parents, EMS = Error mean square for the respective traits.*

T test for heterobeltiosis values

$T = F1ij\text{-}BPij \,/\, \sqrt{1/2}\ EMS$

Where, Fij = The F1 hybrid value of i^{th} *and* j^{th} *parents, BPij = Best parent value of* i^{th} *and* j^{th} *parents, EMS = Error mean square for the respective traits.*

Parents and chilli hybrids were analyzed to estimate the genetic components of means according to Chahal and Gosal (2002) by assuming that there is no non-allelic interaction for the characteristics that were tested in the experiment.

Estimation of mid parent value, m

$m = 1/2(AA + aa)$

Where, AA = Average value of respective trait of parent 1, Aa = Average value of respective trait of parent 2.

Estimation of additive genetic component, a

$a = 1/2(AA - aa)$

Where, AA = Average value of respective trait of parent 1, Aa = Average value of respective trait of parent 2.

Estimation of dominant genetic component, d

$d = \overline{F1} - 1/2(AA + aa)$

Where, $\overline{F1}$ *=Average value of respective trait of the cross, AA = Average value of respective trait of parent 1, Aa = Average value of respective trait of parent 2.*

RESULTS AND DISCUSSION

Analysis of variance and mean separation showed significant difference among parents and crosses for the characters (Table 1) studied indicating the sufficient genetic variability, directional dominance and heterosis.

Heterosis and heterobeltiosis for yield and yield related agronomic characters

Heterosis and heterobeltiosis was observed for all the characters. Number of hybrids showing significant heterosis and names of the hybrid on the basis of heterosis and heterobeltiosis are shown in Table 2. The number of crosses, which indicated significant heterosis among the twelve crosses, were 6 for yield, 4 each for pod length and plant height, 9 for number of pods/ plant, 8 for canopy width, 2 for pod diameter and 1 for pericarp thickness. The number of crosses, which indicated significant heterobeltiosis were 4 each for plant height and canopy width, 3 for yield, 7 for number of pods/ plant. None of the crosses exhibited significant heterobeltiosis for pod length, diameter and pericarp thickness (details are given in Appendix 1). Significant heterosis observed for yield, number of pods per plant and pod length was high and was in varying proportion probably due to dominance gene effect rather than additive gene effect. According to Ahmed and Muzafar (2000) heterosis observed for most of the characters, plant height, plant spread, branch number, fruit length, fruit weight, fruit girth, pericarp thickness, fruit number and fruit yield was high and was in varying proportion. The cross, MI 1-1 x MI Waraniya 1-1 showed highest mean performance and significant heterosis for the characters, yield, number of pods/plant and plant height indicating close agreement between mean performance and heterosis. This positive relationship can be used as one indicator to isolate this cross as successful hybrid. The top heterotic cross for the pod length, MICH 3-1 x CAH 218-1 had significant heterosis for yield, number of pods/per plant, plant height and canopy width. Similar pattern of heterosis was observed by Ahmed and Hurra (2000) in sweet pepper. The cross combination, GK-1 x CAH 218-1 showed significant heterosis for yield and number of pods/plant. Six hybrids over mid parent and 3 hybrid over better parent exhibited positive heterosis for yield. The heterosis was high as 87 % (GK-1 x CAH 218-1) and heterobeltiosis was high as 48 % (MI 1-1 x 985.3-1),

Table 1. Means of yield and some yield related agronomic characteristics of parents and F1 hybrids

Crosses	Yield t/ha	Pod length (cm)	Pod diameter (mm)	Pericarp thickness(mm)	Number of pods per plant	Plant height (cm)	Canopy width (cm)
MICH 3-1 x GK -1	8.31bcdef	8.8c	13.1bcdef	1.6abcd	105defg	46.3bc	47.35def
MICH 3-1 x CAH 218-1	7.79cdef	8.8c	10.9ijk	1.5bcde	127cdefg	66.1ab	56.3bc
GK-1 x CAH 218-1	10.10bcde	8.4c	11.4ghij	1.2cde	187bcd	57.9abc	45.5efg
HB-1 x MI HOT-1	7.92cdef	10.0bc	12.1efgh	1.6abcd	117cdefg	54.7abc	45.25efg
MI 1-1 x MI Waraniya1	35.66a	13.2ab	13.6bcd	1.8abc	353 a	75.8a	34.4jk
MI 1-1 x GK-1	12.22bcd	9.1c	11.8fghi	1.2cde	193bcd	49.6bc	61.05ab
MI 1-1 x MICH 3-1	9.54bcdef	9.3c	11.9fgh	1.6abcde	140bcdef	46.1bc	50cde
CAH 218-1 x CAH 36-1	4.76ef	10.7bc	11.4ghi	1.4bcde	49g	68.3ab	44.15efgh
MI 1-1 x CAH 218-1	7.09def	8.6c	9.48l	0.95e	132cdefg	54.5abc	54.45bcd
MI 1-1 x KA 2-1	12.84bcd	8.9c	11.19ijkh	1.19cde	159bcde	49.15bc	42.8efghi
MI 1-1 x 985.3-1	15.03b	9.7bc	12.72cdefg	1.32bcde	143bcdef	51.6bc	42.25fghi
MI 1-1 x MI Hot-1	14.01bc	8.25c	11.36ghij	1.24cde	217bc	53.6abc	41.65fghij
Parents	**Yield t/ha**	**Pod length (cm)**	**Pod diameter (mm)**	**Pericarp thickness(mm)**	**Number of pods per plant**	**Plant height (cm)**	**Canopy width (cm)**
GK-1	7.60cdef	8.7c	12.5cdefgh	1.5bcde	128cdefg	49.8bc	41.2fghij
MICH 3-1	5.32ef	6.7cd	13.5bcde	1.4bcde	78efg	39.9c	36.6hijk
CAH 218-1	3.20f	4.5d	9.8kl	1.2cde	63efg	50.9bc	39.1ghijk
HB-1	4.74ef	10.5bc	14.2b	1.7abc	61efg	35.7c	34.7jk
MI Waraniya 1-1	34.61a	15.8a	18.5a	2.1a	253 b	64.9ab	63.7a
MI 1-1	10.17bcde	7.5cd	10.0jkl	1.0de	113defg	46.6bc	50.2cde
CAH 36-1	4.55ef	10.5bc	13.9bc	1.9ab	36g	54.1abc	31.7k
KA 2 -1	6.77def	7.3cd	11.1ijkh	1.4bcde	107defg	37.0c	35.6ijk
985.3 -1	9.48bcdef	10.1bc	14.2b	1.5bcde	99defg	49.8bc	46.8ef
MI Hot -1	9.43bcdef	7.5cd	12.46defgh	1.41bcde	140bcdef	51.5bc	45.3efg
CV%	25.53	17.4	5.04	17.59	31.19	18.48	7.11

Note: Within the column, the means followed by the same letters are not significantly different at p=0.05

Table 2. Number of hybrids and names of the hybrids showing significant heterosis and heterobeltiosis

Characters	No.of hybrids showing significant heterosis	Names of the hybrids showing significant heterosis and heterosis %	No.of hybrids showing significant heterobeltiosis	Names of the hybrids showing significant heterobeltiosis and heterobeltiosis %
Yield (t/ha)	6	GK-1 x CAH 218-1 (87), **MICH 3-1 x CAH 218-1** (83), MI 1-1 x MI Waraniya 1-1 (59), **MI 1-1 x 985.3-1** (53), MI 1-1 x KA 2-1 (52), **MI 1-1 x MI Hot-1** (43)	3	MICH 3-1 x CAH 218-1 (46), MI 1-1x MI Hot-1 (38), MI 1-1 x 985.3-1 (48)
Number of pods per plant	9	**MI 1-1 x MI Waraniya 1-1** (103), **GK-1 x CAH 218-1 (96)**, **MICH 3-1 x CAH 218-1** (80), **MI 1-1 x GK-1 (60)**, MI 1-1 x MICH 3-1(46), MI 1-1 x CAH 218-1 (50), **MI 1-1 x KA 2-1** (45), **MI 1-1 x 985.3-1** (35), **MI 1-1 x MI Hot-1**(71)	7	MICH 3-1 x CAH 218-1 (63), MI 1-1 x GK-1 (51), MI 1-1 x MI Waraniya 1-1 (50),GK-1 x CAH 218-1 (46), MI 1-1 x KA 2-1 (41), MI 1-1 x 985.3-1 (26), MI 1-1 x MI Hot-1 (55)
Pod length (cm)	4	MICH 3-1 x CAH 218-1 (55), MI 1-1 x MICH 3-1 (30), CAH 218-1 x CAH 36-1 (43), MI 1-1 x CAH 218-1 (44)	0	-
Pod diameter (mm)	2	MI 1-1 x KA 2-1 (6), MI 1-1 x 985.3-1 (5)	0	-
Pericarp thickness (mm)	1	MI 1-1 x MICH 3-1 (32)	0	-
Plant height (cm)	4	**MICH 3-1 x CAH 218-1** (46), HB-1 x MI Hot-1 (25), **MI 1-1 x MI Waraniya 1-1** (36), **CAH 218-1 x CAH 36-1** (30)	4	MICH 3-1 x CAH 218-1 (30), GK-1 x CAH 218-1 (14), MI 1-1 x MI Waraniya 1-1 (17), CAH 218-1 x CAH 36-1 (26)
Canopy widh (cm)	8	**MICH 3-1 x GK-1** (22), **MICH 3-1 x CAH 218-1** (49), GK-1 x CAH 218-1 (13), HB-1 x MI Hot-1 (13), **MI 1-1 x GK-1** (33), MI 1-1 x MICH 3-1 (15),**CAH 218-1 x CAH** 36-1 (25), MI 1-1 x CAH 218-1 (22)	4	MICH 3-1 x GK-1 (15), MICH 3-1 x CAH 218-1 (44), MI 1-1 x GK-1 (22), CAH 218-1 x CAH 36-1 (13)

Note: Bolt figures indicate crosses of both heterosis and heterobeltiosis respectively. The cross, MI 1-1 x MI Waraniya 1-1 exhibited significant heterosis and heterobeltiosis for number of pods/plant with value of 103 % and 50% respectively and the crosses, MICH 3-1 x CAH 218-1 , MI 1-1 x MI Hot-1, MI 1-1 x GK-1 exhibited significant heterobetiosis for the same character with the value of 63%, 55% and 51%, respectively. The cross MICH 3-1 x CAH 218-1 showed significant heterobeltiosis for yield, number of pods/plant, plant height and canopy width with the value of 46%, 63%, 30% and 44%, respectively. The crosses, especially GK-1 x CAH 218-1, MICH 3-1 x CAH 218-1, MI 1-1 x MI Waraniya 1-1 heterotic for yield and most of the yield related characters like number of pods/plant, pod length, plant height and canopy width. Since, yield and most of the yield related agronomic characters are positively associated, it indicates that high heterosis observed for yield in many crosses is a result of combined heterosis of yield and yield related agronomic characters.

Additive genetic component [a] and dominant genetic component [d]

Numerical values of additive genetic component [a] and dominant genetic component [d] indicated existence of both additive and dominant gene action in the expression of the yield and tested agronomic characters (Table 3). The number of crosses, which exhibited higher numerical value of [d] than [a] were 9 each for yield and plant height, 7 for pod length, 8 for number of pods/plant, 5 for canopy width, 3 for pericarp thickness, 2 for pod diameter.

Numerical values of [d] greater than [a] for yield, plant height, number of pods/plants and pod length in most of the crosses indicate that the genes of those character are dispersed between parents resulting more segregates in the next generation of selfing. Higher numerical value of [a] than [d] for pod diameter and pericarp thickness in the 10 crosses and 9 crosses, respectively indicated the less possibility of segregates in the next generation of selfing. Singh and Singh (1978) told that morphological characters of chilli with none additive gene effect (dominance, overdominance, epistais) are total yield, plant height, number of fruits/ plant and days to maturity. According to Hasanuzzaman and Farug Golam (2011) all three type of gene action, additive, dominance and interaction components were found to play a role in the inheritance of fruit length, fruit width and number of pod/plant of chilli.

Table 3. Genetic effect of yield and some yield related agronomic characteristics of chilli estimated using the F1 hybrids and the parents

Cross	Characteristics							
	Genetic effect	Yield (t/ha)	Pod Length (cm)	Pod Diameter (mm)	Pericarp Thickness (mm)	Number of pods per plant	Plant Height (cm)	Canopy Width (cm)
1.MICH 3-1 x GK-1	M	6.46	7.79	13.01	1.44	103	44.87	38.95
	[a]	1.14	0.95	0.5	0.06	25	4.92	2.3
	[d]	1.85	0.07	0.02	0.15	1	1.48	8.4
2.MICH 3-1 x CAH 218-1	m	4.26	5.66	11.66	1.28	70	45.42	37.85
	[a]	1.06	1.17	1.85	0.09	7.5	5.47	1.2
	[d]	3.52	3.09	-0.73	0.18	57	20.68	18.45
3.GK-1 x CAH 218-1	m	5.4	6.61	11.16	1.34	96	50.35	40.15
	[a]	2.2	2.12	1.35	0.16	32.5	0.55	1.1
	[d]	4.7	1.72	0.25	-0.11	92	7.6	5.35
4.HB-1 x MI Hot-1	m	7.08	9.00	13.36	1.56	100	43.6	40.02
	[a]	2.34	1.52	0.89	0.15	40	7.9	5.32
	[d]	0.84	1.04	-1.21	0.03	17	11.1	5.23
5.MI 1-1 x Waraniya 1-1	m	22.38	11.65	14.26	1.55	174	55.77	57
	[a]	12.22	4.17	4.27	0.55	61	9.17	6.75
	[d]	13.28	2.05	-0.62	0.21	179	20.08	-22.6
6.MI 1-1 x GK-1	m	8.88	8.11	11.25	1.25	120	48.2	45.75
	[a]	1.28	0.63	1.26	0.25	7.5	1.6	4.5
	[d]	3.34	0.97	0.59	-0.04	73	1.45	15.3
7.MI1-1 x MICH 3-1	m	7.74	7.16	11.75	1.19	95	43.27	43.45
	[a]	2.42	0.32	1.76	0.18	18	3.32	6.8
	[d]	1.8	2.16	0.18	0.38	44	2.88	6.55
Cross	**Characteristics**							
	Genetic effect	**Yield (t/ha)**	**Pod Length (cm)**	**Pod Diameter (mm)**	**Pericarp Thickness (mm)**	**Number of pods per plant**	**Plant Height (cm)**	**Canopy Width (cm)**
8.CAH 218-1 x CAH 36-1	m	3.87	7.49	11.88	1.56	50	52.47	35.4
	[a]	0.67	3	2.07	0.38	13.5	1.57	3.65
	[d]	0.89	3.24	-0.44	-0.18	-1	15.8	8.75
9.MI 1-1 x CAH 218-1	m	6.68	5.98	9.90	1.09	88	48.75	44.65
	[a]	3.48	1.49	0.09	0.09	25.5	2.15	5.6
	[d]	0.41	2.65	-0.42	-0.14	45	5.75	9.8

Table 3 Continued

10.MI 1-1 x KA 2-1	m	8.46	7.41	10.56	1.21	110	41.8	42.92
	[a]	1.69	0.06	0.57	0.21	3.5	4.8	7.32
	[d]	4.37	1.45	0.63	-0.02	53	7.35	-0.12
11.MI 1-1 x 985.3-1	m	9.82	8.78	12.12	1.25	106	48.22	48.55
	[a]	0.34	1.3	2.12	0.24	7	1.62	1.7
	[d]	5.21	0.94	0.6	0.07	37	3.38	-6.3
12.MI 1-1 x MI Hot-1	m	9.79	7.48	11.23	1.20	126	49.05	47.8
	[a]	0.37	0	1.23	0.2	13.5	2.45	2.45
	[d]	4.21	0.77	0.13	0.04	91	4.55	-6.15

m = Mid parent value, [a] = Additive genetic effect, [d] = Dominance effect

Negative [d] value for the pericarp thickness in the crosses, GK-1 x CAH 218-1, MI 1-1 x GK, MI 1-1 x CAH 218-1, MI 1-1 x KA 2-1 will provide an opportunity to extract chilli breeding lines with less pericarp thickness suitable for developing chiilli varieties suitable for dry chilli production.

CONCLUSIONS

In the study, none of the crosses was consistent for all the tested characters in case of heterosis and heterobeltiosis. Majority of the crosses showed considerable amount of heterosis in desired direction. The hybrids namely, GK-1 x CAH 218-1, MICH 3-1 x CAH 218-1, MI 1-1 x MI Waraniya 1-1 which revealed higher positive heterosis for yield and yield contributing characters can be utilized to extract higher yielding breeding lines to develop pure lines with great vigour through generation advancement. The cross MI 1-1 x MI Waraniya 1-1 can be utilized for further testing of adaptability to release as a chilli F1 hybrid. Since, both additive and dominant gene actions are presence, pedigree breeding with recurrent selection can be used to extract both dominant and additive genetic effect simultaneously in the improvement of chilli.

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APPENDIX 1

Appendix 1. Heterosis (%), Heterobeltiosis (%) of yield and yield related agronomic characteristics of F1 hybrids.

Cross	Yield t/ha		Pod length cm		Pod diameter		Pericarp thickness	
	Heterosis	HB	Heterosis	HB	Heterosis	HB	Heterosis	HB
MICH 3 X GK	28.6	9.34	13.12	0.85	0.15	-3.58	10.41	5.64
MICH 3 X CAH 218	82.75 *	46.29*	55.00*	28.34	-6.32	-19.15	14.4	6.54

Apendix 1 continued								
GK X CAH 218	87.05*	32.9	26.30	-4.4	2.21	-8.79	-8.55	-18.27
HB X MI Hot	11.75	-16.00	11.58	-4.51	-9.05	-14.76	1.75	-7.53
MI 1 X MI Waraniya 1	59.28*	3.04	12.97	-16.82	-4.36	-26.38	13.00	-16.58
MI 1 X GK	37.56	20.19	12.02	3.94	5.22	-5.35	-3.18	-19.26
MI 1 X MICH 3	23.26	-6.1	30.19*	24.66	1.5	-11.72	31.93*	14.18
CAH 218 X CAH 36	22.87	4.66	43.20*	2.23	-3.74	-18.02	-11.68	-28.86
MI 1 X CAH 218	6.14	-30.23	44.27*	15.44	-4.29	-5.15	-12.78	-19.40
MI 1 X KA 2	51.55*	26.7	19.55	18.51	5.93*	0.49	-1.64	-16.14
MI 1 X 985.3	52.99*	47.87*	10.67	-3.61	4.95*	-10.70	6	-11.37
MI 1 X MI Hot	42.97*	37.77*	10.32	10.28	1.2	-8.82	2.69	-12.05

* - Significance (p=0.05), HB= Heterobeltosis

Appendix 2. Heterosis (%), Heterobeltiosis (%) of yield related agronomic characteristics of F1 hybrids.

Cross	Number of pods/plant		Plant height cm		Canopy width	
	Heterosis	HB	Heterosis	HB	Heterosis	HB
MICH 3 X GK	1.39	-18.51	3.28	-6.92	21.56*	14.78*
MICH 3 X CAH 218	79.78*	62.57*	45.51*	29.86*	48.74*	44.17*
GK X CAH 218	96.36*	46.39*	15.09	13.58*	13.32*	10.30
HB X MI Hot	16.6	-16.4	25.45*	6.21	13.05*	-0.22
MI 1 X MI Waraniya 1	102.78*	50.39*	35.99*	16.78*	-39.64	-46.03
MI 1 X GK	59.91*	50.75*	3.00	-0.30	33.44*	21.49*
MI 1 X MICH 3	46.08*	23.15	6.64	-0.9	15.07*	-0.49
CAH 218 X CAH 36	-9.03	-22.08	30.10*	26.30*	24.71*	13.06*
MI 1 X CAH 218	50.17*	16.72	11.79	7.07	21.94*	8.35
MI 1 X KA 2	44.96*	40.86*	17.58	5.47	-0.29	-14.82
MI 1 X 985.3	34.63*	26.06*	6.99	3.51	-12.97	-15.92
MI 1 X MI Hot	71.2*	54.95*	9.27	4.07	-12.86	-17.11

* - Significance (p=0.05), HB= Heterobeltosis