Heterosis: Kazakhstan and Egyptian Wheats

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ABSTRACT

Egyptian and Kazakhstan wheats were combined in Kazakhstan spring 2007, the hybridization schemes have been performed as follow three Egyptian cultivars; four Kazakhstan cultivars as male parents and lines as female parents, and vice versa. *Aegilops ventricosa* from Egypt was used exclusively as pollen donor (male parent) for respective hybridizations. Eight Parents with their twenty five hybrids were sown at The Experimental Station of Faculty of Agriculture, (Saba Basha) Alexandria University (Abis Farm – Egypt), during 2007-2008 harvest seasons. Then, ten plants for each parents and hybrids were collected and F_1 heterosis was assessed for the morphological characters i.e. plant height (cm); heading date (days); the number of tillers per plant; spike length, (cm); the number of spikelets per spike; seed number in the spike and 1000-grain weight (g) using formula $H= \mu F_1 - (\mu P_1 + \mu P_2/_2)$

Key words: Heterosis, Kazakhstan and Egypt Wheats.

Abbreviations:	E_4 : *Aegilops ventricosa* Tausch	K_4 : Genotroph 1
E_1 : Sakha 161	K_1 : Albidum 16	E_1k_1: Sakha 161 x Albidum 16 k_1E_1: Albidum 16 x Sakha 161 etc ...
E_2 : Sakha 168	K_2 : Kazakhstanskaya 4	
E_3 : Gemmieza 7	K_3 : Kazakhstanskaya 126	

INTRODUCTION

The term heterosis was coined by Shull (1908) defined heterosis concept as "the interpretation of increased vigor, size, fruitfulness, speed of development, resistance to disease and to insect pests, or to climatic rigors of any kind, manifested by crossbred organisms as compared with corresponding inbred, as the specific results of unlikeness in the constitutions of the uniting parental gametes". This definition is often interpreted as not implying a genetic basis for heterosis, because the definition basically describes the phenotype that results from crossing two different inbred lines. Heterosis is defined as the superiority of F_1 hybrids over their inbred parents Shull (1908). Hybrid vigour is expressed by increased biomass, growth rate, fertility, resistance to diseases and insects as well as tolerance to abiotic factors Birchler *et al.*, (2003). Heterosis can be defined as mid-parent heterosis (MPH), the difference between the hybrid and the mean of either parents or high-parent heterosis (HPH), the difference between the hybrid and the parent with the highest trait value

Lamkey and Edwards (1998). Heterosis also is defined as advantageous quantitative and qualitative traits of off-spring over their parents, and the utilization of heterosis principles has been a major practice for increasing productivity of plants and animals Yao *et al.*, (2005).

Three hypotheses tried to explain heterosis: (a) the dominance hypothesis: masking of harmful recessive alleles by superior dominant alleles in the heterozygous hybrid Bruce (1910) and Jones (1917), (b) the over dominance hypothesis: superior phenotypic performance of the heterozygote as compared to both homozygous genotypes Hull (1945) and Crow (1948) and (c) the epistasis hypothesis: interaction of favourable alleles at different loci contributed by the two homozygotes Williams (1959); Li *et al.* (2001) and Meyer *et al.* (2004). Hybrid maize was the first hybrids, in the 1920s, yielded about 15% more than the better open pollinated varieties (Iowa, 1934). Heterosis of six yield components and five spring wheat cultivars were concluded by Khan *et al.* (1995) that half of hybrids showed heterosis over the better parent value for grains per spike the results showed that heterosis of 1000-grain weight, spike weight and grains per spike reached 51.10%, 44.58% and 40.35%, respectively.

MATERIALS AND METHODS

Hybridization of Kazakhstan and Egyptian wheat parents were in the republic of Kazakhstan, Almaty, for 2006-2007 seasons. Parents with their 25 hybrids were sown at The Experimental Station of Faculty of Agriculture, (Saba Basha) Alexandria University, Abis Farm, Arab republic of Egypt. To assess the F_1 heterosis for morphological characters of 25 hybrids from wheat cultivars (*Triticum aestivum* L.) for further ascertain of their capacity for hybridization in breeding programs, ten plants for each cultivar were collected and assessed for different morphological characters including plant height (cm) measured from ground level to the end of spike except awns at maturity (cm); heading date (days) as duration from the date of sowing to the date of 50% spike's exertion beyond the flag leaf sheath; the number of tillers per plant counted at maturity; spike length, (cm); the number of spikelets per spike; seed number in the spike and 1000-grain weight (g). The most standard usage is mid parent heterosis, defined as the F_1 mean exceeding the average means of the two parental lines, $H= \mu F_1- (\mu P_1+\mu P_2/2)$ Schull (1908).

RESULTS AND DISCUSSION

Hybridization between Egyptian and Kazakhstan wheats were achieved high values in heterosis between all hybrids in morphological traits except four hybrids namely (K_4E_1, K_1E_3, K_1E_4 and K_4E_4) which achieved negative heterosis in all traits. These were negative values due to unsuccessful hybrids in the filed experiment. Heterosis can be positive or negative. Both positive and negative heterosis can be useful depending on the trait, for example, positive heterosis for yield and negative heterosis for growth duration.

Plant height: Data in Table 1 and 2 showed that heterosis was positive and very high in all hybrids in plant height ranged from (00.1 to 39.1%). The highest heterosis is recorded for (E_2K_2, K_2E_1, K_4E_2, K_3E_1, K_2E_4, K_4E_3, E_2K_1, E_3K_3, E_3K_1, E_1K_3, E_3K_2, E_1K_1, E_2K_3, K_3E_2, K_3E_3, K_2E_3, E_1K_2, K_1E_1, and K_1E_2) in values (39.1, 36.0, 35.0, 34.2, 33.5, 32.6, 32.5, 30.1, 30.1, 29.8, 28.7, 28.6, 27.7, 27.7, 27.5, 26.3, 23.0, 22.3 and 21.7% respectively), whereas the lowest values were recorded to (E_3E_4 and E_2E_4) in values (00.10 and 0.7 respectively). Four hybrids (K_4E_1, K_1E_3, K_1E_4 and K_4E_4) achieved negative heterosis in all traits.

Heading date: Hybrids had positive heterosis ranged from 8.0% in E_3E_4 to 66.6% in K_2E_1 except the four hybrids had negative heterosis. The high values were (K_2E_1, E_1K_3, E_1K_1, K_1E_1 and E_1K_2) with values (66.6, 65.5 and 62.5%, respectively); the lowest values were recorded to (E_3E_4 and E_2E_4) by means (08.00 and 9.0%). The results clearly indicated that hybridization values were between wild type *Aegilops ventricosa* and domesticated wheat achieved the golden goal in decrease the period in days in heading date between cultivars

Number of tillers/plant: Kazakhstan parents under Egyptian conditions cannot arrived to the full maturity and were stalling in green stage they had high number of stem which effect on heterosis values by negative. Hybrids of E_1K_3, E_2K_1, E_3K_1, E_3K_3, K_3E_3, E_3E_4, K_1E_4, K_4E_4, K_4E_1, and K_1E_3 had values (-00.20, -01.20, -00.50, -01.60, -00.10, -00.60, -20.00, -20.10,-12.20 and -12.70%, respectively). Data in Table 1 and 2 showed that there was positive heterosis in number of stems per plant ranged between (1.20 to 7.30%) Highly heterosis in number of stems per plant effect on number of spike per plant and number of grains in spike depending on the relationships between number of stems spike number per plant (Table 1and 2)

Spike length: Heterosis was positive and high in all hybrids in spike length ranged (0.11 to 12.3%). The highest heterosis was recorded for (E_2K_1, E_1K_1 and K_1E_1) in values (12.03, 12.10 and 11.18% respectively), whereas the lowest values were dated to (E_2E_4 and E_3E_4) in values (0.11 and 2.53% respectively).

Number of spikelets/spike: The results in Table 1 and 2 indicated that all hybrids had positive heterosis with high values ranged between (4.10 to 16.40%).

Number of grains in spike: Hybrid vigor observed as an increase in yield of grain refers to the increase in size or rate of growth of off spring over parents; from the results all hybrids had postive heterosis and the increase in the grain yield per spike ranged from (13.3 to 47.0%).

1000 grain weight: Heterosis was positive and very high in all hybrids in 1000 grain weight ranged from (11.70 to 30.30%), the heterosis values were (30.30, 28.20, 27.85, 27.11, 20.42, 26.11, 25.30, 22.11, 20.14, 22.46, 14.01, 20.86, 25.96, 14.01, 20.86, 23.50, , 25.96, and 11.70% respectively) is recorded for (K_1E_1, K_2E_1, E_3K_1,E_1K_1, E_1K_2, E_1K_3, K_3E_1, K_1E_2, E_2K_2, K_2E_2, E_2K_3, E_3K_2, K_4E_2, K_1E_3, K_2E_3, E_3K_3, K_3E_3, k_4E_3, and K_3E_3), whereas (E_2K_1, E_2E_4, K_4E_4, K_4E, and K_1E_3) lowest values in negative (-1.46, -1.46, -1.40, -17.00, -17.00,-25.00, and -24.62 % respectively). Four hybrids (K_4E_1, K_1E_3, K_1E_4 and K_4E_4) achieved negative heterosis in all traits.

Heterosis is an important cause of the increasingly high yields of wheat, maize, grain sorghum, and oil sunflower but it is not the only cause. Improvements in general combining ability as well as in specific combining ability, in additive genes as well as in dominant, over-dominant or epistatic gene combinations, have been crucial to improvement of hybrids in all crops, studies on the genetic basis of heterosis for polygenic traits in various crops have shown that heterosis is the result of partial to complete dominance, overdominance, and epistasis, and it may be a combination of all these (Zsubori *et al.* 2002). Evidence of real overdominance for quantitative traits is hard to find. However, apparent overdominance caused by nonallelic interaction and linkage disequilibrium is a common contributor to heterosis (Janick 1996). Heterosis may also be due to the specific positive effects of the cytoplasm of the maternal parent on the nuclear component of the paternal parent.

Plant height, heading date, number of stems per plant and spike length are an excellent models character to study heterosis (Duvick, 1997), as heterosis for plant height is substantial and can exceed 70% in maize (Duvick, 1997). Plant height is easy to determine, highly heritable (Lu¨ bberstedt *et al.* 1997, 1998), and closely correlated with important agronomical traits, like biomass production and forage yield (Lu¨ bberstedt *et al.* 1998; Niklas and Enquist 2000). Moreover, significant correlations with plant height were found for number of leaves, grain yield and flowering time (Troyer and Larkins 1985) and determined by complex interaction of many genes (Zsubori *et al.* 2002). Early morphological investigations suggested that 90% of heterosis for plant height is due to an increased cell number, while 10% is due to an increase in cell size (Kiesselbach 1922). Our study is in agreement with other studies (Richey, 1946) which reported that hybrid vigor, or heterosis usually refers to the increase in size or rate of growth of offspring over parents; for example, hybrid vigor in crop plants can be observed as in increase in yield of grain, or reduction in number of days to flower with Duvick (1984) who stated that wheat hybrids can yield up to 30% more than their parents; the author reported that hybrids with heterosis at these levels usually are the product of crosses between different classes of wheat, such as a cross of hard red winter wheat by soft red winter wheat. This study is also in line with Sun *et al.* (2004) and Birchler *et al.* (2003) who differentially-expressed genes between hybrids and their parental inbreed are correlated with heterosis. This study is also in line with Rood *et al.* (1990) who reported that plant height is one of the typical traits showing heterosis in many crop plants. In maize and sorghum, the mid-parent heterosis in plant height can be 40% and 16%, respectively. In wheat, over 10% of mid-parent heterosis was observed in different hybrids the heterosis in plant height mainly results from increased internodes elongation other than increases in the number of internodes (Wu *et al.* 2001). This study is in with Khan *et al.* (1995) who showed that half of hybrids showed heterosis over the better parent value for 1000-grain weight, spike weight and grains per spike reached 51.10%, 44.58% and 40.35%, respectively. Our study is in agreement with other studies. Hassan *et al.* (1996) studied the heterosis in three different environments in F_1 of six half diallel crosses with six parents. They found that heterotic effect were high for some crosses and different among location. The current study is agreeable with Khan and Khan (1996) who studied the heterosis of some important yield component in ten crosses. They found that number of tillers showed 31.91% heterosis, 1000-grain weight showed 17.32%, grains per spike showed 11.37% and plant height showed 5.23%. Highly significant positive heterosis in bread wheat for grain yield ranged from 39.7% to 89.1% was obtained in crosses involving ten diverse parents (Sharma and Menon 1996). In full diallel cross between five genetically diverse red winter wheat Knobel *et al.* (1997) found that some traits had very low or negative levels of heterosis in characters correlated with yield.

Table (1) Heterosis for morphological traits of Egyptian and Kazakhstan wheats hybrids

	Growth characters			Spike characters			
	Plant Height (cm)	Heading date (days)	Number of tillers/ plant	Spike length (cm)	№ of spikelets/ spike	№ of Grain/ spike	1000 grain weight
P_1	100.6	85.00	10.00	12.20	21.80	62.40	50.40
P_2	126.2	00.00	14.20	00.00	00.00	00.00	00.00
(F_1) E_1k_1	142.0	105.0	16.20	18.20	23.60	68.20	52.31
Heterosis %	28.60	62.50	04.10	12.10	12.70	37.00	27.11
P_1	126.2	00.00	14.20	00.00	00.00	00.00	00.00
P_2	100.6	85.00	10.00	12.60	21.80	62.40	50.40
(F_1) K_1E_1	135.7	105.0	17.60	17.26	25.60	75.60	55.50
Heterosis %	22.30	62.50	05.50	11.18	14.70	44.40	30.30
P_1	100.6	85.00	10.00	12.16	21.80	62.40	50.40
P_2	126.6	00.00	15.40	00.00	00.00	00.00	00.00
(F_1) E_1K_2	136.6	105.0	15.80	13.54	21.80	65.40	45.62
Heterosis %	23.00	62.50	03.10	07.46	10.90	34.20	20.42
P1	126.6	00.00	15.40	00.00	00.00	00.00	00.00
P2	100.6	85.00	10.00	12.16	21.80	62.40	50.40
(F_1) K_2E_1	149.6	109.0	20.00	16.00	25.20	74.60	53.40
Heterosis %	36.00	66.50	07.30	09.92	14.30	43.40	28.20
P_1	100.6	85.00	10.00	12.16	21.80	62.40	50.40
P_2	130.2	00.00	16.40	00.0	00.00	00.00	00.00
(F_1) E_1K_3	145.2	108.0	13.00	14.60	23.80	70.40	51.31
Heterosis %	29.80	65.50	-00.20	08.52	12.90	39.20	26.11
P_1	130.2	00.00	16.40	00.00	00.00	00.00	00.00
P_2	100.6	85.00	10.00	12.16	21.80	62.40	50.40
(F_1) K_3E_1	149.6	104.0	13.60	15.00	23.80	68.00	50.50
Heterosis %	34.20	61.50	00.40	08.92	12.90	36.80	25.30
P_1	106.4	93.00	12.20	13.94	22.20	59.80	51.22
P_2	162.2	00.00	14.20	00.00	00.00	00.00	00.00
(F_1) E_2K_1	148.8	101.0	12.00	19.00	26.80	77.80	26.76
Heterosis %	32.50	54.50	-01.20	12.03	15.70	47.90	-01.46
P_1	126.2	00.00	12.20	00.00	00.00	00.00	00.00
P_2	106.4	93.00	10.20	13.94	22.20	59.80	51.22
(F_1) K_1E_2	138.0	102.0	11.80	18.80	25.40	76.00	47.72
Heterosis %	21.70	55.50	00.60	11.83	14.30	46.10	22.11
P_1	106.4	93.00	12.20	13.94	22.20	59.80	51.22
P_2	126.6	00.00	15.4	00.00	00.00	00.00	00.00
(F_1) E_2K_2	155.6	101.0	19.20	14.60	23.80	71.80	45.57
Heterosis %	39.10	54.50	05.40	07.63	12.70	41.90	20.14
P_1	126.6	00.00	15.4	00.00	00.00	00.00	00.00
P_2	106.4	93.00	12.20	13.94	22.20	59.80	51.22
(F_1) K_2E_2	150.0	106.0	16.40	13.60	23.80	72.40	48.07
Heterosis %	33.50	59.50	02.60	06.63	12.70	42.50	22.46
P_1	106.4	93.00	12.20	13.94	22.20	59.80	51.22
P_2	106.4	00.00	16.40	00.00	00.00	00.00	00.00
(F_1) E_2K_3	146.0	106.0	15.00	14.40	23.00	69.00	39.62
Heterosis %	27.70	59.50	01.20	07.43	11.90	39.1	14.01
P_1	130.2	00.00	16.40	00.00	00.00	00.00	00.00
P_2	106.4	93.00	12.20	13.94	22.2	59.80	51.22
(F_1) K_3E_2	146.0	107.0	16.40	15.16	24.80	72.80	46.47
Heterosis %	27.70	60.50	02.10	08.19	13.70	42.90	20.86
P_1	139.6	00.00	14.40	00.00	00.00	00.00	00.00
P_2	106.4	93.00	12.20	13.94	22.2	59.80	51.22
(F_1) K_4E_2	158.0	108.0	15.60	16.00	25.40	75.00	51.57
Heterosis %	35.00	61.50	02.30	09.03	14.30	45.10	25.96
$LSD_{0.05}$ (P)	6.320	10.330	2.250	0.860	1.510	5.040	04.120
$LSD_{0.05}$ (F_1)	1.153	00.448	2.709	1.503	1.372	3.430	0.116

Table (2) Heterosis for morphological traits of Egyptian and Kazakhstan wheats hybrids

	Growth characters			Spike characters			
	Plant Height (cm)	Heading date (days)	Number of Tillers/plant	Spike length (cm)	№ of spikelets/ spike	№ of Grain/ spike	1000-grain weight
P_1	108.0	95.00	11.20	13.70	23.00	62.80	49.24
P_2	162.2	00.00	14.20	00.00	00.00	00.00	00.00
$(F_1)\ E_3K_1$	147.2	104.0	12.20	17.40	26.20	78.60	52.67
Heterosis %	30.10	56.50	-00.50	10.55	14.70	47.20	27.85
P_1	108.0	95.00	11.20	13.70	23.00	62.50	49.24
P_2	126.6	00.00	15.4	00.00	00.00	00.00	00.00
$(F_1)\ E_3K_2$	146.0	105.0	15.20	15.40	23.80	70.20	56.47
Heterosis %	28.70	57.50	01.90	08.55	12.30	38.80	14.01
P_1	126.6	00.00	15.4	00.00	00.00	00.00	00.00
P_2	108.0	95.00	11.20	13.70	23.00	62.50	49.24
$(F_1)\ K_2E_3$	143.6	103.0	21.00	15.48	24.60	73.80	52.40
Heterosis %	26.30	55.50	07.70	08.63	13.10	42.40	20.86
P_1	108.0	95.00	11.20	13.70	23.00	62.50	49.40
P_2	130.2	00.00	16.40	00.00	00.00	00.00	00.00
$(F_1)\ E_3K_3$	149.2	105.0	12.20	14.20	22.20	62.60	48.20
Heterosis %	30.10	57.50	-01.60	.07.35	10.70	31.20	23.50
P_1	130.2	00.00	16.40	00.00	00.00	00.00	00.00
P_2	108.0	95.00	11.20	13.70	23.00	62.50	49.24
$(F_1)\ K_3E_3$	146.6	106.2	12.80	14.14	24.20	69.90	36.32
Heterosis %	27.50	58.70	-00.10	07.29	12.70	38.20	11.70
P_1	139.6	00.00	14.40	00.00	00.00	00.00	00.00
P_2	108.0	95.00	11.20	13.70	23.00	62.50	49.24
$(F_1)\ K_4E_3$	156.4	107.0	16.80	16.50	26.60	78.00	56.28
Heterosis %	32.60	59.50	04.00	09.65	15.10	46.60	25.96
P_1	106.4	93.00	12.20	13.94	22.20	59.80	51.22
P_2	91.00	105.0	12.80	11.84	13.20	34.40	34.00
$(F_1)\ E_2E_4$	99.40	108.0	20.00	13.00	21.80	60.40	41.15
Heterosis %	00.70	09.00	07.50	00.11	04.10	13.30	-01.46
P_1	108.0	95.00	11.20	13.70	23.00	62.80	49.24
P_2	91.00	105.0	12.80	11.84	13.20	34.40	34.00
$(F_1)\ E_3E_4$	99.60	108.0	11.40	15.30	23.00	63.40	40.22
Heterosis %	00.10	08.00	-00.60	02.53	16.40	14.80	-01.40
P_1	162.20	00.00	14.20	00.00	00.00	00.00	00.00
P_2	91.00	105.0	12.80	11.84	13.20	34.40	34.00
$(F_1)\ K_1E_4$	00.00	00.00	00.00	00.00	00.00	00.00	00.00
Heterosis %	-108.6	00.00	-20.00	-05.92	-06.60	-17.20	-17.00
P1	139.0	00.00	14.40	00.00	00.00	00.00	00.00
P2	91.00	105.0	12.80	11.84	13.20	34.40	34.00
$(F_1)\ K_4E_4$	00.00	00.00	00.00	00.00	00.00	00.00	00.00
Heterosis %	-115.3	-52.50	-20.10	-05.92	-06.60	-17.20	-17.00
P_1	139.6	00.00	14.40	00.00	00.00	00.00	50.40
P_2	100.6	85.00	10.00	12.16	21.80	62.40	00.00
$(F_1)\ K_4E_1$	00.00	00.00	00.00	00.00	00.00	00.00	00.00
Heterosis %	-120.1	-42.50	-12.20	-06.08	-10.90	-31.20	-25.20
P_1	126.2	00.00	14.20	00.00	00.00	00.00	00.00
P_2	108.0	95.00	11.20	13.70	23.00	62.80	49.24
$(F_1)\ K_1E_3$	00.00	00.00	00.00	00.00	00.00	00.00	00.00
Heterosis %	-117.1	-47.50	-12.70	-06.85	-11.50	-31.40	-24.62
$LSD_{0.05}$ (P)	6.320	10.330	2.250	0.860	1.510	5.040	04.120
$LSD_{0.05}$ (F_1)	1.153	00.448	2.709	1.503	1.372	3.430	0.116

CONCLUSION

Wheat hybrids can yield up to 30% more than their parents, but hybrids with heterosis at these levels usually are the product of crosses between different classes of wheat, such as a cross of hard red winter wheat by soft red winter wheat. Commercially useful wheat hybrids must be made within a class, to maintain milling and baking quality. Crosses within a quality class typically have less heterosis, only about 5-15% more than their parents. The lower amount of heterosis may be because of relationship among members of a relatively closed gene pool.

Heterosis or hybrid vigor has been one of the most important driving forces for plant breeding in the last decades. When two different populations are crossed to generate a new progeny population, parental populations will certainly transfer their genes and population genetic properties of these genes into their hybrids. Therefore, for the hybrids derived from natural populations, heterosis is a property of the genes concerned as well as of populations. For this reason, the traditional genetic analysis of heterosis based purely on quantitative effects of genes, will not be enough to gain a comprehensive insight into its genetic basis. Demand for hybrid wheat is rapidly increasing due to quickly growing populations, especially in the less-developed countries. Extensive grain production has to be supplied from a reduced area under lower inputs. Hybrid wheat assortments would provide 15–20% higher yield potential comparing to inbred wheats. Moreover, new hybrids have already shown better performance under extremely unfavorable external conditions, especially under drought and high salinity.

Our present study used Kazakhstan and Egyptian wheat cultivars (*Triticum aestivium* L.), parents which were sown in the republic of Kazakhstan, Almaty, for 2006-2007 seasons and during 2007-2008 harvest seasons. Parents with their 25 hybrids were sown on Arab republic of Egypt to assess the F_1 heterosis for morphological characters to further ascertain their capacity for hybridization. Results showed that hybridization between Egyptian and Kazakhstan wheats achieved high heterosis between all hybrids in morphological traits except four hybrids namely (K_4E_1, K_1E_3, K_1E_4 and K_4E_4) which achieved negative heterosis in all traits; these negative values were due to unsuccessful hybrids in the filed experiment.

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REFERENCES

Birchler JA, Auger DL and Riddle NC (2003). In search of the molecular basis of heterosis. *Plant Cell*.15(10):2236-2239.

Bruce AB (1910). The Mendelian theory of heredity and the augmentation of vigour. Science 32:627–628.

Crow JF (1948) Alternative hypotheses of hybrid vigour. Genetics 33:477–487.

Duvick, D. N. (1984). Genetic diversity in major farm crops on the farm and in reserve. Economic Botany 38:161-178.

Duvick, D. N. (1997). The American maize seed industry: An historical overview. *In* M. Morris (ed.) Maize Seed Industries in Developing Countries (in press) México.

Hassan, A.M., M.s, Abdel Sabour, A.A, Abel Shafi, H.S. and A.A., Hamada. (1996). Genetical analysis of diallel cross in bread wheat under different environmental conditions in Egypt.1. F1 and parents. Ind. J. Genet., Plant Breed. 56:34-48.

Hull FH (1945). Recurrent selection for specific combining ability in corn. J Am Soc Agron. 37:134–135.

Iowa, (1934). Part VI. Iowa Corn and Small Grain Growers' Association. p. 135-148. *In* Anonymous (ed.) Thirty-fifth Annual Iowa Year Book of Agriculture, Issued by Iowa State Department of Agriculture. The State of Iowa, Des Moines.

Janick, J. (1996). Hybrids in horticultural crops. CSSA/ASHS Workshop on Heterosis, Indianapolis, IN. November 3, 1996. Report, Dept. Horticulture, Purdue Univ., West Lafayette, IN.,USA.

Jones DF (1917). Dominance of linked factors as a means of accounting for heterosis. Genetics 2:466–479.

Khan M.A and A.S., Khan (1996). Heterosis studies for yield and yield component in some crosses of bread wheat (*Triticum aestivum* L) Pak. J. Agric. Sci. 33:66-68.

Khan, N.U., Gul. Hassan, M.S., Swati, M.A. (1995) Estimation of heterotic response for yield and yield component on chromosome 5 A of wheat. Theor Appl. Genet, 101:1114-1121.

Kiesselbach TA (1922). Corn investigations. Bull Agric Experiment Station Nebraska 20:5–151.

Knobel, H. A., M.T. Labuschagne and C.S. van. Deventer. (1997). The expression of heterosis in the F_1 generation of a diallel cross od diverse hard red winter wheat genotypes. Cereal Res. Coms. 25:911-915.

Lamkey KR, Edwards JW (1998). Guantitative genetics of heterosis. In: Coors JG, Pandey S (eds) The genetics and exploitation of heterosis in crops. CSSA, Madison, WI, pp 31–48.

Li Z-K, Luo JL, Wang DL, Shu QY, Tabien R, Zhong DB, Ying CS, Stansel JW, Khush GS, Paterson AH (2001). Overdominant epistatic loci are the primary genetic basis of inbreeding derpession and heterosis in rice. I. Biomass and grain yield. Genetics. 158:1737–1753.

Lu¨ bberstedt T, Melchinger AE, Fa¨hr S, Klein D, Dally A, Westhoff P (1998). QTL mapping in testcrosses of flint lines of maize: III. Comparison across populations for forage traits. Crop Sci.38:1278–1289.

Lu¨ bberstedt T, Melchinger AE, Scho¨n C, Utz HF, Klein D (1997). QTL mapping in testcrosses of european flint lines of maize: I. Comparison of different testers for forage yield traits. Crop Sci 37:921–931.

Meyer RC, To¨ rje´k O, Becher M, Altmann T (2004). Heterosis of biomass production in Arabidopsis. Establishment during early development. Plant Physiol 134:1813–1823

Niklas KJ, Enquist BJ (2000). Invariant scaling relationships for interspecific plant biomass production rates and body size. Proc Natl Acad Sci USA 98:2922–2927

Richey, F. D.(1946). Hybrid vigor and corn breeding. J. Amer. Soc. Agron. 38:833-841.

Rood SB, Buzzell RI, Major DJ, Pharis RP (1990). Gibberellins and heterosis in maize: quantitative relationships. *Crop Science*, 30:281-286.

Sharma S.NM and Menon (1996) genetic diversity in durum wheat germplasm. Ann. Agric. Res. 15:418-422.

Shull GH (1908). The composition of a field of maize. Am Breeders Assoc Rep 4:296–301 Birchler JA, Auger DL, Riddle NC (2003) In search of molecular basis of heterosis. Plant Cell 15:2236–2239.

Sun Q, Wu L, Ni Z, Meng F, Wang Z, Lin Z (2004). Differential gene expression patterns in leaves between hybrids and their parental inbreds are correlated with heterosis in a wheat diallel cross. *Plant Science (Oxford)*, 166(3):651-657.

Troyer AF, Larkins JR (1985). Selection for early flowering in corn: 10 late synthetics. Crop Sci 25:695–697.

Williams W (1959). Heterosis and the genetics of complex characters Nature (London) 184:527–530.

Wu LM, Ni ZF, Wang ZK, Lin Z, Sun QX (2001). Relationship between differential expression patterns of multigene families and heterosis in a wheat diallel crosses. *Acta Genetica Sinica*, 28:256-266.

Yao Y, Ni Z, Zhang Y, Chen Y, Ding Y, Han Z, Liu Z, Sun Q (2005). Identification of differentially expressed genes in leaf and root between wheat hybrid and its parental in breds using PCR based cDNA subtraction. *Plant Mol Biol*, 58(3):367-384.

Zsubori Z, Gyenes-Hegyi Z, Ille´s O, Po´k I, Ra´cz F, Szoke C (2002). Inheritance of plant and ear height in maize (*Zea mays* L.). J Agric Sci Univer Debrecen 8:34–38

الملخص العربى

قوة الهجين: القمح المصرى الكازخى

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كازخستان (ابريل ٢٠٠٧) أجرى التهجين بين ثلاثة أباء قمح مصرية (سخا ١٦١- سخا ١٦٨- جيميزة ٧) وأربعة أباء كازاخية (البيدوم ١٦- كازخستنيسكى ٤ - كازخستنيسكى ١٢٦- جينيروف ١) مع نوع برى مصرى اجيلوبس فنتراكوزا حيث كان التهجين كالاتى الاباء المصرية مرة أب والكازخية أم والعكس بالعكس. أما بالنسبة للنوع البرى فكان بمثابة الأب لكل الانواع المصرية والكازخية.وفى جمهورية مصر العربية فى نوفمبر من نفس العام ، زرعت الثمانية أباء مع خمسة وعشرون هجين تحت الظروف المصرية فى مزرعة كلية زراعة ساباباشا جامعة الاسكندرية منطقة أبيس العاشرة وذلك لدراسة قوة الهجين الناتجة بين الاقماح المصرية والكازخية للصفات المورفولوجية الاتية (طول النبات–عدد الاشطاء الناتجة–فترة التذهي–طول السنبلة–عدد السنيبلات فى السنبلة الواحدة–عدد الحبوب فى السنبلة الواحدة–وزن الالف حبة) وذلك من خلال معادلة [متوسط النسل–(متوسط الاب الاول+متوسط الاب الثانى/٢)]. أوضحت النتائج أن قوة عالية للهجين ما بين الهجن الناتجه بالنسبة لكل الصفات المورفولوجية، ما عدا أربعة هجن كانت القيمة دائما سالبة وذلك لفشل تلك الهجن اثناء التجربة نفسها مع العلم ايضا ان الاباء الكازخية لم تتمكن من الوصول الى طور النضج التام تحت الظروف المصرية مما اثر على قيم قوة الهجين مثل طول السنبله وعدد السنيبلات ووزن الالف حبة.