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Estimation of Heterosis and Combining Abilities for Body Weights and Measurements in Chickens

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TWO exotic breeds of chickens namely New Hampshire (NH) and White Plymouth (WP) and two native breeds namely Dandarawi (DN) and Silver Montazah (SM) were used in 4x4 diallel crossing experiment . This experiment was carried out at the poultry Research Station in El-Qanater , Animal Production Research Institute , Ministry of Agriculture , Egypt in the period from November 1985 to June 1986. A total of 2413 chicks were included in the present study to estimate heterosis , general (GCA) and specific (SCA) combining abilities , maternal ability (MA) and reciprocal or sex-linked effects (SL) on body weights and measurements at different ages .

Breed group was found to have a significant (P<0.001) source of variation on traits studied. Averages of body weights and body measurements of crossbred chicks were generally higher than those of purebreds. Estimates of heterosis for all traits showed that crossbreeding was usually associated with an increase in most of body weights and measurements. Significant differences were obtained among each crossbred and its reciprocal for most traits studied . The DNxNH crossbred chicks manifested the most superior percent of heterosis (17.8%) while the SMxNH crossbreds were the most inferior ones (3.5%) for body weights and measurements. Crossing between local breeds gave the highest magnitude of heterosis for most traits , followed by crossing between exotic breeds .

The DN sires were the best performing as a sire-breed followed by SM, while WP dams were the best as a dam-breed followed by SM for most traits . General (GCA) and specific (SCA) combining abilities and maternal ability (MA) affected significantly (P<0.01) most traits studied . Non-significant differences due to reciprocal or sex-linked effects (SL) were

obtained for body weights and measurements of most ages, except for later age (16 weeks). The DN breed had the highest estimates of GCA for most traits studied, followed by SM, while WP breed had the highest estimates of MA. Crossbreds of NHxDN and SMxWP had the highest estimates of SCA for all traits. Crossbreds of NHxSM, DNxNH, WPxSM, NHxWP and DNxWP had positive estimates of SL for most traits studied.

Key Words : Chickens, Heterosis, Combining ability, Body weights and Measurements.

In the last ten years, poultry industry in Egypt and chicken, in particular, depends mainly on some exotic breeds while our local breeds are negligible .Although our local breeds are more adapted for the Egyptian conditions , they were not used in the large scale production. Such local breeds have not subjected to intensive selection and consequently, the improvement of most economic traits of these breeds is quit possible. Recently, some Egyptian studies (*e.g.* Shebl *et al.*, 1990) reported that most of the native breeds had high non-additive genetic variance and therefore possibility of improvement of these breeds through crossbreeding is evident. However, results of most crossbreeding experiments carried out in Egypt (Abd EL-Gawad *et al.*, 1979; kosba *et al.*, 1981) reported that crossing between exotic breeds of chickens with other local ones was generally associated with an existence of considerable heterotic effects on most economic traits.

Many attempts had been made to improve the productivity of native breeds of chickens under the Egyptian conditions. Most of these attempts did not determine the best sire and dam breeds which are suitable for crossbreeding programmes . Therefore , the objectives of the present study were : (1) to evaluate genetically some economic traits like body weight and measurements in diallel crossing experiment involving two local breeds (Dandarawi and Silver Montazah) and other two exotic ones (New Hampshire and White Plymouth), (2) to estimate heterosis resulting from crossing between these four breeds , and (3) to estimate general and specific combining abilities, maternal ability and reciprocal or sex-linked effects for such traits .

Material and Methods

Experimental work

This experiment was carried out at the Poultry Research Station in EL-Qanater, Animal Production Research Institute, Ministry of Agriculture, Egypt. The experimental work was carried out for two hatches in the period from November 1985 to June 1986 .

Four breeds of chickens were used in this study; two exotic breeds namely New Hampshire (NH) and White Plymouth Rock (WP) as well as two native breeds namely Dandarawi (DN) and Silver Montazah (SM) . The mating design of the experiment was planned in complete 4x4 diallel mating to get purebred and crossbred progenies. Thirty two breeding pens were used representing 8 single sires of each breed. Each breed-group mating , therefore , was repeated twice . Each sire was concurrently mated to about 10 dams of its own breed and about 10 dams of the other breeds . Each sire was represented in the two hatches . The pedigreed eggs from each individual breeding pen were collected daily for a period of fifteen days . The F1 pure-breds , F1 cross and F1 reciprocal cross progenies were produced in two hatches .

All chicks at hatching were wing-banded to keep their pedigree . Brooding and rearing were carried out on floor system houses up to 16 weeks of age. The floor brooder were heated by kerosene . Chicks were vaccinated at one - day against Marek's disease. They were vaccinated at the sixth day of age against New Castle disease using eye-drop method . At 20 days of age they were revaccinated intramuscularly against New Castle disease with oil vaccine (dead strain) and again at 40 days against New Castle. All chicks fed *ad-libitum* using standard starter ration up to 12 weeks of age and a finisher ration thereafter up to 16 weeks . Data on body weights and measurements of 2413 birds over two hatches were taken at 4 , 8 , 12 and 16 weeks . Body measurements taken were length, circumference and depth of body and shank length .

Statistical analysis

Data of the present study were analyzed using Harvey's Least squares and Maximum Likelihood computer program (Harvey , 1987). The following Linear model was used :

$Y_{ijklm} = \mu + BG_i + A_j + B_k + C_l + (AB)_{jk} + e_{ijklm}$

Where : Y_{ijklm} = the m^{th} observation on the chick from i^{th} breed group, A_j = the fixed effect of j^{th} hatch, B_k = the fixed effect of k^{th} sex, C_l = the fixed effect of l^{th} breeding pen , $(AB)_{jk}$ = the fixed effect of interaction between j^{th} hatch and k^{th} sex, e_{ijklm} = random deviation of m^{th} chick and assumed to be independently randomly distributed $(o, \sigma^2 e)$. Heterosis was estimated and Duncan's multiple range test (DUNCAN, 1955) were used to test the significance of different estimates of heterosis obtained .

Genetic analysis

Data adjusted for the effects of hatch , sex and breeding pen were analyzed using the following linear model :

$Y_{ijk} = \mu + g_i + g_j + m_j + c_{ij} + r_{ij} + e_{ijk}$.

Where : Y_{ijk} = the k^{th} observation on the chick from the i^{th} breed of sire and the j^{th} breed of dam , μ = the overall mean , g_i (g_j)= the effect of general combining ability (GCA) of the i^{th} (j^{th}) breed , m_j = the effect of maternal ability (MA) for the jth breed of dam, C_{ij} = the effect of specific combining ability (SCA) for the chicks of the i^{th} breed of sire with the j^{th} breed of dam or chicks of the j^{th} breed of sire and i^{th} breed of dam r_{ij} = the sex-linked or reciprocal effect (SL) , e_{ijk}= the random error .

Results and Discussion

Variation of uncorrected records

Coefficients of variation (CV) of individual body weights and measurements (across all breed groups) are given in Table 1. CV's for body weights tended to increase as the chick advanced in age. The same findings were observed by many investigators (e.g. VERMA *et al.*, 1980; EL-TURKY, 1981; SINGH *et al.*, 1982). It is clear that high estimates of CV for body weights may be due to high maternal effects up to 16 weeks of age. It ranged from 18.1 to 24.1% which means that an improvement in body weight through phenotypic selection is quit possible. On the other hand, CV' s for body measurements were low in magnitude and ranged from 6.6 to 9.3% over all ages . The same results were reported by some Egyptian studies (e.g. El-TURKY , 1981).

TABLE 1. Means (cm), standard deviations (SD) and coefficients of variation (CV%) of uncorrected body weights and measurements at different ages.

Trait	CV% at				
	Abbreviation	4 Weeks	8 Weeks	12 Weeks	16 Weeks
Body weight	BW	18.2	20.4	18.1	24.1
Body depth	BD	7.1	7.8	6.9	7.2
Body circumference	BC	7.4	7.6	7.3	7.6
Body Iength	BL	7.5	7.5	6.7	6.6
Shank length	LS	8.5	9.3	7.7	7.9

Breed group

Means of purebreds chicks for body weight and measurements at different ages (Table 2) indicate that there was no consistent trend in the superiority of any breed group at all ages studied . However , chicks of NH showed the lowest body weights and measurements at most ages. Averages of body weight and measurements at different ages for NH, SM, DN and WP chicks of the present study were generally lower than those corresponding estimates reported by most Egyptian studies (*ABD-ALLA, 1978; El-TURKY 1981; KOSBA et al* ., 1981).

Breed groups were found to have a significant effect (P<0.001) on all body weights and measurements at different ages (Table 3) . These results are in agreement with those findings reported by other Egyptian investigators (*e.g. ABD El-GAWAD et al.*,1979). Other non-Egyptian studies (*e.g. KHAR et al.*, 1976; *VERMA* and *CHOUDHARY*, 1980; *VERMA et al.*, 1980) reported that breed-group effects contributed a significant source of variation in body weights and / or measurements of chicks at different ages .

TABLE 2. Least-Squares means of body weights (BW), body length (BL), body depth (BD), body circumference (BC) and shank length (SL) in different breed groups at different ages.

Breed+ group	4 Weeks						8 Weeks						12 Weeks						16 Weeks					
	No.	BW	BL	BD	BC	LS	No.	BW	BL	BD	BC	LS	No.	BW	BL	BD	BC	LS	No.	BW	BL	BD	BC	LS
Pure-breds:																								
NH	185	125	11.0	4.4	11.8	4.1	179	346	15.3	6.3	16.5	6.0	159	583	18.7	7.7	20.6	7.6	146	782	20.1	8.6	22.9	8.9
WP	120	141	11.4	4.6	12.1	4.3	117	377	15.4	6.5	16.9	6.3	105	612	18.7	7.9	20.9	7.9	93	881	20.6	9.3	23.7	9.3
DN	165	139	11.1	4.5	12.1	4.2	163	385	15.7	6.4	16.9	6.4	154	606	18.7	7.6	20.5	7.8	149	771	20.1	8.5	22.6	8.7
SM	97	133	11.2	4.6	12.2	4.2	95	395	15.8	6.4	17.0	6.3	90	656	19.2	7.8	20.9	8.0	88	874	20.9	8.7	23.2	9.0
Cross-breds:																								
NHXSM	174	143	11.5	4.7	12.6	4.3	170	425	16.2	6.7	17.8	6.5	147	677	19.6	8.1	21.6	8.1	140	933	21.7	9.4	24.5	9.4
SMXNH	193	141	11.5	4.7	12.6	4.3	175	396	16.0	6.6	17.4	6.3	160	644	19.4	7.9	21.4	7.9	147	816	20.9	8.9	23.2	8.8
NHXDN	129	160	11.7	4.9	12.6	4.4	127	472	16.8	6.9	18.3	6.9	117	734	20.1	8.3	22.4	8.4	108	924	22.2	9.1	25.6	9.5
DNXNH	187	165	11.9	4.8	12.9	4.5	183	472	16.8	6.9	18.4	6.8	172	752	20.3	8.4	22.6	8.4	168	982	22.1	9.4	24.9	9.5
NHXWP	161	162	12.2	4.9	13.2	4.6	157	462	16.7	6.9	18.3	6.8	137	714	20.1	8.4	22.4	8.3	123	953	21.8	9.4	24.8	9.3
WPXNH	151	150	11.6	4.8	12.6	4.4	148	431	16.4	6.8	17.8	6.6	126	691	19.7	8.2	21.9	8.1	121	918	21.6	9.2	24.4	9.2
SMXDN	156	160	11.9	4.8	12.9	4.5	153	466	16.7	6.9	18.2	6.8	140	741	20.1	8.2	22.3	8.3	135	1025	22.6	9.1	25.0	9.6
DNXSM	159	166	11.9	4.8	13.3	4.4	155	484	16.9	6.9	18.5	6.9	140	777	20.3	8.4	22.5	8.5	136	1015	22.4	9.4	25.5	9.5
SMXWP	131	174	12.3	4.9	13.3	4.6	127	481	17.0	6.9	18.5	6.9	109	773	20.4	8.4	22.5	8.5	108	1037	22.4	9.4	25.5	9.8
WPXSM	127	153	11.8	4.8	12.8	4.4	122	460	16.7	6.9	18.1	6.6	108	744	20.1	8.3	22.4	8.3	104	939	21.7	9.2	24.7	9.5
DNXWP	117	161	11.9	4.8	13.1	4.5	114	450	16.7	6.8	18.1	6.7	106	698	19.7	8.1	21.9	8.1	99	981	22.0	9.4	24.8	9.4
WPXDN	161	146	11.4	4.7	12.4	4.2	158	434	16.3	6.7	17.6	6.5	150	711	19.8	8.2	21.9	8.1	137	903	21.6	9.2	24.6	9.3

+ Where NH=New Hampshire; WP=White Plymouth; DN=Dandarawi; SM=Silver Montazah; Breed of sire listed first.
Standard errors ranged between 2.0 and 22.5 for BW; 0.06 and 0.15 for BL; 0.01 and 0.7 for BD; 0.03 and 0.08 for BC; 0.07 and 0.19 for LS.

TABLE 3. F-ratios of Least squares analysis of variance of factors affecting body weights and measurements at different ages.

Source of variation	F-ratio											
	4 Weeks						8 Weeks					
	df	BW	BD	BC	BL	LS	df	BW	BD	BC	BL	LS
Breed group	15	36.5***	30.1***	26.3***	32.8***	31.4***	15	34.0***	28.8***	28.1***	28.7***	31.3***
Hatch (H)	1	682.7***	986.1***	834.3***	926.4***	899.7***	1	1081.4***	726.9***	456.6***	1432.0***	1081.0***
Sex (S)	1	142.9***	87.0***	156.0***	108.1***	93.0***	1	281.4***	165.3***	300.0***	229.0***	218.0***
Breeding pen	1	0.3 ns	0.2 ns	0.4 ns	1.0 ns	0.6 ns	1	3.4 ns	0.8 ns	0.3 ns	2.8 ns	4.2 ns
HXS	1	11.3***	7.7**	2.6**	5.0**	4.9ns	1	47.9***	18.7**	25.4***	19.5***	28.7***
Ramainder df	2393						2323					
Remainder mean square		770	0.8	0.1	0.1	0.9		7951	1.5	0.4	0.3	2.0

Source of variation	F-ratio											
	12 Weeks						16 Weeks					
	df	BW	BD	BC	BL	LS	df	BW	BD	BC	BL	LS
Breed group	15	30.7***	27.0***	24.4***	28.6***	24.8***	15	17.8***	40.9***	23.0***	30.1***	31.6***
Hatch (H)	1	1158.7***	1471.0***	954.0***	1035.0***	1059.0***	1	248.9***	658.0***	771.0***	484.0***	554.0***
Sex (S)	1	443.1***	282.0***	557.0***	365.0***	344.0***	1	205.7***	264.0***	649.0***	406.0***	295.0***
Breeding pen	1	0.0 ns	1.6 ns	0.1 ns	1.0 ns	0.2 ns	1	0.0 ns	2.1 ns	1.6 ns	0.1 ns	0.1 ns
HXS	1	88.2***	25.1***	41.7***	34.8***	37.4***	1	43.9***	19.9***	38.7***	36.0***	24.3***
Ramainder df	2100						1982					
Remainder mean square		16263	0.4	0.4	0.3	2.5		50222	2.0	0.5	0.4	3.4

n s = non - significant; * = $P<0.05$; ** = $P<0.01$; *** = $P<0.001$.

Crossbreeding and heterotic effects

Estimates of heterosis for body weights and measurements (calculated as a percent increase of the crossbreds above their parental breeds) are given in Table 4. For more information , estimates of heterosis based on each single cross and its reciprocal are given in Table 5. Estimates of heterosis for different breed groups given in Table 5 indicated that crossbred of DNxNH and its reciprocal (*i.e.* NHxDN) surpassed those of other crossbreds for body weights and measurements at most ages studied . Means (Table 2) and percentages of heterosis (Table 5) for NHxSM, DNxNH, NHxWP, DNxSM, SMxWP and DNxWP are generally superior in body weights and measurements than those of their reciprocal crosses at all ages. The SMxNH cross manifested inferior percent of heterosis (with an overall average of 3.5%) at all ages as compared to other crosses , *i.e* . SM is better to be used as a breed of dam instead of using it as a breed of sire in any crossbreeding programme. The highest percent of heterosis was 33.1% for 12th week body weight of DNxSM cross, while the lowest percent was - 2.2% for LS of SMxNH cross at 16th week of age (Table 5). Results of Egyptian studies (e.g. HANAFI *et al.*, 1977) and non- Egyptian ones (AGGARWAL *et al* ., 1978; SHARMA, 1978 ; SINGH *et al* ., 1982) reported that body weights and measurements at different ages show varying degrees of heterosis . However , results of many Egyptian studies (*e.g. HANAFI et al.*, 1977; *ABD El- GAWAD et al.*, 1979) reported that crossbreeding was associated with positive heterotic effects on shank length of chicks .

Least squares means of different breed groups (Table 2) show that most crossbred chicks were heavier in weight and longer in measurements than those of their pure parental breeds at different ages. These results and those estimates of heterosis (Table 4) lead to conclude that heterotic effects on body weights and measurements for most crossbreds were evident .

Estimates of heterosis given in Table 4 showed that crossing between exotic breeds (i.e. NH and WP) with other local ones (*i.e.* DN and SM) was usually associated with an existence of heterotic effects on different traits . Estimates of these heterotic effects ranged from 8.2% to 24.9% (with an overall average equal to 16.3%) for body weights while they ranged from 2.3 to 9.1% for body measurements (with an average equal to 6.5%) . Results of most Egyptian studies (*e.g. HANAFI et al.*, 1977 ; *ABD El-GAWAD et al.*, 1979) showed that chicks produced from mating local breeds with exotic ones resulted in heavier body weights with longer body measurements than those of their parental breeds . These results gave more encouragement for the poultry breeders in Egypt to cross their native breeds (either as male or female parents) with the exotic ones . In addition , crossbreds obtained from crossing between local breeds (*i.e.* SMxDN or DNxSM) were found to have positive and high magnitude of heterosis for body weights and measurements at different ages (Table 4). The estimates ranged from 19.5 to 24.0% (with an overall average of 21.4%) for body weights and from 5.7 to 9.6%

(with an overall average of 7.7%) for body measurements . These estimates of heterosis showed that crossbreds resulted from crossing local breeds with each other were superior than crossbreds resulted from the crossing of the two exotic breeds with local ones by about 4.1% for body weight and 0.9% for body measurements . This may be due to that local breeds did not subject to intensive selection programmes and consequently , high additive and non additive genetic variabilities appeared between crossbreds of local breeds . Estimates of heterosis of body weights and measurements for DNxSM crossbred were higher than those corresponding estimates of its reciprocal crossbred (Table 5). Meanwhile , crossbreds produced from crossing exotic breeds with each other gave an evidence to the presence of heterotic effects which ranged from 12.5% to 23.5% (with an average of 17.7%) for body weights , while they ranged from 5.4 to 7.0% (with an average of 6.6%) for body measurements . These estimates of heterosis obtained in the present study may give some attention to chicken breeders in Egypt to give more effort (in terms of the genetic studies) for the local breeds and /or strains (in terms of selection and breeding programmes) in order to produce heavy broilers (through mating some local strains with each other). Similar to the present results, an Egyptian study (ABD El-GAWAD *et al*., 1979) with Dokki-4 and Alexandria strains and their crosses reported that differences between crossbreds and their purebreds were significant in favour of crossbreds ($P<0.01$) On the contrary , another Egyptian study (EL-Turky, 1981) indicated that crossbreeding between local breeds did not improve body weights of their crossbred chicks at 4,8, 12 and 16 weeks of age.

Genetic parameters.

The general combining ability (GCA) for body weights and measurements at all ages differed significantly ($P<0.01$) among the four breeds involved in this study (Table 6). It indicates the presence of high additive genetic variation in such traits as also reported by many investigators (*e.g.* Eisen *et al*., 1967; Ramappa and Gowda, 1973; Singh, 1973: KIM *et al*., 1975 ; Sergeev *et al* ., 1975 ; Hanafi *et al*., 1977; Aggarwal *et al*., 1978 ; Kanavikar *et al*., 1978; OOI *et al*., 1978; Manglik *et al*., 1980; Jain *et al*., 1981; Jain and Choudhary 1984; Chung *et al*., 1985; Jakubec *et al*., 1988; Shebl *et al*., 1990 On the contrary , results of few studies (Amrit, 1978; Sharma, 1978; Jakubec *et al*., 1987) showed non-significant differences in GCA of body weights of different breeds . Differences between the highest (DN) and the lowest (WP) breed for GCA were high at most ages (Table 7). These wide ranges in GCA would give good chance for poultry breeders to select for GCA of body weights and measurements in different breeds . DN breed had the best estimates of GCA at all ages studied followed by SM, while WP and NH breeds had the least constants of GCA at most ages (Table 7). These findings of crossbreeding analysis in addition to those results of pure-breeding analysis (Table 6) lead to conclude that local breeds used in the present study (*i.e.* DN and SM) had higher additive genetic variance in body weights and measurements than those of exotic breeds (i.e. NH and WP). Such high additive variation could be attributed to that local breeds (i.e. NH and WP). Such high additive variation could be attributed to that local breeds have not been subjected to intensive selection programmes in Egypt while exotic breeds had been subjected to intensive selection in their own countries . However , results of the present study and considering the desire of the Egyptian consumers (to use the local breeds in their consumption) may encourage the poultry breeders in Egypt to use DN and SM breeds as a sire-breed in any crossbreeding programme in order to produce commercial broilers characterized by heavy weights and with an acceptable taste for the Egyptian consumer.

The maternal ability (MA) was found to have considerable effects (P<0.01) on all body weights and measurements (Table 6) . Many studies (Aggarwal *et al.*, 1979., Manglik *et al.*, 1980; Jakubec *et al.*, 1988) reported that MA effects on body weights and/or measurements were significant at early ages of growth, while other ones (Hanafi *et al.*, 1977; Amrit, 1978; Jakubec *et al.*, 1987) reported non-significant effects. F-ratios given in Table 6 showed that MA effects on body weights and measurements at early ages of growth (*i.e* during the first four weeks) were more pronounced and of considerable importance than at later age (at 16 weeks of age). This means that MA effects on body weights tended to decrease gradually as the offspring advanced in age . Considering the least squares constants (Table 7), it was found that the highest estimates were reported for WP breed and the lowest ones were for both NH and DN with an average difference equal to 16.0, 26.5, 21.9 and 114.4 grams at 4,8,12 and 16 weeks of age , respectively . This may lead to state that range or variability between breeds in MA effects on body weights and measurements increased as the age of the offspring advanced from its hatching time and up to 16 weeks of age. Consequently , a breed with high MA (as a characteristic of a given breed) should be considered in any crossbreeding programme as a breed of dam. In this respect, (Sharma, 1978) reported that minor differences in egg's size and its contents (as characters of the dam) might have been responsible for such high MA at early ages of growth. Also, results of Vaccaro and Van Vleck (1972) indicated that MA effects was only important for early weights and it could influence body weights and measurements by the transmission of immunities (or even diseases) through the egg . The WP breed ranked the first in MA and it had the highest estimates of MA for most traits studied, while DN and NH had negative estimates for most ages (Table 7). Accordingly , using of WP or SM as a dam-breed in any crossbreeding programme is recommended.

Effects of specific combining ability (SCA) on body weights and measurements were found to be significant (P<0.01) for most ages (Table 6). This leads to conclude that the non-additive gene effects (as measured by the sire x dam interaction component) appear to have considerable influence on these traits . Utilization of such high non-additive gene effects in the production of commercial broilers (with heavy weight and wide body) is quit possible . However , results of the present study were in agreement with other reviewed studies (*e.g.* Amrit, 1978; OOI *et al.*, 1978 ; Sharma , 1978 ; Manglik *et al*., 1980 ; Jain and Choudhary , 1984; Chung *et al*., 1985; Jakubec *et al*.., 1988 ; Shebl *et al*., 1990). On the contrary , some studies (Ramappa and Gowda , 1973 ; Kim *et al*., 1975 ; Hanafi *et al*., 1977 ; Jain *et al*., 1981) reported non-significant differences in body weights and/or measurements due to SCA effects. F-ratios presented in Table 6 proved that SCA effects contributed more than those of either GCA or MA to the total variation of body weights and measurements at different ages. Also and opposite to MA effects, SCA effects on body weights and measurements tended to increase gradually as the offspring advanced in age up to 8 weeks and decreased gradually thereafter up to 16th week of age. Therefore , maternal and non-additive gene effects (*i.e.* dominance , over-dominance and epistasis) on body weights and measurements were more evident at early ages of growth than at later ages. This trend could be explained on the basis that at later ages, young chicks were more influenced to greater extent by environmental factors than at earlier ages . These results completely agreed with the fact that broilers gained their maximum weight at early ages and , therefore , marketing them at such ages must be considered . Crosses of NHxDN and SMXWP had the highest estimates of SCA at most ages studied , while the lowest estimates of SCA were for NHxSM and DNxWP crosses (Table 7) . These results indicate that NH and SM breeds could be crossed advantageously with WP and DN. Utilization of such high non-additive gene effects for these breeds in the production of commercial broilers (characterized by heavy weight and long measurements) is recommended .

Body weights and measurements of the chicks at most ages (except those of later age at 16th week) were found to be nonsignificantly affected by sex-linkage (SL) or reciprocal effects (Table 6). Consequently, an advantage may be obtained by using certain breeds (as either males or females parents) in crossbreeding programmes . Similarly , some studies (Hanafi *et al*., 1977; Amrit , 1978; Sharma , 1978) reported non-significant differences in body weights due to SL effects . On the contrary, many findings (Amrit , 1978 ; Kanavikar *et al*., 1978 ; Manglik *et al*., 1980; Jain *et al*., 1981 ; JAIN and Choudhary , 1984 ; Jakubec *et al*., 1987& 1988 ; Shebl *et al*., 1990) showed that reciprocal-cross differences in body weights and measurements were significant. However , significant effects of SL for body weight at later age (*i.e.* at 16 weeks of age , Table 6) indicating that sex-linked genes were of major importance in affecting body weights and measurements of chickens raised in Egypt for meat production consequently , the choice of sire-breed and dam-breed would be important in the planning of crossbreeding programmes . It is clear that NHxSM , SMxDN and WPxSM crosses had positive estimates of SL and were superior than those of their reciprocals at most ages (Table 7). These results indicate the existence of better maternal ability for these crossbreds .

TABLE 4. Estimates of heterosis percentage+ for body weights and measurements at different ages.

Trait	Breed group					
	NH-SM	NH-DN	NH-WP	SM-DN	SM-WP	DN-WP
BW:						
4 weeks	9.9	23.1	17.4	19.5	18.9	9.7
8 weeks	10.7	29.1	23.5	21.8	21.9	16.0
12 weeks	6.6	24.9	17.6	20.2	19.7	15.7
16 weeks	5.6	22.7	12.5	24.0	12.6	14.0
Average	8.2	24.9	17.7	21.4	18.3	13.8
BD:						
4 weeks	4.4	6.7	8.9	8.9	6.5	6.7
8 weeks	4.7	9.4	7.8	7.7	7.7	4.6
12 weeks	3.8	9.1	6.4	7.8	6.3	5.1
16 weeks	7.0	8.2	4.5	7.0	3.3	4.5
Average	5.0	8.3	6.9	7.9	6.0	5.2
BC:						
4 weeks	5.0	6.7	7.5	5.7	7.4	5.8
8 weeks	4.8	10.2	8.4	8.3	8.3	5.9
12 weeks	3.4	9.2	6.3	8.7	7.2	5.8
16 weeks	3.5	10.1	5.6	9.6	7.3	6.5
Average	4.2	9.1	7.0	8.1	7.6	6.0
BL:						
4 weeks	3.6	6.3	7.2	6.3	8.0	5.4
8 weeks	3.2	8.4	7.8	6.3	8.3	5.8
12 weeks	3.2	8.0	6.4	6.9	6.9	5.9
16 weeks	3.9	10.4	6.4	9.8	6.3	6.9
Average	3.5	8.3	7.0	7.3	7.4	6.0
LS:						
4 weeks	2.4	7.1	7.1	7.1	7.1	4.8
8 weeks	3.2	11.3	8.1	7.8	7.9	3.1
12 weeks	2.6	9.1	5.1	6.3	6.3	2.5
16 weeks	1.1	8.0	1.1	9.1	5.4	4.4
Average	2.3	8.9	5.4	7.6	6.7	3.7
Overall average	4.6	11.9	8.8	10.5	9.2	6.9

+ Heterosis percent = (Cross - midparent) / midparent.

TABLE 5. Estimates of heterosis percentage + of single crosses for body weights and measurements at different ages.

Trait	Breed group											
	NHxSM	SMxNH	NHxDN	DNxNH	NHxWP	WPxNH	SMxDN	DNxSM	SMxWP	WPxSM	DNxWP	WPxDN
BW:												
4 weeks	10.7	9.1	21.3	25.0	21.8[a]	13.0[b]	17.6	21.6	26.4[a]	11.3[b]	15.2[a]	4.1[b]
8 weeks	14.6[a]	6.8[b]	29.1	29.0	27.7[a]	19.3[b]	19.5	24.0	24.7	19.1	18.1	13.8
12 weeks	9.2[a]	3.9[b]	23.5	26.4	19.6	15.6	17.3[a]	33.1[b]	22.0	17.4	14.6	16.7
16 weeks	12.7	-1.5	19.0[a]	26.4[b]	14.7	10.4	24.6	23.4	18.2[a]	7.1[b]	18.8[a]	9.3[b]
Average	11.8	4.6	23.2	26.7	21.0	14.6	19.8	23.0	22.8	13.7	16.7	11.0
BD:												
4 weeks	4.4	4.4	4.4[a]	6.7[b]	8.9[a]	6.7[b]	6.7[a]	8.9[b]	8.7[a]	4.3[b]	6.7[a]	4.4[b]
8 weeks	4.7	3.1	7.8	9.4	9.4[a]	6.2[b]	6.2	7.7	7.7	6.2	4.6	3.1
12 weeks	3.9	2.6	7.8	9.1	7.7[a]	5.1[b]	6.5[a]	9.1[b]	6.3	5.1	3.8	5.1
16 weeks	9.3[a]	4.7[b]	7.1[a]	10.6[b]	5.6[a]	3.4[b]	5.8[a]	9.3[b]	4.4[a]	2.2[b]	5.6[a]	3.4[b]
Average	5.6	3.7	6.8	9.0	7.9	5.4	6.3	3.8	6.8	4.5	5.2	4.0
BC:												
4 weeks	5.0	5.0	5.0[a]	7.5[b]	10.0[a]	5.0[b]	5.7	4.9	9.0[a]	4.9[b]	8.3[a]	2.5[b]
8 weeks	5.9[a]	3.6[b]	9.6	10.2	9.6[a]	6.6[b]	7.7	8.9	9.5[a]	7.1[b]	7.1[a]	4.5[b]
12 weeks	3.9	2.9	8.7	9.7	7.7[a]	5.3[b]	7.7	9.2	7.7	7.2	5.8	5.8
16 weeks	6.1[a]	0.4[b]	11.0	9.2	6.4	4.7	9.2	10.0	9.0[a]	5.6[b]	6.9	6.0
Average	5.2	2.3	8.6	9.2	8.4	5.4	7.6	8.3	8.8	6.2	7.0	4.7
BL:												
4 weeks	3.6	3.6	5.4[a]	7.2[b]	9.9[a]	5.4[b]	6.3	6.3	9.8[a]	5.4[b]	7.2[a]	2.7[b]
8 weeks	3.9	2.6	8.4	8.4	8.4[a]	6.5[b]	5.7	7.0	9.0	7.1	7.1[a]	4.5[b]
12 weeks	3.7	2.6	7.5	8.6	7.5[a]	5.3[b]	6.3	7.4	7.9	6.3	5.3	5.9
16 weeks	5.9[a]	2.0[b]	10.4	10.0	6.9	5.9	10.2	9.3	7.7[a]	4.3[b]	7.8[a]	5.9[b]
Average	4.3	2.7	7.9	8.6	8.2	5.8	7.1	7.5	8.6	5.8	6.9	4.8
LS:												
4 weeks	2.4	2.4	4.8[a]	7.1[b]	9.5[a]	4.8[b]	7.1[a]	4.8[b]	9.5[a]	4.8[b]	7.1[a]	0.0[b]
8 weeks	4.8[a]	1.6[b]	11.3	11.3	9.7	6.5[b]	6.2	7.8	9.5[a]	4.8[b]	4.7[a]	1.6[b]
12 weeks	3.9[a]	1.3[b]	9.1	9.1	6.4	3.8[b]	5.1[a]	7.6[b]	7.6[a]	5.1[b]	2.5	2.5
16 weeks	4.4[a]	-2.2[b]	8.0	8.0	2.2	1.1	9.1	8.0	6.5[a]	3.3[b]	4.4	3.3
Average	3.9	0.8	8.3	8.9	7.0	4.1	6.9	7.1	8.3	4.5	4.7	1.9
Overall average	8.3	3.5	15.6	17.8	14.5	9.9	13.4	15.5	15.5	9.5	11.4	7.5

+ Heterosis percent = (Single cross mean - midparent)/ midparent.

Estimates of heterosis (single cross and its reciprocal) in the same row with different letters are significantly different at P<0.05; otherwise they do.

TABLE 6. F-ratios of least squares analysis of variance for general combining ability (GCA), maternal ability (MA), specific combining ability (SCA) and sex-linked or reciprocal effects (SL) for body weights and measurements at different ages.

Sources of variation	4 weeks	8 weeks	12 weeks	16 weeks
BW:				
GCA	16.1**	8.1**	6.9**	14.4**
MA	23.2**	6.8**	2.5^{ns}	11.5**
SCA	47.3**	38.3**	34.0**	26.1**
SL	1.5^{ns}	1.6^{ns}	1.9^{ns}	12.5**
Remainder mean square	805	8417	18093	27368
BD:				
GCA	6.0**	4.9**	2.5^{ns}	260.2**
MA	23.6**	6.7**	4.7**	12.9**
SCA	26.0**	29.8**	22.3**	59.7**
SL	0.9^{ns}	0.9^{ns}	2.5^{ns}	13.9**
Remainder mean square	0.1	0.3	0.3	0.9
BC:	6.2**	5.2**	4.1**	5.2**
GCA	35.9**	8.6**	2.4ns	11.9**
MA	19.9**	28.1**	28.8**	28.2**
SCA	2.1^{ns}	0.4^{ns}	1.3^{ns}	6.8**
SL	0.7	2.1	2.6	3.0
Remainder mean square				
BL:				
GCA	4.3**	5.1**	159.4**	260.2**
MA	33.8**	7.1**	243.9**	12.9**
SCA	37.5**	22.1**	53.1**	60.0**
SL	0.5^{ns}	0.1^{ns}	4.9**	13.9**
Remainder mean square	0.6	1.5	1.6	0.9
LS:				
GCA	10.1**	8.3**	3.9**	0.2^{ns}
MA	51.3**	8.8**	5.9**	0.3^{ns}
SCA	79.9**	40.7**	37.3**	1.2^{ns}
SL	2.9*	1.7^{ns}	3.2**	0.4^{ns}
Remainder mean square	0.1	0.4	0.4	10.9

ns = non-significant; * = ($P<0.05$); ** = ($P<0.01$).
Degrees of freedom were 3, 3, 2 and 3 for GCA, MA, SCA and SL, respectively. Remainder degrees of freedom were 1834, 1777, 1600 and 1514 at 4, 8, 12 and 16 weeks of age, respectively.

TABLE 7. Least squars constants for effects of general combining ability (GCA), maternal ability (MA), specific combining ability (SCA) and reciprocal effec (SL) for body weight (BW), body length (BL),, body depth (BD), body circumference (BC) and shank length (LS) at different ages.

Item+	4 Weeks					8 Weeks					12 Weeks					16 Weeks				
	BW	BL	BD	BC	LS	BW	BL	BD	BC	LS	BW	BL	BD	BC	LS	BW	BL	BD	BC	LS
µ:	157	11.8	11.8	12.8	4.4	454	16.6	6.8	18.1	6.7	726	20.1	8.3	22.2	8.3	957	21.9	9.3	24.8	8.9
GCA:																				
NH	-3.67	-0.04	-0.05	-0.07	-0.01	-8.64	-0.09	0.03	-0.04	0.00	-21.35	-1.04	0.00	-0.11	-0.03	-35.43	-0.30	0.03	-0.09	-0.10
WP	-4.59	-0.09	-0.02	-0.11	-0.06	-7.99	-0.11	-0.05	-0.18	-0.08	-6.11	-0.28	0.02	-0.04	-0.07	-18.48	-0.12	-0.00	-0.05	-0.03
DN	7.86	0.07	0.02	0.08	0.04	19.46	0.21	0.09	0.23	0.13	23.67	0.39	0.05	0.25	0.09	42-29	0.40	0.07	0.31	0.10
SM	0.39	0.06	0.04	0.10	0.03	-2.83	-0.01	-0.07	-0.01	-0.05	3.79	0.39	-0.06	-0.10	0.01	11.62	0.01	-0.10	-0.18	0.03
MA:																				
NH	-2.45	-0.09	0.00	-0.05	-0.05	-14.61	-0.17	-0.08	-0.20	-0.11	-14.09	-1.74	-0.07	-0.15	-0.12	-25.12	-0.21	-0.11	-0.52	-0.15
WP	-11.99	0.41	0.13	0.44	0.19	16.78	0.27	-0.09	0.33	0.13	11.45	0.89	0.03	0.12	0.09	50.18	0.25	0.13	0.35	0.13
DN	-6.42	-0.20	-0.08	-0.24	-0.06	-7.37	-0.12	0.05	-0.18	-0.05	-7.37	0.29	-0.06	-0.11	-0.02	-28.20	-0.14	-0.16	0.01	-0.05
SM	-3.13	-0.12	-0.05	-0.16	-0.08	5.24	0.02	-0.03	0.14	0.03	10.01	0.55	0.09	0.14	0.05	3.13	0.09	0.14	0.17	0.06
SCA:																				
NH-SM	-8.91	-0.22	-0.08	-0.18	-0.12	-26.39	-0.30	-0.14	-0.36	-0.18	-37.83	-0.34	-0.13	-0.42	-0.18	-48.28	-0.31	-0.03	-0.46	-0.15
NH-DN	6.24	0.12	0.03	0.10	0.06	18.67	0.23	0.08	0.24	0.12	30.13	0.45	0.09	0.30	0.15	19.11	0.11	0.02	0.35	0.18
NH-WP	2.67	0.11	0.05	0.08	0.06	7.72	0.07	0.05	0.12	0.06	7.70	-0.12	0.04	0.12	0.04	24.17	0.21	0.02	0.11	-0.04
SM-DN	2.67	0.11	0.05	0.08	0.06	7.72	0.07	0.05	0.12	0.06	7.70	-0.12	0.04	0.12	0.04	24.17	0.21	0.02	0.11	-0.04
SM-WP	6.24	0.12	0.03	0.10	0.06	18.67	0.23	0.08	0.24	0.12	30.13	0.45	0.09	0.30	0.15	19.11	0.11	0.02	0.35	0.18
DN-WP	-8.91	-0.22	-0.08	-0.18	-0.12	-26.39	-0.30	-0.14	-0.36	-0.18	-37.84	-0.33	-0.13	-0.42	-0.18	-43.28	-0.31	-0.03	-0.46	-0.15
SL:																				
NH-SM	1.48	-0.00	0.01	0.04	0.02	6.88	0.02	0.03	0.06	0.05	6.77	0.01	0.02	-0.02	0.06	44.06	1.10	0.10	0.31	0.16
SM-NH	-1.48	0.00	-0.01	-0.04	-0.02	-6.88	-0.02	-0.03	-0.06	-0.05	-6.77	-0.01	-0.02	0.02	-0.06	-44.06	-1.10	-0.10	-0.31	-0.16
NH-DN	0.08	-0.03	-0.02	-0.07	-0.02	-4.68	0.02	-0.02	-0.04	-0.03	-5.50	-0.18	-0.04	-0.08	-0.04	-22.00	-0.93	-0.07	-0.06	-0.06
DN-NH	-0.08	0.03	0.02	0.07	0.02	4.68	-0.01	0.02	0.04	0.03	5.50	0.18	0.04	0.08	0.04	22.00	0.93	0.07	0.06	0.06
NH-WP	1.56	-0.03	-0.01	-0.03	-0.00	2.20	0.03	0.01	0.02	0.02	1.27	-0.17	-0.02	-0.09	0.01	22.06	0.17	0.03	0.24	0.10
WP-NH	-1.56	0.03	0.01	0.03	0.00	-2.20	-0.03	-0.01	-0.02	-0.02	-1.27	0.17	0.02	0.09	-0.01	-22.06	-0.17	-0.03	-0.24	-0.10
SM-DN	-0.96	0.02	0.01	0.08	0.03	0.15	-0.01	0.01	0.01	0.00	-6.49	0.03	-0.03	-0.06	-0.02	21.12	2.04	0.02	0.00	0.05
DN-SM	0.96	-0.02	-0.01	-0.08	-0.03	-0.15	0.01	-0.01	-0.01	-0.00	6.49	-0.03	0.03	0.06	0.02	-21.12	-2.04	-0.02	-0.00	-0.05
SM-WP	-2.44	0.02	-0.00	0.04	0.00	-6.73	0.03	-0.02	-0.05	-0.05	-13.26	0.02	-0.05	-0.04	-0.08	-22.95	0.95	-0.08	-0.30	-0.11
WP-SM	2.44	-0.02	0.00	-0.04	-0.00	6.73	-0.03	0.02	0.05	0.05	13.26	-0.02	0.05	0.04	0.08	22.95	-0.95	0.08	0.30	0.11
DN-WP	0.88	0.01	0.01	-0.01	-0.01	4.53	-0.05	0.02	0.03	0.03	11.99	0.15	0.07	0.14	0.06	0.89	-1.11	0.04	0.06	0.01
WP-DN	-0.88	-0.01	-0.01	0.01	0.01	-4.53	0.05	-0.02	-0.03	-0.03	-11.99	-0.15	-0.07	-0.14	-0.06	-0.89	1.11	-0.04	-0.06	-0.01

Conclusion

High additive and non-additive genetic variabilities appeared between purebreds and crossbreds of local breeds in the present study lead to conclude that selection and crossbreeding were generally associated with an improvement in body weights and measurements . Accordingly , crossing between the two local breeds (Dandarawi and Silver Montazah) with each others or with other exotic ones will be associated with an existence of heterotic effects . It is worthy to recommend the chicken breeders in Egypt to give more effort in carrying out selection and crossbreeding programmes on these local breeds in order to enhance their rates of growth.

The superiority obtained from crossing of Dandarawi (DN) sires with dams of each of white Plymouth (WP) and Silver Montazah (SM) leads to the conclusion that selection of sires from DN breed and dams from WP or SM breeds could be more effective in any crossbreeding stratification system for producing commercial local broilers .

High estimates of GCA for DN and SM breeds (as local breeds) compared to NH and WP breeds (as exotic ones) may encourage the poultry breeders in Egypt to use DN and SM breeds as a sire-breed in any crossbreeding programme for the purpose of producing chicks with heavy weights and with an acceptable taste for the Egyptian consumer. coupled with this fact and due to high maternal ability for WP and SM breeds , it could be recommended to use WP or SM as a dam-breed in crossbreeding programmes in Egypt . On the basis of high SCA , NH or SM breeds could be crossed advantageously with WP and DN to produce commercial local broilers. High contribution of sex-linked genes in body weights and measurements at later ages (especially for local chickens) could be also exploited in meat production .

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تقدير قوة الخلط وقدرة التوافق لأوزان الجسم في الدجاج .

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استخدمت فى هذه الدراسة سلالتين من الدجاج الاجنبى {النيوهامبشير والبليموث روك الابيض } واثنين من السلالات المحلية {الدندراوى والمنتزة الفضى } فى تجربة خلط متبادل ٤×٤ . أجريت هذه التجربة فى محطة بحوث الدواجن بالقناطر الخيرية التابعة لمعهد بحوث الانتاج الحيوانى بوزارة الزارعة . استخدم فى البحث عدد ٢٤١٣ كتكوتا لدراسة قوة الهجين وقدرة التوافق العامة والخاصةو المقدرة الأمية وكذا تأثير العوامل المرتبطة بالجنس على أوزان الجسم وابعاده عند الأعمار المختلفة . أوضحت النتائج ما يلى :

١- كانت الاختلافات بين المجاميع الوراثية معنوية { عند مستوى ١..ر . } لكل صفات أوزان الجسم وابعاده ، كما وجد أن متوسطات أوزان الجسم وأبعاده للخلطان أعلى من متوسطات الافراد النقية .

٢ - أظهرت النتائج أن الخلط كان مصحوبا بقوة هجين فى معظم الصفات المدروسة ، كما أعطى خلط السلالات المحلية فيما بينها أعلى قوة للهجين مقارنة لقوة الهجين الناتجة من خلط السلالات المحلية مع الاجنبية وهذا يشير الى وجود التأثيرات غير التجمعية للجينات بدرجة كبيرةيمكن استغلالها فى انتاج الهجن التجارية المحلية مما يستحق أن نوصى به مربى الدواجن فى مصر على بذل مجهود أكبر باجراء الانتخاب فى السلالات المحلية للحصول على معدل كبير لسرعة النمو .

٣ – أظهرت الكتاكيت الناتجة من خلط ذكور سلالة الدندراوى بإناث النيوهامبشير تفوقا ملحوظا فى قوة الهجين مقداره ٨ر١٧٪ ، فى حين كانت قوة الهجين للكتاكيت الناتجة من خلط ذكور المنتزة الفضى مع اناث النيوهامبشير ضعيفة { ٥ر٣٪ } .

٤ – وجد أن هناك فروق معنوية { عند مستوى ا.ر. أو ١..ر. } لتأثير كل من ميعاد الفقس والجنس وكذا التفاعل بينهم على معظم صفات وزن الجسم وابعاده .

٥ – كان لقدرة التوافق العامة والخاصة وكذا المقدرة الأمية تأثيرا معنويا { عند مستوى ١. ر. } على معظم الصفات المدروسة مما يشير الى وجود واهمية التأثيرات التجمعية والغير تجمعية فى تباين صفات وزن الجسم وأبعاده وهذا يقودنا الى امكانية التحسين فى هذه الصفات عن طريق الانتخاب والخلط .

٦ – سجلت سلالة الدندراوى تفوقا ملحوظا فى قدرة التوافق العامة لمعظم الصفات يلية سلالة المنتزة الفضى بينما أظهرت سلالة البليموث روك الابيض تفوقا واضحا فى المقدرة الامية ، وهذا يكون مشجعا لمربى الدواجن فى مصر بأستخدام سلالتى الدندراوى المنتزة الفضى كسلالة للآب والبليموث روك الابيض كسلالة للأم بهدف تخطيط استراتجيات برامج الخلط لانتاج بدارى اللحم .

٧ – كان لخليط كل من النيوهامبشير × الدندراوى ، المنتزة الفضى × البليموث روك الابيض أعلى قدرة للتوافق الخاصة ، وعلى هذا الاساس يمكن خلط كل من سلالة المنتزة الفضى أو النيوهامبشير مع كل من البليموث روك الابيض والدندراوى لاستغلال التأثيرات غير التجمعية للجينات لانتاج الهجن التجارية المحلية .

٨ – كان تأثير العوامل المرتبطة بالجنس تأثيرا غير معنويا فى الأعمار المبكرة ، بينما كان تأثيراته معنوية { عند مستوى ١. .} فى الاعمار المتأخرة {١٦ أسبوع} وذلك لمعظم صفات أوزان الجسم وأبعاده ، ولذا يمكن استغلال ذلك فى انتاج اللحم من السلالات المحلية .