SHORT-TERM EVALUATION OF PURE AND CROSSBRED PARENT STOCK PULLETS

BY

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CERTIFICATION

This thesis, 'Short-term evaluation of pure and crossbred parent stock pullets', by Josephine Adejoke ADENOWO(Mrs), meets the regulations governing the degree of Master of Science of Ahmadu Bello University and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

To my husband, Thomas Kehinde Adenowo; and my Children: Agnes Adetutu, Joseph Adekunle, Patrick Adewale.

In grateful recognition and inspiration.

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ABSTRACT

Some traits of economic importance in egg production were studied in eight F_1. genotypes of two grand parent strains. The grand parent stock, each of two lines, were imported as day-old chicks from England.

Diallel crossing was used among the two strains at 28 weeks of age to generate four F_1 progeny groups per line. The F_1 chicks were brooded and reared like the grand-parents on deep-litter pens. Laying pens were also deep litter.

The results showed that the genotypes of both lines responded differently in production characteristics. Age at first egg was generally sire influenced but the inheritance of body weight and egg weight was line dependent. Pullets of male line were lighter at 30 weeks, laid more and heavier eggs and consumed more feed than those of female line.

General combining ability was important for weight of first egg and feed consumption while specific combining ability was important for laying house mortality alone. Heterosis was important for body weight at first egg, weight of first egg, Hen-day egg production, feed consumption, feed efficiency and laying house mortality; and were mostly exhibited by crossbred groups of male line. Reciprocal effect was important for the body weight traits,

weight of first egg and laying house mortality. Sex-linkage was suspected to be more important than maternal effect in the present study.

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CHAPTER 1.

INTRODUCTION

In the last three decades, large scale production of poultry and its products (meat and eggs), in Nigeria, has increased progressively. This is due mainly to the gradual shift from the traditional extensive system of poultry management to the more improved and intensive one with its associated importation of exotic breeds. Consequently, Nigeria has gradually become a big importer of chickens and raw materials used in poultry feed manufacturing industry. Before now, it was evident that the country was not self sufficient in the supply of poultry to meet the growing demand for these products. For instance, Nwosu (1979) gave a comprehensive list of some of the imported breeds found in the country ranging from light layer breeds to heavier types including hybrids and broilers.

In essence, enormous foreign exchange is involved in the importation of these breeds. Our foreign exchange is dwindling daily, yet Nigeria cannot afford to completely ban importation of poultry stocks into the country; but has succeeded only in placing some restrictions. There is need, therefore, for the development of a national poultry foundation stock in order to greatly cut down the

rate of importation of the commercial stocks. Buvanendran (1979) has enumerated the reasons why this is necessary.

From the findings of Warren (1927, 1942) and others reviewed by Merritt and Gowe (1960), it has been understood that the crossing of developed breeds and/or strains was a practical method of taking advantage of the phenomenon of hybrid vigour, otherwise called "heterosis". Thus it is the habit of commercial poultry breeders to cross specialized parent stocks (sire and dam types) to exploit heterosis and obtain the greatest genetic improvement (Sheridan, 1981; Cheje, 1983; and Bernon and Chambers, 1985). The parent stocks are often obtained by crossing lines, strains or breeds which may or may not be inbred themselves.

According to Buvanendran (1979), the poultry stocks, to be developed should possess a genetic make-up that permits them to cope with the inadequacies of locally available ingridients. In this direction, a school of thought has suggested the inclusion of the Nigerian local chicken in the gene pool to obtain birds that are more naturally adapted to local conditions and are comparable in productivity with imported stocks.

A lot of work has been done in the characterization of the Nigerian local chicken in growth, meat and egg

production (Oluyemi and Oyenuga, 1971, 1974; Oluyemi, 1979 a, b; and Nwosu, 1979), while other studies were centered on the comparison of the indigenous fowl with exotic breeds (Oluyemi et al, 1973; Oluyemi et al, 1979; and Akinokun and Dettmers, 1979 a,b,c.). Further effort was directed towards crossbreeding the local birds with exotic chickens for possible improvement (Oluyemi, 1973; Omeje, 1983; Omeje and Nwosu, 1984 a,b). As to whether or not the local chicken should be incorporated in the proposed national foundation stock, Akinokun (1975) had stated that the use of multiple crosses of egg or meat strains with the indigenous fowl, to provide a base population, offers more scope for sampling a wide variety of genes that could increase overall productivity of the chicken in Nigeria. Nwosu (1979) and Omeje (1983), 1985) also believed that it is worthwhile incorporating the local chicken into the national poultry gene pool, since it was uniquely adapted to the harsh environmental conditions prevalent in Nigeria. However, Oluyemi (1979a) found some evidence to conclude that the Nigerian indigenous fowl is essentially a light breed and suggested that scarce resources had therefore better be utilized on imported strains and hybrids than on upgrading the indigenous fowl.

Meanwhile, the National Animal Production Research Institute (N.A.P.R.I.) has acquired some strains of exotic

layer chickens to initiate the development of national foundation stock for the laying hens. However, for a successful establishment of a national foundation stock, there is a need to test the gene pool created from different combinations of strains to see which of them possessed the best "nicking" in production characteristics. The work being reported was conducted for this purpose.

The objectives of the study are: (1) to collect data on short-term egg production and related traits in the parent stock population obtained from two imported strains, each of two lines and crossed in a full diallel pattern and (2) to use the data obtained in testing the performance of the crossbred vis-a-vis those of their parental purebred counterparts; and (3) to evaluate the combining ability of the strains used.

The information gathered can be used in formulating better practical breeding plans for establishing suitable breeds of egg-type chickens for Nigeria.

CHAPTER 2

LITERATURE REVIEW

2.1. Concept of Breed Development.

The first step in breed development is the establishment of a gene pool to serve as a common base or foundation population. From this base population, new strains are produced by conventional selection procedures. The strains developed are then tested in suitable two -, three -, and four - way combinations (Bowman, 1974 and Buvanendran, 1979). According to these authors, most commercial breeders use closed flock selection to develop and improve their strains while a few use inbreeding, and reciprocal recurrent selection. When closed flock selection results in plateaued populations, new genetic material may be incorporated and selection is continued.

The presence of several characters of economic importance in the commercial hybrids is usually achieved by selecting for different characters in different strains and combining them in the final products which are usually three - or four - way crosses. For example, because of the negative genetic correlation between egg number and egg weight, one line may be selected for egg number and another for egg weight. Index line(s) in which index selection (selection for more than one trait at a time) is applied

may also be added. Figure 2.1.1. is a sketch of the procedures involved in producing and improving hybrids.

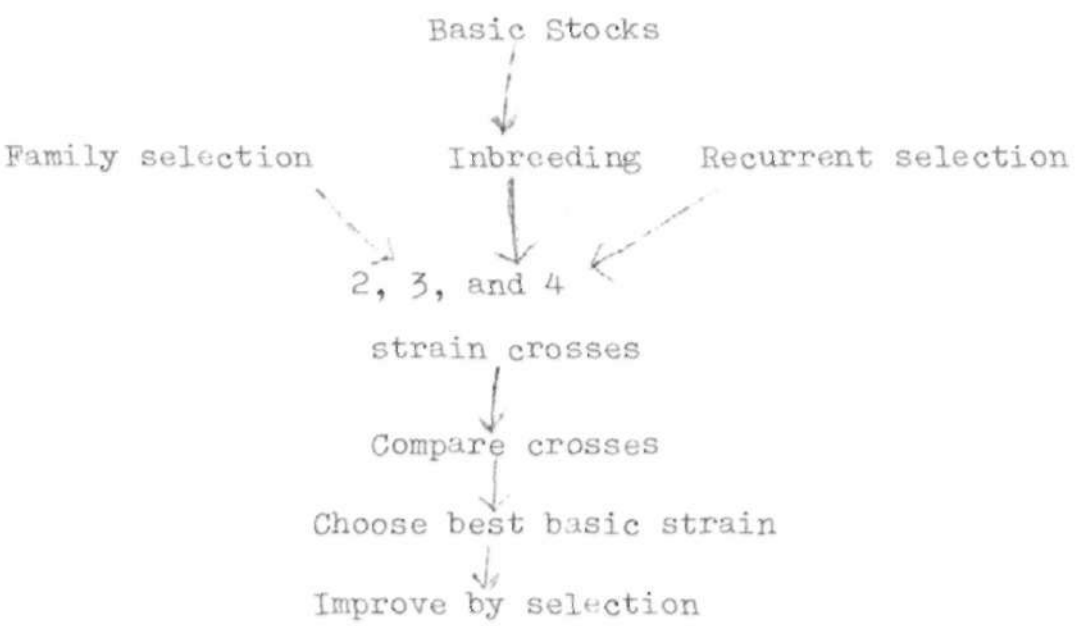


Fig. 2.1.1. Commercial Poultry Breeding

Source: Bowman (1974)

Crosses are generally tested in a variety of environments in different locations so as to provide a reliable measure of performance of different genotypes.

The basic stocks required for a selection programme may not be available in the developing country like Nigeria. It may therefore be necessary to import parent or grand-parent stock and synthesize gene pools from them. Depending on breed and method of breeding, the basis stock can also be obtained from commercial strains available

within the country as was the case with the Scandinavian countries (Liljedahl et al, 1979; Liljedahl and Weyde, 1980; Kolstad, 1980; and Sørensen et al, 1980). However, it is easier to start the breeding of white egg layers from commercial strains than it is for brown egg layers. Bowman (1974) and Buvanendran (1979) elucidated the proceedures to be followed in developing white egg strains from parent stock.

The development of foundation stocks using parent for brown egg strains, would be too tedious. Figure 2.1.2. is an example of the breeding programme used in development of a four-way brown-egg type hybrid.

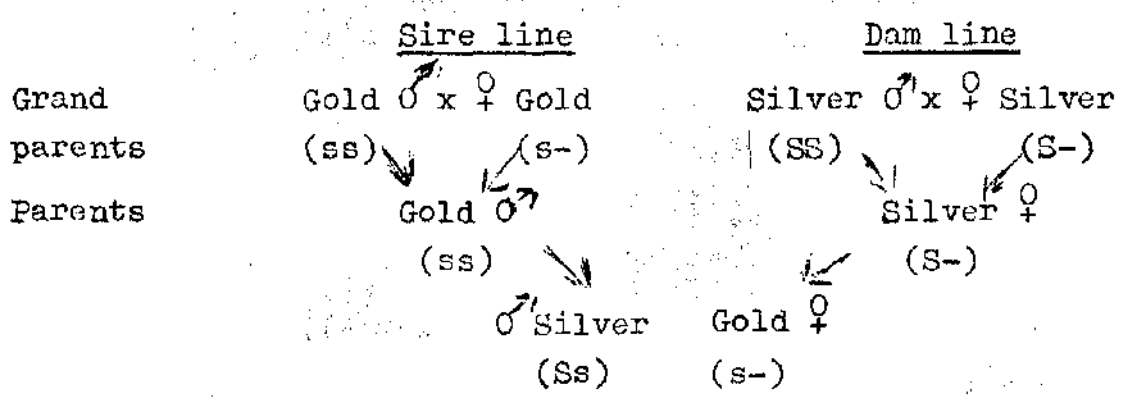


Fig. 2.1.2. Color sexing Hybrid Development

Source: Buvanendran (1979).

From the figure, it is obvious that to start with parent stock in this case, will take a number of generations before pure breeding gold and silver stocks are obtained. Therefore, Buvanendran (1979) recommended that breeding be attempted with grandparents instead of parents. Once populations that breed true for colour are obtained,

they could be treated as closed populations for cross-testing with other lines.

2.2. Performance of Exotic Chickens in Nigeria.

There is an abundant literature on the performance of crossbred chickens in other parts of the world but only very little research has been carried out in this country. Most of the chickens raised in research institutions were in comparison with the local chicken (Oluyemi et al, 1973; Akinokun, 1977; Akinokun and Dettmers, 1979 a,b,c; and Oluyemi et al, 1979).

Akinokun (1977) reported that body weights of crosses between indigenous chicken and Rhode Island Red (RIR) were considerably higher than those of the indigenous fowl. Egg production also was higher than that of the improved breed (RIR), and egg weight was slightly better than that of the indigenous chicken. Omeje (1983) also cited reports to show that the White Leghorn (WL) is inferior, even to the local chicken in body weight from day-old to 20 weeks of age.

Akinokun and Dettmers (1979a,b) compared Apollo, an exotic strain, with the local chickens. They found that Apollo produced more and heavier eggs than the indigenous fowl. Though age at sexual maturity (ASM) varied widely between the exotic breed and years, regressions and simple correlation coefficients indicated that hens which matured late produced more and heavier eggs.

Oluyemi (1978), comparing five laying commercial strains (identified as strains 1 - 5) over a period of 72 weeks reported the ranges in age at first egg (AFE) to be 180 - 204 days; Hen-day percent production, 42.5 - 60.7; feed intake (g/bird/day) 104.1 - 107.1; Hen-housed percent mortality, 11.7 - 13.8; and egg size (g), 51.2 - 55.4. One of the strains used (strain 2) was hatched in the United Kingdom (U.K.). He concluded that the laying performance of the strains were lower than what was reported in other countries especially in the temperate part of the world. Akinokun (1977) also reported that rate of growth and egg production of exotic breeds in Nigeria and other tropical locations are poorer than those reported for the temperate areas. But the report by Olomu (1979) on Warren layers in Nigeria was that the performance of these exotic birds compared favourably with those displayed in the US Random Sample Test of 1978. He concluded that with adequate nutrition, good quality stock and excellent management practices, it would be possible for Nigerian poultry farmers to attain high standard of production.

2.3. Performance in other countries.

Results obtained on crossbred chickens in the temperate and other tropical countries depend largely on the breed, strain or line used and the level of selection carried out on them.

In Uganda, Trail (1963) compared five breeds and crosses of commercial poultry for egg weight, body weight, feed consumption and efficiency, and mortality from 161-500 days of age. The breeds used were Rhode Island Red (RIR), Light Sussex(LS), Black Australorp (BA), LS x RIR and WL x RIR. Table 2.3.1. summarizes the results obtained.

Table 2.3.1. Breed data from 161 to 500 days of age.

Item	LSxRIR	WLxRIR	RIR	LS	BA
Egg production (hen-day)	214.6	212.1	175.1	173.0	167.3
% Egg production (hen-day)	63.1	62.4	51.5	50.9	49.2
Hen-housed average	202.2	189.9	166.3	163.5	153.8
Food consumed per day (hen-day,g)	182.01	174.64	166.41	184.84	181.72
Kg food per kg eggs	5.36	5.14	5.99	6.58	6.60
Egg weight (g)	53.81	54.40	53.92	52.28	56.05
Initial body wt(kg)	2.10	1.76	1.99	2.21	2.21
Final body wt.(kg)	2.50	2.03	2.43	2.43	2.47
% Mortality	12.0	25.0	9.0	25.0	18.0

Source: Trail (1963).

He concluded that if egg production is to be a profitable undertaking in Uganda, a crossbred must be kept, LS x RIR being the best choice as it provided the most profitable type of bird.

In India, Mitra et al (1976) studied the effect of age and body weight at sexual maturity on egg production using White Leghorn fowls. They found that for pullets aged 160-165, 165-170, 170-175, 175-180 and 180-185 days at sexual maturity, number of eggs laid during the test period averaged 235.44, 239.00, 232.87, 227.40 and 209.65 respectively. Also, birds in the body weight range of 1.91 - 2.05kg at sexual maturity had the highest egg production (218.62 - 252.32 eggs) while those weighing 1.36 - 1.5kg had the lowest production (209.65 - 239.00 eggs). A significant partial regression of egg production on body weight (-3.21), but not on age at sexual maturity, was reported.

Also in India, Giri and Patro (1985) reported hen-housed egg production to 280 days of age in the range of 41.34 - 59.64 among strain/crosses. Hen-day egg production was 41.18 - 65.22 and average egg weight from 50.05 - 53.65g. Data on 900 purebred and strain crosses were used.

Using 450 White Leghorn hybrids in the German Democratic Republic, Richter et al (1981) reported increased egg weights with increasing body weights. Their results are summarized in Table 2.3.2.

Table 2.3.2. Production Results Obtained by Richter et al (1981).

g Body weight at 148 days (Range)	Average Age at first Egg (days)	Egg production (eggs)	Egg weight (g)	% Mortality
1075-1174	158	238	55.6	13.0
1175-1274	148	234	57.4	10.0
1275-1374	148	241	57.9	9.5
1375-1500	149	240	58.1	16.5

The length of the test period was, however, not specified.

The reports from other investigations are summarized in Table 2.3.3. from which it is obvious that many factors affected the results apart from the environment where the tests are carried out. These include breed, strain or cross used and length of test period.

2.4. Diallel Experiments.

Diallel crosses are commonly used to estimate combining ability (General Combining Ability - GCA; and Specitic Combining Ability - (SCA). Combining ability is

Table 2.3.3. Production Performance of Egg - type chickens in other countries.

Breed/hybrid	AFE(days)	BFE (kg)	Egg Production (eggs/%)	Egg weight (g	Feed consumption (g/day)	Feed Efficiency (g feed/egg)	Mortality %	Ref	Country
New Hampshire	209.72	1.72	59.50 (1st 100 days)	-	-	-	-	Singh & Singh (1982)	India
White Leghorn Strains:									
IWE	-	-	92.1	59.4	131.9	-	-	Kumar et al (1981)	India
IWP	-	-	87.4 (131 days)	53.[illegible]	130.4	-	-		
Shaver Starcross.									
288	154	-	217.8)[a]	57.4	-	176	8.62)[a]	Satava & El-Abiad(1976)	Czekoslovakia
Tetra S1	174	-	220.9)	59.3	-	196	6.40)		
White Leghorn	-	-	-	-	-	384	-	Ruhumathulla et al (1979)	India
Sinai Bedouin 1	-	-	70.95)[b]	45.36	-	-	-)	Arad et al (1975)	
Sinai Bedouin 2	-	-	65.20)	45.86	-	-	-)		Israel
Leghorn x Bedouin-		-	80.50)	54 .89	-	-	-)		
Leghorn	26.9)[c]	-	159.00)[d]	-	-	-	12.00)	Morris and Skaller	
Australorp	28.5)	-	144.00)	-	-	-	14.00)	(1958)	Australia
L x A	26.4)	-	182.00)	-	-	-	13.50)		
A x L	26.7)	-	178.00)	-	-	-	12.90)		
Lines: C	202.8	1.599	-	-	-	-	-)	Cock and Morton	
I	190.4	1.288	-	-	-	-	-)	(1963)	England
C x I	169.9	1.500	220.10)[e]	-	-	-	-)		
I x C	172.14	1.645	210.71)	-	-	-	-)		

a = hen - housed between 148 - 481 days of age
b = % production for 100 days between 30-40 weeks of age
c = in weeks
d = Hen-day up to 72 weeks of age
e = to 490 days of age.

the relative ability of line/strain, when crossed with another line/strain, to transmit desirable traits, to the next generation. Studies on GCA and SCA give some insight as to the type of gene action involved in the expression of hybrid vigour (heterosis) for important traits, and this knowledge would lead to a better formulation of practical breeding plans (Merritt and Gowe, 1960).

Reports on diallel crossing experiments where egg production and related traits have been measured and used to estimate GCA, SCA, reciprocal effects and heterosis have been published by several workers including Merritt and Gowe (1960), Blyth and Sang (1960), Eisen et al (1967), Fairfull et al (1983), Giri and Patro (1985), Hagger (1985) and Verma et al (1985). Other authors have specifically dealt with the general design and analysis of such diallels. They include Eisen et al (1966), Berker (1967), and those listed by Fairfull et al (1983).

The partitioning of the component effects within each of the GCA and SCA depends on the model used and whether or not data on the purebred are included in the analysis. In the model proposed by Eisen et al (1966), GCA includes both the cumulative additive effect of the autosomes and that of the sex - linked genes whereas SCA contains the effect of dominance at all loci, and epistasis among all combinations of the loci and epistasis

between sex - linked and autosomal genes. This model assumes the presence of maternal effect and does not include data on purebreds. Eisen et al (1967) defined SCA effect as the average inferiority or superiority of a cross relative to the average performance of the lines involved in the cross.

Fairfull et al (1983) stated that from the Wearden model used, maternal effect does not bias estimates of mean squares attributable to GCA. This probably means that maternal effect is assumed to be absent or is of little significance if present. Since data on selected inbred lines were included, the estimates of GCA and SCA were said to be in the broad sense.

The relative magnitude of the variance associated with general and specific combining ability is of utmost importance even though reports and interpretation of results from diallel experiments have been divergent. Merritt and Gowe (1960) reported that for traits of low heritability such as egg production, a small proportion of the total variance was accounted for by the main effects (GCA, SCA and reciprocal effects), the rest was included in the remainder or error variance. On the other hand, large proportion of total variance is accounted for by these effects in case of highly heritable traits such as body weight. For all traits except AFE and egg production

(Hen-housed and survivors') by far the greatest proportion of differences among the sub-classes (Main effects) was accounted for by GCA. Whereas for AFE and egg production SCA accounted for the greatest proportion. In fact egg production which is closely related to reproductive fitness showed the greatest SCA effect. This study indicated that the relative advantage derived from crossing breeds or strains depended, to a large extent, on the particular strain crossed for traits like egg production than it does for traits like body weight.

In an earlier study cited by Merritt and Gowe (1960), it was reported that SCA did not appear to be important for most economic traits. The report further stated that of nine traits studied, only adult body weight and broodiness showed an appreciable amount of SCA. The study involved single and multiple crosses between light and heavy breeds.

Eisen et al (1967) reported that GCA variance was the most important type of genetic variability for the majority of traits studied. Specific combining ability was low in magnitude for most traits except meatiness in heavy crosses and egg weight in heavy x light crosses in which it was remarkably high and significant. They also reported a zero SCA variance for egg weight, and 300 - day hen-housed percent egg production among light-type crosses. Reference was made to previous results of

diallel experiments with poultry which suggest that GCA is the most important single source of genetic variance for most traits while SCA and reciprocal effects may be important for a few traits. Based on the low magnitude of SCA obtained in their study Eisen et al (1967) concluded that dominance and epistatic variance were of little importance.

In the work of Fairfull et al (1983), both the sire strain and dam strain effects were more or less significant for almost all traits at two different stocking rates. Dam strain effects, reportedly due to GCA and uncorrelated maternal effects, were significant for all traits. Similarly, sire strain effects were significant in most traits except full-year laying house mortality and full year food consumption. Sire strain effects were said to be due to GCA and sex-linked effects. On the other hand, SCA effects (strain of sire x strain of dam interaction) were significant for early egg production, sexual maturity, body weight and egg weight in the one bird per cage analysis. In the other stocking rate, there were significant SCA effects for all egg production traits, sexual maturity, egg weight, egg yield, early food consumption and food utilization. With reference to reports by other workers, Fairfull et al (1983)argued that, though results are not necessarily directly comparable due to differences

in strains (or breeds) used, diallel models or stocking rates, the results generally confirm that GCA is important for several traits and is often more important than SCA.

In a related study, Beilharz and McDonald (1961) found that only breed of dam had a large effect on mortality during the laying period, while breed of sire had the greatest effect on final body weight. However, interaction between breed of sire and breed of dam was highly significant for AFE, survival egg and hen-housed egg production. The results given by Giri and Patro (1985), Hagger (1985) and Verma et al (1985) were similar. Giri and Patro (1985) obtained significant GCA and SCA for all traits except for egg weight in the case of SCA. Hagger (1985) reported that all SCA effects were in the expected direction - negetive for AFE and positive for egg weight, body weight at 40 weeks of age, and egg numbers. Verma et al (1985) also reported a significant GCA for initial egg weight, egg weight and egg mass at 35 weeks; and significant SCA on egg production to 285 days and 500 days of age, and egg mass at 35 and 55 weeks of age. These studies showed significant differences among various genetic groups for most of the traits examined.

2.5. Reciprocal Effects.

It seems to be generally accepted that sex-linked and maternal effects are the primary sources of

reciprocal differences in animal experiments. The presence of these reciprocal effects are important in determining which reciprocal cross performs better and in deciding upon the use of either the sire or dam of a line in a cross (Eisen et al, 1966; Bernon and Chambers, (1985).

In the study conducted by Merritt and Gowe (1960), reciprocal effect. accounted for a relatively small proportion of total variance for most traits. They however suggested that since maternal effects would be expected to play only a minor role, the magnitude of the reciprocal effects would indicate the importance of sex-linkage. Hagger (1985) also reported that reciprocal or sex-linked effects were generally smaller than SCA especially for AFE and egg number.

Blyth and Sang (1960) reported significant differences between reciprocals of a 6 x 6 diallel cross for sexual maturity and for 500 - day egg number analysis within lines. They however observed that both sex-linkage and maternal effects were not line attributes but those of specific combinations.

Cock and Morton (1963) reported significant reciprocal effects in a cross between I and C inbred lines, I x C females being heavier than C x I females from hatch to 20 weeks and subsequent ages. They noted that the percent difference (of mean of C x I) remains approximately

constant at all ages and that the significant difference in AFE was far too small to have an appreciable effect on body weight. According to them, the reciprocal differences obtained for only females and not for males in some of the populations rather suggested the involvement of sex-linkage than that of maternal effect. A further mating which involved another line suggested that about one third of differences between reciprocal F_1 females was due to effect of sex-linkage and two-thirds due to maternal effect.

Beilharz and McDonald (1961) could not obtain any significant difference between White Leghorn (WL) x Australorp (AO) and AO x WL reciprocal crosses in the three characters related to reproduction (AFE, Survivor's production and hen-housed production). This was in agreement with the earlier reports by Morris and Skaller (1958) and other cited by Beilharz and McDonald (1961) on the same type of crosses. In a related study, Sheridan and Randall (1977) reported considerable sex-linkage and/or maternal effects in the F_1 crossbred flocks, the WL x AO pullets being superior to the reciprocal cross for both hen-housed production (+ 17.7 eggs) and hen-day egg production (18.3 eggs). Meanwhile, only about one half of this sex-linkage and/or maternal effect was present for total egg mass since egg weight tended to counter-balance egg number. The reason

for these contrasting results may be due to year effect and/or some sort of selection and improvement. Morris and Skaller (1958) had stated that ranking of crosses varied from year to year. This inconsistency was attributed to the sires used. Thus, some selection and improvement may have occurred in the two breeds before they were used by Sheridan and Randall (1977) taking cognisance of the number of years there were between the reports. In addition, the result of Beilharz and McDanald (1961) was said to indicate that maternal effect in adult body weight may be important. In contrast, Bernon and Chambers (1985) reported that maternal effects among stocks (of broiler) were more pronounced in early body weight than mature body weight. They, however, added that maternal effects were not a major factor in accounting for differences in body weight or conformation traits of line crosses of broiler populations at 6 weeks of age. This probably means that maternal effects have greatly reduced by that age.

Fairfull et al (1983) reported that reciprocal effects were important for egg production traits, sexual maturity, egg quality traits and viability, and that in almost every case, one reciprocal was clearly superior to the other. They further indicated that the magnitude of reciprocal effects tended to be greater in the environment in which heterosis was smaller. These results,

they stated, suggested that in addition to direct maternal and sex-linkage effects, genetic interactions particularly with the sex chromosomes may be important in reciprocal differences in the chickens.

Studies with WL lines also indicated significant reciprocal effects. Giri and Patro (1985) obtained reciprocal effects for all traits; Verma et al (1985) reported reciprocal effect for egg production to 285 and 500 days and egg mass at 35 and 55 weeks of age. They concluded that sex linkage had a greater effect on egg production, egg weight and egg mass than did maternal effects.

2.6. Heterosis.

According to Sheridan (1981), the word "heterosis" is used to describe the increased vigour of crossbreds relative to their parents, and refers to any favourable departure from additivity in crossbred populations. In the strict sense, therefore, heterosis is the additional performance, if any, shown by the first generation of crossbred progeny (the F_1) above the mean performance of their two parents. Sometimes the F_1 progeny performance may exceed that of either parent, in which case the crossbreds can be of considerable importance, or may be less than the mean parent performance and this is referred to as "negative heterosis" (Omeje, 1983). The commercial importance of crossbreds has stimulated

considerable research in attempts to understand the genetics of heterosis. The various theories advanced to explain heterosis and the different types of heterosis have been reviewed by Sheridan (1981) and Omeje (1983, 1985). Opinions differ, however, on the relative contribution of the different components proposed but most authors agree that no single component is the sole cause of heterosis.

A lot of experiments have also been conducted to determine the magnitude and the relative importance of heterosis. Morris and Skaller (1958) reported that both of the reciprocal crosses between White Leghorn and Australorp were consistently superior to the better of the parental breed (WL) in egg production to 72 weeks of age and other traits. The crossbred hens laid 14.5% more eggs than the average of the parental breeds. In an earlier study, Skaller (1954) observed that crossbred hens were 30% superior to their purebred half sisters. The heterosis observed from other works involving White Leghorn and Australorp are summarized below:

Table 2.6.1.

Comparison of Mid-Parent (P_n) with the First (F_1) crossbred populations from various experiments involving WL & AO. breeds of fowl.

Traits	P_1	F_1	% heterosis	Reference
Survivors' Egg Production				
Short-term (eggs)	57.10	72.40	26.80	Morris & Binet
Long-term (eggs)	179.00	206.00	14.90	(1966)
Intermediate term (eggs)	126.45	145.00	14.68	Sheridan(1972)
Weight of egg(g)	52.74	54.73	3.77	"
Production(eggs) to 57 wks of age (4-day wk).	91.50	103.30	12.9	Sheridan(1979)
Total egg mass (kg) to 57 wks (4-day wk)	4.60	5.40	16.90	"
Hen-day basis.				
Production (eggs) to 66 wks	192.00	226.50	18.10	Sheridan and Randall(1977)
Total egg mass to 66 wks (kg)	10.00	12.10	22.30	"

Source: Omeje (1983).

In a related study, Beilharz and McDonald (1961) observed considerable heterosis for AFE, survivors' and Hen-housed egg production. They reported an average of 18% more eggs to 500 days of age. In crosses between inbred lines of White Leghorn poultry, Shoffner et al (1966)

reported that the F_1 crossbreds laid 206.50 eggs to 500 days of age while the mid-parent production was 169, exhibiting 22.19% heterosis.

Blyth and Sang (1960) reported heterosis for sexual maturity, 500 day egg number and egg weight. They stated that though 500 - day egg records for hybrids tested varied greatly, most were superior to the better parent line in pen samples, and heterosis increased with increasing mean performance of parents. In the cage sample, heterosis decreased with increasing mean parental performance. However, these differences were said to reflect parental characteristics rather than an expected diversity in heterotic effects. Though the relative and absolute magnitude of heterosis observed by Fairfull et al (1983) was also dependent on the environment, the suggestion by Blyth and Sang (1960) that heterosis might decrease with increasing levels of parental performance was not generally supported. Cunningham (1982) shared the same view with Fairfull et al (1983) and ascertain that heterosis tend to be higher in poorer environments.

CHAPTER 3

MATERIALS AND METHODS

3.1. Stock.

The pullets used in this experiment are the parent stock, F_1 progenies of two original grand parent strains of egg - type chickens. The grand parent strains were: Shaver 579 Starcross and Hubbard Golden Comet, henceforth referred to as S and H respectively. They were imported by the National Animal Production Research Institute (N.A.P.R.I.) as day-old chicks in February, 1985 from two different sources in England. Each of the sources supplied two lines, representing male and female lines and differentiated by their plumage colours. The corresponding lines, however, have the same plumage colour. The male line was brown and the female line was white.

On arrival, the chicks, were housed at the Brooding section of the Poultry Breeding Unit of NAPRI in deep litter pens measuring 2.4m x 3.4m with floor space allowance of $0.074m^2$/bird in accordance with the recommendations by Olomu and Offiong (1978). The brooding pens were shielded by plywood/cardboard sheets, while heat was supplied by means of kerosine stoves in addition to 100-200 Watts electric bulbs. Chick feeders and small plastic drinkers were used throughout the brooding period which lasted 5 weeks.

By the 6th week, the birds were transferred to the rearing pens in tropical type open-sided buildings. The open sides have half walls 1.2m tall, and finished to the roof with 3/4 inch (19mm) wire mesh. Each pen measures 3.4m x 3.4m and housed a maximum of 40 birds. Polythene sheets were used to cover the open sides of the building to protect the young birds from the night and morning drafts. This lasted from 6 - 12 weeks of rearing. By the 19th week, the pullets were placed in mating pens similar to the rearing pens.

3.2. Mating Arrangement.

Cocks were introduced into the pullet pens when all chickens were 28 weeks old. Diallel crossing scheme was employed in mating the two strains, although crossings were restricted to the lines since the progenies were to be parental stock. Thus there were two sets of diallel crosses, one on each of the male and female lines. The mating ratio was approximately 1:10. Table 3.2.1. shows the mating scheme and number of birds housed together with the genotypes of the F_1 progenies.

Table 3.2.1. Mating scheme and the Ratio of the Grandparent Stock with the F_1 Genotypes.

Breeding Groups [1]	Male Line			Female Line		
	No of birds			No of birds		
	Cocks	Hens	F_1	Cocks	Hens	F_1
A (SXS)	10	100	S_1	24	240	S_4
B (SXH)	10	103	H_1	24	240	H_4
C (HXS)	10	100	S_2	24	240	S_5
D (HXH)	10	103	H_2	24	240	H_5

[1] The male breed is written first.

3.3. Housing and Equipment.

Chicks obtained from the matings were brooded and reared to point of lay under management conditions similar to the grand parent stock. A total of 10,008 chicks from the various groups were housed for brooding. Close to sexual maturity, pullets were transferred into the breeding houses which were open sided with full concrete walls at the ends. There are four of such buildings each housing the replicates of the eight genotypes. The open sides of the buildings are made of 1.2m high concrete walls. Between the short wall and the roof is a wire netting. The service room measuring about 3.0m x 1.2m with full walls and doors is in the middle of each building to separate the house into eastern and western wings in

which the brown and white lines were housed respectively. There are four partitions on each wing of the buildings in which four genotypes of either brown or white were randomly assigned to the pens. Three inner sides of the pens were made of wire mesh supported at the base by wooden planks, and extending to the roof. The fourth inner side facing the entrance is one of the low walls, that make the two sides of the building. A 1.2m wide passage separates the pens from the other low wall side. The concrete floor of the pens were littered with wood shavings 12-15cm high. On the whole, 2,954 pullets were housed. Table 3.3.1. gives the breakdown according to the number housed per genotype per replicate pen.

No artificial light was provided at night, thus the birds benefited from natural daylight of at least 12 hours daily. Feeding and watering devices consisted of conical metal containers. Each pen was provided with colony laying nests. The height of each colony nest was 30cm at the front and 50cm at the back with the top sloping from front to the back. Each nest consists of six individual cells of 28cm length and 45cm breadth with an enclosed area of 1260cm^2. There were at least three of such nests per pen, this gives an average of 5 hens per individual cell.

Table 3.3.1. Number of Pullets Housed.

Genotypes	Replicates				Total
	1	2	3	4	
S_1	79	80	100	86	345
S_2	80	80	111	79	350
H_1	85	8●	85	87	337
H_2	86	81	96	87	350
S_4	110	100	97	81	388
H_4	117	100	69	79	365
S_5	125	100	125	121	471
H_5	106	100	68	74	348
Total	788	721	751	694	2954

3.4. Management.

Throughout the period, feed and water were provided ad libitum. Chicks were fed on chick mash from 0-7 weeks, and then grower mash from 8 - 18 weeks and from 19 weeks onward, a breeder mash was given. The composition of each of the chick, grower and breeder ration is given in Table 3.4.1.1. All rations were formulated and mixed at poultry breeding unit of NAPRI.

Table 3.4.1.1. Percent Composition of Diets Fed.

Ingridients	Rations		
	Chick	Grower	Breeder
Maize	51.00	57.25	56.00
Groundnut Cake	27.00	8.00	22.80
Cotton seed meal	-	15.00	-

(Table 3.4.1.1. (Contd.)

Ingridients	Chick	Grower	Breeder
Wheat Bran	17.00	15.00	11.00
Bone meal	2.75	2.75	2.50
Limestone	1.50	1.50	7.00
Salt	0.25	0.30	0.45
[1]Premix	0.25	0.20	0.15
Methionine	0.15	-	0.10
Lysine	0.10	-	-
Nutrient Composition.			
Crude protein	19.25	17.17	17.35
Crude fibre	2.66	3.69	2.91
ME (Kcal/kg)	2591.00	2547.00	2640.69
Calcium	1.64	1.61	3.62
Phosphorus	0.98	1.04	0.86
Lysine	0.88	0.63	0.67
Methionine	0.41	0.28	0.33

[1]The content (per kg diet) of the premix ("Zoodry") supplied by Roche (Nig.) Ltd., and used in ration formulation is presented in Table 3.4.1.2.

Birds were fed twice daily: 8.00 - 10.00 a.m. in the morning and 3.00 - 5.00 p.m. in the afternoon. Eggs were collected throughout the day to prevent being broken by hens, and being dirty. Final recording of eggs laid and mortality was made at the close of each day for every pen and genotype.

Regular innoculation and necessary medications were given. Although there was no major disease outbreak throughout the test period, "Amprolium", a coccidiostat was administered through drinking water when some birds

Table 3.4.1.2. Vitamin and Mineral Content of "Zoodry" Premix Used*.

Content	Chick	Grower	Breeder
Vitamin A	12,500 I.U.	8,000 I.U.	9,000 I.U.
Vitamin D_3	2,750 I.U.	1,760 I.U.	1,500 I.U.
Vitamin E	15 I.U.	8 I.U.	12 I.U.
Vitamin K	2.[illegible] mg	1.6 mg	1.2 mg
Vitamin B_1	1.5 mg	0.4 mg	1.2 mg
Vitamin B_2	6.0 mg	3.6 mg	3.0 mg
Nicotinic Acid	35.0 mg	17.6 mg	18.0 mg
Calcium D. Panto-thenate	10.0 mg	6.4 mg	7.2 mg
Vitamin B_6	3.5 mg	2.4 mg	2.4 mg
Vitamin B_{12}	0.02 mg	0.0096 mg	0.0015 mg
Folic Acid	1.00 mg	-	0.30 mg
Biotin	0.05 mg	-	0.06 mg
Vitamin C	25.0 mg	-	15.00 mg
Choline Chloride	300.0 mg	160.0 mg	150.0 mg
Zinc Bacitracin	20.0 mg	-	-
Methonine	200.0 mg	-	-
Avatec (Lasolocid)	90.0 mg	-	-
Manganese	100.0 mg	80.0 mg	60.0 mg
Iron	50.0 mg	40.0 mg	30.0 mg
Zinc	45.0 mg	36.0 mg	27.0 mg
Copper	2.0 mg	1.6 mg	1.2 mg
Iodine	1.55 mg	1.24 mg	0.93 mg
Cobalt	0.225 mg	0.18 mg	0.135 mg
Selenium	0.10 mg	0.08 mg	0.06 mg

*The quantities indicated for each content are per kg diet.

were suspected to have coccidiosis. Below is the vaccination schedule against the appropriate disease at different ages of the birds (Table 3.4.2.).

Table 3.4.2. Innoculation Schedule for Experimental Birds.

Age of Birds (Week)	Disease Innoculated Against	Vaccine	Route
1 (Dayold)	Marek's	Marek's disease vaccine	1/M
1 (Dayold)	Newcastle	NDV(Hitchner)	1/O
2	Infectious Bursal Disease (Gumboro)	IBDV (Apathogenic)	1/M
2	Newcastle	NDV-Lasota	Oral (in water)
5	Gumboro (IBD)	IBDV(Avirulent)	1/M
6	Newcastle	NDV-Komorov	1/M
16	Newcastle	NDV-Komorov (Booster for laying birds)	1/M
18	Gumboro (IBD)	IBDV(Avirulent) (Booster for laying birds)	1/M

3.5. Weighing and Recording.

Short-term egg production (egg production to 120 days) and related traits were measured on the eight genotypes. Data were collected from four replicate pens per genotype while the means were used in the analyses. Age at first egg was recorded on flock basis rather than individually since the birds were not trap-nested. As a result of this arrangement, AFE was not analysed statistically.

Individual egg weights were taken using a W & T Avery scale (500g x 1g) while bulk eggs and birds were weighed by Salter model 250 scale (5kg x 500g).

3.6. Statistical Analysis.

Analyses of data collected were carried out using the pen means. Percent mortality were transformed into arcsine angles and body weights converted to $\log_{10}$ values before analyses. Two models were generally used. The first analysis (Model I) was a general assessment of all data. The second (Model II) was an analysis of combining ability. They are:-

Model I: $x_{ijk} = U + A_i + L_j + (AL)_{ij} + e_{ijk}$

Where x_{ijk} = Mean observation on pullets of the ith breeding group and jth line.

U = Overall population mean.

A_i = Effect of the ith breeding group i = 1,..,4

L_j = Effect of the jth line j = 1,2

$(AL)_{ij}$ = Effect of the interaction between ith breeding group and jth line.

e_{ijk} = Experimental error; normally and independently distributed about zero mean and error variance:

$\simeq$ NID $(0, \sigma_e^2)$.

Model II: A genetic model, is given by Becker (1967) but modified to include an additional main effect which is line.

$$x_{ijk} = U + g_i + g_j + l_k + s_{ij} + r_{ij} + e_{ijk}$$

where = mean observation on pullets of a cross between the ith sire breed and jth dam breed of kth line.

g_i = general combining ability of the ith sire breed (additive effect of the autosomal genes of the ith breed + sex-linked effects).

g_j = general combining ability of the jth dam breed (additive effect of the autosomal genes of the jth breed + maternal effects).

l_k = line effect.

s_{ij} = the interaction of the ith and jth breeds - specific combining ability (non-additive genetic effect of the cross ij and ji)

r_{ij} = reciprocal effects of the ijth and jith cross (maternal and sex-linked effects).

e_{ijk} = random error.

Other interactions are considered not important in this model.

The GCA in the analyses of variance (ANOVA) is the sum of g_i and g_j. Reciprocal effects were calculated by $\frac{1}{2}\sum(r_{ij}-r_{ji})^2$ as given by Becker (1967). Heterosis (deviation) was estimated as

the mean of a cross minus the unweighted average of the respective means of the two approriate parents. The significance of heterosis was determined by t - test.

Further tests of significance were done using Duncan's Multiple Range Test (DMRT) as presented by Middlebrooks (1976). Details of the analyses are found in the Appendices. To aid interpretation of results, data on some traits were displayed graphically. Tables were also used to present various data either as descriptive statistics or summary of analyses of variance.

3.7. Definitions of Traits Measured.

AFE: Age at first egg (days) - the number of days from hatch to the day the first egg was laid in a given genetic group.

BFE: Body weight at first egg; weight of each live pullet (to the nearest 0.01kg) averaged over the number of pullets weighed per group.

B30: Body weight at 30 weeks of age, averaged over the number of birds weighed per group.

B40: Body weight at 40 weeks of age, averaged over the number of pullets weighed per genotype.

WFE: Average weight of first egg; average of the weights of first ten eggs laid consecutively.

W30: Average weight of eggs at 30 weeks of age. The weights of samples of eggs laid per group on two consecutive days at 30 weeks of age were averaged.

W40: Average weight of eggs at 40 weeks of age. Measurement as in W30.

HHE: Hen-housed egg number; total number of eggs laid by a given genetic group divided by the number of hens housed in that group. Record taken over the first four 30-day-periods i.e. 120 days.

HDE: Hen-day egg number - total number of eggs laid by each group divided by average number of birds at the beginning and end of each period.

HDR: Hen-day rate of lay (percent) - the number of eggs laid by each group divided by average number of hens and number of days (x100).

FC: Feed consumption (g/bird/day) - total feed consumed per pen divided by the number of hen-days. Known quantities of feed were given and recorded for each pen regularly. At the end of each period, the left-overs were weighed and subtracted from total quantity given.

$$\frac{\text{Weight of feed given - wt. of left over.}}{\text{no of days x average no. of birds.}}$$

FE: Feed efficiency: Feed consumed to produce a dozen eggs (kg feed/doz. eggs).

$$= \frac{\text{Total feed consumed x 12}}{\text{Total no. of eggs laid}}$$

Records taken over the four periods.

LHM: Laying house mortality (percent) - number of hens that died in a group during the test period divided by the number of hens housed for the group (x 100).

CHAPTER 4

RESULTS

4.1. Age at First Egg.

Age at first egg for the eight genotypes are shown in Table 4.1.1. From both lines, pure Hubbard (HxH groups) were the first to come into lay followed by crossbreds from Hubbard sires (S_2 and S_5). Those of Shaver sires with Hubbard dams (H_1 and H_4) came to lay much later and the Shaver purebred (SxS groups) were the last to start laying. A gap of at least 24 days existed in AFE between the progenies of H-sires and those of S-sires. This result evidently shows the sire influence on the inheritance of AFE with H-sires showing earlier maturity in their progenies than S-sires. However, there was no difference as such between the line means.

Table 4.1.1. Age at First Egg (AFE)

Breeding group	MALE LINE		FEMALE LINE		B/group Means±SE
	Genotype	AFE(days)	Genotype	AFE(Days)	
A (SXS)	S_1	202	S_4	217	209.5±7.5
B (SXH)	H_1	201	H_4	193	197 ± 4.0
C (HXS)	S_2	177	S_5	163	170 ± 7.0
D (HXH)	H_2	149	H_5	154	151.5±2.5
Mean		182.25		182.00	182.00
SE (SEM)		12.50		14.30	13.09

The phenotypic correlations between AFE and body weight at first egg (BFE); AFE and weight of first egg (WFE); and BFE and WFE were mostly positive. On male and female line basis, these correlations were respectively; 0.45 and 0.40; 0.96 and -0.11; and 0.65 and 0.85 (Table 4.1.2.). The correlations between AFE and body weight at 30 weeks (0.17 and -0.60); AFE and egg weight at 30 weeks (0.90 and -0.04); and body weight and egg weight at 30 weeks (0.29 and 0.74) were also mostly positive. Those between AFE, body weight at 40 weeks (B40) and egg weight at 40 weeks (W40) were equally high and positive with the exception of that between AFE and W40 for female line (-0.33) which was low and negative. For the other traits, their correlations with AFE were generally positive except fourth month egg number, and mortality.

Figures 4.1.1. and 4.1.2. show the relationship between BFE, AFE and WFE by line and how these traits were differently inherited and influenced. Line effect seems to be very important in the mode of inheritance especially for BFE and WFE. The AFE appears to be sire - influenced on both lines as shown in Figure 4.1.1.

4.2. Body weight.

The mean ($\bar{x}$), standard error (SE) and percent coefficient of variation (cv) for body weight of the different genotypes at various age periods are presented,

Table 4.1.2.' Simple Linear Correlation Coefficients Among Egg Production Traits.

Traits	Age at first Egg (AFE)		Body weight at 1st Egg (BFE)		Body wt. at 30 Wks B30		Body wt. at 40Wks (B40)		Wt.of 1st Egg (WFE)		Wt.of Egg at 30Wks (W30)		Wt.of Egg at 40Wks (W40)		Egg no 1st Month (E1M)		Egg no 2nd Month (E2M)		Egg no 3rd Month (E3M)		Egg no 4th Month (E4)		Production to 4 Month (HDE)		Feed consump (FC)		Feed Effic. (FE)		Mortality (LHM)	
Line	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
AFE																														
BFE	.45	.40																												
B30	.17	-.60	.26	.24																										
B40	.84	.70	.18	.55	.62	.14																								
WFE	.96	-.11	.65	.85	.33	.46	.94	.08																						
W30	.90	-.04	.78	.84	.29	.74	.93	.49	.98	.84																				
W40	.91	-.33	.78	.73	.29	.74	.93	.10	.98	.94	1.00	.92																		
E1M	.70	.06	.81	.60	-.20	.77	.59	.73	.75	.45	.85	.87	.85	.64																
E2M	.82	.99	.39	.50	.70	-.51	.94	.75	.96	-.00+	.78	.08	.78	-.22	.33	.16														
E3M	.88	.90	.04	.34	.44	-.55	.72	.75	.79	-.18	.64	-.05	.64	-.37	.27	.11	.87	.98												
E4M	-.43	-.48	-.01	-.01	.36	-.26	-.34	.69	-.50	-.76	-.04	-.84	.64	-.67	-.94	-.69	-.08	-.58	.07	-.44										
HDE	.84	.93	.18	.05	.56	-.66	.82	.61	.81	-.46	.68	-.34	.65	-.63	.23	-.10	.96	.89	.97	.96	-.11	-.16								
FC	.51	.54	.21	.34	.16	-.17	.67	.94	-.69	-.19	.81	.47	.91	-.22	.81	.47	.77	.39	.67	.90	-.56	-.49	.16	.87						
FE	-.09	.36	.71	.48	-.16	.47	.69	.91	.10	.04	.30	.56	.70	.20	.61	.88	-.25	-.42	-.54	.44	-.51	-.54	-.48	.32	.79	.79				
LHM	-.06	-.07	.71	-.49	-.63	.47	-.73	-.76	-.10	-.31	.04	-.78	-.79	-.50	.56	-.96	-.59	-.16	-.48	-.19	-.77	.60	-.61	.03	.38	-.67	.69	-.93		

+ The actual value is 0.000.

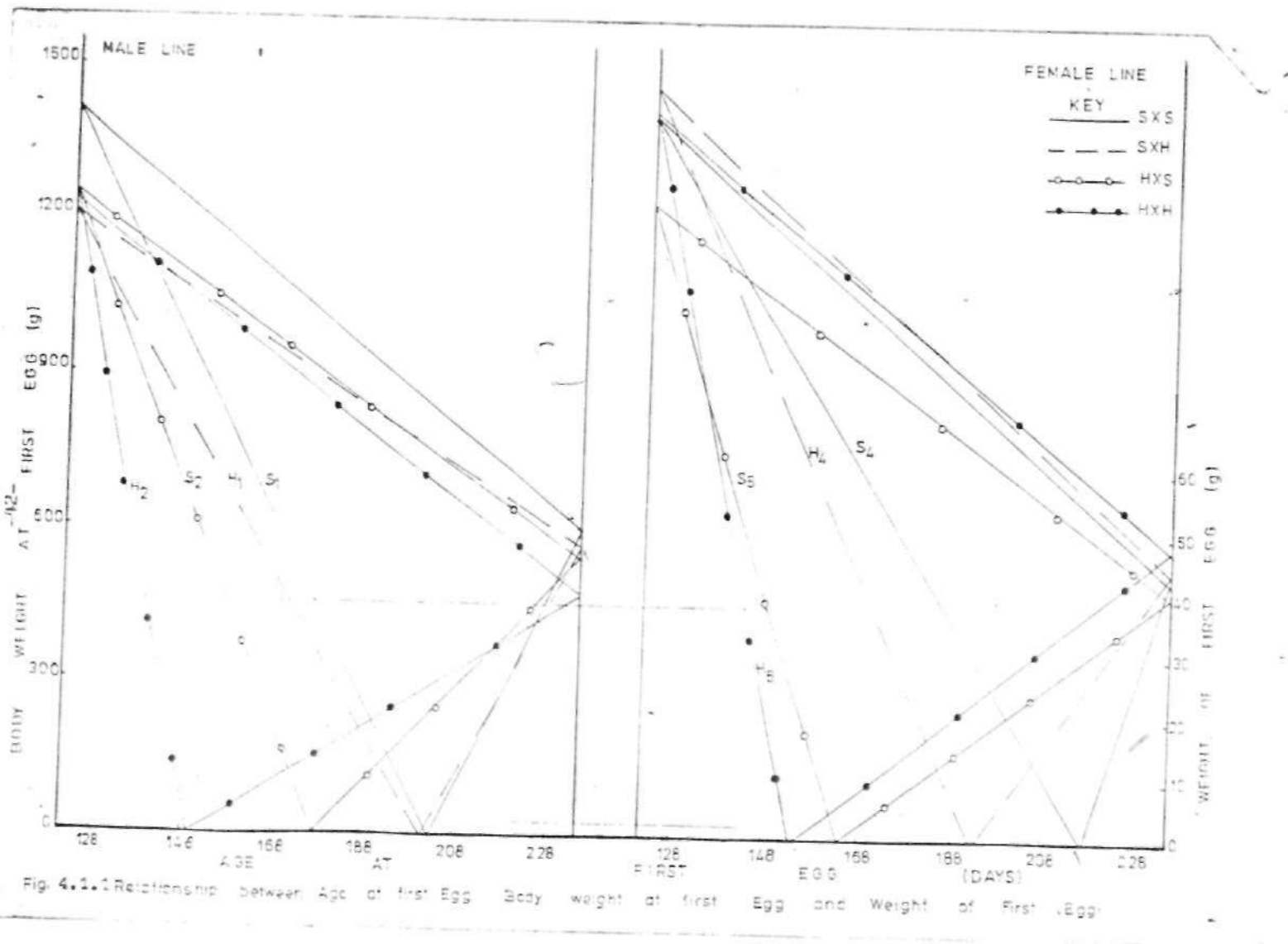


Fig. 4.1.1 Relationship between Age at first Egg, Body weight at first Egg and Weight of First Egg

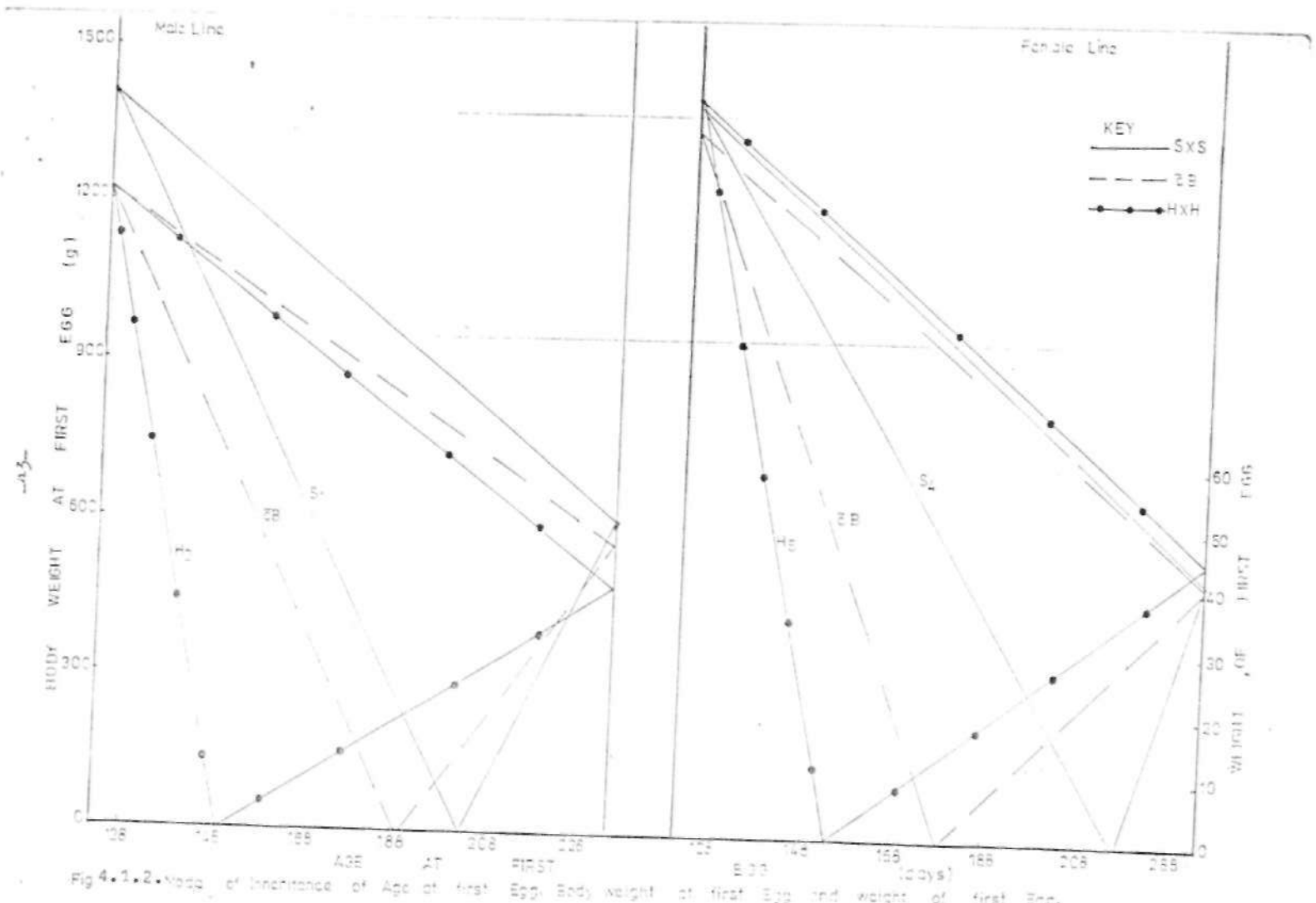


Fig 4.1.2. Mode of Inheritance of Age at first Egg, Body weight at first Egg and weight of first Egg.

on line basis, in Table 4.2.1. Graphical presentation of the means are also shown in Figure 4.2.1. Within the male line, dam influence is evident with progenies of S-dams (S_1 and S_2) being persistently heavier than the other groups. However, such influence was not obtained in the female line. While H_4 (H-dam progeny group) remained heavier than others, H_5 (another H-dam progeny group) showed superiority only up to 30 weeks of age after which it fell even below the means of the S-dam progeny groups. It is also shown that while the other groups of birds continued to grow up to 40 weeks of age, the S_2 (male line) and H_5 (female line) groups seemed to be reaching maximum growth at 30 weeks of age (Fig. 4.2.1.)

Body weight at 30 and 40 weeks of age showed highly significant differences ($P/0.01$) due to breeding group and breeding group x line interaction effects (Table 4.2.3.). Line effect was highly significant($P/0.01$) only for B30 (Table 4.2.2.), with female line birds being heavier. However, while none of these effects was significant in case of BFE, Tables 4.2.4. and 4.2.5. show a highly significant($P/0.01$) reciprocal effect in the trait (BFE).

The phenotypic correlation coefficients among the body weight traits and with other traits are presented in Table 4.1.2. It shows that the correlations among the three body weight traits were positive but mostly low.

Table 4.2.1: Descriptive Statistics for Body Weight of Pure and Crossbred Groups.

Traits	Statistics	SxS	SxH	HxS	HxH
Male line: Body Weight.					
At First Egg	$\bar{x}$ (kg)	1.41	1.21	1.25	1.23
	± SE	0.21	0.03	0.07	0.06
	CV%	26.95	8.26	18.40	15.45
At 30wks**	$\bar{x}$ (kg)	1.41^{b}	1.29^{c}	1.58^{a}	1.26^{c}
	± SE	0.03	0.01	0.01	0.02
	CV%	19.15	11.63	8.86	15.08
At 40wks*	$\bar{x}$ (kg)	1.59^{a}	1.51^{b}	1.54^{b}	1.40^{c}
	± SE	.02	0.01	0.01	0.02
	CV%	12.58	8.61	10.39	11.43
Female Line: Body Weight.					
At First Egg*	$\bar{x}$ (kg)	1.40^{a}	1.46^{a}	1.23^{b}	1.41^{a}
	± SE	0.07	0.04	0.07	0.10
	CV%	16.43	9.59	18.70	21.99
At 30wks*	$\bar{x}$ (kg)	1.32^{c}	1.55^{a}	1.45^{b}	1.51^{a}
	± SE	0.02	0.02	0.07	0.02
	CV%	16.67	11.61	11.76	11.92
At 40wks**	$\bar{x}$ (kg)	1.55^{b}	1.63^{a}	1.49^{c}	1.46^{c}
	± SE	0.02	0.02	0.02	0.02
	CV%	14.19	8.59	10.74	10.96
Combined lines; Body Weight.					
At first Egg	$\bar{x}$ (kg)	1.36	1.32	1.22	1.31
At 30wks*	$\bar{x}$ (kg)	1.35^{c}	1.41^{b}	1.51^{a}	1.41^{b}
At 40wks*	$\bar{x}$ (kg)	1.57^{a}	1.56^{a}	1.51^{b}	1.44^{c}

(Means with different superscript letters differ as indicate

* P/0.05

** P/0.01.

Table 4.2.2: Line Means for the Body Weight Traits.

	Traits	Male line	Female line
1.	Body weight at First Egg, Kg.	1.27	1.37
2.	Body weight at 30 weeks, Kg.	1.38[b]	1.46[a]
3.	Body weight at 40 weeks, Kg.	1.51	1.53

(Means with different superscript letters differ P/0.01).

Table 4.2.3: Variance Analyses for various production Traits Using Model 1.

	Means Squares				
Traits[a]	Line(1)	Breeding groups(3)	LxB(3)	Error	Error d.f.
b_{BFE}	0.020	0.008	0.008	0.0077	72
b_{B30}	0.090**	0.090**	0.25**	0.004	842
b_{B40}	0.006	0.057**	0.026**	0.002	773
WFE	153.76**	84.99**	187.19**	11.27	72
W30	0.46	6.33	9.39	5.19	16
W40	0.14	4.49	14.02	12.57	16
HHE	63.78	12.51	2.96	15.62	24
HDE	64.66	13.12	2.55	17.91	24
FC	2621.06**	1166.52*	660.00	311.25	24
FE	0.01	0.26	0.56	0.23	24
c_{LHM}	31.06	22.06	12.59	19.15	24

a Traits are defined earlier in the text.

b. Converted to $\log_{10}$ values

c Transformed into Arcsine Angles

Df (Degrees of freedom) for the sources of variance are written in parentheses

* P/0.05 ** P/0.01.

Table 4.2.4: Variance Analyses for the Production Traits Using Model II.

Traits	MEAN SCUARES							[1]Error df
	Line	Sire(g_i)	Dam(g_j)	GCA(g_i+g_j)	SCA(SXD)	REC.	Error	
	(1)	(1)	(1)	(1)	(1)	(1)		
BPE	0.02	0.013	0.001	0.014	0.011	0.131**	0.006	74
WPE	153.76**	249.53**	3.65	253.18**	1.78	322.82**	14.19	74
W90	0.46	17.58	1.42	19.00	0.00	11.05	5.56	18
W40	0.14	13.11	0.01	13.12	0.34	12.70	12.81	18
FPE	63.78*	13.78	11.35	25.13	12.40	27.86	13.69	26
FDE	64.66*	17.36	12.59	29.95	9.42	30.44	15.66	26
FC	2621.06**	2110.06*	1058.80	3168.86**	330.70	448.09	346.23	26
FE	0.01	0.11	0.04	0.15	0.63	0.76	0.25	26
LHM	31.06	10.18	0.12	10.30	55.89*	171.15**	12.55	26

[1] Except for error degrees of freedom which varies according to traits, all other sources of variance takes one df each irrespective of trait as indicated within paretheses.

* P/0.05 ** P/0.01.

Table 4.2.5. Proportions of Main effects (%) from the variance Analyses (Model II).

Sources	Traits								
	HHE	HDE	BFE	WFE	W30	W40	FC	FE	LHM
GCA	17.65	20.03	7.69	33.96**	53.10	34.14	45.91**	8.38	3.67
SCA	8.71	6.30	6.04	0.24	0.01	0.89	4.79	35.19	19.93*
REC	19.57	20.35	71.98**	43.30**	30.88	33.05	6.49	42.46	61.02**
Line	44.81**	43.24*	10.99	20.62**	1.29	0.36	37.98**	0.56	11.07
Error	9.26	10.08	3.30	1.88	14.72	31.56	4.83	13.41	4.31

* F/0.05 ** F/0.01.

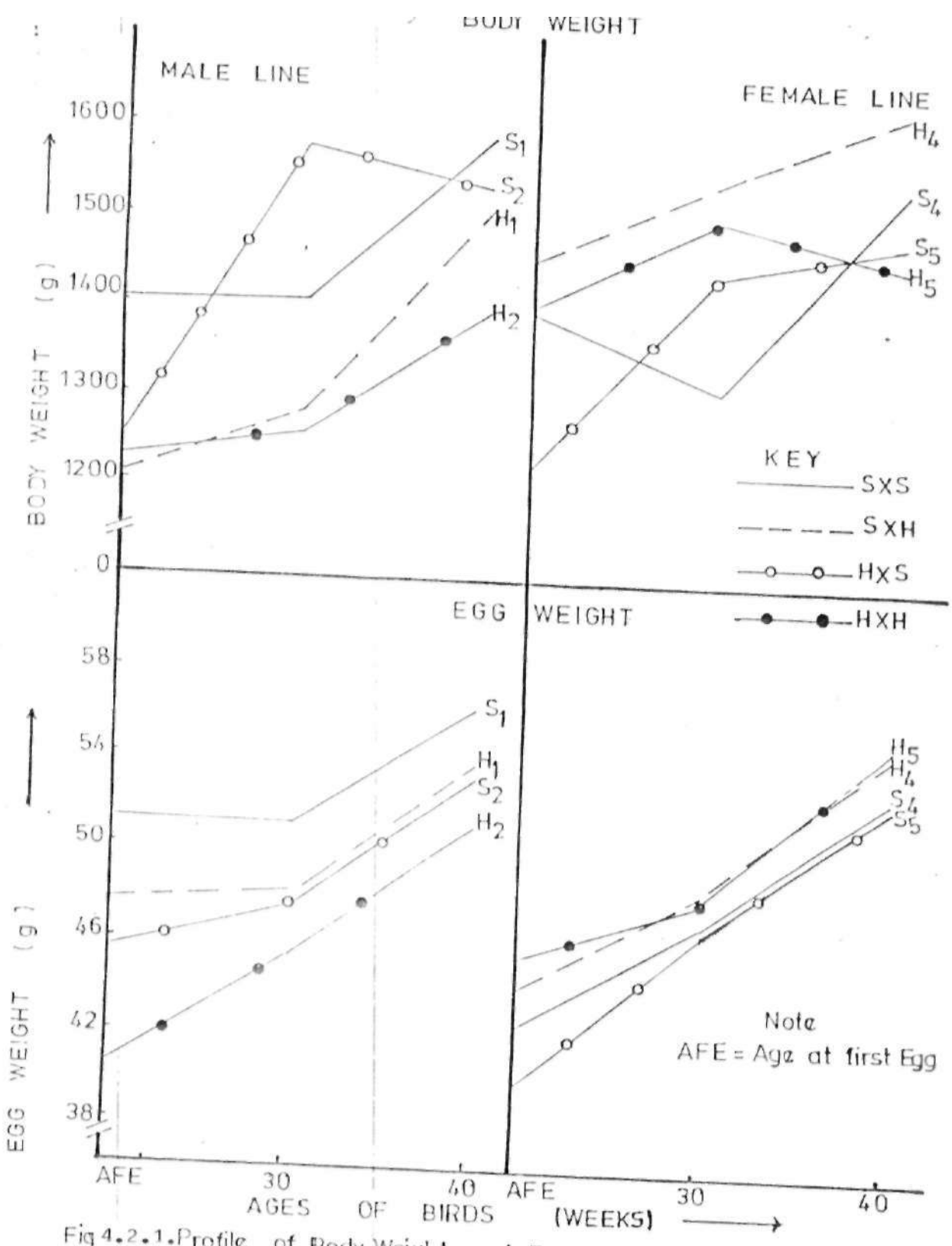


Fig 4.2.1. Profile of Body Weight, and Egg Weight at various Ages.

As expected, all the body weight traits were positively correlated with egg weights. The values were also high except in the correlation of B30 with W30, and with W40 (male line) which were both 0.29 and those of B40 with WFE, and with W40 which were 0.08 and 0.10 respectively for the female line.

The heterosis observed in body weights are shown in Table 4.2.6. Negative heterotic effects were exhibited by most of the genetic groups, especially the HxS of dam line (S_5) whose heterosis in BFE was statistically significant ($P/0.05$).

4.3. Egg Weight.

The mean, standard error, and coefficient of variation for egg weight at various ages are presented in Table 4.3.1. and the graphical presentations have been shown in Figure 4.2.1. It is clearly evident that additive effect is the mode of inheritance of egg weight for male line since the crossbred means lie between those of the pure bred parental groups with the S_1 clearly showing superiority over the H_2 breed. The crossbred egg weights appeared to be largely influenced by sire effects. The egg weights of the groups in the female line did not follow a similar trend, instead, the progenies of H-dams (H_4 and H_5) laid the heaviest eggs. Among the progenies of S-dams, S_4 (purebred groups) consistently laid heavier eggs.

Table 4.2.6: Mean and standard Error Statistics for Heterosis in Body Weights of Crossbred Groups.

[1]Traits	Body weight(kg) $\bar{P}$	$\overline{CB}$	Cross-bred Deviations(kg) SXH	HXS	$\overline{CB}$	% Heterosis SXH	HXS	$\overline{CB}$
	Male line							
BFE	1.32	1.23	-0.10	-0.06	-0.08	-5.23	-4.11	-4.67
			±0.08	0.06	0.07	6.46	4.38	3.80
B30	1.34	1.44	-0.05	0.24	0.10	-3.73	17.91	7.09
B40	1.50	1.53	0.01	0.04	0.03	0.67	2.67	1.67
	Female line							
BFE	1.41	1.35	0.07	0.16*	0.05	7.98	-10.95*	-1.48
			±0.10	0.07	0.06	7.63	4.80	4.89
B30	1.42	1.50	0.13	0.03	0.08	9.15	2.11	5.63
B40	1.51	1.56	0.12	-0.02	0.05	7.95	-1.32	3.32

* = P/0.01

1 = Traits are defined earlier in the text.

$\bar{P}$ = Mean body weight of the two parental groups (Mid-parent value).

$\overline{CB}$ = Mean body weight of two crossbred groups (S X H and H X S).

Table 4.3.1: Descriptive Statistics for Egg Weight of the Pure and Crossbred groups.

Traits	Statistics	SXS	SXH	HXS	HXH
Male Line:					
Weight of First egg**	$\bar{X}$ (g)	50.71^{a}	47.63^{b}	45.60^{c}	39.73^{d}
	$\pm$ SE	0.77	1.12	1.24	0.73
	CV %	4.79	7.45	8.60	5.86
At 30wks	$\bar{X}$ (g)	50.61	48.28	47.50	45.38
	$\pm$ SE	0.62	0.79	0.80	0.38
	CV %	3.87	5.16	5.33	2.67
At 40wks	$\bar{X}$ (g)	56.39	54.08	53.30	51.18
	$\pm$ SE	0.87	0.25	0.35	1.08
	CV %	4.88	1.44	2.10	6.64
Female Line:					
Weight of First egg*	$\bar{X}$ (g)	42.61^{b}	44.24^{a}	40.06^{c}	45.67^{a}
	+ SE	1.38	1.02	0.96	1.10
	CV %	10.26	7.30	7.54	7.64
At 30wks	$\bar{X}$ (g)	47.21	48.54	46.87	48.04
	$\pm$ SE	0.77	0.54	1.22	0.002
	CV %	5.13	3.54	8.21	0.01
At 40wks	$\bar{X}$ (g)	53.00	54.74	52.67	55.15
	$\pm$ SE	1.15	1.37	1.99	0.89
	CV %	6.87	7.89	11.96	5.11
Combined lines:					
Weight of First egg**	$\bar{X}$ (g)	44.66^{a}	45.94^{a}	42.83^{b}	42.70^{b}
At 30 wks	$\bar{X}$ (g)	48.91	48.41	47.19	46.71
At 40 wks	$\bar{X}$ (g)	54.70	54.41	52.98	53.17

Means with different superscript letters differ as indicated.

*$P/0.05$ **$P/0.01$.

The line, breeding groups and line x breeding groups interaction effects were highly significant ($P/0.01$) only for WFE while none of these effects was found significant for W30 and W40 (Table 4.2.3.). Similar results are shown in Table 4.2.4. and 4.2.5. In table 4.2.4., sire breed, GCA, reciprocal, and line effects were highly significant ($P/0.01$) for WFE only while in Table 4.2.5, it is shown that for egg weight generally, GCA effect accounted for the greatest proportion (53.10%) of the total effects, and SCA, the least proportion (0.01%).

The mean and standard error for heterosis in egg weight at different periods of production are presented in Table 4.3.2. Most of the deviations were negative. In the male line, the heteroses were not significant and the crossbred groups did not differ from each other. In the female line, however, the negative heterosis expressed by S_5 at first egg was highly significant ($P/0.01$) hence the reciprocal groups (S_5 and H_4) expressed significantly different ($P/0.05$) heteroses.

4.4. Egg Production.

The results of short-term egg production on both hen-housed (HHE) and hen-day (HDE) basis are shown in Table 4.4.1. Analysis of variance using both models showed no significant effect due to any source except line ($P/0.05$), thus line accounted for the highest proportion (44.81% and 43.24% respectively for HHE and HDE) of the total variance

Table 4.3.2. Mean and Standard Error Statistics for Heterosis in Egg Weights of the Cross bred groups.

[1]Traits	Egg Weights(g) $\bar{P}$	$\overline{CB}$	Crossbred deviations(g) SXH	HXS	$\overline{CB}$	% SXH	Heterosis HXS	$\overline{CB}$
Male line								
WFE	45.22	46.62	2.41	0.38	1.40	5.51	1.14	3.33
			± 1.30	1.59	1.03	2.93	3.60	2.31
W30	48.00	47.89	0.29	-0.46	-0.09	0.63	-0.94	-0.16
			± 1.31	1.59	0.98	2.79	3.64	2.08
W40	53.79	53.69	0.29	-0.49	0.10	0.71	-0.71	0.003
			± 1.31	1.72	0.98	2.46	3.24	1.85
Female line.								
WFE	44.14	42.15	0.10[a]	-4.08**[b]	-1.99	0.58	-8.85*	-4.14
			±1.03	1.28	0.93	2.39	2.81	2.10
W30	47.63	47.71	0.91	-0.76	0.08	1.91	-1.64	0.14
			±0.73	1.73	0.96	1.54	3.92	2.05
W40	54.08	53.71	0.66	-1.41	-0.38	1.16	-2.82	-0.83
			±0.85	1.89	1.04	1.50	3.55	1.94

1 = Traits are defined earlier in the text.

$\bar{P}$ = Mean egg weight of the two parental groups (Mid-parent value).

$\overline{CB}$ = Mean egg weight of each two crossbred groups (SXH and (HSX).

Means with different superscript letters differs significantly ($P/0.05$).

* = $P/0.05$ **$P/0.01$.

Table 4.4.1: Short-Term Mean Monthly Egg Number per hen for the Pure and Crossbred Groups.

	SXS	SXH	HXS	HXH
A. HEN-HOUSED:				
Male line				
Mean	15.51	16.33	16.57	12.85
± SE	1.34	2.41	2.87	2.04
CV %	17.21	29.45	34.58	31.65
Female line				
Mean	13.56	12.85	12.37	11.20
± SE	1.83	1.28	2.09	1.42
CV %	2.92	19.92	33.71	25.31
Combined lines				
Mean	14.54	14.59	14.47	12.03
B. HEN-DAY:				
Male line				
Mean	16.08	16.77	16.65	13.23
± SE	1.47	2.54	2.90	2.26
CV %	18.28	30.29	34.77	34.16
Female line				
Mean	14.09	13.06	12.73	11.48
± SE	1.98	1.35	2.35	1.58
CV %	28.03	20.60	36.84	27.53
Combined lines				
Mean	15.08	14.91	14.69	12.35

(Table 4.2.5.). As shown in Table 4.4.2. birds of the male line laid significantly more eggs (P/0.05) than those of the female line.

The correlations between egg production and other traits are also shown in Tables 4.1.2. and 4.4.4. Egg production in the fourth month of lay was mostly negatively correlated with other traits as shown in Table 4.1.2.

The hen-day rate of lay (HDR) on monthly basis are presented in Figure 4.4.1. The Figure shows that there was no real difference between the groups in their rate of lay in the first month especially for female line. Differences, however, occurred after the first month. For both lines, the progenies of H-sires continued to increase both in rate of lay and egg number up to the fourth month while their S-sired counterparts peaked in the third months of lay and declined afterwards. The results followed a sire breed pattern.

The heterosis in the short-term hen-day egg number of the crosses is shown in Table 4.4.3. On mean monthly basis only the combined crossbred group (male line) showed significant deviation (P/0.05) of 2.06 eggs (11.9%). However, on weekly basis, both mean deviation and percent heterosis were highly significant (P/0.01) for SxH groups and the combined crossbred. Mean deviation was also significant (P/0.05) for the HxS group. There was no significant difference between the heterosis exhibited by

Table 4.4.2; Line Means for the Egg Production Traits.

Traits	Male line	Female line
Hen-Housed eggs	15-32 [a]	12.49'
Hen-Day eggs	15.68 [a]	12.84[1]

i _ > [b] (p/0.05)

Table 4.4.3: Heterosis of Short-term Hen-day Egg Number Among the crossbred (F/.) Groups.

MEAN MONTHLY			CROSSBRED GROL.	
Male line(m)		;XH	HXS	CB
Mean of parents,? = 14.66 eggs				
Mean deviation from P ,	eggs	2.11	2.00	2.06
	+ SE	1.10	1.50	0.85
% deviation (heterosis)		12.79	11.02	11.91
Female line(f)				
Mean of parents, P_f = 12o'78 eggs				
Mean deviation from P~,	eggs	0.28	-0.05	0.11
	+ I	0.74	1.26	0.68
% deviation (heterosis)		3.46	-1.46	1.00
2. MM WEEKLY				
Male line				
Mean of parents, P = 3.^3 eggs				
Mean deviation from P ,	eggs	0.58**	0.53	0-56
	+ SE	0.14	0.23	0.13
% deviation (heterosis)		14.44*	13.79	14.12*
Female line				
Mean of parents, P_f = 3#o9 esgS				
Mean deviation from P_f,	eggs	0.08	-0.10	-0.01
	+ SE	0.14	0.14	0.10
% deviation (heterosis)		4.05	-3.61	0.22

* p/o.05

** P/0.Q1

P Mid-parent value

CB Mean of the crossbred groups (each pair)

Table 4.4.4: Simple Correlation Coefficients Among Some Production Variables in the Eight Poultry Genotypes.

Traits	Hen-Day Egg Number (HDE)								Feed Consumption (FC)								Feed Efficiency (FE)								Mortality (LHM)
Gero-types	S_1	H_1	S_2	H_2	S_4	H_4	S_5	S_5	S_1	H_1	S_2	H_2	S_4	H_4	S_5	H_5	S_1	H_1	S_2	H_2	S_4	H_4	S_5	H_5	$S_1H_1S_2H_2S_4H_4S_5H_5$
HDE																									
FC	.68	.89	.88	.90	.87	.62	.97	.91																	
FE	-.58	-.89	-.84	-.88	-.95	-.73	-.97	-.78	.20	-.62	-.48	-.59	-.66	.08	-.92	-.46									
LHM	-.08	-.05	.40	.07	-.35	.62	.54	-.08	.55	.41	-.39	.31	-.75	.54	.37	-.19	.71	.44	-.53	.14	.07	.26	-.71	-.19	

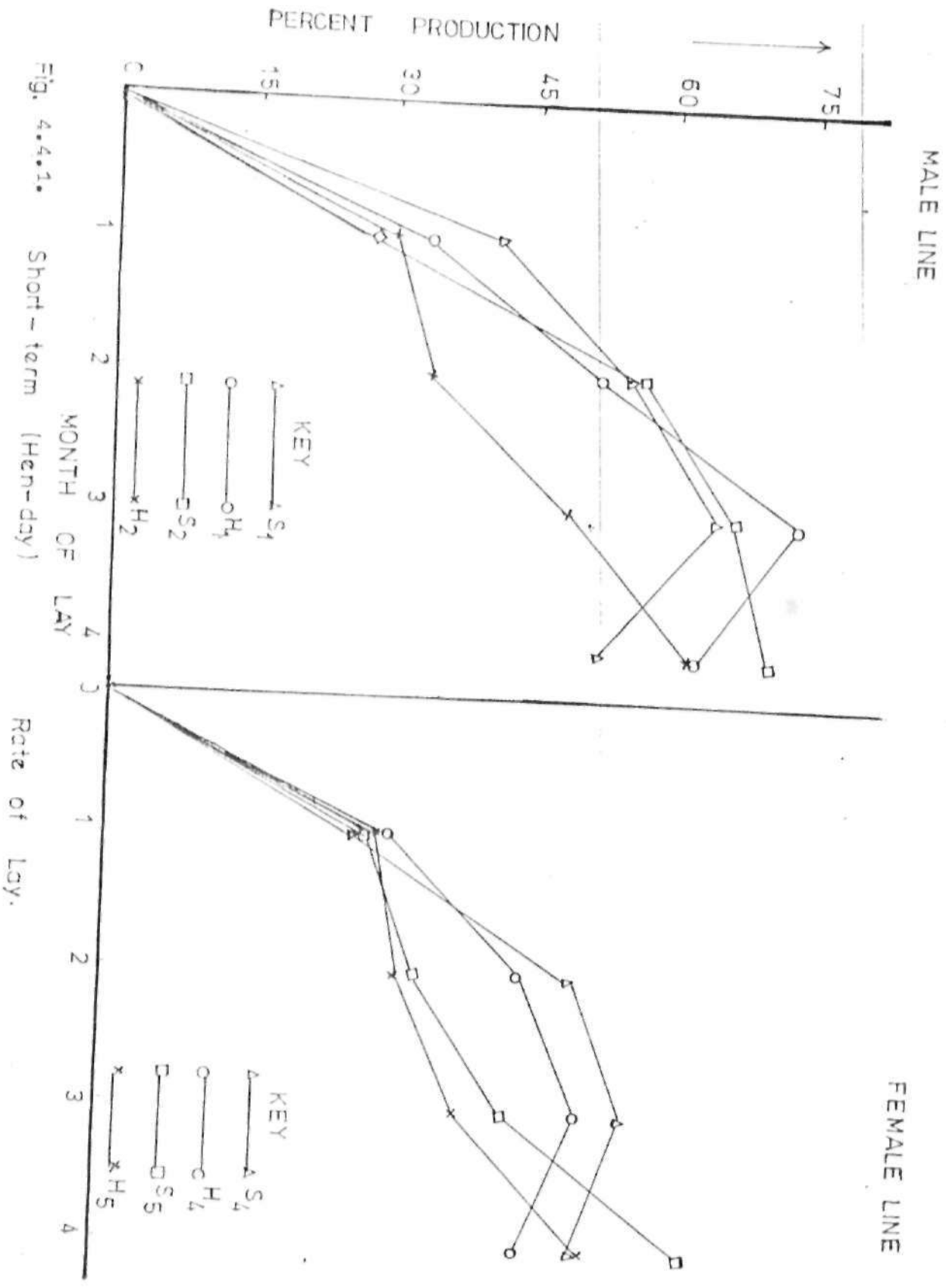


Fig. 4.4.1. Short-term (Hen-day)

the reciprocals in both lines.

The heterosis obtained in the hen-day production of the crossbred groups is presented in Figure 4.4.2. It shows that while the SXH groups peaked in the third month, the HxS groups, despite slight flunctuations, continued to increase to the fourth month.

4.5. Feed consumption and Efficiency.

The results of feed consumption (FC) and feed efficiency (FE) of the laying pullets are presented in Table 4.5.1., and the analyses of variance are shown in Tables 4.2.3., 4.2.4. and 4.2.5. The latter three Tables show highly significant line effect (P/0.01) on FC but not on FE. Table 4.5.2. indicates that birds of the male line consumed more feed than those of the female type. Based on model I (Table 4.3.2.), breeding group effect was found to be significant (P/0.05) for FC. In a further analysis (Model II) sire breed and GCA effects were shown in Table 4.2.4. to be significant (P/0.05) and P/0.01 respectively. None of these effects, however, was significant for FE.

From Table 4.5.3., the H_1 (SxH group of male line) exhibited highly significant P/0.01) heterosis in both FC and FE, but those for S_5 (HxS group of female line) was significant (P/0.05) for FC alone. On the other hand, both crossbred groups of the female line exhibited non significant heterosis for the two traits.

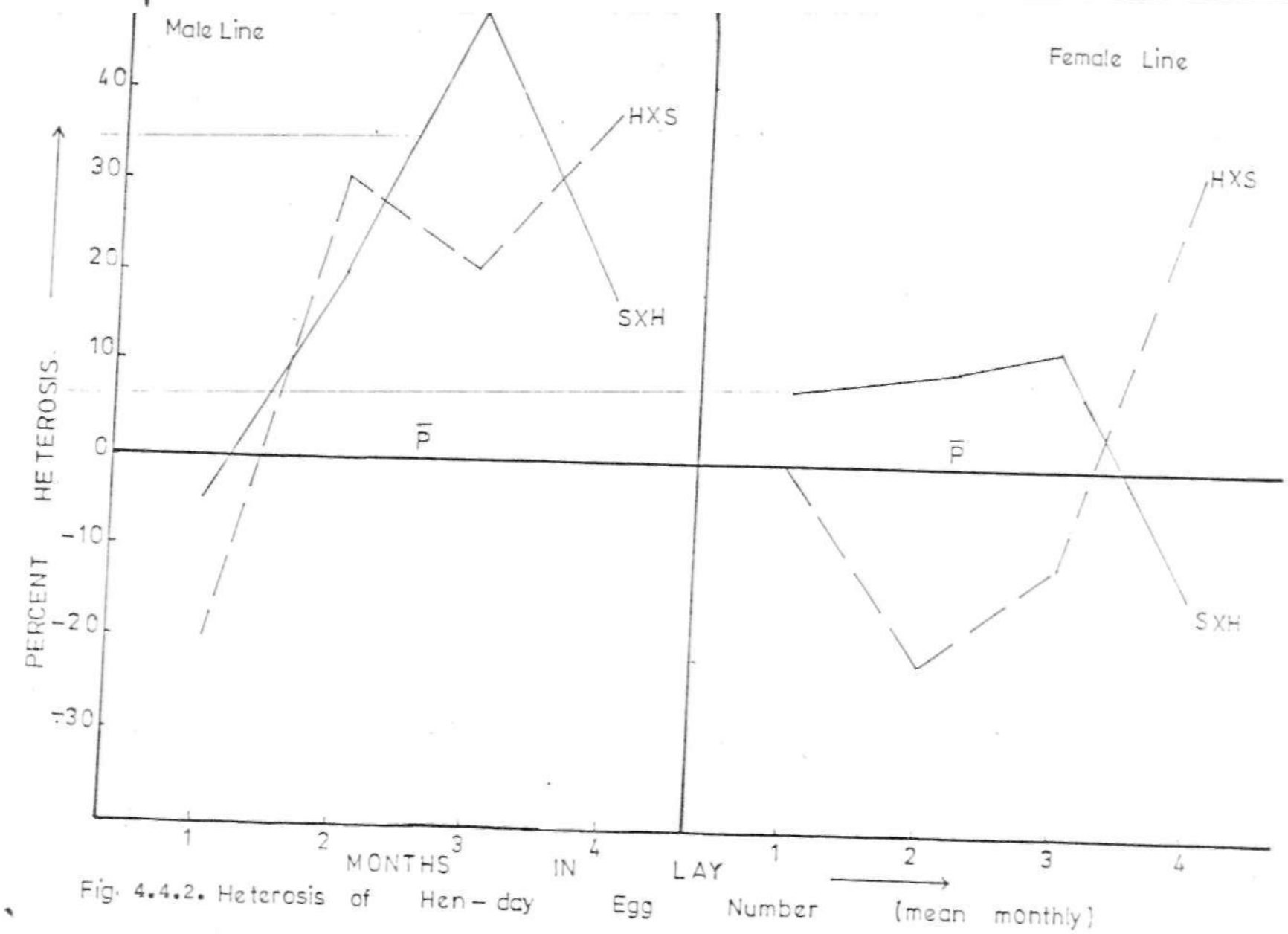


Fig. 4.4.2. Heterosis of Hen-day Egg Number (mean monthly)

Table 4.5.1: Descriptive Statistics for Feed Consumption (g/bird/day) and Feed Efficiency (kg feed/ doz. eggs) for the Pure and Crossbred groups.

	SXH	SXH	HXS	HXH
1.Feed Consumption				
Male Line				
Mean**	133.86[a]	94.07[b]	96.94[b]	95.49[b]
± SE	10.37	8.91	12.33	8.82
CV %	15.49	18.94	25.44	18.48
Female Line				
Mean*	92.40[a]	96.31[a]	83.97[ab]	75.28[b]
± SE	6.74	7.84	7.46	6.59
CV %	14.58	16.27	17.76	17.49
Combined Lines				
Mean**	113.13[a]	95.19[b]	90.46[b]	85.38[b]
2.Feed Efficiency				
Male line				
Mean	3.03	2.10	2.22	2.72
± SE	0.21	0.19	0.29	0.26
CV %	13.53	17.62	26.13	19.12
Female line				
Mean	2.48	2.71	2.50	2.40
± SE	0.30	0.25	0.23	0.18
CV %	23.79	18.08	18.00	14.88
Combined lines: Mean	2.75	2.40	2.36	2.57

* P/0.05 Means with different superscripts differ as indicated.

** P/0.01.

Table 4.5.2: Line Means for Feed Consumption and Feed Efficiency.

Traits	Male Line	Female line
Feed consumption	105.09[a]	86.11[b]
Feed Efficiency	2.5[illegible]	2.53

a, b

* P/0.01

Table 4.5.3: [1]Heterosis in Feed Consumption and Feed Efficiency of the Crossbred (F_1) groups.

	CROSSBRED GROUPS		
A. FEED CONSUMPTION.			
Male line			
Mean of parents, $\bar{P}_m$ = 114.67g/bird/day			
	SXH	HXS	$\overline{CB}$
Mean deviation, g/bird/d	-20.60**	-17.73*	-19.16**
± SE	0.49	3.68	1.80
% deviation	-18.28**	-16.40*	-17.34**
Female line			
Mean of parents, $\bar{P}_f$ = 83.84g/bird/day			
Mean deviation, g/bird/d	12.47	0.13	6.30
± SE	5.27	4.87	3.93
% deviation	14.63	-0.28	7.18
B. FEED EFFICIENCY.			
Male line			
Mean of parents, $\bar{P}_m$ = 2.88kg/doz. eggs			
Mean deviation, kg/doz.eggs	0.78**	-0.65	-0.71**
± SE	0.11	0.24	0.12
% deviation	-27.39**	-23.01	-25.20**
Female line.			
Mean of parents, $\bar{P}_f$ = 2.45kg/doz.eggs			
Mean deviation, kg/doz.eggs	0.26	0.04	0.15
± SE	0.22	0.11	0.12
% deviation	11.95	2.02	6.99

[1]Negative values are desirable as they represent positive heterosis.

* P/0.05

** P/0.01

$\overline{CB}$ Mean value of the crossbred groups.

4.6. Laying House Mortality.

The results presented by Table 4.2.3. show that there was no significance due to line, breeding group or line x breeding group interaction effect but Table 4.2.4. and 4.2.5. show SCA to be significant ($P/0.05$). They also indicate the effect due to the reciprocal difference to be highly significant ($P/0.01$), accounting for the greatest proportion (61.02%) of all the variations. Further testing of the reciprocal difference by line using DMRT revealed that the significance ($P/0.05$) was restricted to the male line as shown in Table 4.6.1. which also confirms the significance of the SCA combined effect.

As shown in Table 4.6.2., only the HxS group of female line (S_2) showed significant heterosis ($P/0.05$) and none of the reciprocal groups exhibited any significantly different heterotic effects.

Table 4.6.1: Percent Short-term (Mean Monthly) Laying House Mortality of the Pure and Crossbred Groups.

Male Line	SXS	SXH	HXS	HXH
Mean*	1.90	1.40[a]	0.26[b]	2.04
± SE	0.64	0.95	0.26	0.88
Female line				
Mean	2.40	1.28	2.20	2.20
± SE	0.98	0.43	1.05	1.15
Combined lines				
Mean*	2.15[a]	1.34[ab]	1.23[b]	2.12[a]
± SE	0.55	0.48	0.62	0.69

Means with different Superscript letters differ P/0.05.

Table 4.6.2: [1]Heterosis in Laying House Mortality of the Crossbred (F_1) Groups.

Male line	Crossbred Groups		
Mean of parents, $\bar{P}_m$ = 7.88%	SXH	HXS	$\overline{CB}$
Mean deviation	-2.68	-5.91*	-4.28
± SE	3.49	1.62	1.88
% deviation	-11.69	-83.45	-47.57
Female line			
Mean of parents, $\bar{P}_f$ = 9.20%			
Mean deviation	- 1.40	-0.63	-1.02
± SE	1.84	1.66	1.16
% deviation	-9.63	-19.72	-14.67

[1] Negative values are desirable

* P/0.05

$\overline{CB}$ Mean values of the crossbred groups.

CHAPTER 5

DISCUSSION

The current study was based on genotype comparisons hence genetic differences among groups were tested. Thus, the error variance in the present study may be larger than expected, as the term would include variations due to genetic, maternal, sex-linked and environmental differences among individuals within the genotype group. Consequently, some variances and means which seemed to be significant could not be so statistically.

5.1. General performance.

5.1.1. Age at First Egg.

The results in Table 4.1.1. and Figure 4.1.1. show that sire influence on AFE was very important because from both lines, the genotypes of H-sires had lower AFE than those of S-sires. However, on the male line, it appear S-sires genes dominate more than S-sires genes of the female line. In constrast, H-sires genes seemed to dominate more in the female line than in the male line. The fact that the value of the crossbred groups lie between those of the two parents suggests the additive nature of inheritance and Figure 4.1.2. confirms this additivity. This result is in accordance with what was reported by Omeje (1983). The wide gaps between the genotypes are also in line with those reported by Blyth and Sang (1960) which they claimed was due to genotype - environmental interaction effect

on maturity. Despite their attempt to get pullets to start production before the season of rapidly decreasing daylength which introduces marked genotype - environmental interaction into maturity variance, wide disparity with a range of the order of 10 weeks was still obtained for mean mature ages of separate progenies.

When compared with BFE and WFE, the mode of inheritance for these two traits was different as it was line dependent. While AFE was generally sire - influenced, BFE seemed to be controlled by non-additive effect since the mean of crossbred in male line was equal to the value of one of the parents and in female line the mean crossbred value fell below those of the two parents (Fig. 4.1.2). With regard to WFE, additive gene action seemed to be more important in the male line while non-additivity and/or maternal effects appeared to be the case for female line birds.

There appeared to be some relationship, between the three traits (AFE, BFE and WFE). From the results shown in Table 4.1.2., phenotypic correlation between AFE and BFE (Male line, 0.45; Female line, 0.40); betwen AFE and WFE (0.96 and -0.11) and between WFE and BFE (0.33 compared with 0.46) were mostly positive as those obtained by Omeje (1983). In addition, the correlation between AFE and short-term egg production (0.84 and 0.93) was positive and high. Similar results have been reported by other workers. Akinokun and Dettmers (1979a) reported that hens which mature late produced more and heavier eggs and that AFE significantly affect

early rate of production. El-Hossari (1978) obtained a greater phenotypic correlations between AFE and BFE than that with 12 months body weight and that the largest relationship coefficient was found between AFE and WFE. He further cited other results which showed that early maturing pullets laid smaller eggs at the beginning of lay. Thus early sexual maturity reduced weight of first ten eggs and also mean annual egg weight. The results obtained from the present study agreed with those of other workers even though the relationship between AFE, BFE and WFE as obtained by Omeje (1983) was from birds of the male line. No such clear-cut association existed for female line. The reason for this discrepancy could be due to line difference obtained in WFE (Tables 4.2.3. and 4.2.4.). However, irrespective of the line, the crossbred groups appeared to have been at advantage given the additive differences between the parents in the AFE, BFE, and WFE when the three traits are related. With a slightly delayed sexual maturity in the progeny due to the difference between the two parents, egg size together with the correlated body size of the birds would invariably be increased. This was demonstrated in Figure 4.1.2. and is supported by a similar observation by Oluyemi (1978) and Omeje (1983).

5.1.2. Body Weight.

From the results presented in Table 4.2.3., highly significant (P/0.01) breeding groups as well as line x breeding group interaction effects were found for B30 and B40. Line effect was highly significant (P/0.01) for

B30 only. There was no significant effect due to any other sources except reciprocal differences (P/o.01)with regards to BFE as shown in Table 4.2.4. This was observed between crosses of female line only (P/0.05) using DMRT. The reason for these results may be due to smaller number of replicates used for BFE than for other body weight measurements.

Further testing of the significance of the breeding group (combined lines) and the interaction (genotypes by line) effects showed differences as indicated in Table 4.2.1. The results also confirm reciprocal differences at 30 and 40 weeks of age. In terms of variability, S_1 and S_4 (S x S purebred groups) were the most variable, at least for two out of the three body weight traits. This indicates the different rates at which individuals of these groups showed response to the prevailing management conditions. This finding reveals that there is much scope for the selection of the birds towards higher or lower body weight provided there is no negative influence on egg weight.

The heterosis observed was mostly not significant except that exhibited by S_5 (H x S group of the female line) which was negative. This is not surprising since S_5 was particularly light compared to the other genotypes of the line (Table 4.2.1. and Fig. 4.2.1.). This probably made it to be significantly (P/0.05) different from its reciprocal cross (H_4) in body weight.

It looks like not much study has been conducted on body weight during laying periods. Apart from body weight at sexual maturity, the body weights mostly

studied are early body weights as at 0 - 20 weeks of age (Akinokun and Dettmers, 1979a,b; Oluyemi, 1978; and Omeje, 1983, 1985). Mature body weights up to 364 days of age were also studied by Bernon and Chambers (1985) and 12 months body weight by EL-Hossari (1978). Bernon and Chambers (1985) reported significant ($P/0.01$) mating combinations (SCA) effect on mature body weight (364 days) for two-way crosses of the sire population. Mating combination differences (reciprocal differences) were also found for 4 - way crosses of both sire and dam populations in respect of this trait. In addition, dam population also showed significant ($P/0.05$) sire differences for mature body weight. Beilharz and McDonald (1961) also found that breed of sire had the greatest effect on final body weight (72 weeks).

Since no reports were available on body weight at 30 and 40 weeks of age, comparison was difficult. However, significant ($P/0.01$) reciprocal effect was found for BFE as was obtained for 364 days body weight by Bernon and Chamber (1985). The 136, 265, 365 and 497 days body weights studied by Fairfull et al (1983) were discussed under combining ability.

In the present study, phenotypic correlation among the body weight traits were positive. Also positive were their correlation with egg weights, egg production (except 4th month production which was generally negatively correlated with other traits), feed consumption and feed effeciency. These are not unexpected as Akinokun and Dettmers (1979a), Nikolov

and Belorechkov (1978) and Omeje (1983) obtained similar positive results. However, the negative correlation of the 4th month production with other traits particularly body and egg weights indicates that the birds were generally egg-type, and as they age maternal influences on the pullets will no longer support the body size and egg weights of the birds. This characteristic reduction in body and egg weight consequent to increased rate of production will result in negative correlation with egg number as this finding reveals. The results presented in Figures 4.2.1. and 4.4.1. confirm these facts especially for S_2 and H_5 and of male and female line respectively.

5.1.3. Egg Weight

As shown in Table 4.3.1., only WFE showed significant ($P/0.01$) differences among the genotypes. It is also evident that first eggs from male line were heavier than those from the female line. The difference between the genotypes of each line could be attributed to differences in their AFE, as well as their body weight at first egg. It has been observed from earlier studies that AFE influences egg weight especially during the early part of the laying period (Akinokun and Dettmers, 1979a; El-Hossari, 1978; Omeje, 1983). The phenotypic correlation coefficients between AFE and the three egg weight traits seems to confirm this fact.

Heterosis for the three egg weight traits were not important except the negative value obtained for

S_5 (HxS group of the female line) at first egg which was highly significant (P/0.01). This made the crossbred group (S_5) to be significantly different (P/0.05) from its reciprocal cross (H_4) both in WFE and its heterosis. Blyth and Sang (1960) observed that hybrid means were consistently close to the mid-parent value and averaging less than one gramme above the latter and that the largest deviation from mid-parent levels were increases of 3.4 and 3.5g. A similar result was obtained in the present study with a maximum of 2.41g for WFE by H_1 (S x H of male line) and -4.05g for WFE by S_5 (H x S of female line). It was also consistent with the findings of Arad and Marder (1982) and Omeje and Nwosu (1984a).

5.1.4. Egg Production.

As presented in Table 4.4.1., the genotypes showed no significant difference in egg production except that male line pullets laid more eggs (P/0.05) than the female line birds (Table 4.4.2.). It was shown in Table 4.4.3. that heterosis observed in the crossbred groups were significant (P/0.01) for male line only on weekly basis. Mean monthly heterosis for the same line failed to attain significance probably due to high variability among the individuals and pens belonging to the groups which brought about high standard error used in the test. However, the mean crossbred heterosis was significant because of its relatively low standard error between the group means. From the results in the

male line, one may be inclined to conclude that dominant gene action was responsible for the hybrid vigour of the crossbred groups as suggested by Omeje (1983). But, considering the fact that the genotypes were not significantly different from each other even when the lines were considered separately, one may agree with Fairfull et al (1983) that the two original breeds were not sufficiently different genetically to effect any difference in the performance of the groups.

Both the hen-housed and hen-day egg number results showed the inferiority of the female line groups to those of the male line. Apart from this, the short-term egg number results generally conform with what have been reported for exotic breeds in Nigeria (Akinokun and Dettmer 1979a; Olomu, 1979; Omeje, 1983). The rates of lay were equally comparable. However, it was found that sire breed influenced the rate of lay as progenies of H-sires from both lines continued to increase both in egg number and rate of lay up to the fourth month while their S-sired counterparts peaked in the third month (Table 4.4.1. and Figure 4.4.1.). This pattern of lay by the H-sired groups is similar to that observed by Omeje (1983) on the local chicken and according to him, such is undersirable. He argued that it is best to peak in the second month for, the time of peak production is the time the farmer begins to reap huge revenue from the more eggs that are produced at minimal feed cost.

5.1.5 Feed consumption and Efficiency.

The high proportion of feed costs in total operating expenses indicates that feed efficiency in laying hens

is the most important trait for the egg producer because feed conversion has a strong influence on the profitability of a poultry operation. The result presented in Table 4.5.1. shows that S x S groups, especially in the male line, consumed more feed than other groups and were the least efficient. According to Hurnik et al (1977), feed conversion is affected by a wide range of traits embodied in feed intake, metabolism and the production performance of the birds. Judging by the strong association they obtained between feed conversion and egg production, and between feed conversion and egg mass, they concluded that the number of eggs produced was the most important factor. By examining the correlation coefficients obtained in the present study as presented in Table 4.1.2., the kind of relationship obtained by these workers was not the type obtained in the lines. However, when the genotypes were considered separately as shown in Table 4.4.1., there was a very good agreement between the present work and that of Hurnik et al (1977).

The relatively high correlation between feed consumption and egg production (Table 4.1.2. and 4.4.1.) also confirms that on the average, the largest proportion of feed consumed was utilized for the production itself. In fact, it is well known that selection for higher egg production has also improved feed efficiency of laying birds, mainly because the amount of feed needed for maintenance remained almost constant while any extra amount of feed consumed was utilized for increased egg production Hagger and Abplanalp, 1978; Olomu, 1979; Omeje, 1983;

Hagger and Marguerat, 1985). It has been shown also that AFE significantly (P/0.05) affects feed consumption. The distinct influence of AFE on FC as compared with FE is in line with the findings by Hagger and Abplanalp (1978) and Hagger and Marguerat (1985).

The general interpretation of these results is that, as expected, the crossbreds were better than the purebred groups. On the average, they consumed less and were more efficient because they produced more eggs even though not significantly so. The significant heterosis obtained in the two traits, especially for male line confirms this.

5.1.6. Laying House Mortality.

As in most traits, significant (P/0.05) difference in laying house mortality was found between genotypes of the male line but none for the female line. Within the male line, the parental groups did not differ significantly from one another. There was, however, reciprocal cross difference as could be seen in Table 4.2.4; 4.2.5; and 4.6.1. This may have been responsible for the significant heterosis (P/0.05) observed only for H x S of male line (S_2). The heterosis for the same cross (H x S) in the female line, though high could not attain significance due to large standard error.

The phenotypic correlation coefficients (Table 4.1.2. and 4.4.1.) indicated negative association between mortality rate and most of the other traits. Of particlar importance is its negative association with egg production especially for S_4 which has the highest level of mortality.

It should be noted that S_4 was among the groups which recorded the lowest rate of production, to confirm that in this study, the higher the mortality level the lower the production. It was also the last group to come to lay. No evidence exists to support this association between AFE and LHM, but according to Omeje (1983), any environmental condition which depressed production will also increase mortality.

5.2. Combining Ability.

Diallel crossing schemes have been widely used to assess poultry stocks particularly for combining ability. Comparisons of the results of such studies depend upon environments and management practices used. In addition, the interpretation depends upon the diallel model used, sex, and the type of crosses made.

Most traits of importance in egg production strains are sex-linked and can be measured only in the female chicken. Depending on the diallel model used, this means that estimates of GCA should be expected to be influenced by maternal effects, sex-linkage effects or both if present, and estimates of reciprocal effects using females will contain maternal and sex-linkage effects (Eisen et al, 1966; Fairfull et al, 1983).

Estimates of GCA and SCA may depend on the model used for other reasons too. As cited by Fairfull et al (1983), Wearden et al (1965) stated that estimates of GCA for models without the pure strains may be inflated due to interactions resulting from strains that perform well in the crosses and poorly as pure strains or vice versa. Eisen et al (1967) stated that estimates of GCA

and other genetic effects from model with pure strains included may be confounded with inbreeding effects. Both are valid concerns more so as the inbreeding coefficients of the original grandparent strains were not known.

GCA was important for only two of the traits studied, WFE and FC. And the GCA due to sire breed appeared more important than that due to dam breed. In addition, estimates of GCA due to dam breed were generally lower than those due to sire breed as can be seen in Table 4.2.4. This fact suggests sex-linkage effect on all traits studied. Cock and Morton (1963) suggested that when sire components of variance is larger than the dam component in female offspring of domestic fowl, it indicates sex-linkage unambigously, but will not necessarily mean that maternal effects are absent. It means however, that if maternal effects are present, they are smaller than those due to sex-linkage. Thus the result of the present study indicates that maternal effect may be important but not as important as sex-linkage effects.

Most other studies have concluded that GCA was important (Merritt and Gowe, 1960; Beilharz and McDonald, 1961; Eisen et al; 1967; Fairfull et al, 1983; Giri and Patro, 1985). The results of these studies indicate that the strains or breeds used and how they are mated can significantly affect estimates of GCA and consequent conclusions. So, although the results are not necessarily directly comparable due to differences in strains or breeds used and the diallel models, they generally confirm that GCA is important for several straits and is often more important than SCA.

In the present study, SCA was important for LHM only where it accounted for 19.93% of total variance as compared

with 3.67% by GCA. As with GCA, SCA, was less important for egg production traits and FE (a ratio that involves egg production). Merritt and Gowe (1960) and Eisen et al (1967) obtained similar results. In the report by Eisen et al (1967), they obtained zero SCA variance for egg weight which was similar with the finding of zero SCA for egg weight at 30 weeks in the present study. Eisen et al (1967) argued that low SCA indicates that dominance and epistatic variance are of little importance for the trait. In the study by Fairfull et al (1983), SCA was reported to be generally more important than in the results from other studies. They attributed this to the high performance of the strains used and each strain has been selected for one or more of the traits measured. They, however, suggested reasons why SCA may not have been as important in some other studies. One of these reasons is that the strains used may not have been sufficiently different genetically. This seems to be the case with the strains used in the present study. In addition, measurements on groups, and not individual birds were used here. This could also affect the results presented as most other workers used individual measurements.

5.3. Heterosis and Reciprocal Effects.

Heterosis and reciprocal effects are two of the most important non-additive genetic effects affecting strain-/breed-cross performance. In this study, both are important in some of the traits studied.

The heterosis obtained for egg production (hen-day), feed consumption, feed efficiency and mortality were

exhibited, by H_1 and S_2 (crossbred groups from male line). The heterosis for body weight at first egg and weight of first egg were negative and were exhibited by S_5 (H x S crossbred groups of female line). None of the heterosis exhibited by H_4 was significant. For BFE and WFE, the heterotic difference between the two crossbred groups of each line are attributable to those between the parental breeds and to reciprocal effect which was highly significant ($P/0.01$) especially for female line. The S-sired pullets (including the S x S) were heavier than H-sired ones, so also were their egg weights. Thus any crossbred bearing the S-sire had a higher additive effect to be surmounted before registering significant heterosis due to the high value by the S x S better parental group. Other workers have reported higher heterosis than were found in this study (Blyth and Sang, 1960; Merritt and Gowe, 1960; Cock and Morton, 1963; Sheridan and Randall, 1977; Fairfull et al, 1983; Omeje, 1983). As reviewed by Omeje (1985), when animals are crossed, provided that they differed genetically as in races, species or genera, heterosis occurred. However not all crosses show positive heterosis (if at all, especially when dominance was absent) but it was the positive heterosis that should be called hybrid vigour. Thus a hybrid or an animal showing hybrid vigour is the one that is better than the mean of both parents. In essence, a crossbred animal showing no or negative heterosis (i.e. animal whose performance is less than the mid-parent) lack the hybrid vigour. In view of the above, H_1 appears the best cross of all since all but one of the heteroses exhibited were positive and many were highly significant ($P/0.01$).

According to Mason et al (1958), heterosis can be attained by crossing co-adopted groups, but negative heterosis can be attained if selection has been toward different physiological patterns which produce the same phenotype. The relatively low heterosis reported here could be attributed to the fact that the original strains were insufficiently different genetically, more so for the female line.

Reciprocal effects were found to be important for BFE, WFE, and LHM (Table 4.2.4). For these traits, reciprocal effects accounted for the largest proportion of the total variance as shown in Table 4.2.5. From Table 4.2.1, it could be deduced that reciprocal effects existed also for B30 and B40. However, the reciprocal difference in BFE was found to be restricted to the female line.

The reciprocal differences observed for BFE and WFE resulted from the very low weights recorded for S_5 (H x S of female line) which was also responsible for the negative heterosis. Also reciprocal difference was obtained for mortality between crosses in the male line only. Fairfull et al (1983) reported that the magnitude of reciprocal effects tended to be greater in the environment in which heterosis was smaller, this was not generally suported in this work. The overall reciprocal effects reported by Blyth and Sang (1960) were larger than obtained here for egg production. Higher reciprocal effects were also found by Cock and Morton (1963) for egg weight and body weight; Sheridan and Randall (1977) for

food utilization, egg production and egg weight. In essence, this study shows that non-additive genetic effects were not particularly as important in the stock used as reported by other investigators.

CHAPTER 6

SUMMARY AND CONCLUSION

Diallel mating scheme was used to test the performance of the F_1 progenies of the two grand parent ~~strains~~ S and H, each of which had two lines. From the results presented and discussed, it was shown that:

1. Genotypes of both lines responded differently in production characteristics.
2. The H-sires were responsible for transmitting genes for early AFE and consequently the H x S groups from both lines laid much earlier than their reciprocals.
3. Body weight showed incomplete dominance for male line with dam breed having upper hand in the additivity. In the female ine, non-additive effect was suspected.
4. Heteroses observed were generally low and many were negative especially those obtained among S_5 pullets. This situation probably contributed to its being inferior to its reciprocal cross (H_4).
1. Significant heteroses were obtained for BFE, WFE, HDE, FC, FE and LHM.
5. Reciprocal effect was important for the body weight traits (BFE, B30 and B40), WFE and LHM. GCA was important for WFE and FC but SCA showed significance for LHM only.
6. No considerable improvement was made in egg weight as crossbred pullets of both lines laid aggs of average weight of the parental groups or even lower as in the case of S_5.

7. Pullets from the male line generally laid more eggs than those of the female line. In the male line, the crossbreds showed superiority over the mean of the parental groups hence significant heterosis was observed for that line.
8. The crossbred groups consumed less feed and were more efficient in converting it into eggs than the parental groups especially for the male line. Consequently, heterosis was also important particularly in this line.
9. Mortality was generally lower in the crossbreds but only the crossbred groups of male line showed significant reciprocal effect. In addition only the H x S group of that line (S_2) showed significant heterosis due to its very high viability.
10. Sex-linkage effect was suspected to be more important than maternal effect in the present study.

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APPENDIX 1

Age at First Egg

Breeding Group	Male Line		Female Line		Breeding group		
	Genotype	AFE(days)	Genotype	AFE(days)	Means	±	S.G
A(SxS)	S_1	202	S_4	217	209.5	±	7.5
B(SxH)	H_1	201	H_4	193	197	±	4.0
C(HxS)	S_2	177	S_5	163	170	±	7.0
D(HxS)	H_2	149	H_5	154	151.5	±	2.5
Total, Σx.	-	729	-	728	-		
$\bar{x}$	-	182.25	-	182	182	±	13.09
± SE	-	12.50	-	14.30			
Σx^2	-	134735.00	-	134950.00			
n	-	4	-	4			

Using Winer's (1971) t - test* to compare the lines

	Male line	Female line
x	729	728
x^2	134735	134950
$\bar{x}$	182.25	182.00
$L = 4\ (134735) - (729)^2$;	$= 7499$	$L = 4(134950) - (728)^2$
		$= 9816$
$S^2 = \frac{7499}{4(3)}$	$= 624.92$	$S^2 = \frac{9816}{4(3)}$
		$= 818.00$

$$t^2 = \frac{(4 + 4 - 2)\ \{4\ (729 - 728)\}^2}{(4 + 4)\ \{4(7499 + 9816)\}}$$

$$= \frac{(6)\ (16)}{(8)\ (69260)} = 0.00017$$

$t = \sqrt{0.00017} = 0.013^{NS}$

$t\ (0.05,6) = 2.447$

*See Appendix II for detail of formulae

APPENDIX II

Analysis of Body Weight at First Egg

Models used:

I. $X_{ijk} = U + A_i + L_j + (AL)_{ij} + e_{ijk}$

where X_{ijk} = Observation on pullets of the ith breeding group and j^{th} line

U = overall population mean

A_i = effect of the ith breeding group, i = 1,2, ..., 4.

L_j = Effect of the j^{th} line, j = 1,2

$(AL)_{ij}$ = effect of the interaction between ith breeding group and j^{th} line.

e_{ijk} = experimental error: Normally and independently distributed about zero mean and error variance.

II. Given by Berker (1967) but modified to include an additional main effect, which is line.

$$x_{ijk} = U + g_i + g_j + l_k + s_{ij} + r_{ij} + e_{ijk}$$

Where X_{ijk} = Observation on pullets of a cross between ith sire breed and j^{th} dam breed of k^{th} line.

U = Overall population mean

g_i = general combining ability of the ith sire breed, i = 1,2.

g_j = general combining ability of the j^{th} dam breed, j = 1,2.

l_k = line effect, k = 1,2,

s_{ij} = interaction of the ith and j^{th} breeds (specific combining ability)

r_{ij} = reciprocal effects of the ij^{th} and jith cross.

e_{ijk} = random error.

Data on parental control groups were included in the analysis

using model II thus estimates of GCA and SCA effects are in the broad sense as stated by Fairfull et al (1983).

Observed Data (kg)

Breeding Groups	A		B		C		D	
Genotypes	S_1	S_4	H_1	H_4	S_2	S_5	H_2	H_5
Rep: 1	0.56	1.70	1.20	1.50	0.96	1.10	1.30	0 84
2	0.92	1.45	1.18	1.14	1.01	1.65	1.56	1.79
3	1.80	1.48	1.25	1.35	1.63	1.43	1.19	1.60
4	1.67	1.48	1.23	1.40	1.20	1.30	1.01	1 52
5	1.54	1.65	1.13	1.48	1.13	1.05	1.12	1 54
6	1.58	1.25	1.05	1.50	1.60	1.48	1.18	1.30
7	1.32	1.08	1.40	1.58	1.30	0.93	1.12	1 22
8	1.58	1.00	1.26	1.50	1.18	1.03	1.52	1 05
9	1.66	1.50	1.12	1.65	1.40	1.12	1.04	1 40
10	1.46	1.45	1.26	1.50	1.08	1.20	1.25	1.80
Total	14.09	14.04	12.08	14.60	12.49	12.29	12.30	14 06
Mean	1.41	1.40	1.21	1.46	1.25	1.23	1.23	1 41
SD	0.38	0.23	0.10	0.14	0.23	0.23	0.19	0 31

SD = Standard Error.

Data to Log_{10} Values

	A		B		C		D	
Rep:	S_1	S_4	H_1	H_4	S_2	S_5	H_2	H_5
1	-0.252	0.230	0.079	0.176	-0.018	0.041	0.114	-0 07
2	-0.036	0.161	0.072	0.056	0.004	0.217	0.193	0.25
3	0.255	0.170	0.097	0.130	0.212	0.155	0.076	0.20
4	0.223	0.170	0.090	0.146	0.079	0.114	0.004	0.18
5	0.188	0.217	0.053	0.170	0.053	0.021	0.049	0.18
6	0.199	0.097	0.021	0.176	0.204	0,170	0.185	0 11
7	0.121	0.033	0.146	0.199	0.114	-0.032	0.049	0.08
8	0.199	0.000	0.100	0.176	0.072	0.013	0.185	0.02
9	0.220	0.176	0.049	0.217	0.146	0.049	0.017	0.14
10	0.164	0.161	0.100	0.176	0.033	0.079	0.097	0.25
Total	1.281	1.415	0.807	1.622	0.899	0.827	0.969	1.37
Mean	0.128	0.142	0.081	0.162	0.09	0.083	0.097	0.13

Summary into Breeding groups by line.

Line	A	B	C	D	Total	Mean
Male	1.281	0.807	0.899	0.969	3.956	0.099
Female	1.415	1.622	0.827	1.378	5.242	0.131
Total	2.696	2.429	1.726	2.347	9.198	0.115
Mean	0.135	0.121	0.086	0.117		

Summary into Sire breeds and dam breeds by line.

Line	S-Sire	H-Sire	S-dam	H-dam
Male	2.088	1.868	2.180	1.776
Female	3.037	2.205	2.242	3.004
Total	5.125	4.073	4.422	4.776
Mean	0.128	0.102	0.111	0.119

Reciprocal difference = $X_{ij} - X_{ji}$

where X_{ij} = an observation on the cross between ith Sire and jth dam breeds.

X_{ji} = an observation on the reciprocal cross i.e. the cross between jth Sire and ith dam breeds

Reciprocal Differences

Rep.	Male line $(H_1 - S_2)$		Female line $(H_4 - S_5)$	
1	0.097	(0.079 - (-0.018)	0.135	(0.176 - 0.041)
2	0.068	(0.072 - 0.004	-0.161	(0.056 - 0.217)
3	-0.115	(0.097 - 0.212)	-0.025	(0.130 - 0.155)
4	0.011	(0.090 - 0.079)	0.032	(0.146 - 0.114)
5	0.000	(0.053 - 0.053)	0.149	(0.170 - 0.021)
6	-0.183	(0.021 - 0.204)	0.006	(0.176 - 0.170)
7	0.032	(0.146 - 0.114)	0.231	(0.199 - (-0.032)
8	0.028	(0.100 - 0.072)	0.163	(0.176 - 0.013)
9	-0.097	(0.049 - 0.146)	0.168	(0.217 - 0.049)
10	0.067	(0.100 - 0.033)	0.097	(0.176 - 0.079)

Computation of sums of squares

$CF = \frac{9.198^2}{80} = 1.058$

$SS = -0.252^2 + \text{-------} + 0.255^2 - CF = 1.679 - 1.058$

$= 0.621.$

Total

Model I

$SS_{Line} = \frac{3.956^2 + 5.242^2}{40} - CF = .078 - 1.058 = 0.02$

$SS_{\substack{Breeding \\ Group}} = \frac{2.696^2 + \cdots + 2.3\,7^2}{20} - CF = 1.083 - 1.058 = 0.025$

$SS_{BG \times Line} = \frac{1.281^2 + \cdots + 1.3\,8^2}{10} - (CF + SS_{Line} + SS_{BG})$

$= 1.126 - 1.103 = 0.023$

$SS_{error} = 0.621 - (0.02 + 0.025 + 0.023) = 0.621 - 0.068$

$= 0.553.$

Model II

$SS_{Line} = 0.020$

$SS_{\substack{Sire\ breed \\ (g_j)}} = \frac{5.125^2 + 4.073^2}{40} - CF = 1.071 - 1.058 = 0.013$

$SS_{\substack{dam\ breed \\ (gj)}} = \frac{4.422^2 + 4.776^2}{40} - CF = 1.059 - 1.058 = 0.001$

$SS_{\substack{Sire \times dam \\ (S_{ij})}} = \frac{2.696^2 + \cdots + 2.3\,7^2}{20} - (CF + SS_{Sire} + SS_{dam})$

$= 1.083 - 1.072 = 0\ 011$

$SS_{\substack{rec \\ (rij)}} = \frac{0.097^2 + \cdots + 0.097^2}{2} = \frac{0.262}{2} - 0.131$

$SS_{error} = 621 - (0.020 + \cdots + 0\ 131) = 0.621 - 0.176$

$= 0.445$

Analysis of Variance I

Sources of variance	df	SS	MS	F	F.95	F.99
Line	1	0.020	0.020	2.60	3.952	6.942
Breeding group	3	0.025	0.008	1.04	2.482	3.542
Line x Breeding group	3	0.023	0.008	1.04		
Error	72	0.552	0.0077	-		
Total	79	0.621				

None of the effects is significant.

Analysis of Variance II

Sources of Variance	df	SS	MS	F	F.95	F.99
Line	1	0.020	0.020	3.33	3.94	6.91
Sire breed (g_i)	1	0.013	0.013	2.17		
Dam breed (g_j)	1	0.001	0.001	0.17		
Sire x Dam (SCA)	1	0.011	0.011	1.83		
Reciprocal (rij)	1	0.131	0.131	21.83**		
Error	74	0.445	0.006	-		
Total	79	0.621				

Reciprocal effect is highly significant ($P \angle 0.01$).

Using Winers' (1971) t - test to compare the reciprocals by line

	Male line		Female line	
.	H_1	S_2	H_4	S_5
$\Sigma X.$	0.807	0.899	1.622	0.827
ΣX^2	0.076	0.137	0.281	0.125
X	0.081	0.090	0.162	0.083

$L = 10(0.076)-0.807^2; 10(0.137)-0.899^2$ | $L = 10(0.281)-1.622^2; 10(0.125)-0.827^2$

$= 0.109 = 0.562$ | $= 0.179 = 0.566$

$S^2 = \frac{0.109}{10(9)}; \frac{0.562}{90}$ | $S^2 = \frac{0.179}{90}; \frac{0.566}{90}$

$= 0.0012 = 0.0062$ | $= 0.002 = 0.0063$

$t^2 = \frac{(10+10-2)\{10(0.807-0.899)\}^2}{(10+10)\{10(0.109+0.562)}$ | $t^2 = \frac{(10+10-2)\{10(1.622-0.82}{(10+10)\{10(0.179+0.556}$

$= \frac{(18)(0.846)}{(20)(6.71)} = 0.113$ | $= \frac{(18)(63.20)}{(20)(7.45)} = 7.64$

$t = \sqrt{0.113} = -0.34^{NS}$ | $t = \sqrt{7.64} = 2.76^*$

$t\ (0.05,18) = 2.10;\ t(0.01,18) = 2.878$

Thus S_2, though heavier, is not significant different from H_1, but H_4 is significantly ($P \angle 0.05$) heavier than S_5.

Note: $L = n\Sigma x^2_2 - (\Sigma x)^2_2$

$$t^2 = \frac{(n_1 + n_2 - 2)(n_2 \Sigma x_1 - n_1 \Sigma x_2)^2}{(n_1 + n_2)(n_2 L_1 + n_1 L_2)}$$

$$S^2 = \frac{L}{n(n-1)}$$

$df = n + n - 2$

The formulae are given by Winder (1971)

$t_{(male\ line)}$ takes negative value because $\bar{H}_1 - \bar{S}_2$ is negative.

Heterosis in Body Weight at First Egg

A. Comparison of the two crossbreds with the mean performance of the parents.

Let $\bar{P}$ = mean parents

Dev. = Deviation (kg) = crossbred value - $\bar{p}$

Assumption: It is assumed that each of the two breeding groups (i.e. $\bar{P}$ and any of the crossbred group) had the same effect on body weight at first egg i.e. each of the crossbred groups did not differ significantly from $\bar{P}$. Then the differences or deviations observed from each replicate were distributed in approximately normal form about zero mean. This assumption was put forward by Yule and Kendall (1968) and adopted by Omeje (1983).

Thus: H_0: S x H = $\bar{P}$; H x S = $\bar{P}$

H_1: S x H ≠ $\bar{P}$; H x S ≠ $\bar{P}$

a) Male Line:

	(i) Within SxH crossbred group				(ii) Within H x S group		
Rep.	$\bar{P}$	H_1	dev.	%dev.	S_2	dev.	%dev.
1	0.85	1.20	0.35	41.18	0.92	0.11	12.94
2	1.20	1.18	-0.02	- 1.67	1.01	-0.19	-15.83
3	1.46	1.25	-0.21	-14.38	1.63	0.17	11.64
4	1.30	1.23	-0.71	- 5.38	1.20	-0.10	- 7.69
5	1.31	1.13	-0.18	-13.74	1.13	-0.18	-13.74
6	1.56	1.05	-0.51	-32.69	1.60	0.04	2.56
7	1.22	1.40	0.81	14.75	1.30	0.08	6.56
8	1.56	1.26	-0.30	-19.23	1.18	-0.38	-24.36
9	1.31	1.12	-0.19	-14.50	1.40	0.09	6.87
10	1.35	1.26	-0.09	- 6.67	1.80	-0.27	-20.00
Mean deviation			-0.10	- 5.23	-	-0.06	- 4.11
SE. of deviation			0.08	6.46		0.06	4.38

$t = \frac{-0.10-0}{0.08} = -1.25^{NS}$; $\frac{-5.23-0}{6.46} = -0.81^{NS}$

$t = \frac{-0.06-0}{0.06} = -1.00^{NS}$; $\frac{-411-0}{4.38} = 0.98^{NS}$

t (0.05,9) = 2.262; t (0.0[illegible],9) = 3.25

Summary: None of the observed negative heterosis is significant

[1] Antilog values are used in the calculations.

b) Female line

(i) Within SXH group					(ii) Within H x S group		
Rep	P	H_4	dev.	%dev.	S_5	dev.	%dev.
1	1.20	1.50	0.30	25.00	1.10	-0.10	- 8.33
2	1.60	1.14	-0.46	-28.75	1.65	0.05	3.13
3	1.54	1.35	-0.19	-12.34	1.43	-0.11	- 7.14
4	1.50	1.40	-0.10	- 6.67	1.30	-0.20	-13.33
5	1.59	1.48	-0.11	- 6.92	1.05	-0.54	-33.96
6	1.27	1.50	0.23	18.10	1.48	0.21	16.54
7	1.15	1.58	0.43	37.39	0.93	-0.22	-19.13
8	1.02	1.50	0.48	47.06	1.03	0.01	0.98
9	1.45	1.65	0.20	13.79	1.12	-0.33	-22.76
10	1.61	1.50	-0.11	- 6.83	1.20	-0.41	-25.47
Mean deviation			0.067	7.98	-	-0.164	-10.95
S.E. of dev.			0.096	7.63	-	0.07	4.80
t =			$\frac{0.067-0}{0.096}$;	$\frac{7.980-0}{7.63}$	t =	$\frac{0.164-0}{0.07}$;	$\frac{-10.95-0}{4.80}$
			$= 0.7^{NS}$	$= 1.05^{NS}$		$= -2.34^{*}$	-2.28^{*}

Summary: The heterosis exhibited by H_4 is not significant whereas the negative heterosis observed in S_5 is significant ($P < 0.05$).

B. Comparison of the crossbred groups among themselves (within line basis) using Winer's (1971) t-test. Deviation in kg were used.

a) Male Line			(b) Female Line)	
Rep.	H_1	S_2	H_4	S_5
1	0.35	0.11	0.30	-0.10
2	-0.02	-0.19	-0.46	0.05
3	-0.21	0.17	-0.19	-0.11
4	-0.07	-0.10	-0.10	-0.20
5	-0.18	-0.18	-0.11	-0.54
6	-0.51	0.04	0.23	0.21
7	0.18	0.08	0.43	-0.22
8	-0.30	-0.38	0.48	0.01
9	-0.19	-0.09	0.20	-0.33
10	-0.09	-0.27	-0.11	-0.41
Σx	-1.04	-0.63	0.67	-1.64
Σx^2	0.63	0.35	0.88	0.73

L	$10(0.63)-(-1.04^2)$	$;10(0.35)-(-0.63^2)$	$L=10(0.88)-067^2$	$;10(0.73)-(-1.64^2)$
=	5.22	3.10	8.35	4.61
S^2=	$\frac{5.22}{10(9)}$	$\frac{3.10}{10(9)}$	$\frac{8.35}{10(9)}$	$\frac{4.61}{10(9)}$
=	0.058	0.034	0.093	0.051

$$t^2 = \frac{(10+10)\{10(-1.04+0.63)\}^2}{(10+10)\{10(5.22+3.10)\}}$$

$$= \frac{(18)916.81)}{(20)(83.2)} = 0.18$$

$$t = \sqrt{0.18} = -0.43^{NS}$$

$$t\,t_{0.05(18)} = 2.101$$

$$t^2 = \frac{(10+10-2)\{10(0.67+1.64)\}^2}{(10+10)\{10(8.35+4.61)\}}$$

$$= \frac{(18)(533.61)}{(20)(129.6)} = 3.71$$

$$= \sqrt{3.71} = 1.93^{NS}$$

$$t\,(0.01,18) = 2.878$$

Summary: None of the heterosis exhibited by each of the paired crossbred groups is significantly different from the other.

APPENDIX III

Analysis of Body Weight at 30 weeks of age

Model: I only.

*Summary of Data to $\log_{10}$ values

Breeding Group	A		B		C		D		
Genotype	S_1	S_4	H_1	H_4	S_2	S_5	H_2	H_5	Total
Rep.(birds)	79	123	124	114	97	120	78	115	850
$\sum X$.	11.79	14.64	13.87	21.80	19.83	19.08	7.70	20.91	129.62
$\sum X^2$	2.43	2.41	1.89	3.48	4.17	3.31	1.09	4.14	23.92
$\bar{X}$	0.15	0.12	0.11	0.19	0.20	0.16	0.10	0.18	0.15
S.D.	0.27	0.22	0.15	0.18	0.14	0.17	0.19	0.18	

*Birds were weighed individually at 30 and 40 weeks of age.

SD = Standard Deviation of actual weights.

Summary into Breeding groups by line

Line	A	B	C	D.	Total	Rep.	Mean
Male	11.79	13.87	19.83	7.70	53.19	378	0.14
Female	14.64	21.80	19.09	20.91	76.43	472	0.16
Total	26.43	35.67	38.92	28.61	129.62		
Rep.	202	238	217	193	7	850	
Mean	0.13	0015	0.18	0.15			0.15

Computation of sums of squares.

$$CF = \frac{129.62^2}{850} = 19.77$$

$$SS_{Total} = 2.43 + \text{------} + 4.14 - CF = 23.92 - 19.77 = 4.15$$

$$SS_{Line} = \frac{53.19^2}{378} + \frac{76.43^2}{472} - CF = 7.48 + 12.38 - 19.77 = 0.09$$

$$SS_{\substack{Breeding \\ group}} = \frac{26.43^2}{202} + \text{-----} + \frac{28.61^2}{193} - CF$$

$$= (3.46 + 5.35 + 6.98 + 4.24) - CF\ 20.03 - 19.77$$

$$= 0.26$$

$$SS_{Line \times BG} = \left\{\frac{11.79^2}{79} + \text{-------} + \frac{20.91^2}{135}\right\} - \left\{CF + SS_{Line} + SS_{BG}\right\}$$

$$= \left\{1.76 + 1.74 + 1.55 + 4.17 - \left\{19.77 + 0.09 + 0.26\right\}\right.$$

$$\left.4.05 + 3.03 + 0.76 + 3.80\right\} = 20.87 - 20.12 = 0.75$$

$$SS_{error} = 4.15 - (0.26 + 0.09 + 0.75)$$

$$= 4.15 - 1.10 = 3.05$$

Analysis of Variance I

Sources of Variance	df	SS	MS	F	F.95	F.99
Line	1	0.09	0.09	22.50**	3.84	6.63
Breeding group	3	0.26	0.09	22.50**	2.60	3.78
Line x B/group	3	0.76	0.25	62.50**		
Error	842	3.05	0.004			
Total	849	4.15				

All the three sources have highly significant effect (P/0.01)

Duncan's Multiple Range Test

$$SE = \sqrt{\frac{EMS}{K}} = \sqrt{\frac{0.004}{105.82}} = 0.006$$

$$K = \frac{1}{a-1}\left\{N - \frac{\sum ni^2}{N}\right\} = \frac{1}{7}\left(850 - \frac{92860}{850}\right) = 105.82$$

Where:

a = 8 genotypes

N = 850 (total observations)

$ni^2 = 79^2 + \text{---} + 115^2 = 9286($

EMS = Error Mean Square

Least Significant Range (LSR) Values at 5% and 1% levels

	5%			1%		
Values of P	2	3	4	2	3	4
SSR (842 Edf)	2.77	2.92	3.02	3.62	3.80	3.90
LSR (SSRxSE)	0.017	0.018	0.018	0.022	0.023	0.023

SSR = Significant Studentized Range - obtained from Statistical tables.

1. To Test Breeding group means

	C	B	D	A
	0.18	0.15*	0.15	0.13
A 0.13	0.05**	0.02*	0.02*	-
D 0.15	0.03**	0.00^{ns}	-	
B 0.15	0.03**	-		
C 0.18	-			

* P/_ 0.05
** P/_ 0.01
ns = not significant

Summary: (1) C^a $\underline{B^b \ D^b \ A^b}$ P/_ 0.01

(2) C^a $\underline{B^b \ D^b}$ A^c P/_ 0.05

2. To test Breeding group x line interaction means i.e. to test the genotypes by line.

(a) Male line

	S_2	S_1	H_1	H_2
	0.20	0.15	0.11	0.10
H_2	0.10**	0.05**	0.01^{ns}	-
H_1	0.09**	0.04**	-	
S_1	0.05**	-		
S_2	-			

Summary: $S_2^a \ S_1^b \ \underline{H_1^c \ H_2^c}$ P/_ 0.01

(b) Female Line

	H_4	H_5	S_5	S_4
	0.19	0.18	0.16	0.12
S_4	0.07**	0.06**	0.04**	-
S_5	0.03**	0.02*	-	
H_5	0.01^{ns}	-		
H_4	-			

(1) Summary: $\underline{H_4^a \ H_5^{ab}} \ S_5^b \ S_4^c$ P/_ 0.01

(2) $\underline{H_4^a \ H_5^a} \ S_5^b \ S_4^c$ P/_ 0.05

Heterosis in Body Weight at 30 weeks of Age

Within line comparison of the two crossbred groups with the mean performance of the parents. Body weights in kilogrammes are used.

A. Male line

$\bar{P} = \frac{1.41}{2} + \frac{1.26}{2} = 1.34$

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Crossbreds	Body weight	dev.	%dev.
H_1	1.29	-0.05	-3.73
S_2	1.58	0.24	17.91

B. Female line

$$\bar{P} = \frac{1.32 + 1.51}{2} = 1.42$$

Crossbred	Body Weight	dev.	%dev.
H_4	1.55	0.13	9.15
S_5	1.45	0.03	2.11

Conclusion: The heterosis obtained for S_2 is quite high and is expected to be significant.

APPENDIX IV

Analysis of Body Weight at 40 weeks of age

Model: I only

*Summary of Data to $\log_{10}$ values

B/groups	A		B		C		D		
Genotypes	S_1	S_4	H_1	H_4	S_2	S_5	H_2	H_5	Total
Rep.	76	115	120	94	98	100	74	104	781
$\Sigma x.$	15.346	21.999	21.574	19.907	18.392	17.336	10.847	17.214	142.615
$\Sigma x.^2$	3.215	4.691	4.034	4.351	3.628	3.195	1.773	3.072	27.959
$\bar{x}$	0.202	0.191	0.180	0.212	0.188	0.173	0.147	0.166	0.183
SD (Actual)	0.20	0.22	0.13	0.14	0.16	0.16	0.16	0.16	

*as stated in appendix III.

Summary into Breeding groups by line

Line	A	B	C	D	Total	Rep	Mean
Male	15.346	21.574	18.392	10.847	66.159	368	0.180
Female	21.999	19.907	17.336	17.214	76.456	413	0.185
Total	37.345	41.481	35.728	28.061	142.615		
Rep.	191	214	198	178		781	
Mean	0.196	0.194	0.180	0.158			0.183

Computation of Sums of Squares

$$CF = \frac{142.615^2}{781} = 26.042$$

$$SS_{Total} = 3.215 + \text{---} + 3.072 - CF = 29.959 - 26.042$$

1.917.

$$SS_{line} = \frac{66.159^2}{369} + \frac{76.456^2}{413} - CF$$

$$= 11.894 + 14.154 - 26.042 = 26.048 - 26.042 = 0.006$$

$$SS_{\substack{Breeding \\ group}} = \left\{\frac{37.345^2}{191} + \text{---} + \frac{28.061^2}{178}\right\} - CF$$

$$= \left\{7.302 + 8.041 + 6.447 + 4.424\right\} - 26.042$$

$$= 26.214 - 26.042 = 0.172.$$

$$SS_{\substack{line\ x \\ BG}} = \left\{\frac{15.346^2}{76} + \text{---} + \frac{17.214^2}{104}\right\} - \left\{CF + SS_{line} + SS_{BG}\right\}$$

$$= (3.099 + 4.208 + 3.879 + 4.216) - (26.042 + 0.006 + 0.172)$$

$$(3.462 + 3.005 + 1.590 + 2.849)$$

$$26.220 = 0.078$$

SS_{error} = 1.917 - 0.256 = 1.661.

Analysis of Variance

Sources of variance	df	SS	MS	F	F.95	F.99
Line	1	0.006	0.006	[illegible].00	3.84	6.63
Breeding group	3	0.172	0.057	28.50**	2.60	3.78
Line x Breeding group	3	0.078	0.026	13.00**		
Error	773	1.661	0.002	-		
Total	780	1.917				

Both breeding group and its interaction with line are highly significant (P$\leq$0.01).

Duncan's Multiple Range Test

$SE = \sqrt{\frac{LMS}{K}}$

$= \sqrt{\frac{0.002}{97.28}}$

$= 0.0045$

$K = \frac{1}{a-1}\left(N - \frac{\sum ni^2}{N}\right)$

$K = 1/7\left(781 - \frac{[illegible]}{781}\right)$

$= 1/7\ (781 - 100.04)$

$= 97.28$

Where:

a = 8

N = 781

$ni^2 = 76^2 + \text{----} + 104^2 = 78133$

Least Significant Range Values at 5% and 1% levels

	5%			1%		
Values of P	2	3	4	2	3	4
SSR (773 Edf)	2.77	2.92	3.02	3.64	3.80	3.90
LSR	0.013	0.013	0.014	0.017	0.017	0.018

1. To test Breeding group means

Significance of the Differences between means

	A	B	C	D
	0.196	0.194	0.180	0.158
D	0.038**	0.036**	0.022**	-
C	0.16*	0.014*	-	
B	0.002^{ns}	-		
A	-			

Summary: (1) $\underline{A^a\ B^a\ C^a}\ D^b$ (P$\leq$0.01)

(2) $\underline{A^a\ B^a}\ C^b\ D^c$ (P$\leq$0.05)

2. To compare the interaction means i.e. to compare the genotype means by line.

a) Male line

	S_1	S_2	H_1	H_2
	0.202	0.188	0.180	0.147
H_2	0.055**	0.041**	0.033**	-
H_1	0.022**	0.008^{ns}	-	
S_2	0.014*	-		
S_1	-			

*P/0.05

**P/0.01

ns = not significant

Summary:

(1) $\underline{S_1^a \quad S_2^{ab}}$ H_1^b H_2^c (P/0.01)

(2) S_1^a $\underline{S_2^b \quad H_1^b}$ H_2^c (P/0.05)

(b) Female line

	H_4	S_4	S_5	H_5
	0.212	0.191	0.173	0.166
H_5	0.046**	0.025**	0.007^{ns}	-
S_5	0.039**	0.018**	-	
S_4	0.021**	-		
H_4	-			

Summary:

H_4^a S_4^b $\underline{S_5^c \quad H_5^c}$ P/0.01

Heterosis in Body Weight at 40 weeks of Age

Within line comparision of the two crossbred groups with mean performance of the parents. Body weights in kilogrammes are used.

A. Male line

$$\bar{P} = \frac{1.59 + 1.40}{2} = 1.50$$

$\bar{P}$	Crossbreds	Body weight	dev.	%dev.
1.50	H_1	1.51	0.01	0.67
	S_2	1.54	0.04	2.67

B. Female line

$$\bar{P} = \frac{1.55 + 1.46}{2} = 1.51$$

$\bar{P}$	Crossbreds	Body weight	dev.	%dev.
1.51	H_4	1.63	0.12	7.95
	S_5	1.49	-0.02	-1.32

APPENDIX V

Analysis of Weight of First Egg

Models I and II.

Observed Data (g)

B/groups	A		B		C		D	
Genotypes	S_1	S_4	H_1	H_4	S_2	S_5	H_2	H_5
Rep: 1	47.00	40.10	52.00	40.10	43.80	39.20	41.00	42.30
2	51.90	46.70	49.10	42.00	40.20	40.10	44.20	41.50
3	47.10	35.30	47.20	41.30	53.00	39.00	36.50	38.90
4	49.20	38.10	41.70	47.20	42.00	38.30	38.00	47.00
5	52.50	42.90	51.80	41.00	45.30	38.90	37.00	48.00
6	51.50	48.00	47.50	43.10	49.70	36.00	38.96	46.20
7	49.10	49.10	51.00	48.00	43.20	42.80	41.00	47.30
8	53.70	43.20	44.10	49.40	49.10	39.10	39.00	48.00
9	52.00	41.70	48.20	45.20	43.80	40.00	40.05	49.10
10	53.10	41.00	43.70	45.10	45.90	47.10	41.60	48.40
Total	507.10	426.10	476.30	442.40	456.00	400.60	397.31	456.70
Mean	50.71	42.61	47.63	44.24	45.60	40.06	39.73	45.67
SD	2.43	4.37	3.55	3.23	3.92	3.02	2.33	3.49

Summary into Breeding groups by line.

Line	A	B	C	D	Total	Mean
Male	507.10	476.30	456.00	397.31	1836.71	45.92
Female	426.10	442.40	400.60	456.70	1725.80	43.15
Total	933.20	918.70	856.60	854.01	3562.51	44.53
Mean	46.66	45.90	42.83	42.70		

Summary into Sire breeds and Dam breeds by line.

Line	S-sire	H-sire	S-Dam	H-Dam
Male	983.40	853.31	963.10	873.61
Female	868.50	857.30	823.70	899.10
Total	1851.90	1710.61	1789.80	1772.71
Mean	46.30	42.77	44.75	44.32

Computation of Sums of Squares.

$$CF = \frac{3562.52^2}{80} = 158643.47$$

$$SS_{Total} = 47.00^2 + \text{----} + 48.40^2 - CF$$

$$= 160424.93 - 158643.47 = 1781.46$$

Model I.

$$SS_{line} = \frac{1836.71^2 + 1725.80^2}{40} - CF = 158797.23 - 158643.47 = 153.76.$$

$$SS_{\substack{Breeding \\ group}} = \frac{933.20^2 + \cdots + 854.01^2}{20} - CF$$

$$= 158898.43 - 158643.47 = 254.96$$

$$SS_{\substack{line\ x \\ BG}} = \frac{507.10^2 + \cdots + 456.70^2}{10} - (CF + SS_{line} + SS_{BG})$$

$$= 159613.76 - 159052.19 = 561.57$$

$$SS_{error} = 1781.46 - (153.76 + 254.96 + 561.57)$$

$$= 1781.46 - 970.29 = 811.17$$

Model II.

	Reciprocal Differences $(X_{ij} - X_{ji})$	
Rep.	Male line $(H_1 - S_2)$	Female line $(H_4 - S_5)$
1	8.2 (52.00 - 43.80)	0.9 (40.10 - 39.20)
2	8.9 (49.10 - 40.20)	1.9 (42.00 - 40.10)
3	-5.8 (47.20 - 53.00)	2.3 (41.30 - 39.00)
4	-0.3 (41.70 - 42.00)	8.9 (47.20 - 38.30)
5	6.5 (51.80 - 45.30)	2.1 (41.00 - 38.90)
6	-2.2 (47.50 - 49.70)	7.1 (43.10 - 36.00)
7	7.8 (51.00 - 43.20)	5.2 (48.00 - 42.80)
8	-5.0 (44.10 - 49.10)	10.3 (49.40 - 39.10)
9	4.4 (48.20 - 43.80)	5.2 (45.20 - 40.00)
10	-2.2 (43.70 - 45.90)	-2.1 (45.10 - 47.20)

$SS_{line} = 153.76$

$$SS_{\substack{sire\ breed \\ (gi)}} = \frac{1851.90^2 + 1710.61^2}{40} - CF = 158893.00 - 158643.47 = 249.53.$$

$$SS_{\substack{dambreed \\ (g_j)}} = \frac{1789.80^2 + 1772.70^2}{40} - CF = 158647.12 - 158643.47 = 3.65$$

$$SS_{sire\ x\ dam} = \frac{933.20^2 + \cdots + 854.01^2}{20} - (CF + SS_{sire} + SS_{dam})$$

$$= 158898.43 - 158896.64 = 1.78.$$

Analysis of variance I

Sources	df	SS	MS	F	$F_{.95}$	$F_{.99}$
Line	1	153.76	153.76	13.64**	3.95	6.94
Breeding group	3	254.96	84.99	7.54**	2.48	3.54
Line x BG	3	561.57	187.19	16.61**		
Error	72	811.17	11.27	-		
Total	79	1781.46				

**P/0.01.

Analysis of variance II

Sources	df	SS	MS	F	$F_{.95}$	$F_{.99}$
Line	1	153.76	153.76	10.84**	3.94	6.91
Sire breed(g_i)	1	249.53	249.53	17.84**		
Dam breed (g_j)	1	3.65	3.65	0.26NS		
Sire x Dam breed (SCA)	1	1.78	1.78	0.13NS		
Reciprocal(rij)	1	322.82	322.82	22.75**		
Error	74	1049.92	14.19			
Total	79	1781.46				

NS = Not significant

** P/0.01.

Duncan's Multiple Range Test

$SE=\sqrt{\frac{EMs}{nxr}}=\sqrt{\frac{11.27}{10x4}}=0.53$ where n = 10 rep. samples

r = 4 rep. pens

Least significant Range Values at 5% and 1% levels

	5%			1%		
Values of P	2	3	4	2	3	4
SSR (72)	2.81	2.96	3.07	3.72	3.88	4.00
LSR	1.49	1.57	1.63	1.97	2.06	2.12

Heterosis in Weight of First Egg

A. Comparison of the crossbred with mean performance of the parents

A. To test Breeding group means.

Significance of differences of means

	A 46.66	B 45	90	C 42.83	D 42.70
D	3.96^{**}	3.22^{**}		0.13^{NS}	-
C	3.83^{**}	3.09^{**}		-	
B	0.74^{NS}	..			
A	-				

Summary $\underline{A^a \quad B^a}$ $\underline{C^b \quad D^b}$ (P/0.01)

B. To test interaction mean (genotypes by line)

a) Male line

	S_1	H_1	S_2	H_2
	50.71	47.63	45.60	39.73
H_2	10.98^{**}	7.9^{**}	5.87^{**}	-
S_2	5.11^{**}	2.03^{**}	-	
H_1	3.08^{**}	-		
S_1	-			

Summary: $S_1^a \; H_1^b \; S_2^c \; H_2^d$ P/0.01

(b) Female line

	H_5	H_4	S_4	S_5
	45.67	44.24	42.61	40.06
S_5	5.61^{**}	4.18^{**}	2.55^{**}	-
S_4	3.06^{**}	1.63^{*}	-	
H_4	1.43^{NS}			
H_5	-			

Summary:

1. $\underline{H_5^a \quad H_4^{ab}} \quad S_4^b \quad S_5^c$ P/0.01
2. $\underline{H_5^a \quad H_4^a} \quad S_4^b \quad S_5^c$ P/0.05

C. To test sire breed means by line to see if S - sires remained superior in both lines.

Significance of Difference of means

Line	S-sire	H-sire	Difference
Male	49.17	42.67	6.50^{**}
Female	43.43	42.87	0.54^{NS}

S - sires are superior for male line only.

D. To test reciprocal means by line.

Significance of Difference of means

Line	S x H (B)	H x S (C)	Difference
Male	47.63	45.60	2.03^{**}
Female	44.24	40.06	4.18^{**}

The S x H (B groups) are superior for both lines.

$t = \frac{0.10-0}{1.03}; \frac{0.58-0}{2.39}$ $\quad t = \frac{-4.08-0}{1.25}; \frac{-8.85-0}{2.81}$

$= 0.097^{NS} = 0.24^{NS}$ $\quad = -3.26^{**} \quad -3.15^{*}$

Conclusion: The heterosis observed in H_4 is not significant, but S_5 expressed a highly significant (P/0.01) negative heterosis.

B. Comparison of the crossbred groups among themselves (within line basis) using deviations in grammes.

a) Male line			(b) Female line	
Rep.	H_1	S_2	H_4	S_5
1	8.00	-0.20	-1.10	-2.00
2	1.05	-7.85	-2.10	-4.00
3	5.40	11.20	4.20	1.90
4	-1.90	-1.60	4.65	-4.25
5	7.05	0.55	-4.45	-6.55
6	2.27	4.47	-4.00	-11.10
7	5.95	-1.85	-0.20	-5.40
8	-2.25	2.75	3.80	-6.50
9	2.17	-2.23	-0.20	-5.40
10	-3.65	-1.45	0.40	2.50
Σx	24.09	3.79	1.00	-40.80
Σx^2	211.22	228.01	95.37	314.61
$\bar{x}$	2.41	0.38	0.10	-4.08

$L = 10(211.22)-24.09^2; 10(228.01)-3.79^2$ $\quad L = 10(95.37)-1.00^2;$

$= 1531.87$ $\quad = 2265.74$ $\quad 10(314.61)-(-40.8)^2$

$952.70; = 1476.96$

$s^2 = \frac{1531.87}{10(9)}; \frac{2265.74}{90}$ $\quad s^2 \frac{952.70}{(10(9)}; \frac{1475.96}{90}$

$= 17.02 \quad = 25.17$ $\quad = 10.59 \quad = 16.40$

$t^2 = \frac{((18)(-10(20.3)^2}{(20)\{10(3797.61)}$ $\quad t^2 = \frac{((18)\{10(41.8)\}^2}{((20)\{10\ 2429.66\}}$

$= \frac{((18)(241209)}{(20)(37976.1)} = 0.98$

$t = \sqrt{0.98} = 0.99^{NS}$ $= \frac{18(174724)}{485932} = 6.47$

$t = \sqrt{6.47} = 2.54^{*}$

$t = (0.05,18) = 2.101;$ $(0.01,18) = 2.878$

Conclusion: No significant difference between heterosis exhibited by H_1 and S_2 but those exhibited by H_4 and S_5 are significantly ($P/0.05$) different from each other.

APPENDIX VI

Analysis of Average Egg Weight at 30 weeks of Age

Model I and II

Observed Data(g)

B/groups	A		B		C		D	
Genotypes	S_1	S_4	H_1	H_4	S_2	S_5	H_2	H_5
Rep. 1	52.87	45.07	50.07	46.57	48.07	42.47	46.57	48.04
2	49.47	49.83	49.34	49.31	49.70	48.50	44.15	48.05
3	49.48	46.74	45.44	49.74	44.74	49.64	45.42	48.04.
Total	151.82	141.64	144.85	145.62	142.51	140.61	136.14	144.13
Mean	50.61	47.21	48.28	48.54	47.50	46.87	45.38	48.04
SD	1.96	2.42	2.49	1.72	2.53	3.85	1.21	0.005

Summary into breeding group per line.

Line	A	B	C	D	Togal	Mean
Male	151.82	144.85	142.51	136.14	575.32	47.94
Female	141.64	145.62	140.61	144.13	572.00	47.67
Total	293.46	290.47	283.12	280.27	1147.32	47.81
Mean	48.91	48.41	47.19	46.71		

Summary into Sire breeds and Dam breeds by line.

Line	S-sire	H-sire	S-dam	H-dam
Male	296.67	278.65	294.33	284.99
Female	287.26	284.74	282.25	289.75
Total	587.93	563.39	576.58	570.74
Mean	48.66	46.95	48.05	47.56

Reciprocal Differences

Rep.	Male line (H_1-S_2)		Female line $(H_4 - S_5)$	
1	2.00	(50.07-48.07)	4.10	(46.57 - 42.47)
2	-0.36	(49.34-49.70)	0.81	(49.31 - 48.50)
3	0.70	(45.44-44.74)	0.10	(49.74 - 49.64)

Computation of sums of squares.

$$CF = \frac{1147.32^2}{24} = 54847.63$$

$$SS_{Total} = 52.87^2 + \text{-----} + 48.04^2 - CF = 54978.30 - 54847.63 = 130.67.$$

Model I.

$$SS_{Line} = \frac{575.32^2 + 572.00^2}{12} - CF = 54848.09 - 54847.63 = 0.46$$

$$SS_{Breeding\ group.} = \frac{293.46^2 + \text{--------} + 280.27^2}{6} - CF = 54866.63 - 54847.63 = 19.00.$$

$$SS_{Line\ x\ BG} = \frac{151.82^2 + \text{----} + 144.13^2}{3} - \{CF + SS_{line} + SS_{BG}\}$$

$$SD = 54895.25 - 54867.09 = 28.16$$

$$SS_{error} = 130.67 - \{0.46 + 19.00 + 28.16\}$$

$$= 130.67 - 47.62 = 83.05.$$

Model II.

$$SS_{line} = 0.46$$

$$SS_{g_i} = \frac{583.83^2 + 563.39^2}{12} - CF = 54865.21 - 54847.63 = 17.58.$$

$$SS_{g_j} = \frac{576.58^2 + 570.74^2}{12} - CF = 54849.05 - 54847.63 = 1.42$$

$$SS_{sij} = \frac{293.46^2 + \text{------} + 280.27^2}{6} - \{CF + SS_{gi} + SS_{gj}\}$$

$$= 54866.63 - 54866.63 = 0.00$$

$$SS_{rij} = \frac{2.00^2 + \text{--------} + 0.10^2}{2} = \frac{22.10}{2} = 11.05$$

$$SS_{error} = 130.67 - \{0.46 + \text{--------} + 11.05\}$$

$$= 130.67 - 30.51 = 100.16$$

(b) Female line

Analysis of Variance I

Sources	df	SS	MS	F	F.95	F.99
Line	1	0.46	0.46	0.09	4.49	8.59
Breeding group	3	19.00	6.33	1.22	3.24	5.29
Line x BG	3	28.16	9.39	1.81		
Error	16	83.05	5.19	-		
Total	23	130.67				

None is significant.

Analysis of Variance II

Sources	df	SS	MS	F	F.95	F.99
Line	1	0.46	0.46	0.08	4.41	8.29
Sire breed	1	17.58	17.58	3.16		
Dam breed	1	1.42	1.42	0.26		
SCA (S_{ij})	1	0.00	0.00	-		
Rec. (r_{ij})	1	11.05	11.05	1.99		
Error	18	100.16	5.56	-		
Total	23	130.67				

None is significant.

Heterosis in Egg Weight at 30 weeks of Age.

A. Comparison of the crossbred groups with the mean performance of the parents.

a) Male line

	(i) Within SxH group				(ii) Within HxS group		
Rep.	$\bar{P}$	H_1	dev.	%dev.	S_2	dev	%dev.
1	49.72	50.07	0.35	0.70	48.07	-1.65	-3.32
2	46.80	49.34	2.54	5.43	49.70	2.90	6.20
3	47.45	45.44	-2.01	4.24	44.74	- 2.71	-5.71
Mean deviation			0.29	0.63	-	-0.49	-0.94
S.E of deviation			1.31	2.79	-	1.72	3.64

$t = \frac{0.29-0}{1.31} = 0.22^{NS}$; $\frac{0.63-0}{2.79} = 0.23^{NS}$; $t = \frac{-0.49-0}{1.72} = -0.27^{NS}$; $\frac{-0.94-0}{3.64} = -0.26^{NS}$

$t = (0.05,2) = 4.303$

APPENDIX VII

Analysis of Egg Weight at 40 weeks of Age

Model I and II

Observed Data

Breeding groups	A	B			C		D	
Genotypes	S_1	S_4	H_1	H_4	S_2	S_5	H_2	H_5
Rep. 1	56.82	49.03	54.05	50.54	52.04	46.47	50.56	52.01
2	53.45	53.80	53.32	54.51	53.68	52.47	48.13	55.98
3	58.91	56.17	54.87	59.17	54.17	59.07	54.85	57.47
Total	169.18	159.00	162.24	164.22	159.89	158.01	153.54	165.46
Mean	56.39	53.00	54.08	54.74	53.30	52.67	51.18	55.15
SD	2.75	3.64	0.78	4.32	1.12	6.30	3.40	2.82

Summary into Breeding group per line!

Line	A	B	C	D	Total	Mean
Male	169.18	162.24	159.89	153.54	644.85	53.74
Female	159.00	164.22	158.01	165.46	646.69	53.89
Total	328.18	326.46	317.90	319.00	1291.54	53.81
Mean	54.70	54.41	52.98	53.17		

Summary into sire breed and Dam breed by line.

Line	S-sire	H-sire	S-dam	H-dam
Male	331.42	313.43	329.07	315.78
Female	323.22	323.47	317.01	329.68
Total	654.64	636.90	646.08	645.46
Mean	54.55	53.08	53.84	53.79

Reciprocal Differences ($x_{ij} - x_{ji}$)

Rep.	Male line (H_1-S_2)	Female line (H_4-S_5)
1	2.01 (54.05-52.04)	4.07 (50.54-46.47)
2	-0.36 (53.32-53.68)	2.04 (54.51-52.47)
3	0.70 (54.87-54.17)	0.10 (59.17-59.07)

Computation of sums of squares.

$$CF = \frac{1291.54^2}{24} = 69503.15$$

$$SS_{Total} = 56.82^2 + \cdots + 57.47^2 - CF = 69759.97 - 69503.15 = 256.82.$$

Model I.

$$SS_{line} = \frac{644.85^2 + 646.69^2}{12} - CF = 69503.29 - 69503.15$$

$$= 0.14$$

$$SS_{\substack{Breeding \\ Group}} = \frac{328.18^2 + \cdots + 319.00^2}{6} - CF = 69516.61 - 69503.15$$

$$= 13.46$$

$$SS_{\substack{line\ x \\ BG}} = \frac{169.18^2 + \cdots + 165.46^2}{3} - (CF + SS_{line}\ SS_{BG})$$

$$= 69558.80 - 69516.75 = 42.05$$

$$SS_{error} = 256.82 - (0.14 + 13.46 + 42.05)$$

$$= 256.82 - 55.65 = 201.17$$

Model II.

$$SS_{line} = 0.14$$

$$SS_{gi} = \frac{654.64^2 + 635.90^2}{12} - CF = 69516.26 - 69503.15$$

$$= 13.11$$

$$SS_{gj} = \frac{646.08^2 + 645.46^2}{12} - CF = 69503.16 - 69503.15$$

$$= 0.01$$

$$SS_{sij} = \frac{328.18^2 + \cdots + 319.00^2}{6} - (CF + SS_{gi} + SS_{gj})$$

$$= 69516.61 - 69516.27 = 0.34$$

$$SS_{rij} = \frac{2.01^2 + \cdots + 0.10^2}{2} = \frac{25.40}{2} = 12.70$$

$$SS_{error} = 256.82 - (0.14 + \cdots + 12.70) = 230.52$$

Analysis of Variance I

Sources	df	SS	MS	F	F.95	F.99
Line	1	0.14	0.14	0.01	4.49	8.59
Breeding group	3	13.46	4.49	0.36	3.24	5.29
Line x BG	3	42.05	14.02	1.12		
Error	16	201.17	12.57	-		
Total	23	256.82				

Analysis of Variance II

Sources	df	SS	MS	F	F.95	F.99
Line	1	0.14	0.14	0.01	4.41	8.29
Sire breed	1	13.11	13.11	1.02		
Dam breed	1	0.01	0.01	0.0007		
SCA (Sij)	1	0.34	0.34	0.03		
Reciprocal (rij)	1	12.70	12.70	0.99		
Error	18	230.52	12.81	-		
Total	23	256.82				

No significant effect due to any of the components.

Heterosis in Egg Weight at 40 weeks of Age

A. Comparison of crossbred groups with the mean performance of the parents.

a) Male line.

(ii) Within SxH group

Rep	$\bar{P}$	H_1	dev.	%dev.
1	53.69	54.05	0.36	0.67
2	50.79	53.32	2.53	4.98
3	56.88	54.87	-2.01	-3.53
Mean deviation			0.29	0.71
S.E. of deviation			1.31	2.46

$t = \frac{0.29-0}{1.31} ; \frac{0.71-0}{2.46}$

$= 0.22^{NS} \quad 0.29^{NS}$

$t_{(0.05,2)} = 4.303.$

(ii) Within HxS group.

S_2	dev.	%dev.
52.04	-1.65	-3.07
53.68	2.89	5.69
54.17	-2.71	-4.76
-	-0.49	-0.71
-	1.72	3.24

$t = \frac{-0.49-0}{1.72} ; \frac{-0.71-0}{3.24}$

$-0.28^{NS} \quad -0.22^{NS}$

b) Female line.

(i) Within SxH group

Rep.	$\bar{P}$	H_4	dev.	%dev.
1	50.52	50.54	0.02	0.04
2	54.89	54.51	-0.38	-0.69
3	56.82	59.17	2.35	4.14
Mean deviation			0.66	1.16
S.E. of deviation			0.85	1.50

$t = \frac{0.66-0}{0.85} ; \frac{1.16-0}{1.50}$

$= 0.78^{NS} \quad 0.77^{NS}$

(ii) Within HxS group

S_5	dev.	%dev.
46.47	-4.05	-8.02
52.47	-2.42	-4.41
59.07	2.25	3.96
-	1.41	-2.82
-	1.89	3.55

$t = \frac{-1.41-0}{1.89} ; \frac{-2.82-0}{3.55}$

$-0.75^{NS} \quad -0.79^{NS}$

Conclusion: None of the heterosis observed in the groups is significant.

B. Within line comparison of the crossbred groups, (deviation in grammes used).

Male line			Female line	
Rep.	H_1	S_2	H_4	S_5
1	0.36	-1.65	0.02	-4.05
2	2.53	2.89	-0.38	-2.42
3	-2.01	-2.71	2.35	2.25
Σx	0.88	-1.47	1.99	-4.22
Σx^2	10.57	18.48	5.67	27.32
$\bar{x}$	0.29	-0.49	0.66	-1.41
$L = 3(10.57)-0.88^2$; $3(18.42)-(-1.47^2)$			$L = 3(5.67)-1.99^2$; $3(27.32)-(-4.22^2)$	
$= 30.94$		$= 53.51$	$= 13.05$	$= 64.15$
$s^2 = \frac{30.94}{3(2)}$		$\frac{53.10}{6}$	$= \frac{13.05}{6}$	$\frac{64.15}{6}$
$= 5.16$		8.85	2.18	10.69
$t^2 = \frac{(3+3-2)\{3(0.88-3(-1.47)\}^2}{(3+3\{3(30.94+53.10)\}}$			$t^2 = \frac{(3+3-2)\{3(1.99)-(-4.22$ / $(3+3\{3(13.05+64.15)\}$	
$= \frac{(4)(49.7)}{(6)(252.12)} = 0.13$			$= \frac{(4)(347.08)}{(6)(231.60)} = 1.00$	
$t = \sqrt{0.13} = 0.36^{NS}$			$t = \sqrt{1.00} = 1.00^{NS}$	
df = 4 $t(0.05,4) = 2.571$.				

Conclusion: No significant difference in heterosis for 40 weeks egg weight between the crossbred groups of both lines.

APPENDIX VIII

Analysis of Hen - Housed Egg Number

Model: I & II.

Observed Data

Breeding group	A		B		C		D	
Genotype	S_1	S_4	H_1	H_4	S_2	S_5	H_2	H_5
Rep: 1	12.30	8.25	10.20	9.23	8.37	8.36	9.00	8.53
2	16.10	14.98	15.44	13.55	16.95	10.22	10.16	9.80
3	18.73	16.57	21.64	15.27	19.96	12.93	14.44	11.40
4	14.92	14.53	18.02	13.36	21.00	17.95	17.85	15.07
Total	62.05	54.23	65.30	51.41	66.28	49.46	51.45	44.80
Mean	15.51	13.56	16.33	12.85	16.57	12.37	12.86	11.20
S.D.	2.67	3.65	4.81	2.56	5.73	4.17	4.07	2.83

Summary into Breeding groups by line

Line	A	B	C	D	Total	Mean
Male	62.05	65.30	66.28	51.45	245.08	15.32
Female	54.23	51.41	48.46	44.80	199.90	12.49
Total	116.28	116.71	115.74	96.25	444.98	13.91
Mean	14.54	14.59	14.47	12.03		

Summary into sire breeds and Dam breeds by line

Line	S-Sire	H-Sire	S-dam	H-dam
Male	127.35	117.73	128.33	116.75
Female	105.64	94.26	103.69	96.21
Total	232.99	211.99	232.02	212.96
Mean	14.56	13.25	14.50	13.31

Reciprocal Differences

Rep.	Male line ($H_1 - S_2$)	Female line ($H_4 - S_5$)
1	1.83 (10.20- 8.37)	0.87 (9.23 - 8.36)
2	-1.51 (15.44-16.95)	3.33 (13.55 - 10.22)
3	1.68 (21.64-19.96)	2.34 (15.27 - 12.93)
4	-2.98 (18.02-21.00)	-4.59 (13.36 - 17.95)

Computation of sums of squares.

$$CF = \frac{444.98^2}{32} = 6187.73$$

$$SS_{Total} = 12.30^2 + \text{-----} + 15.07^2 - CF = 6672.09 - 6187.73 = 485.06$$

Model I

$SS_{line} = \frac{245.08^2+199.90^2}{16} - CF = 6251.51 - 6187.73 = 63.78$

$SS_{\substack{Breeding \\ group}} = \frac{116.28^2 + \text{---} + 96.25^2}{8} - CF = 6225.26-6187.73$

$= 6225.26 - 6187.73 = 37.53.$

$SS_{\substack{line \\ x\ BG}} = \frac{62.05^2+\text{---}+44.25^2}{4} - (CF + SS_{line} + SS_{Bg})$

$= 6297.91 - 6289.04 = 8.87$

$SS_{error} = 485.06 - (63.78 + 37.53 + 8.87) = 485.06-110.18=374.88$

Model II.

$SS_{line} = 63.78$

$SS_{gi} = \frac{232.99^2 + 211.99^2}{16} - CF = 6201.51 - 6187.73 = 13.78$

$SS_{gj} = \frac{232.02^2 + 212.96^2}{16} - CF = 6199.08 - 6187.73 = 11.35$

$SS_{sij} = \frac{116.28^2+\text{---}+96.25^2}{8} - (CF + SS_{gi} + SS_{gj})$

$= 6225.26 - 6212.86 = 12.40$

$SS_{rij} = \frac{1.83^2+\text{----}+(-4.59^2)}{2} = \frac{55.72}{2} = 27.86$

$SS_{error} = 485.06 -(63.78+\text{-----}+27.86) = 355.89$

Analysis of Variance I

Sources	df	SS	MS	F	F.95	F.99
Line	1	63.78	63.78	4.08	4.26	7.82
Breeding group	3	37.53	12.51	0.80	3.01	4.72
Line x Breeding group	3	8.87	2.96	0.19		
Error	24	374.88	15.62	-		
Total	31	485.06				

No effect is significant.

APPENDIX IX

Analysis of Hen - Day Egg Number

Model: I and II.

Observed Data

Breeding groups	A		B		C		D	
Genotypes	S_1	S_4	H_1	H_4	S_2	S_5	H_2	H_5
Rep: 1	12.42	8.28	10.24	9.24	8.37	8.36	9.00	8.53
2	16.61	15.39	15.70	13.68	17.01	10.28	10.21	9.87
3	19.57	17.15	22.11	15.58	20.09	13.18	14.87	11.70
4	15.70	15.52	19.01	13.73	21.14	19.11	18.84	15.80
Total	64.30	56.34	67.06	52.23	66.61	50.93	52.92	45.90
Mean	16.08	14.09	16.77	13.06	16.65	12.73	13.23	11.48
S.D.	2.34	3.95	5.08	2.69	5.79	4.69	4.52	3.16

Summary into Breeding group by line

Line	A	B	C	D	Total	Mean
Male	64.30	67.06	66.61	52.92	250.89	15.68
Female	56.34	52.23	50.93	45.90	205.40	12.84
Total	120.64	119.29	117.54	98.82	456.29	14.26
Mean	15.08	14.91	14.69	12.35		

Summary into sire breed and Dam breed by line

Line	S-Sire	H-Sire	S-dam	H-dam
Male	131.36	119.53	130.91	119.98
Female	108.57	96.83	107.27	98.13
Total	239.93	216.36	238.18	218.11
Mean	15.00	13.52	14.89	13.32

Reciprocal Differences

Rep.	Male line ($H_1 - S_2$)	Female line ($H_4 - S_5$)
1	1.87 (10.24 - 8.37)	0.88 (9.24 - 8.36)
2	-1.31 (15.70 - 17.01)	3.40 (13.68 - 10.28)
3	2.02 (22.11 - 20.09)	2.40 (15.58 - 13.18)
	.13 (19.01 - 21.14)	-5.38 (13.73 - 19.11)

f sums of squares.

= 6506.27

Model I.

$SS_{line} = \frac{250.89^2 + 205.40^2}{16} - CF = 6570.93 - 6506.27 = 64.66$

$SS_{\substack{Breeding \\ group}} = \frac{120.64^2 + \cdots + 98.82^2}{8} - CF = 6545.64 - 6506.27 = 39.37$

$SS_{\substack{line\ x \\ BG}} = \frac{64.30^2 + \cdots + 45.80^2}{4} - (CF + SS_{line} + SS_{BG})$

$= 6617.95 - 6610.3 = 7.65$

$SS_{error} = 541\ 50 - (64.66 + 39.37 + 7.65) = 541.50 - 111.68$

$= 429.82$

Model II.

$SS_{line} = 64.66$

$SS_{gi} = \frac{239.93^2 + 216.36^2}{16} - CF = 6523.63 - 6506.27 = 17.36$

$SS_{gj} = \frac{238.18^2 + 218.11^2}{16} - CF = 6518.86 - 6506.27 = 12.59$

$SS_{sij} = \frac{120.64^2 + \cdots + 98.82^2}{8} - (CF + SS_{Sire} + SS_{dam})$

$= 6545.64 - 6536.22 = 9.42$

$SS_{rij} = \frac{1.87^2 + \cdots + (-5.38)^2}{2} = \frac{60.87}{2} = 30.44$

$SS_{error} = 541.50 - (64.66 + \cdots + 30.44) = 541.50 - 134.47$

$= 407.03$

Analysis of Variance I

Sources	df	SS	MS	F	F.95	F.99
Line	1	64.66	64.66	3.61	4.26	7.82
Breeding group	3	39.37	13.12	0.73	3.01	4.72
Line x BG	3	7.65	2.55	0.14		
Error	24	429.82	17.91	-		
Total	31	541.50				

Analysis of Variance II

Sources	df	SS	MS	F	F.95	F.99
Line	1	64.66	64.66	4.13	4.23	7.72
Sire breed	1	17.36	17.36	1.11		
Dam breed	1	12.59	12.59	0.80		
SCA	1	9.42	9.42	0.60		
Reciprocal	1	30.44	30.44	1.94		
Error	26	407.03	15.66	-		
Total	31	541.50				

Analysis of variance II (Pooled)

Sources	df	SS	MS	F	F.95	F.99
Line	1	64.66	64.66	4.29*	4.21	7.68
GCA ($g_i + g_j$)	1	29.95	29.95	1.99		
SCA	1	9.42	9.42	0.62		
Reciprocal	1	30.44	30.44	2.02		
Error	27	407.03	15.08	-		
Total	31	541.50				

Line effect alone is significant (P/0.05).

Heterosis in Hen-Day Egg Production

A_1. Comparision of the crossbred group with mean performance of the parents (on monthly basis).

(i) Male line

(a) Within S x H group					(b) Within HxS group		
Rep.	$\bar{P}$	H_1	dev.	%dev.	S_2	dev.	%dev.
1	10.71	10.24	-0.47	-4.40	8.37	-2.23	-21.85
2	13.41	15.70	2.29	17.08	17.01	3.60	26.85
3	17.22	22.11	4.89	28.40	20.09	2.87	16.67
4	17.27	19.01	1.74	10.08	21.14	3.87	22.11
Mean deviation	-		2.11	12.79	-	2.00	11.02
S.E. of deviation			1.10	6.86		1.50	11.15

$t = \frac{2.11-0}{1.10} = 1.92^{NS}$; $\frac{12.79-0}{6.86} = 1.86^{NS}$

$t = \frac{2.00-0}{1.5}$; $\frac{11.02-0}{11.15} = 1.33^{NS} = 0.99^{NS}$

t (0.05,3) = 3.182.

(ii) Female line.

(a) Within S x H group					(b) Within H x S group		
Rep.	$\bar{P}$	H_4	dev.	%dev.	S_5	dev.	%dev.
1	8.41	9.24	0.83	9.87	8.36	-0.05	-0.59
2	12.63	13.68	1.05	8.31	10.28	-2.35	-18.61
3	14.43	15.58	1.15	7.97	13.18	-1.25	- 8.66
4	15.66	13.73	-1.93	-12.32	19.11	3.45	22.03
Mean deviation	-		0.28	3.46	-	-0.05	- 1.46
S.E. of deviation			0.74	5.28		1.26	8.65

$t = \frac{0.28-0}{0.74} = 0.38^{NS}$; $\frac{3.46-0}{5.28} = 9.66^{NS}$

$t = \frac{-0.05-0}{1.26}$; $-\frac{1.46-0}{8.65} = 0.04^{NS}$ 0.17^{NS}

Conclusion: No heterosis is significant despite the high values for male line.

A_2 Comparision of the crossbred groups with mean performance of the parents (weekly basis).

(i) Male line

(a) Within S x H crossbred group					(b) Within H x S group		
Rep.	$\bar{P}$	H_1	dev.	%dev.	S_2	dev.	%dev.
1	2.03	2.02	-0.01	-0.49	1.92	-0.11	-5.42
2	2.34	2.37	0.03	1.28	1.90	-0.44	-18.80
3	2.97	2.55	-0.42	-14.14	1.87	-0.10	-37.04
4	3.04	2.93	-0.11	- 3.64	2.32	-0.72	-23.68
5	2.99	3.39	0.40	13.38	3.46	0.47	15.72
6	2.91	3.02	0.11	3.78	3.80	0.89	30.55
7	2.82	3.16	0.34	12.06	4.33	1.51	53.55
8	3.82	4.39	0.57	14.92	4.37	0.55	14.40
9	4.06	5.35	1.29	31.77	4.21	0.15	3.69
10	4.39	5.12	0.73	16.63	4.03	-0.36	- 8.20
11	3.94	5.65	1.71	43.40	4.69	0.75	19.04
12	4.25	5.00	0.75	17.65	5.67	1.42	33.41
13	4.00	5.28	1.28	32.00	4.94	0.94	23.50
14	3.80	4.61	0.81	21.32	6.07	2.27	59.74
15	3.65	4.60	0.95	26.03	5.23	1.58	43.29
16	4.40	5.06	0.66	15.00	5.14	0.74	16.82
Mean dev.		-	0.58	14.44	-	0.53	13.79
SE of dev.		-	0.14	3.71	-	0.23	6.68

$t = \frac{0.58-0}{0.14} = 4.14^{**}$; $\frac{14.44-0}{3.71}$

$= 3.89^{**}$

$t = \frac{0.53-0}{0.23}$; $\frac{13.79-0}{6.68}$

$= 2.30^{*} = 2.06^{NS}$

$t(0.05,15) = 2.131$; $t(0.01,15) = 2.947$

Conclusion: The heterosis by H_1 is highly significant ($P/0.01$) and that by S_2 is significant ($P/0.05$).

(ii) Female line

	Within S x H group				Within H x S group		
Rep.	$\bar{P}$	H_4	dev.	%dev.	S_5	dev.	%dev.
1	1.93	1.91	-0.02	-1.04	2.04	0.11	5.70
2	2.00	2.00	0.00	0.00	2.10	0.10	5.00
3	2.20	2.32	0.12	5.45	2.22	0.02	0.91
4	2.22	2.75	0.53	23.87	1.95	-0.27	-12.16
5	2.45	3.31	0.86	31.62	2.15	-0.30	-12.24
6	2.75	3.40	0.68	25.00	2.49	-0.23	- 8.46
7	3.34	3.02	-0.32	- 9.58	2.65	-0.67	-20.06
8	3.43	2.98	-0.45	-13.12	2.51	-0.92	-28.82
9	3.32	3.84	0.52	15.66	2.93	-0.39	-11.75
10	3.39	4.13	0.74	21.83	3.12	-0.27	- 7.56
11	3.59	4.21	0.62	17.27	2.82	-0.77	-21.45
12	3.61	3.61	0.00	0.00	3.26	-0.35	- 9.70
13	3.55	3.24	-0.31	- 8.73	3.76	0.21	5.92
14	3.73	3.69	-0.04	- 1.07	4.90	1.17	31.37
15	3.85	3.53	-0.32	8.31	4.71	0.86	22.34
16	4.03	2.66	-1.37	-34.00	4.61	0.13	3.23
Mean deviation			0.08	4.05	-	-0.10	-3.61
S.E. of deviation			0.14	4.35		0.14	3.94
$t = \frac{0.08-0}{0.14} = 0.57^{NS}$; $\frac{4.05-0}{4.35} = 0.93^{NS}$					$t = \frac{-0.10-0}{0.14}$; $\frac{-3.61-0}{3.94}$ $= -0.7^{NS} = -0.92^{NS}$		

Conclusion: None of the heterosis is significant.

B. Within line comparison of the crossbred groups among themselves.

a) Male line

	Male line		Female line	
Rep	H_1	S_2	H_4	S_5
1	-0.01	-0.11	-0.02	0.11
2	0.03	-0.44	0.00	0.10
3	-0.42	-1.10	0.12	0.02
4	-0.11	-0.72	0.53	-0.27
5	0.40	0.47	0.86	-0.30
6	0.11	0.89	0.68	-0.23
7	0.34	1.51	-0.32	-0.67
8	0.57	0.55	-0.45	-0.92
9	1.29	0.15	0.52	-0.39
10	0.73	-0.36	0.74	-0.27
11	1.71	0.75	0.62	-0.77
12	0.95	1.42	0.00	-0.35
13	1.28	0.94	-0.31	0.21
14	0.61	2.27	-0.04	1.17
15	0.95	1.58	-0.32	0.86
16	0.66	0.74	-1.37	0.13

Σx =	9.29 8.54	1.24 -1.57
Σx^2 =	10.46 17.34	5.08 4.64
$\bar{x}$ =	0.58 0.53	0.08 -0.10

$L = 16(10.46)-9.29^2;\ 16(17.34)-8.54^2$ $\quad L = 16(5.08)-1.24^2;\ 16(4.64)-(-1.51^2)$

$= 81.06 \quad 204.51 \quad 79.74 \quad 71.78$

$S^2 = \frac{81.06}{16(15)} = 0.34 \quad \frac{204.51}{16(15)} = 0.85 \quad \frac{79.74}{16(15)} = 0.33 \quad \frac{71.78}{16(15)} = 0.30$

$t^2 = \frac{(16+16-2)\{16(9.29-8.54)\}^2}{(16+16)\{16(81.06+204.51)\}}$ $\quad t^2 = \frac{(16+16-2)\{16(124)-16(-1.57)\}^2}{(16+16)\{16(79.74+71.78)\}}$

$= \frac{(30)(144)}{(32)(4569.12)} = 0.03 \quad \frac{(30)(2021.40)}{(32)(2424.32)} = 0.78$

$t = \sqrt{0.03} = 0.17^{NS} \quad t = \sqrt{0.78} = 0.88^{NS}$

$t = (0.05,30) = 2.042$

APPENDIX X

Analysis of Feed consumption (G/bird/day).

Model: I and II

Observed Data

Breeding groups	A		B		C		D	
Genotypes	S_1	S_4	H_1	H_4	S_2	S_5	H_2	H_5
Rep: 1	113.42	76.58	73.71	84.37	71.02	70.09	73.24	68.90
2	118.57	98.46	85.12	81.22	83.42	73.47	94.99	68.21
3	152.38	107.52	104.96	109.04	106.87	90.38	97.34	68.97
4	151.05	87.02	112.50	110.61	126.46	101.93	116.36	95.03
Total	535.42	369.58	376.29	385.24	387.77	335.87	381.93	301.11
Mean	133.86	92.40	94.07	96.31	96.94	83.97	95.48	75.28
SD	20.74	13.47	17.82	15.67	24.66	14.91	17.64	13.17

Summary into Breeding Groups by line

Line	A	B	C	D	Total	Mean
Male	535.42	376.29	387.77	381.93	1681.41	105.09
Female	369.58	385.24	335.87	301.11	1391.80	86.11
Total	905.00	761.53	723.64	683.04	3073.21	96.04
Mean	113.13	95.19	90.46	85 .38		

Summary into Sire breed and Dam breed by line

Line	S-Sire	H -Sire	S- dam	H- dam
Male	911.71	769.70	923.19	758.22
Female	754.82	636.98	705.45	686.35
Total	1666.53	1406.68	1628.64	1444.57
Mean	104.16	87.92	101.79	90.29

Reciprocal Differences

Rep.	Male	Line ($H_1 - S_2$)	Female	Line ($H_4 - S_5$)
1.	2.69	(73.71 - 71.02)	14.28	(84.37 - 70.09)
2.	1.70	(85.12 - 83.42)	7.75	(81.22 - 73.47)
3.	-1.91	(104.96 - 106.87)	18.66	(109.04 - 90.38)
4.	-13.96	(112.50 - 126.46)	8.68	(110.61 - 101.93)

Computation of sums of squares

$CF = \frac{3073.21^2}{32} = 295144.37$

$SS_{Total} = 113.42^2 + \text{-------} + 95.03^2 - CF = 310715.02 - 295144.37$

15570.65

Model I

$$SS_{line} = \frac{1681.42^2 + 1391.80^2}{16} - CF = 2977.65.43 - 295144.37 = 2621.06$$

$$SS_{\substack{Breeding \\ group}} = \frac{905.00^2 + \text{-----} + 683.04^2}{8} - CF = 298643.93 - 295144.37$$

$$= 3499.56$$

$$SS_{line \times BG} = \frac{535.42^2 + \text{---} + 301.11^2}{4} - CF + SS_{line} + SS_{BG})$$

$$= 303244.99 - 301264.99 = 1980.00$$

$$SS_{error} = 15570.65 - (2621.06 + 3499.56) + 1980.00)$$

$$= 15570.65 - 8100.62 = 7470.03$$

Model II:

$$SS_{line} = 2621.06$$

$$SS_{gi} = \frac{1666.53^2 + 1406.68^2}{16} - CF = 297254.43 - 295144.37$$

$$= 2110.06$$

$$SS_{gj} = \frac{1628.64^2 + 1444.57^2}{16} - CF = 296203.17 - 295144.37 = 1058.80$$

$$SS_{sij} = \frac{905.00^2 + \text{----} + 683.04^2}{8} - (CF + SS_{gi} + SS_{gj})$$

$$= 298643.93 - 298313.23 = 330.70$$

$$SS_{rij} = \frac{2.69^2 + \text{------} + 8.68^2}{2} = \frac{896.17}{2} = 448.09$$

$$SS_{error} = 15570.65 - (2621.06 + \text{------} + 448.09)$$

$$= 15570.65 - 6568.71 = 9001.94$$

Analysis of Variance I.

Sources	df	SS	MS	F	F_{95}	F_{99}
Line	1	2621.06	2621.06	8.24**	4.26	7.82
Breeding group	3	3499.56	1166.52	3.75*	3.01	4.72
Line x Breeding group	3	1980.00	660.00	2.12	-	
Error	24	7470.03	311.25	-		
Total	31	15570.65				

* $P \leq 0.05$

** $P \leq 0.01$

Analysis of Variance II

Sources	df	SS	MS	F	$F_{.95}$	$F_{.99}$
line	1	2621.06	2621.06	7.57*	4.23	7.72
Sire breed (gi)	1	2110.06	2110.06	6.09		
Dam breed (gj)	1	1058.80	1058.80	3.06		
SCA (sij)	1	330.70	330.70	0.96		
Rec. (rij)	1	448.09	448.09	1.29		
Error	26	9001.94	346.23	-		
Total	31	15570.65				

Analysis of Variance II (Pooled)

Sources	df	SS	MS	F	$F_{.95}$	$F_{.99}$
Line	1	2621.06	2621.06	7.86**	4.21	7.68
GCA ($g_i + g_j$)	1	3168.86	3168.86	9.50*		
SCA	1	330.70	330.70	0.99		
Rec.	1	448.09	448.09	1.34		
Error	27	9001.94	333.41			
Total	31	15570.65				

* P/0.05

** P/0.01

Duncans Multiple Range Test

$SE = \sqrt{\frac{EMS}{nxr}} = \sqrt{\frac{311.25}{4x4}} = 4.41$ Where n = 4 months
r = 4 rep. pens

Least significant Range at 5% and 1% levels

	5%			1%		
Values of P	2	3	4	2	3	4
SSR (24 edf)	2.92	3.07	3.15	3.96	4.14	4.24
LSR	12.88	13.54	13.89	17.46	18.26	18.70

1. To test Breeding group means

Significance of means differences

	A 113.13	B 95.19	C 90.46	D 85.38
D	27.75**	9.81	5.08	-
C	22.67**	4.73	-	
B	17.94**	-		
A	-			

Summary: A^a B^b C^b D^b P/0.01

2. To test genotypes by line

A)	Male line				b)	Female line			
	S_1 133.86	S_2 96.96	H_2 95.48	H_1 94.07		H_4 96.31	S_4 92.40	S_5 83.97	H_5 75.28
H_1	39.99**	2.87	1.41	--	H_5	21.03**	17.12*	8.69	-
H_2	38.38**	1.46	-		S_5	12.34	8.43	-	
S_2	36.92**	-			S_4	3.91	-		
S_1	-				H_4	-			

Summary: S_1^a $\underline{S_2^b\ H_2^b\ H_1^b}$ P/0.01

Summary:
1. $\underline{H_4^a\ S_4^{ab}\ S_5^{ab}}$ H_5^b P/0.01
2. $\underline{H_4^a\ S_4^a\ S_5^{ab}}$ H_5^b P/0.05

3. To compare Sire-breed means by line in order to determine if S-Sire birds consumed more feed on both lines.

Significance of Difference in means

Line	S-Sire	H-Sire	Difference
Male	113.96	96.21	17.75**
Female	94.35	79.62	14.73*

On both male and female lines, S-Sired pullets consumed significantly more feed (P/0.01 and P/0.05 respectively)

[1]Heterosis in Feed consumption

A. Comparison of the crossbred group with the mean performance of the parents.

a) Male line

(i) Within SXH GROUP					(ii) Within HXS group		
Rep.	$\bar{P}$	H_1	dev.	%dev.	S_2	dev.	%dev.
1.	93.33	73.71	-19.62	-21.02	71.02	-22.31	-23.90
2.	106.78	85.12	-21.66	-20.28	83.42	-23.36	-21.88
3.	124.87	104.96	-19.91	-15.94	106.87	-18.00	-14.41
4.	133.70	112.50	-21.20	-15.87	126.46	- 7.24	- 5.42
Mean Deviation			-20.60	-18.28	-	-17.73	-16.40
S.E. of deviation			0.49	1.38	-	3.68	4.19
$t = \frac{-20.60-0}{0.49}$; $\frac{-18.28-0}{1.38}$					$t = \frac{-17.73-0}{3.68}$; $\frac{-16.40-0}{4.19}$		
$= -42.04^{**}$ $= -13.25^{**}$					$= -4.82^{*}$ $= -3.91^{*}$		
$t_{(0.05,3)} = 3.182$					$t_{(0.01,3)} = 5.841$		

b) Female line

(i) Within SXH group					(ii) Within HXS group		
Rep	$\bar{P}$	H_4	dev.	%dev.	S_3	dev.	%dev.
1.	72.74	84.37	11.63	15.99	70.09	- 2.65	- 3.64
2.	83.34	81.22	- 2.12	- 2.54	73.47	- 9.89	-11.84
3.	88.25	109.04	20.79	23.56	90.38	2.13	2.41
4.	91.03	110.61	19.58	21.51	101.93	10.90	11.97
Mean deviation			12.47	14.63	-	0.13	-0.28
S.E. of deviation			5.27	5.94		4.87	5.02
$t = \frac{12.47-0}{5.27}$; $\frac{14.63-0}{5.94}$					$t = \frac{0.13-0}{4.87}$; $\frac{-0.28-0}{5.02}$		
$= 2.37^{NS}$ $= 2.46^{NS}$					$= 0.03^{NS}$ -0.06^{NS}		

[1] Negative values are desirable and regarded as positive heterosis.

B. Within line comparis on ofthe crossbred groups

Rep.	Male line H_1	Male line S_2	Female line H_4	Female line S_5
1	-19.62	-22.31	11.62	-2.65
2	-21.66	-23.36	-2.12	-9.87
3	-19.91	-18.00	20.79	2.13
4	-21.20	- 7.24	19.58	10.90
Σx	-81.39	-70.91	49.88	0.51
Σx^2	1699.95	1419.84	955.35	227.79
$\bar{x}$	20.60	17.73	12.47	0.13
	$L= 4(1699.95)-(-82.39^2)$ = 11.69	4(1419.84)-(-70.91^2) = 651.13	$L=4(955.35)-49.88^2$ =1333.39	$4(227.79)-0.51^2$ = 910.90
	$S^2 = \frac{11.69}{4(3)} = 0.97$	$\frac{651.13}{4(3)} = 54.26$	$S^2 = \frac{1333.39}{12} = 111.12$	$\frac{910.90}{12}$ = 75.91
	$t^2 = \frac{(4*4-2)(4(-82.39)-4(-70.91))^2}{(4*4)(4(11.69+651.13))}$ = $\frac{(6)\ (2108.65)}{(8)\ (2651.28)} = 0.596$		$t^2 = \frac{(4*4-2)(4(49.88-0.51))^2}{(4+4)(4(1333.39+910.90))}$ = $\frac{(6)\ (38998.35)}{(8)\ (8977.16)} = 3.26$	
	$t = \sqrt{0.596} = 0.77^{NS}$		$t = \sqrt{3.26} = 1.81^{NS}$	
	df = 4 + 4 - 2 = 6			
	t (0.05,6) = 2.447			

Conclusion: Each pair of crossbred groups produced statistically the same heterosis.

APPENDIX XI

Analysis of Feed Efficiency (kg Feed/dozen Eggs)

Model: I and II

Observed Data

Breeding group	A		B		C		D	
Genotypes	S_1	S_4	H_1	H_4	S_2	S_5	H_2	H_5
Rep. 1.	3.28	3.34	2.59	3.29	3.06	3.02	2.94	2.90
2	2.57	2.30	1.95	2.14	1.76	2.57	3.35	2.49
3	2.80	2.26	1.71	2.52	1.92	2.47	2.36	2.12
4	3.46	2.02	2.13	2.90	2.15	1.92	2.22	2.17
Total	12,11	9.92	8.38	10.85	8.89	9.98	10.87	9.68
Mean	3.03	2.48	2.10	2.71	2.22	2.50	2.72	2.42
S.D.	0.41	0.59	0.37	0.49	0.58	0.45	0.52	0.36

Summary into Breeding groups by line

Line	A	B	C	D	Total	Mean
Male	12.11	8.38	8.89	10.87	40.25	2.52
Female	9.92	10.85	9.98	9.68	40.43	2.53
Total	22.03	19.23	18.87	20.55	80.55	2.52
Mean	2.75	2.40	2.36	2.57		

Summary into sire breed and Dam breed by line

Line	S-Sire	H-Sire	S-dam	H-dam
Male	20.49	19.76	21.00	19.25
Female	20.77	19.66	19.90	20.23
Total	41.26	39.42	40.90	39.78
Mean	2.58	2.46	2.56	2.49

Reciprocal Differences

Rep.	Male line (H_1-S_2)	Female line (H_4-S_5)
1	-0.47 (2.59-3.06)	0.27 (3.29 - 3.02)
2	0.19 (1.95-1.76)	-0.43 (2.14 - 2.57)
3.	-0.21 (1.71-1.92)	0.05 (2.52 - 2.47)
4	-0.02 (2.13-2.15)	0.98 (2.90 - 1.92)

Computation of sums of squares.

$$CF = \frac{80.68^2}{32} = 203.41$$

$$SS_{T_{total}} = 3.28^2 + \text{------} + 2.17^2 - CF = 211.40-203.41 = 7.99$$

Model I

$$SS_{line} = \frac{40.25^2 + 40.43^2}{16} - CF = 203.42 - 203.41 = 0.01$$

$SS_{\text{Breeding group}} = \frac{22.03^2 + \cdots + 20.55^2}{8} - CF$

$= 204.19 - 203.41 = 0.78$

$SS_{\text{line x BG}} = \frac{12.11^2 + \cdots + 9.68^2}{4} - (CF + SS_{\text{line}} + SS_{BG})$

$= 205.87 - 204.19 = 1.68$

$SS_{\text{error}} = 7.99 - (0.01 + 1.68 + 0.78) = 7.99-2.47 = 5.52$

Model II.

$SS_{\text{line}} = 0.01$

$SS_{gi} = \frac{41.26^2 + 39.42^2}{16} - CF = 203.52-203.41 - 0.11$

$SS_{gj} = \frac{40.90^2 + 39.78^2}{16} - CF = 203.45-203.41 - 0.04$

$SS_{(sij)} = \frac{22.03^2 + 20.55^2}{8} - (CF + SS_{gi} + SS_{gj})$

$= 204.19 - 203.56 = 0.63$

$SS_{rij} = \frac{-0.47^2 + \cdots + 0.98^2}{2} = \frac{1.52}{2} = 0.76$

$SS_{\text{error}} = 7.99 - (0.01 + \cdots + 0.76) = 7.99-1.55$

$= 6.44$

Analysis of Variance I

Sources	df	SS	MS	F	$F_{.95}$	$F_{.99}$
Line	1	0.01	0.01	0.04	4.26	7.82
Breeding group	3	0.78	0.26	1.13	3.01	4.72
Line x Breeding group	3	1.68	0.56	2.43		
Error	24	5.52	0.23	-		
Total	31	7.99				

Analysis of Variance II

Sources	df	SS	MS	F	$F_{.95}$	$F_{.99}$
Line	1	0.01	0.01	0.04	4.23	7,72
Sire breed	1	0.11	0.11	0.44		
Dam breed	1	0.04	0.04	0.16		
SCA	1	0.63	0.63	2.52		
Rec.	1	0.76	0.76	3.04		
Error	26	6.44	0.25	-		
Total	31	7.99				

No effect is significant.

Heterosis in Feed Efficiency

(negative values are desirable)

A. Comparison of the crossbred groups with mean performance of the parents.

a) Male line

Within S x H group					Within H x S group		
Rep.	$\bar{P}$	H_1	Dev.	%dev.	S_2	dev.	%dev.
1	3.11	2.59	-0.52	-16.72	3.06	-0.05	-1.61
2	2.96	1.95	-0.01	-34.12	1.76	-1.20	-40.54
3	2.58	1.71	-0.87	-33.73	1.92	-0.66	-25.58
4	2.84	2.13	-0.71	-25.00	2.15	-0.69	-24.30
Mean deviation			-0.78	-27.39	-	-0.69	-23.01
S.E. of deviation			0.11	4.13		0.24	8.03
$t = \frac{-0.78-0}{0.11}$			$\frac{-27.39-0}{4.13}$		$t = \frac{-0.65-0}{0.24}$		$\frac{-23.01}{8.03}$
$= 7.09^{**}$			$= -6.63^{**}$		$= -2.71^{NS}$		$= -2.87^{NS}$

$t_{(0.05,3)} = 3.182$; $t_{(0.01,3)} = 5841$

b) Female line

Within SxH group					Within H x S group		
Rep.	$\bar{P}$	H_4	dev.	%dev.	S_5	dev.	%dev.
1	3.12	3.29	0.17	5.45	3.02	-0.01	-3.21
2	2.40	2.14	-0.26	-10.83	2.57	0.17	7.08
3	2.19	2.52	0.33	15.07	2.47	0.28	12.79
4	2.10	2.90	0.80	38.10	1.92	-0.18	-8.57
Mean deviation			0.26	11.95	-	0.04	2.02
S.E. of deviation			0.22	10.23	-	0.11	4.84
$t = \frac{0.26-0}{0.22}$			$\frac{11.95-0}{10.23} = 1.17^{NS}$		$t = \frac{0.04-0}{0.11}$		$\frac{2.02-0}{4.84}$
$= 1.18^{NS}$					$= 0.36^{NS}$		$= 0.42^{NS}$

B. Within line comparision ofthe crossbred groups among themselves.

Male line			Female line	
Rep	H_1	S_2	H_4	S_5
1	-0.52	-0.05	0.17	0.10
2	-1.01	-1.20	-0.26	0.17
3	-0.87	-0.66	0.33	0.28
4	-0.71	-0.69	0.80	-0.18
$\sum x$	-3.11	-2.60	1.04	0.17
$\sum x^2$	2.55	2.35	0.85	0.15
$\bar{x}$	-0.78	-0.65	0.26	0.04
$L = 4(2.55)-(-3.11)^2$;		$4(2.35)-(-2.6^2)$	$L=4(0.85)-1.04^2$;	$4(0.15)-0.17^2$
= 0.53		2.64	2.32	0.57
S^2 $\frac{0.53}{4(3)}$		$\frac{2.64}{12}$	$\frac{2.32}{12}$	$\frac{0.57}{12}$
= 0.04		0.22	0.19	0.05
$t^2 = \frac{(4+4-2)\{4(-3.11)-4(-2.60)\}^2}{(4+4)\{4(0.53+2.64)\}}$			$t^2 = \frac{(4+4-2)\{4(1.04-0.17)\}^2}{(4+4)\{4(2.32+0.57)\}}$	
$= \frac{(6)(4.16)}{(8)(12.68)} = 0.25$			$= \frac{(6)(12.11)}{(8)(11.56)} = 0.79$	
$t = \sqrt{0.25} = 0.5^{NS}$			$t = \sqrt{0.79} = 0.89^{NS}$	
t (0.05,6) = 2.447				

Conclusion: The heterosis exhibited by each pair are not statistically different.

APPENDIX XII

Laying House Mortality

Model: I and II.

Observed Data (% Mortality)

Breeding groups	A		B		C		D	
Genotypes	S_1	S_4	H_1	H_4	S_2	S_5	H_2	H_5
Rep: 1	1.27	3.20	1.60	0.86	0	0	0	0
2	1.27	0.80	0	0.85	1.02	4.00	3.49	5.60
3	1.27	0.80	0	2.56	0	0.80	3.49	1.60
4	3.80	4.80	4.00	0.85	0	4.00	1.16	1.60
Total	7.61	9.60	5.60	5.11	1.02	8.80	8.14	8.80
Mean	1.90	2.40	1.40	1.28	0.26	2.20	2.04	2.20
S.D.	1.27	1.96	1.89	0.86	0.51	2.10	1.75	2.38

Transformation into Arc sine Angles

Rep:	S_1	S_4	H_1	H_4	S_2	S_5	H_2	H_5
1	6.55	10.31	7.27	5.29	0	0	0	0
2	6.55	5.13	0	5.29	5.74	11.54	10.78	13.69
3	6.55	5.13	0	9.28	0	5.13	10.78	7.27
4	11.24	12.66	11.54	5.29	0	11.54	6.29	7.27
Total	30.89	33.23	18.81	25.15	5.74	28.21	27.85	28.23
Mean	7.72	8.31	4.70	6.29	1.44	7.05	6.96	7.06

Summary into Breeding group by line

Line	A	B	C	D	Total	Mean
Male	30.89	18.81	5.74	27.85	83.29	5.21
Female	33.23	25.15	28.21	28.23	114.84	7.18
Total	64.12	43.96	33.95	56.08	198.11	6.19
Mean	8.02	5.50	4.24	7.01		

Summary into Sire breed and Dam breed by line

Line	S-Sire	H-Sire	S-dam	H-dam
Male	49.70	33.59	36.63	46.66
Female	58.38	56.44	61.44	53.38
Total	108.08	90.03	98.07	100.04
Mean	6.76	5.63	6.13	6.25

APPENDIX XII

Laying House Mortality

Model: I and II.

Observed Data (% Mortality)

Breeding groups	A		B		C		D	
Genotypes	S_1	S_4	H_1	H_4	S_2	S_5	H_2	H_5
Rep: 1	1.27	3.20	1.60	0.86	0	0	0	0
2	1.27	0.80	0	0.85	1.02	4.00	3.49	5.60
3	1.27	0.80	0	2.56	0	0.80	3.49	1.60
4	3.80	4.80	4.00	0.85	0	4.00	1.16	1.60
Total	7.61	9.60	5.60	5.11	1.02	8.80	8.14	8.80
Mean	1.90	2.40	1.40	1.28	0.26	2.20	2.04	2.20
S.D.	1.27	1.96	1.89	0.86	0.51	2.10	1.75	2.38

Transformation into Arc sine Angles

Rep:	S_1	S_4	H_1	H_4	S_2	S_5	H_2	H_5
1	6.55	10.31	7.27	5.29	0	0	0	0
2	6.55	5.13	0	5.29	5.74	11.54	10.78	13.69
3	6.55	5.13	0	9.28	0	5.13	10.78	7.27
4	11.24	12.66	11.54	5.29	0	11.54	6.29	7.27
Total	30.89	33.23	18.81	25.15	5.74	28.21	27.85	28.23
Mean	7.72	8.31	4.70	6.29	1.44	7.05	6.96	7.06

Summary into Breeding group by line

Line	A	B	C	D	Total	Mean
Male	30.89	18.81	5.74	27.85	83.29	5.21
Female	33.23	25.15	28.21	28.23	114.84	7.18
Total	64.12	43.96	33.95	56.08	198.11	6.19
Mean	8.02	5.50	4.24	7.01		

Summary into Sire breed and Dam breed by line

Line	S-Sire	H-Sire	S-dam	H-dam
Male	49.70	33.59	36.63	46.66
Female	58.38	56.44	61.44	53.38
Total	108.08	90.03	98.07	100.04
Mean	6.76	5.63	6.13	6.25

Reciprocal Differences

Rep.	Male line ($H_1 - S_2$)	Female line ($H_4 - S_5$)
1	7.27 (7.27 - 0.00)	5.29 (5.29 - 0.00)
2	-5.74 (0.00 - 5.74)	-6.28 (5.29 - 11.54)
3	0 (0.00 - 0.00)	4.15 (9.28 - 5.13)
4	11.54 (11.54 - 0.00)	-6.25 (5.29 - 11.54)

Computation of sums of squares

$$CF = \frac{198.11^2}{32} = 1226.49$$

$$SS_{Total} = 6.55^2 + \cdots + 7.27^2 - CF = 1821.06 - 1226.49 = 594.57$$

Model I.

$$SS_{line} = \frac{83.29^2 + 114.82^2}{16} - CF = 1257.55 - 1226.49 = 31.06$$

$$SS_{Breeding\ group} = \frac{64.12^2 + \cdots + 56.08^2}{8} - CF = 1292.68 - 1226.49 = 66.19$$

$$SS_{line\ xBG} = \frac{30.89^2 + \cdots + 28.23^2}{4} - (CF + SS_{line} + SS_{BG})$$

$$= 1361.52 - 1323.74 = 37.78$$

$$SS_{error} = 594.57 - (31.06 + 66.19 + 37.78) = 594.57 - 135.03$$

$$= 594.57 - 135.03 = 459.54$$

Model II.

$$SS_{line} = 31.06$$

$$SS_{gi} = \frac{108.08^2 + 90.03^2}{16} - CF = 1236.67 - 1226.49 = 10.18$$

$$SS_{gj} = \frac{98.07^2 + 100.04^2}{16} - CF = 1226.61 - 1226.49 = 0.12$$

$$SS_{sij} = \frac{64.12^2 + \cdots + 56.08^2}{8} - (CF + SS_{sire} + SS_{dam})$$

$$= 1292.68 - 1236.79 = 55.89$$

$$SS_{rij} = \frac{7.27^2 + \cdots + (-6.25)^2}{2} = \frac{342.31}{2} = 171.15$$

$$SS_{error} = 594.57 - (31.06 + \cdots + 171.15)$$

$$= 594.57 - 268.40 = 326.17$$

Analysis of Variance I

Sources	df	SS	MS	F	$F_{.95}$	$F_{.99}$
Line	1	31.06	31.06	1.62	4.26	7.82
Breeding group	3	66.19	22.06	1.15	3.01	4.72
Line x breeding group	3	37.78	12.59	0.66		
Error	24	459.54	19.15			
Total	31	594.57				

Analysis of Variance II.

Sources	df	SS	MS	F	$F_{.95}$	$F_{.99}$
Line	1	31.06	31.06	2.47	4.29	7.72
Sire breed	1	10.18	10.18	0.18		
Dam breed	1	0.12	0.12	0.01		
SCA	1	55.89	55.89	4.45*		
Reciprocal	1	171.15	171.15	13.64**		
Error	26	326.17	12.55	-		
Total	31	594.57				

Duncan's Multiple Range Test

$SE = \sqrt{\frac{EMS}{nxr}} = \sqrt{\frac{12.55}{4x4}} = 0.89$ Where n = 4 months
r = 4 rep. pens.

Least Significant Range Values at 5% and 1% level

	5%			1%		
Values of $\bar{P}$	2	3	4	2	3	4
$SSR_{(26)}$	2.91	3.06	3.14	3.93	4.11	4.21
LSR	2.59	2.72	2.79	3.50	3.66	3.75

1. To compare the Reciprocal means

S X H	H x S	Difference
5.50	4.24	1.26^{NS}

2. To compare the reciprocal means by line

Significance of differences in mean

Line	S x H	H x S	Difference
Male	4.70	1.44	3.26^{*}
Female	6.29	7.05	0.76^{NS}

SxH group of male line (H_1) is inferior to its reciprocal (S_2) in terms of livability.

3. To test SCA means.

Significance of difference in Means

	A 8.02	D 7.01	B 5.50	C 4.24
C	3.78^{**}	2.77^{*}	1.26^{NS}	-
B	2.52^{NS}	1.51^{NS}	-	
D	1.01^{NS}	-		
A	-	Summary:		
		(1) $\underline{A^{a} \quad D^{ab} \quad B^{ab} \quad C^{b}}$		$P/0.01$
		(2) $\underline{A^{a} \quad D^{a} \quad B^{ab} \quad C^{b}}$		$P/0.05$

Heterosis in Laying House Mortality

A. Comparision of the crossbred groups with mean performance of the parents. Negative values are desirable.

a) Male Line

	Within SxH group				Within HxS group		
Rep.	$\bar{P}$	H_1	dev.	%dev.	S_2	dev.	%dev.
1	3.28	7.27	3.99	121.65	0	-3.28	-100.00
2	8.67	0	-8.67	-100.00	5.74	-2.93	- 33.79
3	8.67	0	-8.67	-100.00	0	-8.67	-100.00
4	8.77	11.54	2.77	31.58	0	-8.77	-100.00
Mean deviation			-2.65	- 11.69	-	-5.91	- 83.45
S.E. of deviation			3.49	54.20		1.62	16.55
$t = \frac{-2.65-0}{3.49}$			$\frac{-11.69-0}{54.20}$		$t = \frac{-5.91-0}{1.62}$		$\frac{-83.45-0}{16.55}$
$= -0.76^{NS}$			$= -0.22^{NS}$		$= -3.65^{*}$		$= -5.04^{*}$

$t(0.05,3) = 3.182$; $t(0.01,3) = 5.841$

[1] Negative values indicate positive heterosis.

B) Female line

	Within SxH group				Within HxS group		
Rep.	P	H_4	dev.	%dev.	S_5	dev.	%dev.
1	5.16	5.29	0.13	2.53	0	-5.16	-100.00
2	9.41	5.29	-4.12	-43.78	11.54	2.13	22.64
3	6.20	9.20	3.08	49.68	5.13	1.07	-17.26
4	9.97	5.29	-4.68	-46.94	11.54	1.57	15.75
Mean deviation			-1.40	- 9.63	-	-0.63	-19.72
S.E. of deviation			1.84	22.77	-	1.66	28.14
$t = \frac{-1.40-0}{1.84}$; $\frac{-9.63-0}{22.77}$					$t = \frac{-0.63-0}{1.66}$; $\frac{-19.72-0}{28.14}$		
= 0.76^{NS} = -0.42^{NS}					= -0.38^{NS} = -0.70^{NS}		

Note: Transformed data were used.

B. Within line comparison of the crossbred groups.

	Male line		Female line	
Rep	H_1	S_2	H_4	S_5
1	8.99	-3.28	0.13	-5.16
2	-8.67	-2.93	-4.12	2.13
3	-8.67	-8.67	3.08	-1.07
4	2.77	-8.77	-4.68	1.57
$\sum x$	-10.58	-23.65	-5.59	-2.53
$\sum x^2$	173.93	171.43	48.38	34.77
$\bar{x}$	-2.65	-5.91	-1.40	-0.63
$L = 4(173.93)-(-10.58^2)$; $4(171.43)-(-23.65^2)$			$L = 4(48.38)-(-5.59^2)$; $4(34.77)-(-2.55^2)$	
= 583.78		= 126.40	=162.27	=132.68
S^2 $\frac{583.78}{4(3)}$		$\frac{126.40}{12}$	$\frac{162.27}{12}$	$\frac{132.68}{12}$
$t^2 = \frac{(4+4-2)\{4(-10.58)-4(-23.65)\}^2}{(4+4)\{4(583.78+126.40)\}}$			$t^2 = \frac{(4+4-20\{4(-5.59)-4(-2.53)\}^2}{(4+4)\{4(162.27+132.68)\}}$	
$= \frac{(6)(2733.20)}{(8)(2840.72)}$ = 0.72			$\frac{(6)(149.82)}{(8)(1179.8)}$ = 0.095	
$t = \sqrt{0.72}$ = 0.85^{NS}			$t = \sqrt{0.095}$ = 0.31^{NS}	
t (0.05,6) = 2.147.				

Conclusion: Within each line, there is no significant differences between the heterosis exhibited by the crossbred groups.