STUDIES ON THE PROSPECTS OF IMPROVING THE PERFORMANCE OF THE LOCAL CHICKEN POPULATION IN TANZANIA BY CROSSBREEDING

BY

ANDALWISYE M. KATULE

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ABSTRACT

The present study was initiated to explore the possibilities for developing high performing dual purpose strains of chickens adapted to low input production conditions in Tanzania.

Exotic meat type, egg type and local chickens were compared for performance along with the crosses between these breeds in one year. In the following year the comparison involved the three basic breeds, the second generation crosses (F_2), backcrosses, and three-breed crosses of these breeds. Additional data were acquired from a crossbreeding experiment in Egypt, in which two Egyptian breeds, two White Leghorn lines from Norway, and crosses between Egyptian and Norwegian stocks were involved.

Constant estimates of various genetic components (additive genetic, heterosis and reciprocal) were obtained as coefficients of a multiple regression equation, in which the observation on each individual for a given trait was the dependent variable. The independent variables consisted of coded values ranging from 0 to 1.

The general superiority of the germplasm from exotic breeds to that of indigenous breeds was demonstrated for nearly all traits considered. However, there was an indication for this superiority to decline as environmental conditions deteriorated.

Important heterosis effects were revealed, mainly for juvenile body weights and egg production traits, including the age of sexual maturity. Evidence was revealed to suggest the existence of negative heterosis for body weights and egg size in some crosses.

Reciprocal effects were found to be important in crosses involving heavy breeds and light breeds, as well as in crosses involving crossbred parents.

It is concluded from these results that the high potential inherent in exotic breeds for productive traits would not be fully realized under environments pertinent with low input production systems. Some adjustment in the genetic content of the stocks would be necessary in order to make them adaptable to less optimum conditions. One of the most prospective approaches is to make some kind of crosses between exotic and indigenous chickens, followed by selection for high productivity under the sub-optimum conditions. Selection for specific adaptive qualities would be carried out if such qualities were detected.

DECLARATION

I, ANDALWISYE, M. KATULE, hereby declare to the Senate of Sokoine University of Agriculture, that the work presented in this thesis is my own original work and has neither been submitted, nor being concurrently submitted for a similar degree in any other institution .

Signature: A.M. Katule

Date: 30th August, 1989

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DEDICATION

To Mary

Ntwa-Alinamaka

Gwamaka

Lwitiko, and

Lusekelo

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LIST OF ABBREVIATIONS

T_1 Experimental birds used in the first experiment of the study. These consisted of a meat type, egg type and local breed and F_1 crosses between the breeds.

T_2 Experimental birds used in the second experiment of the study. They consisted of a meat type, egg type, and local breed, F_2 crosses produced by the F_1 crossbred parents of experiment 1, backcrosses and three-breed crosses of the parental breeds mentioned above.

E Experimental birds consisting of Egyptian and Norwegian stocks and their F_1 crosses.

MM Purebred meat type birds

EE Purebred egg type birds

LL Local strain of chickens

ME F_1 or F_2 cross between a meat type and egg type breed

LM F_1 or F_2 cross between meat type and a local breed

FF Fayoumi breed of chickens from Egypt

BB Baladi breed of chickens from Egypt

L_2L_2 Norwegian strain of White Leghorn breed which had been selected for high egg production intensity

L_7L_7 Norwegian composite line of White Leghorn breed which had been selected for large egg size

LE F_1 or F_2 cross between an egg type and a local breed

FL_2 and L_2F	Reciprocal crosses between Fayoumi and L_2L_2 strain
FL_7 and L_7F	Reciprocal crosses between Fayoumi and L_7L_7 line
BL_2 and L_2B	Reciprocal crosses between Baladi and L_2L_2 strain
BL_7 and L_7B	Reciprocal crosses between Baladi and L_7L_7 line
BW4	Body weights of chickens at four weeks of age
BW8	Body weights of chickens at eight weeks of age
BW12	Body weights of chickens at twelve weeks of age
BW16	Body weights of chickens at sixteen weeks of age
BWSM	Body weights of chickens at the onset of sexual maturity
ADBW	Adult body weights of chickens, measured at 38 - 39 weeks
AGESM	Age of birds (in weeks) at the onset of sexual maturity
EN90	Number of eggs laid per hen in ninety days from the date of the first egg
EN500	Number of eggs laid per hen at 500 days of age.
EP	Hen-day egg production intensity (%)
EGGWT	Egg weights
F	Female birds
M	Male birds
CV	Coefficient of variation (%)
Min	Minimum
Max	Maximum
Add.	Additive

GM, GE and GL	Constant estimates for the additive genetic values of the meat type (GM), egg type (GE) and local (GL) breed, expressed as deviations from the general mean of material T_2.
GF, GB, GL_2 and GL_7	Constant estimates for the additive genetic values of the Fayoumi (GF), Baladi (GB), L_2L_2 (GL_2), and L_7L_7 (GL_7) expressed as deviations from the general mean of material E.
HME, HLM and HLE	Constant estimates for the heterosis effects in meat type x egg type (HME), Local x Meat type (HLM), and Local x Egg type (HLE) crosses.
HFL_2, HFL_7, HBL_2	Constant estimates for the heterosis effects in Fayoumi x L_2L_2, (HFL_2), Fayoumi x L_7L_7 (HFL_7), Baladi x L_2L_2 (HBL_2), and Baladi x L_7L_7(HBL_7) crosses.
RM, RE, RL, RME, RLM and RLE	Constant estimates for reciprocal effects due to the meat type (RM), egg type (RE), and the local (RL) breed and their crosses (RME; RLM and RLE).
RF, RB, RL_2 and RL_7	Constant estimates for reciprocal effects due to the Fayoumi (RF), Baladi(RB) L_2L_2 (RL_2) and L_7L_7 (RL_7) lines.

CHAPTER 1

INTRODUCTION

At present Tanzania relies on the traditional sector for most (possibly over 80%) of her supply of poultry products (Ministry of Livestock Development, 1983). The per capita consumption of these products is very low mainly due to the fact that the traditional sector is far too inefficient to meet the country's evergrowing needs for meat and eggs. The poor performance of the traditional sector is due partly to the fact that the genetic potential of the indigenous stocks has not been developed through selection and other breeding methods and partly to the extremely poor environmental conditions to which these birds are exposed. On the other hand the high genetic potential inherent in the improved exotic strains has not been effectively utilized in Tanzania. This is because the standards of management required by these strains are too high to be afforded by any significant proportion of the Tanzanian farmers. Even the handful enterprising farmers cannot produce much due to problems which have deep roots in the country's economic, technological, and infrastructural underdevelopment. Judging from past and present economic trends there seems to be no strong basis for counting on drmatic improvements at least within a foreseeable future. Thus it is only fair to assess that it will take some time before Tanzania is able to sustain a sophisticated poultry industry of the size that would be necessary to meet her population's needs for meat and eggs.

The development and subsequent emergence of the present improved (or better known as industrial) chicken strains in advanced countries has been cognizantly or uncognizantly guided by two main factors - the consumer demand for high performance standards in specific characters and the general environmental conditions prevailing or contemplated during the course of development of these strains. In most cases performance has been evaluated and genetic improvement sought within the limits of the general management standards affordable in those countries at any particular time. Although the achievements have been spectacular they have certainly taken a lot of effort and resources to come by, and the time involved cannot be said to have been short, except when measured on an evolutionary time scale.

The present trend in most developing countries is to transplant both the improved strains and the technology and infrastructure needed for their high performance into their areas. As an alternative to this strategy, they just sit back and are satisfied with their unimproved indigenous chickens and the traditional free range production systems. This is an all-or-none situation. This approach, taken by animal production strategists in developing countries, has a lot of demerits and has been the subject of much criticism by most geneticists who have had occassion to ponder the matter (Barker, 1982; Hickman, 1982 and Rendel, 1982).

From the foregoing considerations it is apparent that while considerable dependence continues to be placed on the traditional sector and while efforts are being made to modernize Tanzania's poultry industry, a third and intermediate approach should be envisaged. Currently the most widely advocated development strategy for poor developing countries entails the development and extensive application of intermediate technology. If this philosophy is taken to be universally valid for all aspects of development then much should be expected to be gained by starting off with breeds or strains of chickens which are intermediate between indigenous and improved exotic stocks in terms of both productivity and environmental requirements, coupled with moderate improvements in husbandry practices.

For reasons to be considered in the next chapter it seems reasonable to presume that the most prospective starting point in the development of strains that would compromise fairly well between productivity and environmental requirements would be the formation of crosses between indigenous and improved exotic chickens. Exactly how these crosses ought to be made and their subsequent treatment would be a matter to be much experimented on, and this would have to be done within the dictates of the country's general economic development. It is expected that our current understanding of genetic principles together with the experiences acquired from breeding studies elsewhere would provide some useful clues to this problem .

Therefore the main objective in the present study is to determine the most prospective way of developing high performing dual-purpose strains of chickens that would be adapted to Tanzanian normal production conditions. It has been preconceived that this main objective would be realized by :-

i. Comparing the performance of genetic groups possessing different proportions of genes from the meat type, egg type and local chickens;

ii. Determining the contributions of additive genetic, heterosis and reciprocal effects of the above mentioned parental breeds or breed combinations to the overall merits of different genetic groups derived from the parental breeds.

On the basis of the information generated from the above stated undertakings it would be possible to :

iii. Formulate strategies for the development of suitable strains of chickens.

CHAPTER 2

LITERATURE REVIEW

2.1 Genotype - environment interactions and their effects on selection gains

The economic worth of a breed or strain of farm animals depends upon the ability of the members of that breed or strain to survive, produce and reproduce well in the environment in which they are kept. This ability is a function of the genotype of the animals and the environment to which they are exposed. For this reason the performance of a particular breed or strain is bound to vary from one environment to another.

Of greater significance is the phenomenon that different genotypes (breeds/strains) may rank differently or their differences may vary from one environment to another. This phenomenon, termed genotype x environment interaction, has been extensively studied in poultry (Gowe and Wakely, 1954; Gowe, 1956; Fox et al., 1960; Thornton and Whittett, 1960; Abplanalp et al., 1962; Harms and Waldroup, 1962; Cook et al., 1963;Moreng et al., 1964; Deaton and Quisenbery, 1965; and Lewis and Blow, 1965). Despite some contradictions in the findings from among these studies the general conclusion is that genotype x environment interactions would assume considerable importance when large differences exist between the environment in which a breed is developed and that in which it is required to perform. Genotype x environment interactions are known to be the main factor behind the unsatisfactory performance of improved breeds of animals from temperate regions in the tropics.

2.2 Adaption of animals to stressful environments

Some authors, e.g. Nitter (1978), have regarded environments in which improved temperate breeds fail to perform satisfactorily to be insufficient. But this notion has been challenged by Hickman (1982) who contends that in such cases it would be disputable whether it is the environment or the genotype that is insufficient. Similar views have been expressed by Cartwright (1982) and Gregory et al. (1982) who have maintained that the challenges posed by tropical environments, though different in nature and magnitude, are conceptually the same as those posed by temperate or intensive management environments and that the problem of selecting animals for adaptability are basically the same in both cases. The challenge in both cases has been viewed as one of synchronizing the germ plasm resources with other production resources in the most economically favourable way to maximize the output of animal products. This line of thought has been advocated by many geneticists who have had occasion to address themselves to the problem of livestock improvement in sub-optimal or in low input production conditions (FAO, 1973, 1981; Alberro, 1982; Barker, 1982; Cartwright, 1982; Frisch and Vercoe, 1982; Gregory et al., 1982; Hickman, 1982; Horst, 1982; and Rendel, 1982). The basis of this line of thought is apparent from the circumstances that have surrounded the development of present day breeds and strains of industrial chickens (Lerner, 1954; Bell, 1982; Rendel, 1982; and Crawford, 1984). Certainly the adaptive qualities of breeds, strains or individuals within strains have all along played a major role in influencing their overall selective advantage in the prevailing environmental conditions.

2.3 Artificial selection for productive traits in relation to natural selection for tolerance to environmental stresses

Breed adaptation is being increasingly recognized as an essential part of breeding programmes (Cunningham, 1974; Dickerson, 1974; Hickman, 1980 and Horst, 1982). Frisch and Vercoe (1982) have pointed out that realized productivity is a function of both the adaptive value and the productive potential of the animals. From his experiment with beef cattle in tropical Australia Frisch (1981, after Alberro, 1982) concluded that genetic improvement in productive performance under stressful environments was possible. The author considered that selection for a productive performance character in a sub-optimal environment was primarily selection for resistance or tolerance to environmental stresses which limit the expression of the character for which selection is practiced. Some workers (e.g. Albero, 1982) have suggested that the genetic factors that contribute to adaptation also contribute to above average performance, thus implying the existence of a high positive genetic correlation between adaptability and productivity in poor environments. A similar view had been expressed by Hicks (1958) who considered that under depressive environments a complex of the genotype associated with livability would assume significance in the performance of the animal, and hence artificial selection for higher productivity under these conditions would simply reinforce natural selection for tolerance to stressful environment. These contentions are apparently difficult to reconcile with the findings reported by Frisch and Vercoe (1982) in which an antagonistic relationship between adaptation and productive potential was indicated, at least across breeds. These workers, however, were

not able to conclude whether or not these two categories of traits were inherited antagonistically or whether it would be possible to maximize both of them in one and the same breed. This discrepancy could possibly be explained by the concept introduced by Falconer (1952) who reasoned out that the performance in a favourable environment had a different genetic basis from performance in an unfavourable environment, hence a superior genotype in one environment could not be expected to be superior in a different environment. It is conceivable that due to many years of selection for high productivity under good feeding and management many improved breeds or strains of animals from advanced countries might have lost most of the genes necessary for resistance to stressful environments. This view is in line with the views expressed by Price and King (1968); Sutherland (1968); and McDowell (1972) who have agreed that when animals are raised under good environments the genes necessary for survival or competitiveness under stressful environments lose their importance in conferring selective advantage to the animals and hence the frequencies of these genes in the population will decrease progressively and some genes might get lost in the course of time.

It is conceded that the genetic base being currently utilized in the production of industrial chickens is extremely narrow (Crawford, 1984) due to the loss of many breeds and lines that would not respond well to intensive or industrial production systems (Rendel, 1982). Such a degree of loss of genetic variability must inevitably be accompanied by reduced fitness of the animals under harsher natural conditions (Falconer, 1960).

2.4 Genetic variation of traits under selection forces directed to optimum phenotypes

In many developing countries the task of selection has been left almost entirely to nature. Thus the genetic situation in indigenous populations would be very difficult to predict just from theoretical considerations alone. However, one would expect the situation to vary depending on the trait being considered as well as the nature and constancy of the environmental factors operating on it. In relation to fitness under natural selection Falconer (1960)distinguishes three main tyeps of traits i.e. those that are neutral, those with an intermeidate optima, and those which are major components of fitness. The effects of natural selection are different for each of these types of traits and hence the genetic constitution of a population under natural selection will vary from one trait to another. Thus for traits that are components of fitness genetic variation is expected to be depleted very rapidly whereas for neutral characters considerable genetic variation should be expected. However, it is to be noted that one character could be neutral under one set of environmental conditions, but could be a major component of fitness under another set of conditions. For example plumage or coat colour may be a neutral character under domestication, but is certainly a component of fitness in the wild. Price and King (1968); Sutherland (1968); and McDowell (1972) have explained that when the environmental trends affecting a character are unidirectional or persistent from one generation to another then the genetic change in that population will also be directional so that the genetic diversity for that character will be progressively depleted. But if environmental trends are erratic the

population will be in genetic polymorphism.

Waddington (1953); and Rendel (1959)(after Kinghorn, 1980) have reported the existence of selection pressure for stabilizing homeostatic systems that canalize the phenotypic development and expression of genetically diverse individuals to an adaptive norm. Thus in a population that has been subjected for a long time to selection for stabilizing homeostatic influences individuals may have the same level of performance, not necessarily because they have the same or similar genotypes, but rather because their phenotypic development is regulated to a common level by some other factors. Kinghorn (1980) has contended that since considerable genetic variation is expected for traits which are under the influence of canalizing forces then considerable selection response should be achieved if the optimum or adaptive phenotype could be changed by changing the environment. Kinghorn (1980) has also envisaged the existence of genetic variation in the regulatory mechanisms themselves, a point which would make valid the extension of his contention to include selection for higher phenotypic optima or adaptive norms without changing the environment.

2.5 Adaptive characteristics of animals native to the tropics

Horst (1982) and Frisch and Vercoe (1982) have stressed the importance of searching for the sources of adaptive qualities (morphological, physiological or behavioural) in breeds that exhibit adaptability and the need to determine the genetic bases of these qualities. McDowell (1972) and Horst (1982) have reviewed findings from their own studies and from the studies of other

workers on adaptability of animals to hot tropical environments. It is generally contended that animals native to the tropics are able to cope with the environmental stresses of this region through their small sizes which minimize maintenance feed requirements and through their small digestive tracts which minimize food consumption and hence minimize metabolic heat production. However, other evidence indicates the existence of adaptive mechanisms which do not necessarily demand any reduction in the metabolic heat production of the animal (Mérat et al., 1974; Mérat, 1980 after Horst, 1982). Horst (1982) has cited an example from his experiments with laying chickens in which the naked-neck gene (Na) was found to reduce feathering by 30 - 40%, and this was considered to have a sparing effect on high quality protein, and possibly had a favourable effect on body heat loss as well. This gene was found to have a 7.4% advantage over its allele (na) with respect to egg mass production. The findings from the studies by Mérat et al. (1974, after Horst, 1982) showed that the naked-neck gene was associated with a 9 - 12% improvement in growth rate and a 6 - 9% improvement in egg weight of meat type chickens in hot environments.

Another well documented evidence that adaptability of animals could be conditioned without any associated compromise on productivity is demonstrated by the use of the dwarf gene (dw) to confer small body size and hence to enhance egg production rate and food efficiency of meat type breeding hens without affecting the growth rate of their progeny (Mérat, 1975 after Sellier, 1982).

2.6 Genetic resistance of animals to diseases

One of the major disadvantages from which improved temperate breeds of animals suffer in tropical regions is their extreme vulnerability to tropical disease problems. Although available evidence indidates the existence of genetic resistance in temperate breeds of chickens (Hutt, 1958; van Albadan, 1964; and Fredeen,1965 after Hartman, 1982; and Hartman, 1982) accumulation of the genetic factors to the level that would confer adequate tolerance of these breeds to tropical diseases would take a very long time. On the other hand breeds native to tropical regions are known to be very hardy (French, 1942 and Hill 1954). Hence fairly high frequencies of genes for resistance to diseases should be expected in these populations. It is recognized that genetic resistance to most poultry diseases is conditioned by genes at the multi-allelic B-locus which is considered to be the major histocompatibility locus and hence to have more fitness value than any other in chickens(Gilmour, 1960; Schierman and Nordskog, 1961; and Critteden et al., 1972). Since resistance controlled by this locus is inherited largely in a Mendelian way (Pevzner et al., 1975) it should be quite possible to transfer alleles with favourable effects from breeds with high frequencies of these alleles to originally less resistant, but otherwise highly productive breeds.

2.7 Prospects for exploiting indigenous chickens

Although exotic animals can be raised with reasonable success in the tropics the infrastructural development, and hence the costs necessary for sustenance of such an endeavour are prohibitive

to most countries of this region. On the other hand the ability of indigenous animals to tolerate harsh environmental conditions is considered to be the most important attribute of these animals. Ironically, this point seems to have been recognized only by scientists from developed countries, who have persistently voiced concern over the extent to which planners and livestock development strategists in developing countries ignore the animal genetic resources within their countries (Alberro, 1982; Barker, 1982; Hickman, 1982 and Rendel, 1982). It is very surprising how little is known, let alone done, about the actual merits and demerits of indigenous animals, nor are the environmental requirements of the animals known. For example in Tanzania the only documented study on the performance of local chickens was that of French (1942). The findings from this study indicated that there was room for improvement of egg production and egg quality traits in the indigenous chicken population. For example under good management and feeding the indigenous chickens of Central Tanzania laid an average of 118 eggs weighing about 38 g during their first year of laying. However, about ten percent of the hens laid over 150 eggs and some birds persistently laid eggs which were 45 - 56 g heavy. Despite these apparently interesting findings of French there has been a total lack of follow up studies in the intervening forty four years. The findings from Nigeria indicate little if any prospect for the Nigerian indigenous chickens to be improved for efficient meat production (Oluyemi and Oyenuga, 1974). However, the prospect for improvement of these birds for egg production appear to be good. For example Omeje and Nwonsu (1984) have reported the average first year egg production of these birds to be

146 and egg size to be 38.6 g under good management. Similar findings have been reported for unimproved Egyptian breeds (Ragab and Assem, 1953; and Abdou and Kolstad, 1984) and for the Bedouin breed of the Sinai Peninsula (Arad and Marder, 1982a and 1982b). The results from Uganda, however, have been at great variance with those reported for unimproved breeds elsewhere (Trail, 1963a and 1963b). The author has reported the egg production of Uganda local chickens to be only about 70 - 100 eggs in their first laying year, but the figures 35 - 45 g for egg size agree fairly well with those reported for other unselected populations.

2.8 Crossbreeding as a tool for genetic improvement

Although the overal picture from the above review indicates that some room might exist for genetic improvement by selecting among and within local populations crossbreeding between indigenous and improved temperate breeds might be necessary to speed up genetic progress. The need for great flexibility when developing a breed of animals for any environment has been stressed by Hickman (1982) who has argued that breeds must be a dynamic entity and therefore should be continuously selected, blended judiciously, and their gene content adjusted to suit certain production requirements and management conditions.

2.8.1 Crossbreeding effects on fitness and neutral traits

The beneficial effects of crossbreeding on the performance of chickens has long been recognized and documented (Warren, 1927; Dickerson et al., 1950; Glazener et al., 1952; Hutt and Cole, 1952 and King and Bruckner, 1952). Ever since, numerous studies

have been conducted with poultry as well as with other species of farm and laboratory animals to determine both the genetic basis for this beneficial effect and the traits affected by it (Bell et al., 1952; Nordskog and Ghostley, 1954; Hill and Nordskog, 1958; Bowman, 1959; Goto and Nordskog, 1959, Merritt and Gowe, 1960; Yao, 1961; Sheridan and Randall, 1977; and Sheridan, 1981 and 1982). The findings from these studies have indicated that the superior performance of crossbred animals is due mainly to heterosis and that those traits that are closely linked to fitness are most affected by this phenomenon. The same traits have long been known to be adversely affected by inbreeding. The genetic bases of heterosis have been established to be dominance, over-dominance and epistasis (Hull, 1945; Comstock et al. 1949; Yao, 1958; Bowman, 1959; Sheridan and Randall, 1977; Kinghorn, 1980 and 1982b; Sheridan,1981 and 1982; Cunningham, 1982; and Hill, 1982), but the relative importance of these gene actions in causing heterosis has been a matter of much controversy. Despite this controversy the general recognition that dominance, overdominance and epistasis constitute the non-additive part of gene action provides a way for predicting traits for which heterotic effects are likely to be important by comparing the relative magnitudes of additive and non-additive genetic components of variation within purebred populations. Thus traits for which the non-additive genetic component of variance is large are generally expected to exhibit large heterotic effects on crossbreeding and vice versa (Jerome et al., 1956; Yao, 1958; Falconer, 1960; Goodman and Jaap, 1960, 1961; and Saadeh et al.,1968). However, complications

introduced by maternal and sex-linked effects in many experiments designed to estimate these components as well as by the effects of inbreeding and selection restrict the predictive value of the above criterion. Crossbreeding experiments designed to estimate the relative magnitude of variance components due to general and specific combining ability provide useful information on the extent to which different traits are likely to be influenced by heterosis (Jerome et al., 1956; Hill and Nordskog, 1958; Goto and Nordskog, 1959; Merritt and Gowe, 1960; Redman and Shoffner, 1961; Yao, 1961; Wearden et al., 1965, 1967; Eisen et al., 1966; Gowe and Fairful, 1982; and Sellier, 1982).

In chickens heterosis effects have been found to be substantial for egg production traits, fertility, hatchability and early life livability (Nordskog and Ghostley, 1954; Yao 1958, 1961; Hale and Clayton, 1965). Juvenile or early life growth rates have also been shown to be considerably affected by heterosis. Large heterotic effects for egg production traits have been reported also by Morris and Skaller (1958), Bielharz and McDonald (1961); Sheridan and Randall (1977). In most of these studies heterosis effect have been observed to be either small or non-existent for highly heritable traits such as adult body weight and egg size.

Whereas there seems to have been general agreement among different workers on the absence of heterosis effects for highly heritable traits e.g. adult body weight and egg size, contr·versial findings have been reported by different workers for egg production

and early life traits. For example Goto and Nordskog (1959) have reported findings suggesting that general combining ability was more important than specific combining ability for all the traits considered in their study, except for brooder mortality, hatchability and laying house mortality. Similar conclusions have been reported from the studies by Hill and Nordskog (1958); Merritt and Gowe (1960); Redman and Shoffner (1961); Wearden et al. (1965) and Eisen et al. (1966), and are also apparent from the findings reported by Kolstad (1973). Sellier (1982) has summarized findings from a number of crossbreeding studies involving different species of farm and laboratory animals. The general conclusion from these studies has been that greater importance should be attached to the general combining ability of the pure breeds to be crossed, rather than to the specific combining ability of the crosses unless the variance of the latter was more than twice that of the former. Most of the findings reviewed by Sellier (1982) have indicated that this condition is a rare occurrence. One possible explanation for the lack of agreement among findings from different crossbreeding studies is that the expression and magnitude of heterosis resulting from crossing animals depends not only on the trait under consideration, but also on the degree of genetic differentiation between the lines/strains or breeds taking part in the cross (Falconer, 1960; and Hickman, 1982b). Whereas most of the early studies on heterosis involved lines or strains of the same or related stocks some more recent studies have included crosses between more genetically distant stocks (Kolstad and Lien, 1970; Kolstad, 1978; Arad and Marder, 1982; Omeje and Nwonsu, 1982; Abdou and Kolstad, 1984; and Omeje and

Nwonsu, 1984). Despite some discrepancies among the findings from these studies, there is a general indication that more pronounced heterosis should be expected for most fitness traits when genetically diverse stocks are crossed than if the animals being crossed are less remotely related.

2.8.2 Heterosis x environment interaction

Another explanation for discrepancies among crossbreeding results reported from different studies could be the differences in the environmental conditions under which these studies have been carried out. Some evidence has been presented to indicate that realization of heterosis effects also depends upon the severity of the environment in which the animals are kept (Orozco, 1974; Horn, 1980; and Cunningham, 1981, 1982). It has been recognized that heterosis effects tend to be more pronounced in unfavourable than in favourable environments. This phenomenon which has been termed as "heterosis x environment interaction" (Barlow, 1981 after Cunningham, 1982) has been considered to be due to the higher ability of crossbred animals to ameliorate stressful environments, and hence to express their genetic merit in these environments better than the less adapted or both parental breeds (Orozco, 1974; Clarke, 1982; Cunningham, 1982; and Hickman, 1982). However, this apparent advantage conferred to crossbred animals in stressful environments becomes irrelevant in favourable environments.

2.8.3 Heterosis in the F_2 and subsequent generations -recombination loss

Another complication which tends to limit the utilization of heterosis in animal production is that some of the heterosis advantage endowed in the first generation crossbred animals (F_1) is lost in the second (F_2) and subsequent generations. This presents a big practical problem because the benefits from heterosis may not always offset the cost (in terms of money and time) required to make the necessary breeding arrangements for its exploitation. In accordance with the dominance theory adopted by Falconer (1960) and later illustrated by McGloughlin (1980) and Cunningham (1982) to explain the genetic basis of heterosis, the F_2 generation should lose only one half of the heterosis contained in the F_1 generation since only one half of the heterozygosity is lost in passing from the F_1 to the F_2 generation. However, field experiments have revealed many cases where the performance of the F_2 animals was far below the expectations based on the dominance model. This discrepancy has been attributed by some workers to the recombination loss or breackdown of parental epistasis in the F_2 generation (Sheridan and Randall, 1977; Kinghorn, 1980; Hickman, 1982; Hill, 1982 ; and Sheridan, 1981 and 1982). Cunningham (1982) however, has maintained that if heterosis is realized through the ability of crossbred animals to tolerate environmental stresses then cases should be expected where the buffering capacity conferred by the 50% heterozygosity of the F_2 and subsequent generations is below the threshold value necessary to confer tolerance to the animals. In such cases the performance of the F_2 animals will be at variance with the expected level. Kinghorn

(1980) has advanced two convincing arguments suggesting that the dominance model might not be the only genetic explanation for heterosis. In the first of his arguments this author contends that non-linearity or non-additivity of gene effects may not necessarily be due to the effect of dominance but rather the result of either an approach to some physiological limit in the expression of the trait or canalization of the phenotype to an adaptive norm. If one of the parental breeds has reached the above mentioned level of phenotypic expression while the other has not, then the mean of the crossbred animals will be closer to that of the parent which is at its maximum or optimum level of phenotypic expression, and hence the progeny mean will exceed the mid-parent value. According to this notion there should not be any decrease in the phenotype of the F_2, since it is independent of heterygosity. In the second of these arguments Kinghorn (1980) explains that as a result of selection for superior performance, groups of genes that interact favourably tend to be selected together quite independently of their individual merits and with time these groups of genes may be fixed together in one breed. However, this group advantage is lost due to independent segregation and association of genes when the F_2 individuals are formed, hence the F_2 individuals will be less fit than can be accounted for by the decrease in the level of heterozygosity in the population.

From the foregoing review it is apparent that, much as the prospects are for exploiting heterosis to enhance animal productivity many complications arise that tend to limit the effective utilization of this phenomenon. It seems that any questions

concerning the potential gains from heterosis should be settled finally through empirical studies and evaluations, rather than on the basis of theoretical considerations alone.

2.9 Exploitation of breed differences

In recent years there have been renewed and concerted interest in crossbreeding. This new impetus is no longer centred on just utilizing heterosis alone but rather every possible advantage opportune in this method of breeding. To date, apart from heterosis, three potential gains from crossbreeding are recognized. These include the creation and subsequent exploitation of genetic variation, utilization of breed differences or breed complementariness and the storage of genetic diversity for future use (Mason, 1966; Dickerson, 1974; Fewson, 1974; Clarke, 1982; and Sellier, 1982).

The need to create and maintain genetic variability in animal populations arises from the fact that market preferences for animal products as well as production conditions often change much faster than genetic changes can be brought about through selection and other breeding methods within populations. Genetic flexibility is necessary in order to be able to manipulate the genetic resources in the direction most pertinent with the prevailing production requirements and conditions (Dickerson, 1974; Rendel, 1982; and Sellier, 1982). Another point in favour of creating and maintaining genetic variability is the prospect of surpassing selection limits arising from either the exhaustion of genetic variability or the antagonism between artificial and natural selection. Liljedahl

(1973, after Anonymous, 1974) has reported observing increased genetic variability for laying intensity of hens in the synthetics from commercial F_1 hybrids. The increased variability should result in higher selection response in the synthetic population.

There are two situations in which the utilization of breed differences presents great advantages in maximizing the efficiency of animal production. The first of these situations arises when it becomes apparent that an otherwise excellent breed is lacking in one or a few traits for which another, mediocre breed, is particularly good. In this case crossbreeding offers a fast way of incorporating the desired trait in the favoured breed and this is a great advantage especially when the trait to be incorporated is lowly heritable. This point has been discussed by Dickerson (1974) who noted that the real, opportune advantage in this method of breeding is the rapidity and flexibility with which breed differences can be exploited to produce individuals best suited to a particular management system and market preference. Clarke (1982) has pointed out that breed differences were often equivalent to many generations of effective intrabreed selection.

The exploitation of breed differences is rendered opportune also in the optimum utilization of two or more traits whose association in a single (same) breed is contrary to the desired situation. This may apply to either those traits which are genetically negatively correlated (e.g. egg production rate and egg size in laying chickens) or those which are genetically positively correlated but for which the desired combination runs contrary to

their association (e.g. body weight and egg size in egg type chickens. However, the advantages of this form of breed difference utilization have been better demonstrated in mammals (e.g. reviews by Fewson, 1974, and Sellier, 1982).

2.10 Problems posed by genetic antagonism among economic traits and solutions to the problems

Genetically opposed traits pose difficulties in the improvement of the overall efficiency of farm animals because selection for one or more of them would be accompanied by a correlated response of one or more of the other traits in the undesirable direction. Furthermore, the response to simultaneous selection for such traits in the same population is greatly hampered.

Two genetic theories have been put forward to explain the occurrence of the phenomenon. In one of the theories genetic antagonism between some traits is attributed to the increased contribution of pleiotropic genes with (+-) or (-+) effects to the genetic covariance between the traits as the genes with (++) and (--) effects become progressively fixed or lost as a result of selection (Lush, 1948; Lerner, 1950; Sheridan and Barker, 1974; after Liljedahl and Weyde, 1980; Falconer, 1960). Rendell (1963, 1967) and Sheridan and Barker (1974 after Liljedahl and Weyde, 1980) propounded an alternative theory contending that a genetic correlation between traits would move in a negative direction if the selection pressure on a group of genes controlling the distribution of the total amount of available metabolic

resources were greater than on another group of genes controlling the total amount of the available resources in itself.

It has been postulated (Fisher,1930 after Kolstad, 1980; Falconer,1960) that in naturally occurring populations intermediate values for metric traits (e.g. body weight and egg weight) would be optimum for fitness traits (e.g. reproduction). This has led Kolstad (1980) to reason out that the sign for the genetic correlation between body weight and egg production in chickens would depend on whether the body weight is below or above the optimum for the population. This contention is in line with the findings from the study by Nordskog (1960) in which the phenotypic correlation between egg production and body weight was found to be close to zero in Leghorn hens while it was highly negative for heavy-type chickens. Further, it has been pointed out by Sørensen et al. (1980) that the genetic correlation between egg production and egg size in any population would depend on the origin of the population concerned as well as on the selection pressure applied on the population.

In accordance with both theories the negative genetic correlation between the traits concerned should increase in magnitude but in the negative direction as selection for one of them proceeds. This phenomenon has been actually observed in the Scandinavian selection studies with laying hens (Liljedahl and Weyde, 1980; Kolstad, 1980; and Sørensen et al., 1980). In all these studies the genetic correlation between egg number up to 42 weeks of age of the hens and egg size was found to increase from about zero in the base population to highly

negative values in the specialized selection lines.

The solution to the problem of improving genetically opposed traits is apparent from the results of the Scandinavian selection studies (Liljedahl et al., 1979; Liljedahl and Weyde, 1980; Kolstad, 1980; and Sørensen et al., 1980). Though at variance in a few cases the findings from these studies have generally demonstrated the value of single trait selection followed by line crossing as a tool for avoiding the counteractive effect of genetic antagonism between egg production and egg size in breeding programmes aimed at improving both traits. Most probably the method would be effective in dealing with other groups of genetically opposed traits.

However, it is evident from the results of the studies that one has to pay attention to the choice of the paternal and maternal lines in making the line crosses.

Furthermore, Kolstad (1980) has suggested the use of restricted selection index in single trait selection programmes in order to control genetically opposed traits.

2.11 Formation of synthetic populations

The scope for breed difference utilization has recently been widened to include breed differences for adaptive traits (Alberro, 1982). This aspect is probably the most important as far as the development of breeds for tropical regions is concerned. Many workers (e.g. Gregory et al., 1982) have envisaged possibilities

for combining the productive potential of improved exotic breeds and the adaptive quality of breeds native to tropical regions. However, there is some uncertainty on the question of whether or not it is best to form synthetic breeds which could then be further improved through selection rather than aim at the F_1 as the final commercial stock. Arguments have been presented both in favour of and against both these two alternatives (Anonymous, 1974; Dickerson, 1974; and Fewson, 1974). Arguments that seem to favour synthetic breeding include the higher selection response expected in the synthetic breed than in the parental breeds, possibilities for getting a better initial combination of desirable traits on a purely additive basis, flexibility in adapting to changing environment or market situations and safeguard against erosion of genetic variability. Liljedahl (1973, after Anonymous, 1974), has, however, pointed out that synthetic breeding could be disadvantagenous or at least would not be of any advantage if recombination loss is large or if the synthetic breed is segregating for the same genes as the better of the parental breeds. Evidence of recombination loss of 3 - 6% in laying intensity of hens has been reported by Liljedahl (1973, after Anonymous, 1974). Other disadvantages of synthetic breeding include the high cost of forming and maintaining synthetics and the long period of time taken to develop commercially utilizable synthetics.

The choice of breeds to be used in forming a synthetic breed and the proportionate contribution of genetic material from selected parental breeds presents a rather difficult problem. Bickard (1974) has suggested that in deciding breeds to be used

for crossbreeding the general combining abilities of the candidate breeds should be the criterion for comparison. This author, however, has cautioned against the use of purebred performance to estimate general combining ability as this criterion could be misleading if maternal influences are large. Kinghorn (1982a) has theoretically dealt with the question of optimising the proportions of contributing breeds in the synthetic breed. However, as noted by the author, the exact solution to the problem should be sought by empirical means. In cattle breeding the literature summarized by Maule (1953) seems to suggest that for most tropical environments the total proportion of exotic germplasm in the synthetics should not exceed 87.5%. In most of the studies reviewed by this author upgrading to the temperate breeds was associated with a progressive decline in the adaptability of the animals. This led to pronounced decline in the productive traits in animals with more than 87.5% contribution from temperate breeds. The situation would probably be similar with poultry.

CHAPTER 3

MATERIALS AND METHODS

The data used in the present study was obtained from three experiments, two of which were carried out at the Sokoine University of Agriculture in Tanzania, and one at the Monoufia University in Egypt. The experiments in Tanzania involved Tanzanian local chickens, imported meat type and egg type breeds, and crosses among these parental or basic breeds. The experiment in Egypt involved two Egyptian local breeds, two white leghorn lines of Norwegian stock as well as reciprocal crosses between Egyptian and Norwegian chickens. Despite the similarity in the general approach of the experiments the data structures from these experiments (which were dictated upon mainly by the availability of facilities)required different statistical procedures for their analyses, and hence the need for separate description of the experiments. Hereafter the experiments in Tanzania as well as the chickens used in the experiments will be referred to as experiment or material T_1 and T_2 respectively. The experiment carried out in Egypt or the birds used in the experiment will be referred to as experiment E or material E.

3.1 Crossbreeding between Tanzanian local and exotic breeds of chickens (Experiment T_1)

Two exotic breeds (one specialized egg type and one specialized meat type) of chickens were imported from England and raised at the University Farm in Morogoro in 1983. After attainment of sexual maturity the birds were placed in 30 mating pens each holding

about five hens and one cock. Twenty of the pens had egg type hens and the rest were allocated for the meat type hens. Ten cocks from each of the three parental or basic breeds were used and the matings were made in shifts. In the first shift meat type cocks were mated to egg type hens, whereas the local cocks were mated to meat type hens. In the second shift the local and meat type cocks were interchanged. However, the egg type cocks were mated to females of their own breed in both shifts. The time interval between the two shifts was about 2.5 weeks. The mating cycle was repeated two more times so that three hatches were produced for each of the progeny genetic groups. These were designated as MM, EE, ME, LM and LE; where MM, and EE stand for pure meat type and pure egg type chickens respectively. ME stands for the cross between the meat type (MM) and egg type (EE) breeds, whereas LM and LE stand for the crosses of the local breed (LL) with meat type and egg type breeds respectively. Indigenous chicks were brought in from villages at a time coincident with the hatching of the second batch of eggs from the mating pens. These were designated as genetic group LL.

All the chicks were wing-banded and brooded on the floor intermingled by breed type and sex. After about four weeks of brooding the birds were transferred to floor rearing pens where they were raised intermingled by breed and sex up to the age of 16 weeks, when most of the males were disposed of. All the females were transferred to battery cages where they were recorded individually until they reached the age of 38 weeks. Throughout the experimental period the birds received ad libitum feed (compounded by the Tanzanian

Animal Feeds Manufacturing Company). The rations had been formulated to meet the birds' nutritional requirements at the respective stages of development. The mean minimum and maximum ambient temperatures during the experimental period were 20°C and 28°C respectively. However, diurnal temperatures of the order of 30°C or above were often observed.

A comprehensive disease control programme was followed in the experiment. This included vaccinations against Newcastle disease, prophlactic use of drugs against coccidiosis, salmonellosis and worms, isolation of sick birds, and general cleanliness.

All birds were weighed at 4, 8, 12 and 16 weeks of age. Additional body weight records were taken from pullets when they attained sexual maturity as well as at 38 weeks of age. In addition to body weights, records on the age at attainment of sexual maturity, egg production up to 38 weeks of age, and egg weight were kept on individual basis. Average egg weights were calculated from 5 consecutive eggs laid when the birds were about 38 weeks of age.

Preliminary analysis of the data was done in accordance with the following mathematical model (Snedecor and Cochran, 1967).

$$Y_{ijk} = \mu + h_i + b_j + (hb)_{ij} + e_{ijk} \quad - - - - (1)$$

where :

Y_{ijk} - refers to the observation on the k-th individual belonging to the j-th genetic g: and i-th hatch

μ is the general mean

h_i is the effect of the i-th hatch

b_j is the effect of the j-th genetic group

$(hb)_{ij}$ is the interaction between the i-th hatch and the j-th genetic group,

e_{ijk} is a residual effect peculiar to the k-th individual from the j-th genetic group and i-th hatch

The data was analysed on an IBM computer using the SAS (1983) general linear models procedure, which made it possible to get, among other things, least square means for hatches. Since the interaction effects between genetic groups and hatches were not statistically significant, the least square means for hatches were used to correct for hatch effects. This was achieved by multiplying each observation by the ratio of the least square mean for the entire data set to the least square mean for the hatch to which the observation belonged. The data was then re-analysed on the basis of the model which included only the general mean, μ; the effect of genetic groups, b_j, and residual effects, e_{jk}. Correction for hatch effects was done to minimize undue devotion to the analysis and discussion of these influences, as they were not central to the subject of the investigation. Secondly, the correction for hatch was done to this data in conformity with the analyses of the data from material T_2, where correction for hatch was more or less necessitated by the need to isolate various components of merit using multiple regression techniques. The equations for the estimation of these components would have been too long if hatch had been included as a factor in the model. Since there has been no wish to obtain constant estimates for hatches

there was no necessity of including them in the equations for the estimation of constant estimates. Thus the new model was

$$Y_{ijk} = \mu + b_j + e_{jk} \quad - - - - - \quad (2)$$

The case of interaction between hatches and genetic groups may be handled in an analogous manner, except that in this case separate correction factors would have to be applied within each genetic group.

The least square means for the genetic groups were tested for significant differences using an SAS (1983) general linear models computer programme which computes the probability of finding a larger difference between the least square means for any given pair of genetic groups under comparison if the genetic groups were drawn from the same population.

Heterosis was calculated as the percent deviation of a cross mean performance from the midparent value. In addition standard deviations, minimum and maximum values, and coefficients of variation for each genetic group were computed for each of the traits considered. These were used to calculate the probabilities of the different genetic groups attaining or exceeding some specified performance levels. Explanations on how this was done will be given in the next chapter.

3.2 F_2, backcrosses, and three-breed crosses between local and exotic chickens (Experiment T_2)

The birds used in the first experiment were mated to produce progeny groups with different proportions of inheritance from local, egg type and meat type parental breeds. Altogether fifteen genetic groups were produced. These were designated as follows:-

MM, EE and LL = meat type, egg type and indigenous parental breeds respectively;

ME = F_2 generation resulting from the initial cross between the meat type and egg type parental breeds;

LM = F_2 generation resulting from the initial cross between the indigenous and the meat type parental breeds;

LE = F_2 generation resulting from the initial cross between the indigenous and the egg type parental breeds;

3/4L1/4M = backcross to the local breed with 25% inheritance of the meat breed;

1/4L3/4M = backgross to the meat breed with 25% inheritance of the local breed;

3/4L1/4E = backcross to the local breed with 25% inheritance of the egg breed;

1/4L3/4E = backcross to the egg breed with 25% inheritance of the local breed;

3/4M1/4E = backcross to the meat breed with 25% inheritance of the egg breed

1/4M3/4E = backcross to the egg breed with 25% inheritance of the meat breed;

1/2L1/4M1/4E = three-breed cross with 50% inheritance of the local breed and 25% inheritance of each of the two exotic breeds;

1/4L1/2M1/4E = three-breed cross with 50% inheritance of the meat breed, 25% inheritance of the local breed and 25% inheritance of the egg breed;

1/4L1/4M1/2E = three-breed cross with 50% inheritance of the egg breed, 25% of the local breed and 25% inheritance of the meat breed.

Thus there were basically four types of progeny genetic groups: the parental breeds, F_2 crosses from F_1 parents of experiment T_1, backcross to each of the parental breeds, and three-breed crosses of the parental breeds. Due to the small number of local x meat type (LM) breeding birds the three-breed cross with 50% inheritance of the egg type breed had to be produced by mating ME cocks with LE hens.

Four hatches were produced for each genetic group. The time interval between the first and second hatch and that between the third and fourth hatch was about 6 days, whereas the second and third hatch were separated by about two weeks.

At hatching all the chicks were wing-banded and pedigreed to the sire and dam breeds. The chicks were brooded on the floor intermingled by genetic grouping and sex. After five weeks the birds were transferred to rearing pens where they were reared also intermingled until they reached the age of 16 weeks. Most of the cockerels were disposed of at this time, whereas the pullets were transferred to laying pens. Here the pullets were housed and recorded separately by genetic grouping until they were 32 weeks of age. Due to the shortage of pens it became necessary to combine together the first and second hatch, and also the third and fourth hatch in the laying pens.

In this experiment a restricted feeding programme was imposed beginning the seventh week of age of the birds and was continued up to the end of the experimental period.

The feed restriction was such that the birds received about 85% of their expected ad libitum intake. Furthermore, the rations used had been formulated such that they contained about 15% less metabolizable energy, protein, and other nutrients than is normally recommended for the respective stage of development of the chickens.

Ambient day temperatures ranged from 25 to 35^{o}C. Measures taken against diseases included vaccination against Newcastle disease, general cleanliness, and treatment following specific disease out breaks.

Individual observations were made for body weights at 4, 8, 12 and 16 weeks of age. The egg production rates were computed on weekly basis. Therefore pen egg production rates of 50% or higher had to be sustained in a pen for a good part of the week in order for the weekly average to reach the 50% mark. The age of the birds at this point was recorded on pen basis. The egg laying intensity was measured on the basis of the average survivors percent production from the first egg up to 32 weeks of age. Average egg weights were recorded on pen basis from all the eggs produced in the pen in 10 days at about the age of 32 weeks.

The methods of processing the data obtained in this experiment differed depending on whether individual observations or pen records were available. In the case of body weights, for which individual observations were made, the data were preliminarily analysed in accordance with model 1, page 31 .

An IBM computer was used to process the data, using the SAS (1982) general linear models procedure. The least square means for hatches obtained in these analyses were used to correct the data for hatch effects as was explained on page 31 . After correction, the data was re-analysed using the same general linear models procedure as mentioned above, with the option which computes the probabilities of finding larger differences between least square means of genetic groups being compared if the groups were drawn from the same population.

In addition, standard deviations, minimum and maximum values, as well as coefficients of variation were calculated for body size and egg size for all the genetic groups.

Each of the observations in the data set may be considered to consist of the following components (hereafter referred to as components of merit):

- the general population mean, μ ;
- the additive genetic value, g_i, of the parental breed(s) contributing to the progeny group from which the observation is drawn;
- heterosis/specific combining ability, h_{ij}, between pairs of parental breeds contributing to the genetic group under consideration;
- reciprocal (sex-linked and maternal) influence, r_i, due to the i-th breed.

Thus these components may be put together in a multiple regression equation :

$$Y = \mu + \sum_{1}^{n} g_i \cdot f_i + \sum_{1}^{m} h_{ij} \cdot f_{ij} + \Sigma\, r_i \cdot f_i' \qquad (3)$$

for i = 1, 2,. ., n breeds and ij = 1, 2, . . , m crosses;

where f_i, f_{ij} and f_i' are the frequencies with which each of the components in the model occurs in the progeny group from which an observation is drawn.

f_i refers to the proportionate contribution of the i-th parental breed to the genotype of the progeny group in which an observation is made;

f_{ij} refers to the level of heterozygosity (in the progeny group under consideration) due to the i-th and j-th parental breeds;

f_i' is the coefficient for reciprocal effects of the i-th breed. The coefficient was coded 0.0 if the parents were drawn from the same genetic group, and either -1.0 or +1.0 if the parents were from different genetic groups.

Considering the entire data set, the equation may be conveniently represented in a matrix notation as a system of equations

$$Y = 1\mu + F_g G + F_h H + F_r R \qquad - - - - - \qquad (4)$$

or simply as

$$Y = (1 \; F_g \; F_h \; F_r) \; (\mu \; G \; H \; R)'$$

where F_g, F_h and F_r are vectors of frequencies corresponding to f_i, f_{ij} and f_i' and μ, G, H, and R are vectors of the components of merit corresponding to g_i, h_{ij} and r_i above.

On the basis of this model a design matrix was formed whose elements in each row were the frequencies (coded from 0.0 to 1.0) with which each component of merit was expected to occur in every observation in the data set. The coding of the frequencies was as follows :

The frequency for the additive genetic value of a given breed was coded 1.0 if the genetic group under consideration was a pure breed whose additive genetic value is being considered. Otherwise the proportionate inheritance from the breed of interest in the progeny group considered was used. The coding for heterosis effects due to the various combinations of the parental breeds corresponded with the expected level of heterozygosity (in the progeny) due to the pair of parental breeds being considered. The frequencies for reciprocal effects were coded 0.0 for pure-bred genetic groups and for F_2 progeny; 1.0 for genetic groups from dissimilar parents with the parent of interest on the paternal side, and -1.0 for genetic groups from dissimilar parents with the parent of interest on the maternal side. This type of coding for reciprocal effects made it possible to disentagle the non-heritable parental effects from breed additive genetic effects. One row of the design matrix is shown in Table 3.2.1 for each genetic group included in the study.

The data were processed on an IBM computer using the general linear models procedure. This yielded constant estimates for breed additive genetic values, heterosis and reciprocal effects. However, except for heterosis, all the constant estimates were biased, the bias being imposed by the procedure used to compute the constant estimates (Harvey, 1960).

To obtain unbiased constant estimates for additive genetic and reciprocal effects a balanced population (i.e. one in which the parental breeds would contribute equally to the total germplasm of the population) was considered. The balanced population mean is

Table 3.2.1 : Design matrix for the analysis of data from material T_2

Mating types			Components of merit											
Sire breed	Dam breed	Progeny genetic groups	GM	GE	GL	HME	HLM	HLE	RM	RE	RL	RME	RLM	RLE
MM	MM	MM	1	0	0	0	0	0	0	0	0	0	0	0
EE	EE	EE	0	1	0	0	0	0	0	0	0	0	0	0
LL	LL	LL	0	0	1	0	0	0	0	0	0	0	0	0
ME	ME	ME	1/2	1/2	0	1/2	0	0	0	0	0	0	0	0
LM	LM	LM	1/2	0	1/2	0	1/2	0	0	0	0	0	0	0
LE	LE	LE	0	1/2	1/2	0	0	1/2	0	0	0	0	0	0
MM	ME	3/4M1/4E	3/4	1/4	0	1/2	0	0	1	0	0	-1	0	0
ME	EE	1/4M3/4E	1/4	3/4	0	1/2	0	0	0	-1	0	1	0	0
LM	MM	1/4L3/4M	3/4	0	1/4	0	1/2	0	-1	0	0	0	1	0
LL	LM	3/4L1/4M	1/4	0	3/4	0	1/2	0	0	0	1	0	-1	0
LL	LE	3/4L1/4E	0	1/4	3/4	0	0	1/2	0	0	1	0	0	-1
EE	LE	1/4L3/4 E	0	3/4	1/4	0	0	1/2	0	1	0	0	0	-1
LL	ME	1/2L1/4M												
		1/4E	1/4	1/4	1/2	0	1/2	1/2	0	0	1	-1	0	0
ME	LE	1/4L1/4M												
		1/2E	1/4	1/2	1/4	1/4	1/4	1/4	0	0	0	1	0	-1
MM	LE	1/4L1/2M												
		1/4E	1/2	1/4	1/4	1/2	1/2	0	1	0	0	0	0	-1

In the above design matrix the symbols for the genetic groups in the third column are as have already been previously defined on pages 34 and 35. GM, GE, and GL refer to the additive genetic values for the meat type, egg and local chickens respectively; HME = heterosis between exotic meat type and egg type breeds; HLM = heterosis between local and exotic meat type chickens; HLE = heterosis between local and exotic egg type chickens; RM, RE, RL, RME, RML and RLE are reciprocal effects due to parental breeds or their crosses as indicated by the corresponding symbols in the subscript.

simply the general mean, μ . The mean additive genetic value in the population (expressed as a deviation from the general mean, μ) is zero ,

$$\text{i.e. } \sum_{i}^{n} f_i \cdot g_i \;/\; \sum_{i}^{n} f_i = 0; \text{ for } i = 1, 2, \ldots, n \text{ breeds; - - (6)}$$

where g_i is the additive genetic value of the i-th parental breed, expressed as a deviation from the general mean, μ ;

f_i is the proportionate contribution of the i-th parental breed to the germplasm of the balanced population.

In the same way the mean reciprocal effect in the balanced population is zero,

$$\text{i.e. } \sum_{i}^{n} r_i f_i' \;/\; \sum_{i}^{n} f_i' = 0 \qquad - - - - \qquad (7)$$

where r_i = reciprocal effect due to the i-th breed and

f_i' = coefficient for the reciprocal effects due to the i-th breed and is equal to the difference between the frequency with which the i-th breed occurs on the sire side and that with which it occurs on the dam side.

In this case $f_1 = f_2 = \ldots f_n = f$ (since the breeds are contributing equally to the germplasm of the population) and

$$\sum_{i}^{n} f_i = 1$$

Also $f_i' = f_2' = \ldots = f_n' = f'$, and $\sum_1^n f_i' = 1$

Thus the mean additive genetic value in the balanced population

$$= \sum_1^n f \cdot g_i \; / \sum_1^n f = f \sum_1^n g_i \; / \; n \cdot f = \sum_1^n g_i \; / \; n = 0 \; - - - \quad (8)$$

Also the mean reciprocal effect in the balanced population equals zero :

$$\text{i.e.} \quad \sum_1^n r_i \; / \; n = 0 \qquad - \quad - \; - - \; - - - - \quad (9)$$

On the basis of the above reasoning unbiased constant estimates for the additive genetic value and reciprocal effects of the parental breeds were computed from the biased estimates of these constants as shown below:-

The biased constant estimates obtained directly from the analysis were deviations from one of the estimates which is used as the reference point and therefore is given the value zero. This is a pre-requisite step for solving systems of equations in which linear dependencies exist among some equations or among some components of the equations (Harvey, 1960). In this case the dependencies were imposed by the dependencies in the sources of information used to estimate the constants. Thus the constant estimate G_i, obtained from the analysis, for the additive genetic value of the i-th breed is the difference between the unbiased additive genetic value g_i for the i-th breed and that of the reference breed, j which may be represented as g_j:

i.e. $G_i = g_i - g_j$ and hence $g_i = G_i + g_j$ - - - - (10)

for $i = j$ or $i \neq j$.

Therefore the mean additive genetic value (as a deviation from the general mean, μ)

$$\sum_1^n g_i / n = \sum_1^n (G_i + g_j) / n = 0$$

$$= (\sum_1^n G_i + \sum_1^n g_j) / n = (\sum_1^n G_i + n \cdot g_j) / n = \sum_1^n G_i/n + g_j = 0$$

Therefore : $g_j = - \sum_i^n G_i / n$ - - - - - - - - - - - - - - (11)

where g_j is the unbiased additive genetic estimate for the reference breed. The additive genetic estimates for the other breeds may be computed from the identity :

$g_i = G_i + g_j$ (equation 10)

The value G_i is read directly from the results of the analysis. The constant estimates for reciprocal effects were computed in an analogous manner.

The general population mean μ , was computed by subtracting the additive genetic value g_j, for the reference breed from the biased population me , μ' .

i.e. $\mu = \mu' - g_j$, (after Harvey, 1960) - - - (12)

Standard errors of the constant estimates

The standard errors as obtained directly from the analysis were those of the differences between the constant estimate for a given breed and that of the reference breed.

i.e. $\sigma'_i = \sigma (c_i - c_j)$ and hence $\sigma'^2 = \sigma^2 (c_i - c_j) = \sigma^2_{c_i} + \sigma^2_{c_j}$

- - - - (13)

where σ'_i is the standard error of the biased constant estimate and σ'^2_i is its variance.

c_i and c_j refer to the parameter names of the constant estimates and $\sigma^2_{c_i}$ and $\sigma^2_{c_j}$ are the variance of the constant estimates for the i-th breed and that of the reference breed, j respectively.

To compute the standard errors σ_c of the constant estimates the data were reprocessed with the reference breed interchanged with another. Using the standard errors of the biased estimates obtained in the two runs it was possible to set up sets of three simultaneous equations in which the standard errors of the unbiased estimates or their variances were the unknwons. For example if three parental breeds, x, y, z are considered first and if breed z was used as the background in the first run, then the standard error of the biased estimate for breed x is :

$\sigma'_{\bar{x}} = \sigma_{(\bar{x} - \bar{z})}$ and hence $\sigma'^{2}_{\bar{x}} = \sigma^{2}_{\bar{x}} + \sigma^{2}_{\bar{z}}$ - - - - (14)

The standard error of the biased estimate for breed y is :

$\sigma'_{\bar{y}} = \sigma_{(\bar{y} - \bar{z})}$ and hence $\sigma'^{2}_{\bar{y}} = \sigma^{2}_{\bar{y}} + \sigma^{2}_{\bar{z}}$ - - - - - (15)

where x, y and z are parameter names for the constant estimates of breed x, y and z respectively. Now if breed z is interchanged with breed y as the background, then

$\sigma''_{\bar{x}} = \sigma_{(\bar{x} - \bar{y})}$ and hence $\sigma''^{2}_{\bar{x}} = \sigma^{2}_{\bar{x}} + \sigma^{2}_{\bar{y}}$ - - (16)

where $\sigma''_{\bar{x}}$ is the standard error of the biased estimate for breed x when breed y is used as the background.

The set of euqations :

$\sigma'^{2}_{\bar{x}} = \sigma^{2}_{\bar{x}} + \sigma^{2}_{\bar{z}}$ (17) - - - (17)

$\sigma''^{2}_{\bar{x}} = \sigma^{2}_{\bar{x}} + \sigma^{2}_{\bar{y}}$ (18) - - - (18)

$\sigma'^{2}_{\bar{y}} = \sigma^{2}_{\bar{y}} + \sigma^{2}_{\bar{z}}$ (19) - - - - - (19)

has only three unknwons (i.e. $\sigma^{2}_{\bar{x}}$, $\sigma^{2}_{\bar{y}}$ and $\sigma^{2}_{\bar{z}}$ and hence can be solved by usual normal equations procedure.

The standard errors or variances of the unbiased estimates were used to test the significance of the differences between corresponding constant estimates for different breeds.

In the case of the data for which only pen records were available (i.e. egg production) computation of the constant estimates were handled in accordance with the procedure described by Searle (1966), using the same design matrix as described previously. The design matrix, x, was first premultiplied by its transpose x', to get the product matrix x'x, whose elements in each row were the coefficients in the equations for the constant estimates sought. A similar operation on a column vector y, whose elements were the mean performance values of the different genetic groups with respect to a given trait yielded the vector x'y whose elements are the right-hand members of the equations for the constant estimates. The row and column for the additive genetic as well as for the reciprocal constant estimates of the breed to be used as the reference point were dropped out from the product matrix x'x to give a new matrix M. A similar operation on corresponding rows (elements) of the vector x'y yielded the vector V. The constant estimates were then obtained by premultiplying the vector V by the generalized inverse of the matrix M. The system of equations needed to get the solution is:

$$\hat{b} = M^{-1} \cdot V \qquad - \quad - \quad - - \quad (20)$$

where $\hat{b}$ is a vector of biased constant estimates. To get unbiased constant estimates the results were computed in the same way as was described on page 39 to 44.

The constant estimates so obtained were used to compute the additive genetic, heterosis and reciprocal components contributing

to the overall merit of each genetic group. The components were obtained by reconstituting the constant estimates of the individual merit components described in the foregoing discussion. The reconstitution process entailed adding together the corresponding merit component estimates for the breeds contributing to a given genetic group or for the breed combination of interest, taking into account the appropriate multipliers (coded values) for the contributing breeds or for the breed combinations. For example the additive genetic component for the crossbred between the meat and local breed was obtained by adding together one half the additive genetic estimate for the meat breed and one half that of the local breed, and then adding the result to the constant estimate for the balanced population. When dealing with heterosis effects, however, it is to be kept in mind that only one half of the values of the constant estimates for heterosis ought to be accredited to the F_2 crosses and backcrosses since the level of heterozygosity in these groups is supposed to be only 50% of that in the first generation crosses. In the reconstitution process care must also be exercised in interpreting the signs associated with the constant estimates for reciprocal effects before accrediting them to the respective genetic groups. For instance it may appear that the constant estimate for a particular breed is associated with a minus sign. The minus sign only means that the breed would be generally better represented in crosses with other breeds when it is on the dam rather than on the sire side and vice versa. Thus the negative quantity will be accredited to only those genetic groups for which the breed considered is on the dam side. If it is on the sire side then the sign of the constant estimate should be reversed.

The additive genetic, heterosis and reciprocal components for the different genetic groups were scored for statistical significance of differences among them. In the case of the additive genetic components the standard error for testing the significance of difference between a given pair of genetic groups were computed according to the formula;

$$SE = \sqrt{\sum_{1}^{n} \lambda_i \sigma_i^2} \qquad \text{- - - - - (21)}$$

where i = 1, 2, 3 ...., n parental breeds

λ_i is the difference between the pair of genetic groups being compared with respect to their proportionate inheritance of genes from the i-th parental breed

σ_i^2 is the variance of the additive genetic estimate for the i-th parental breed

The above formula is derived in accordance with the rules for the variances of sums as described by Snedecor and Cochran (1967) and it takes care of any covariance that might exist between the additive genetic values of the genetic groups being considered. The standard errors for comparing the genetic groups for heterosis and reciprocal components were obtained in an analogous manner. The degrees of freedom for these tests were computed as

$$df = \sum_{1}^{k} n_i - k \quad \text{(Alder and Roesler, 1976)} \qquad \text{- - - - - (22)}$$

where n is the total count of the additive genetic entries used to estimate the additive genetic value of the i-th parental

breed; and

k is the total number of breeds associated with the pair of genetic groups being compared.

The degrees of freedom for comparing the genetic groups for heterosis and reciprocal effects were obtained in a similar way.

With the use of equation (3), on page 37 , the constant estimates for additive genetic, heterosis and reciprocal effects may also be used to predict the mean of any population constituted by the breeds tc which the constant estimates apply. The population whose mean is to be predicted may be homogenous or heterogenous, and it may consist of pure breeds or crossbreds or both, provided the proportionate contribution of each parental breed of interest to the germ plasm of the population and the frequencies of the various types of heterozygotes in the population are known.

In the case of a random mating population or a synthetic breed the prediction equation on page 37 simplifies to

$$P = \sum_{1}^{n} f_i \cdot g_i + 2 \sum_{i}^{m} f_i \cdot f_j \cdot h_{ij} \quad - - - - - - \quad (23)$$

for m = number of breed combination, since there would be two kinds of crosses for every pair of parental breeds, and reciprocal effects in the population as a whole would sum up to zero.

The above equation may be more conveniently presented in matrix notation as :

$$P = F'G + F'HF \qquad - - - - - - - \quad (24)$$

where : P is a 1 x 1 vector of mean phenotypic values attainable in a random mating or synthetic population with a given composition.

G is a vector of additive genetic values for the contributing breeds.

F is a vector of proportionate contributions of different breeds to the germ plasm in the population; and

H is a matrix of heterosis effects of crosses between different pairs of parental breeds. The matrix H has all its diagonal elements equal to zero.

3.3 Cross-breeding between Egyptian breeds and Norwegian strains (Experiment E)

Data were extracted from a part of the larger project aimed at improving the genetic potential of Egyptian breeds of chickens for egg production traits. This data pertains to two Egyptian local breeds (Fayoumi and Baladi), two lines (L_2 and L_7) from the Norwegian strain of white leghorns, and crosses between the Egyptian and the Norwegian stocks.

The data structure consisted of individual records on 839 birds which had survived up to 500 days of age. The birds belonged to twelve different genetic groups which were designated as FF, L_2L_2, L_7L_7, FL_2, L_2F, FL_7, L_7F, BL_2, L_2B, BL_7 and L_7B.

where F stands for Fayoumi breed;

B stands for Baladi breed;

L_2 stands for line L_2 ; and

L_7 stands for line L_7

Repeat or double representation of breed symbol in the designation of a genetic group indicates that the group comprised purebred birds. Genetic groups designated by heterogenous breed symbols were crosses between the breeds represented by the respective symbols, the first symbol referring to the paternal breed, and the second to the maternal breed. Line L_2 is a derivative of white leghorn chickens of Norwegian stock which had been closed for several generations and had been selected intensively for high egg production rate. Line L_7 is a synthetic line derived from several white leghorn strains and had been selected for large egg size.

The birds had been brooded, reared and later housed in battery cages, and had been fed nutritionally balanced rations appropriate for each stage of development. Prophylactic measures against diseases had been taken.

Individual records had been taken for age at sexual maturity (i.e. age at first egg), body weight at sexual maturity, adult body weight, number of eggs produced in 90 days from the onset of sexual maturity, egg weight and number of eggs produced up to the age of 500 days. From the egg production records the average intensity of egg production for the entire recording period was calculated as :

$$EP\ (\%) = \frac{\text{Number of eggs at 500 days of age}}{501 - \text{age}_{\text{at}}\ \text{sexual maturity (in days)}} \times 100 \quad - - - \quad (25)$$

where EP = intensity of egg production.

The statistical treatment of the data from this experiment was in most cases the same as has already been described for the material T_2 in the foregoing section. The design matrix for the computation of constant estimates in this case was as shown in Table 3.3.1.

Table 3.3.1 : Design matrix for the analysis of data from material E

Mating type			Components of merit											
Sire breed	Dam breed	Progeny genetic group	GF	GB	GL_2	GL_7	HFL_2	HFL_7	HBL_2	HBL_7	RF	RB	RL_2	RL_7
F	F	FF	1	0	0	0	0	0	0	0	0	0	0	0
F	L_2	FL_2	1/2	0	1/2	0	1	0	0	0	1	0	-1	0
L_2	F	L_2F	1/2	0	1/2	0	1	0	0	0	-1	0	1	0
F	L_7	FL_7	1/2	0	0	1/2	0	1	0	0	1	0	0	-1
L_7	F	L_7F	1/2	0	0	1/2	0	1	0	0	-1	0	0	1
B	B	BB	0	1	0	0	0	0	0	0	0	0	0	0
B	L_2	BL_2	0	1/2	1/2	0	0	0	1	0	0	1	-1	0
L_2	B	L_2B	0	1/2	1/2	0	0	0	1	0	0	-1	1	0
B	L_7	BL_7	0	1/2	0	1/2	0	0	0	1	0	1	0	-1
L_7	B	L_7B	0	1/2	0	1/2	0	0	0	1	0	-1	0	1
L_2	L_2	L_2L_2	0	0	1	0	0	0	0	0	0	0	0	0
L_7	L_7	L_7L_7	0	0	0	1	0	0	0	0	0	0	0	0

The symbols for the genetic groups in the first and third column are as have already been defined on page 51.

G and R stand for the additive genetic and reciprocal effects respectively for the different breeds as suggested by the subscripts, and

H stands for heterosis between different pairs of parental breeds as suggested by subscripts

CHAPTER 4

RESULTS AND DISCUSSION

For reasons which were mentioned in chapter 3 the results in this study may be conveniently presented and discussed in three separate parts corresponding to the three sets of data described in that chapter. However, a common and more general disucssion of the results will be given in chapter 5.

4.1 Performance of exotic and local breeds of chickens and their first generation crosses (material T1)

The number of birds observed in this experiment are presented in Table 4.1.1a. The coefficients of variation for the various traits are summarised in Table 4.1.1b. With the exception of a few cases the sample sizes used in this experiment were considered to have been large enough to give reasonably reliable information about the population represented by the samples. For a given population the largest deviation of a sample mean of size n from the population mean that can be considered to be insignificant may be given by the formula modified from the formula of Snedecor and Cochran (1967).

For a given population, the deviation, d of a sample mean, $\bar{x}$ from the true population mean, m may be given by the formula of Snedecor and Cochran (1967) as :-

$$d = \bar{x} - m = \frac{t\sigma}{\sqrt{n}} , \qquad \text{- - - - -} \qquad (26)$$

where : t = tabulated t - value at a given probability level;

σ = standard deviation of the population;

n = sample size

If the deviation is expressed as a percentage of the population mean then the formula becomes :-

$$d' = \frac{(\bar{x} - m)}{m} 100 = \frac{100\ t\ .\sigma}{m \cdot \sqrt{n}}$$

Since the population standard deviation, σ may be expressed in terms of the coefficient of variation, cv and the population mean as :-

$$\sigma = \frac{m.cv}{100},$$

then the deviation may be rewritten as :-

$$d' = \frac{100\ t.}{m\sqrt{n}} \frac{m.cv}{100} = \frac{cv.t}{\sqrt{n}} \qquad - - - - - \ (27)$$

Using this formula it can be shown that for most of the genetic groups deviations of sample means of the order of 10% from the respective population means would be highly significant, (although differences of this size would in most practical conditions be considered to be rather small). This suggests that the samples considered in the present experiment would provide reasonably reliable information about the populations from which they were drawn.

Table 4.1.1a : Numbers of birds recorded summarized by genetic groups, sexes and traits (material T_1)

Sex*	Trait	Genetic groups					
		Meat type (MM)	Egg type (EE)	Local (LL)	Meat x Egg type (ME)	Local x Meat type (LM)	Local x Egg type (LE)
F	Body wt (g) at 4 wks (BW4)	33	38	47	48	25	81
	Body wt (g) at 8 wks (BW8)	33	38	47	48	25	81
	Body wt (g) at 12 wks (BW12)	33	38	47	48	25	81
	Body wt (g) at 16 wks (BW16)	33	38	47	48	25	81
	Body wt at sexual mat. (BWSM)	32	36	40	48	25	80
	Adult body wt, g (ADBW)	23	36	35	45	23	73
	Age at sexual maturity, days (AGESM)	32	36	40	48	23	79
	Egg number in 90 days (EN 90)	23	36	35	45	23	73
	Egg weight (EGGWT)	23	36	35	45	23	73
M	Body wt at 4 wks (BW4)	32	26	35	29	24	68
	Body wt at 8 wks (BW8)	32	26	35	29	24	68
	Body wt at 12 wks (BW12)	32	26	35	29	24	68
	Body wt at 16 wks (BW16)	32	26	35	29	24	68

* F = Female chickens

M = Male chickens

Table 4.1.1b : Coefficients of variation (%) for the various genetic groups and traits (material T_1)

Sex	Trait	Genetic groups					
		Meat type (MM)	Egg type (EE)	Local (LL)	Meat x Egg type (ME)	Local x type (LM)	Local x Egg type (LE)
F	Body wt at 4 wks (BW4)	34	33	32	32	32	30
	Body wt at 8 wks (BW8)	27	21	30	27	16	25
	Body wt at 12 wks (BW12)	30	19	30	28	18	28
	Body wt at 16 wks (BW16)	35	15	25	22	13	26
	Body wt at sexual mat. (BWSM)	16	18	19	19	22	14
	Adult body wt (ADBW)	17	14	9	19	23	20
	Age at sexual maturity, days (AGESM)	11	7	8	7	9	9
	Egg number in 90 days (EN 90)	23	13	19	23	28	22
	Egg weight (EGGWT)	9	6	8	11	8	9
M	Body wt at 4 wks (BW4)	33	41	45	58	21	25
	Body wt at 8 wks (BW8)	27	25	30	25	21	23
	Body wt at 12 wks (BW12)	24	23	31	23	21	23
	Body wt at 16 wks (BW16)	24	22	25	22	19	19

In Table 4.1.2a are shown the mean performances of the birds summarized by genetic groups, sexes and traits. Table 4.1.2b shows the relative performance of the different genetic groups with the meat breed as the reference point. The results in these tables reveal that, except for the body weights of cockerels during the first 8 weeks of age, the ranking of the genetic groups with respect to juvenile body weights was persistently the same. In both pullets and cockerels meat type birds weighed heaviest, followed by the crosses of the meat breed with local breed and with egg breed in that order. Crossbred birds between egg type and local chickens outperformed both parental breeds, and the local breed was in all cases the smallest of all the groups. Whereas the meat type birds were nearly always significantly heavier than all the other groups, the differences between the two crosses of the meat breed with local and egg type breeds were significant in cockerels, but not in pullets. Similarly, whereas the local chickens were decidedly the smallest throughout the juvenile period the differences between the egg breed and its cross with the local breed were in most cases insignificant except for the body weights at 4 and 8 weeks of age of cockerels.

Thus with respect to juvenile (0 - 16 weeks of age) body weights of pullets four performance categories of the genetic groups are discernible.

In females the first category (i. e. the meat type breed) were 30 - 35 % heavier than the second category (consisting of crosses with the meat breed as one of the parents) and the

Table 4.1.2a : Mean performance of parental breeds and their crosses (material T_1)

Sex	Genetic groups	Traits*								
		BW4 (g)	BW8 (g)	BW12 (g)	BW16 (g)	BWSM (g)	ADBW (g)	AGESM(days)	EN 90	EGGWT (g)
F	MM	243.3a	737.1a	1528.8a	2358.2a	3763.0a	4051.6a	192.2a	44.0c	57.1a
	LM	181.6b	565.8b	1024.7b	1563.8b	2458.7b	2737.9b	178.6b	52.9b	51.3c
	ME	161.5bc	494.1c	945.0b	1483.1b	2481.3b	2764.1b	184.0b	54.8b	54.2b
	LE	141.6c	347.0d	693.1c	1057.6c	1638.8c	1852.5c	169.5c	55.3b	46.4d
	EE	117.0d	345.2d	653.5c	1025.7c	1760.6c	1869.4c	184.6b	61.7a	54.5b
	LL	61.8e	229.8e	489.8d	731.6d	1542.1d	1651.9a	195.4a	52.0b	38.2e
M	MM	224.1a	737.8a	1613.9a	2494.6a					
	LM	216.4a	683.9a	1237.2b	2050.1b					
	ME	153.7bc	515.8b	1088.9b	1710.1c					
	LE	156.3b	413.4c	919.6c	1438.4d					
	EE	125.0c	440.5bc	832.5c	1303.5d					
	LL	67.4d	334.3d	597.1d	946.3e					

* Means with no subscript letters in common in the same column and within the same sex are significantly different ($P < 0.01$).

differences seem to have been maintained at this level not only throughout the juvenile period but also in the adult period. The differences in body weights between these two categories were much wider after the first 8 weeks of life than before this period. The third category which consisted of the pure egg breed and its cross with local breed, weighed only about half as much as the meat breed during the first 8 weeks of life, but the disparity between these two groups increased by about 5 percent units subsequently and was maintained at this level in adulthood. On the other hand the performance of the local breed relative to all the other groups seems to have been improving with increasing age from the very low level of 25% of the weight of the meat breed at 4 weeks of age to about 41% at the onset of sexual maturity and in adulthood.

In the case of cockerels the superiority of the meat breed over its cross with the local breed was demonstratable only after 12 weeks of age of the birds. Even then the gap between these two groups never reached the level observed for the pullets. Another disparity between the males and females in the relative performance of the genetic groups was that whereas in females the two crosses of the meat breed with the local and with the egg breed performed statistically similarly nearly for all body weight measures the two groups appeared to be quite distinct from each other in the males, though the difference between them narrowed from 30% at 4 weeks of age to less than 20% at 16 weeks of age.

Table 4.1.2b : Performance of different genetic groups relative to the meat breed (material T_1)

Sex	Traits	Meat type (MM)	Egg type (EE)	Local (LL)	Meat x Egg type (ME)	Local x Meat type (LM)	Local x Egg type (LE)
F	Body wt (g) at 4 wks (BW4)	100.0	48.1	25.4	66.3	74.5	58.0
	Body wt (g) at 8 wks (BW8)	100.0	46.8	31.2	67.0	67.7	47.1
	Body wt (g) at 12 wks (BW12)	100.0	42.7	32.0	61.8	67.0	45.4
	Body wt (g) at 16 wks (BW16)	100.0	43.5	31.0	62.9	66.3	44.8
	Body wt at sexual mat. (BWSM)	100.0	43.5	41.0	65.9	65.3	46.8
	Adult body wt, (g) (ADBW)	100.0	46.1	40.8	68.0	67.6	45.7
	Age of sexual mat. days (AGESM)	100.0	95.8	101.7	95.8	92.3	88.0
	Egg number in 90 days (EN 90)	100.0	143.8	119.2	127.1	119.2	126.6
	Egg weight, (g) (EGGWT)	100.0	94.8	66.8	94.9	90.2	81.4
M	Body wt at 4 wks (BW4)	100.0	55.8	29.9	68.3	96.4	69.6
	Body wt at 8 weks (BW8)	100.0	59.7	56.0	69.9	92.7	56.0
	Body wt at 12 wks (BW12)	100.0	51.6	37.0	67.5	76.7	57.0
	Body wt at 16 wks (BW16)	100.0	52.2	37.9	68.6	82.2	57.5

For egg production traits the results in Tables 4.1.2a and 4.1.2b reveal that, except for egg size, the meat breed performed rather unsatisfactorily. This breed took about one week longer than the egg breed to reach sexual maturity and was surpassed only by the local breed in lateness of onset of sexual maturity. With respect to this trait the cross between local and the egg breed was decidedly superior to all the other genetic groups. The egg breed and the two crosses with the meat breed as one of the parents were intermediate in the rate of sexual maturation. The ranking of the genetic groups with respect to the total number of eggs produced per hen in 90 days after the first egg is rather unclear, except for the egg breed which laid significantly more eggs than all the other groups, and for the meat breed which produced the fewest eggs. It is interesting to note that the local breed which is widely known to be a poor egg producer appeared to compete favourably with the other genetic groups and was even significantly superior to the meat breed. With the exception of the egg breed, the ranking of the genetic groups with respect to egg size closely corresponded with their ranking for body weights at sexual maturity and adult body sizes. Despite its much smaller size (only about 45% that of the meat breed at 38 weeks of age) the egg breed compared very favourably with the meat breed with respect to egg size at the same age. The local breed laid the smallest eggs of all genetic groups. Whereas the egg size for the cross between the local and egg breed was exactly midway between the egg sizes of the parental breeds the case was different for the two crosses of the meat breed. The cross of the meat breed to the egg breed produced eggs which were of the same size as those of the pure egg parent. However, in the case of the cross of the meat

breed to the local breed egg size was closer to the superior parent rather than to the inferior parent.

Table 4.1.3 shows the heterosis (calculated as the percentage deviations of the crosses from their respective mid-parent values) for the three crosses and for the various traits. It is interesting to note that except for egg number the cross between the meat and the egg breed showed negative heterosis with respect to all the traits considered in the present experiment. However, in the case of the cross involving the meat and local breed negative heterosis was observed only for later life body sizes and for age at sexual maturity. All other traits including juvenile body weights in both sexes, egg production rate and egg sizes showed positive heterosis. The heterosis for early life body sizes (i.e. at 4 and 8 weeks of age) in cockerels were surprisingly high (48.5 and 27.6% respectively). The cross involving the egg and local breed showed pronounced negative heterosis only with respect to the age at sexual maturity. There was little or no evidence of heterosis for body size at sexual maturity, egg production rate and egg weight in this cross. However, the trend for all juvenile body weights in both sexes was similar to that of the cross between the meat and local breeds.

The breed of chickens envisaged in this study should be one in which the cockerels are large enough to be slaughtered for meat when they are about 12 weeks of age. Thus in this study the body sizes of cockerels at 12 weeks as well as at other recorded periods immediately preceding and proceeding this period would be of special interest. The pullets in the target population should be able to lay satisfactorily, reasonably sized eggs and should yield reasonably

Table 4.1.3 : Heterosis (%) exhibited in crosses among the meat, egg and local breeds of chickens (material T_1)

Sex	Traits	Types of crosses and levels of heterosis		
		Meat x Egg type	Meat x Local type	Egg x local type
F	BW4	- 10.4	19.3	58.4
	BW8	- 8.7	17.0	20.7
	BW12	- 13.4	1.5	21.2
	BW16	- 12.4	1.2	20.4
	BWSM	- 10.9	-7.3	-0.8
	ADBW	- 6.6	-4.0	6.9
	AGESM	- 2.3	-7.8	-10.8
	EN 90	3.7	10.2	-2.7
	EGGWT	- 2.9	7.7	0.1
M	BW4	- 11.9	48.5	62.5
	BW8	- 12.5	27.6	6.7
	BW12	- 11.0	11.9	28.7
	BW16	- 10.0	19.2	27.9

heavy carcasses at the end of their pullet year. Thus it would be interesting to veiw the spread or variability of different genetic groups with respect to body weights at 8, 12 and 16 weeks of age age at sexual maturity, egg production rate, egg size and adult body sizes of hens. The statistics of variation for each of these traits are summarised in Table 4.1.4 for the various genetic groups.

To simplify the problem of deciding the most prospective source of genetic material for the improvement of a trait in the face of great variation within candidate sources Cunningham (1974) has proposed the use of probabilities of finding individuals with a specified level of performance in each candidate breed as the guiding criterion. Such probabilities were calculated for each genetic group and for some traits of special interest. These appear as the last column for each trait in Table 4.1.4. The probabilities were obtained by first dividing the deviation of the mean of a given genetic group from the specified performance standard by the standard deviation of the trait in that group to get a Z value. The area under the normal probability curve (as given in Table 1 of Alder and Roesler, 1976) corresponding to the calculated Z value was then read off either directly as the probability in question or after appropriate transformations were carried out to get the required solution.

The headings p(x) for the columns refer to the performance levels which were used as the reference points and the entries in the columns are the probabilities that the reference points are reached or exceeded by members of a particular genetic group. In the case of age at sexual maturity the specification is an upper

Table 4.1.4 : Overview of the performance of different genetic groups (material T_1)

Sex	Traits	Meat type					Egg type					Local				
		Mean	Std	Min	Max	P(X)	Mean	Std	Min	Max	P(X)	Mean	Std	Min	Max	P(X)
F	AGESM	192.5	21.9	151	226	0.14	182.5	13.2	157	214	0.16	195.4	15.0	173	222	0.04
	EN 90	43.6	14.2	21	71	0.09	62.7	7.9	47	83	0.50	52.0	9.7	29	70	0.13
	EGGWT	57.2	5.5	46.0	66.0	0.50	54.2	3.1	48.7	63.4	0.16	38.2	3.4	31.5	46.5	0.00
	ADBW	4056.1	672.7	1797	5000	0.00	1856.1	267.7	1435	2980	0.03	1651.9	154.3	1300	2010	0.00
M	BW8	710.8	195.3	303.0	1149.0	0.50	445.3	112.7	248.0	667.0	0.03	334.3	100.3	109.0	498.0	0.00
	BW12	1582.4	374.8	1010.0	2675.0	0.50	849.2	198.0	520.0	1280.0	0.00	597.1	182.2	176.0	979.0	0.00
	BW16	2484.3	606.2	1410.0	4370.0	0.50	1330.9	288.3	890.0	1960.0	0.00	946.3	242.5	324.0	1414	0.00

		Meat x Egg Type					Local x Meat Type					Local x Egg Type				
		Mean	Std	Min	Max	P(X)	Mean	Std	Min	Max	P(X)	Mean	Std	Min	Max	P(X)
F	AGESM	183.8	12.9	157	233	0.13	180.8	16.3	146	206	0.24	169.3	15.3	140	203	0.50
	EN 90	55.4	12.6	26	79	0.27	52.1	14.5	17	88	0.23	55.2	12.0	25	82	0.26
	EGGWT	54.3	5.7	40.6	65.7	0.30	51.6	4.2	44.0	64.5	0.09	46.6	4.4	37.5	54.0	0.00
	ADBW	2810.8	535.5	1500	4400	0.09	2803.3	656.1	1700.0	4200	0.08	1854.7	371.9	1292	2350	0.05
M	BW8	498.8	124.6	308.0	869.0	0.04	670.3	139.8	401.0	980.0	0.38	428.2	98.4	195	607.0	0.00
	BW12	956.8	225.8	620.0	1660.0	0.00	1247.8	264.2	700.0	2085.0	0.10	925.0	215.2	379.0	1070.0	0.00
	BW16	1534.6	332.9	933	2450.0	0.00	2084.2	391.7	1200.0	3200.0	0.15	1464.9	277.6	629.0	2118.0	0.00

Performance standards:

169.3 days for age of sexual maturity (AGESM); 62.7 for egg production (EN 90); 57.2 g for egg weight (EGGWT); 711 g for body weight at 8 weeks (BW8); 1582 g for body weight at 12 weeks (BW12); 2484 g for body weight at 16 weeks (BW16); and 2330 - 2490 g for adult body weight (ADBW).

limit whereas for all other traits excluding adult body size the indicated figures are the lower limits. For adult body size the specification includes both a lower and an upper limit and the entries in the column for that trait refer to the probability that the adult body size of a given genetic group will be within the specified limits. Since all the genetic groups were raised and maintained under the same conditions then as far as environmental contribution to the phenotypic expression of the animals was concerned every genetic group had equal chance to perform as much as the other. Thus it was considered most appropriate to use the genetic group with the most desirable performance level under prevailing experimental conditions as the reference point. Thus for each trait the figure represented by x at the top of the last column is the mean for the best genetic group for that trait. However, in the case of adult body size the median and the mean of the means for the six genetic groups appeared to fall in the most desired range and were therefore used as the lower and upper limit respectively for this trait.

It is apparent from the results in Table 4.1.4 that considerable variation existed within all the genetic groups with respect to all the traits considered. For example with respect to age at sexual maturity and egg production in 90 days the performance range in nearly all the genetic groups was much wider than the difference between the mean performance of the best group and that of the lowest one (i.e. in every genetic group some individuals performed worse than the mean performance of worst group, some others performed even better than the mean performance of the best

group, and still others were between the means of worst and the best groups). However, the situation was somewhat different for body sizes where only the cross between the meat and the egg breed appeared to spread out from values lower than the lowest genetic group to those higher than the mean of the heaviest group. There were no individuals from the meat breed or its cross with the local breed performing as poorly as the lowest (local) breed. Similarly there were no individuals from the local, egg type or the cross between these breeds performing as highly as the meat breed.

Egg size showed much less variation than body size and the genetic groups were clearly divided into two classes. The first of the classes consisted of the meat and egg breeds as well as crosses with the meat breed as one of the parents. There were no members from any of the genetic groups in this class producing as small eggs as the mean for the local eggs. The other class, consisting the local breed together with its cross to the egg breed, did not produce eggs as large as the mean for the meat breed. It is also evident from the figures in Table 4.1.4 that for most of the traits considered in this study the probability of finding local chickens with the desired level of performance was very low.

As for the other genetic groups the probabilities fluctuated widely from one trait to another.

Discussion

The general impression presented by the data from the present experiment is that the performance of both the meat breed and the

egg breed with respect to traits for which they had been specially developed for exceeded not only that of the local breed but also those of the crosses. The only exception was age at sexual maturity for which the crosses appeared to perform fairly well. In the face of the current scarcity of literature on the relative performance of local and exotic chickens in the tropics it is difficult to decide whether or not these results are in accordance with some expectations. The only documented work on the comparative performance of indigenous Tanzania chickens and exotic breeds was that of French (1942).

It seems reasonable to consider that within the limits of experimental error and sampling variation the results in the present study were in fairly good agreement with those reported by French. The only serious discrepancy between the two studies were in the mean body weights of local chickens at 4 weeks of age. The general agreement between French's data and those of the present study is not surprising notwithstanding the forty intervening years between the two studies. This is because the areas from which the experimental birds for the two studies were sampled are only about one hundred and fifty kilometers apart and there are no geographical barriers between them. It is thus reasonable to assume that the two samples were taken from about the same population. Furthermore there has not been any selection or immigration of chicken stock from elsewhere in this population.

As for the exotic breeds, however, great differences should have been expected between the data in the two studies. Whereas the source of the material used by French is unknown the birds used in the present study were obtained from a large commercial breeding company in England and it is supposed that substantial genetic changes must have been achieved during the forty years at least with respect to egg production and egg size traits. Unfortunately no mention is made in French's report about the performance of the exotic birds with respect to these traits.

The performance of the exotic breeds in the present study was quite at variance with the standards commonly quoted for similar stocks (for example those summarized by North, 1972).

Whereas the birds in the present study were much lighter than normally reported for similar breeds during the juvenile period the trend was reversed during the later part of life. However, this may not be surprising because in layer or breeding stocks the weights of the birds are regulated to levels desired by the flock owner through feeding programmes.

The disparity between the present data and the standards with respect to age at sexual maturity can also be explained by the fact that this trait can be easily manipulated through feeding and lighting programmes. In Tanzania pullets are exposed to natural day light only and day length is almost constant all year round. This lighting programme should result into more delayed date of sexual maturity than the step-down/step-up programmes used in temperate countries.

It is worth noting, however, that in the present study the birds were transferred to laying cages at a much later age than is usually recommended. This might have affected the maturation rate of the birds as they had to take some time to adapt themselves to the battery cages. This is most likely to have been the case with the meat breed for which the cages were rather too small.

For egg production the performance of the egg breed was quite comparable to standards for similar breeds. A similar observation may be made about the egg sizes of the egg breed in this experiment, bearing in mind that this trait was measured a little too early. The results achieved with the egg breed cannot be said to have been spectacular since the birds were fairly well managed and received fairly good rations.

It is interesting to note that the local breed seemed to compete fairly well with respect to egg production intensity during the first three months of production. However, this result must be interpreted with caution on account of the shortness of the period in which the observations were taken. Kolstad (1972) has reported phenotypic and genetic correlations of 0.66 and 0.71, respectively between survivors' egg production up to 270 days and that up to 518 day in White Leghorn lines of Norwegian strain. This suggests that the complete or annual egg production performance can be predicted fairly accurately from as short production periods as that of up to 270 days of age of the birds. However, in the case of local chickens more data is needed before part time records

can be relied upon. This is becuase the incidence of broodiness is known to be quite high among local chickens. For example French (1942) has reported culling 17% of the local chickens in his study on account of persistent broodiness, and that was only part of the total number of hens which went broody at least for some part of their pullet year.

The controversial picture presented by the present data on heterosis with respect to nearly all the traits considered is difficult to explain. Apparently negative heterosis was observed for all the traits in the cross between the two exotic breeds whereas this parameter was positive and rather large for juvenile body weights in crosses between the local and the two exotic breeds. It is worth mentioning here that the calculation of heterosis from the present data did not take account of maternal or sex-linked influences as there were no reciprocals to supply information needed for the isolation of these influences. However, it is doubtful whether maternal and sex-linked influences could have been so large as to account for the observed controversy. On the other hand the large heterosis observed for juvenile body weights in crosses involving the local breed could have resulted from the underestimation of the juvenile body weights of the local breed, a factor that would lower the mid-parent value, thus tending to augment the figures for heterosis. As it has been mentioned in the previous chapter the local birds used in this experiment had been brought in directly from the villages. It is reasonable to assume that the influence of the environment to which these birds had been exposed (including the pre-hatching environment) prior to their shipment to the

experimental unit might have persisted for several weeks after the change to the new environment. In view of the apparent inadequacy of the present data this matter is deferred to the next chapter.

The results in Table 4.1.4 showing the variability of different genetic groups should be treated with some caution in that these statistics are bound to have considerable hatch effects confounded with other effects in them. However, their validity as a guideline in the search for the most suitable starting point in breed improvement for desired traits should be recognized. As pointed out by Cunningham (1974) the procedure of assessing the relative merits of genotypes by comparing the probabilities of obtaining members with a given level of performance in the different genotypes makes it easier to appreciate the relative financial value of genetic gains from various breeding strategies.

The calculation of probabilities to be used in this way must be, as illustrated by Cunningham (1974), based on genetic rather than on phenotypic parameters.

Nevertheless, if the data in Table 4.1.4 are taken to be reasonably enough indicative of the relative magnitudes of the respective genetic values of the genetic groups it is apparent that the cross between the meat and the egg breed would be the most favoured of the groups considered in as far as the desired performance standards for hens are concerned. However, with respect to body weights of cockerels the meat breed and its cross

with the local breed compete most favourably. Thus it seems that the breed that would most closely meet the performance requirements envisaged in this study would have to draw its inheritance from all three of the parental breeds investigated.

4.2 Performance of chickens with various proportions of inheritance from meat type, egg type and local breeds (material T2)

The numbers of birds recorded in this experiment are summarized by genetic groups, sex and traits in Table 4.2.1. In the last column of the table are the numbers of eggs weighed for each of the genetic groups. Except for the meat breed and both backcrosses to this breed the sample sizes for the various genetic groups are considered to have been satisfactorily large. The reason for the much smaller numbers of the meat breed and its backcrosses were that either too few hatching eggs were produced or too few of them hatched from the mating types with the meat breed as one of the parents. The problem of low hatchability was common to all matings involving males of heavy breeds (including the crosses to the meat breed). Thus it seems that the main cause of the low hatchability of eggs from these matings was low mating activity. However, in matings where the hens were not of the meat breed, this disadvantage was somehow compensated by the high egg production of the hens. Furthermore a large proportion of the meat breed and the backcrosses to the meat breed had to be culled in the course of time due to leg weakness. Also some birds from these genetic groups died due to heat stroke.

Table 4.2.1 : Number of birds in different genetic groups, summarised by sexes and traits (material T_2)

Sex	Type	Genetic group	Numbers of birds for each trait*					
			BW4	BW8	BW12	BW16	EP	EGGWT
F	Pure breed	MM	9	9	9	7	-	-
	Pure breed	EE	89	87	81	57	47	47
	Pure breed	LL	134	121	106	92	50	45
	F_2 cross	ME	50	46	44	35	33	31
	F_2 cross	LM	42	39	36	25	23	23
	F_2 cross	LE	92	91	88	66	41	40
	Backcross	3/4M1/4E	22	22	22	16	11	11
	Backcross	1/4M3/4E	54	53	50	35	38	38
	Backcross	1/4L3/4M	26	24	24	9	8	7
	Backcross	3/4L1/4M	52	46	46	35	19	19
	Backcross	3/4L1/4E	111	101	95	72	48	48
	Backcross	1/4L3/4E	119	113	108	98	48	48
	Three-breed cross	1/2L1/4M1/4E	71	68	67	57	50	50
	Three-breed cross	1/4L1/2M1/4E	61	56	52	43	35	35
	Three-breed cross	1/4L1/4M1/2E	29	27	27	23	17	17
M	Pure breed	MM	4	4	4	1		
	Pure breed	EE	36	36	34	18		
	Pure breed	LL	10	10	10	9		
	F_2 cross	ME	51	48	47	30		
	F_2 cross	LM	18	18	17	14		
	F_2 cross	LE	37	37	35	26		

Infectious diseases and deaths resulting therefrom did not appear to have more occurence in any one genetic group than in others, probably due to the disease control measures (including vaccinations against Newcastle disease, treatment against coccidiosis and other bacterial diseases, and sanitation) which were undertaken.

Table 4.2.2 shows the mean body weights of pullets and cockerels at four, eight, twelve and sixteen weeks of age summarized by genetic groups. The spread or variation within the genetic groups with respect to these traits are presented as minimum and maximum values as well as coefficients of variation in Appendix Tables 1a and 1b. The first salient feature of the results in Table 4.2.2 is that despite much overlapping the ranking of the genetic groups is fairly consistent for all the traits and in both sexes. The backcrosses to the meat breed (i.e. 1/4L3/4M and 3/4M1/4E) and the three breed cross with one half heritage of the meat breed (1/4L1/2M1/4E) were the heaviest at all periods of weighing. There were no significant differences between these genetic groups. The F_2 cross between the meat and egg breed (ME) seemed to compare favourably with the above genetic groups only in females, but not in males. Apparently the meat breed ranked lower than the crosses with one half or more heritage from this breed (LM; ME, 1/4L3/4M, 3/4M1/4E). But the differences between this breed and the genetic group LM were not statistically significant. The three-breed cross with one half heritage from the local breed (1/2L1/4M1/4E) also appeared to compete favourably with the meat breed. In the case of females no significant

difference was observed between the body weights of the meat breed and those of the genetic groups LM and 3/4M1/4M. The backcross with three quarters heritage from the egg breed and one quarter from the meat breed (1/4M3/4E) as well as the three-breed crosses with one quarter heritage from the meat breed (1/2L1/4M1/4E and 1/4L1/4M1/2E) performed less satisfactorily than the rest of the genetic groups with some inheritance from the meat breed. The local and egg breeds together with all their F_2 and backcrosses had the lowest body weights.

It is surprising that the meat breed which had been expected to outperform all the other groups was superceded by both its backcrosses and the three-breed cross with one half of the inheritance from the meat breed (1/4L1/2M1/4E). In fact this breed tended to rank even lower than its F_2 crosses and in one or two cases it was superceded by the local backcross possessing only one quarter of the meat breed inheritance (3/4L1/4M).

Another interesting feature of the results in Table 4.2.2 is that whereas the F_2 cross between the meat and the egg breed (ME) generally performed better than the corresponding cross with the local breed (LM), the trend was reversed in backcrosses. Thus the backcross to the meat breed with the egg breed as the alternative parent (3/4M1/4E) tended to rank lower than the equivalent backcross with the local breed as the alternative parent (1/4L3/4M). In the same way the backcross to the egg breed with one quarter inheritance from the meat breed (1/4M3/4E) performed

Table 4.2.2 : Mean juvenile body weights (g) of different genetic groups of material T_2

Sex	Type	Genetic group	Mean body weights at different ages (weeks):			
			4	8	12	16
F	Pure breed	MM	210.3fg	455.2d	762.2d	1061.1d
	Pure breed	EE	159.0bcd	395.1bc	663.4b	845.7ab
	Pure breed	LL	138.2a	355.5a	635.7ab	883.6b
	F_1 cross	ME	227.0g	526.0fgh	915.8gh	1206.2e
	F_1 cross	LM	210.3fg	498.9efg	834.2ef	1165.5de
	F_1 cross	LE	147.8ab	353.0a	607.0a	819.8a
	Backcross	3/4M1/4E	228.5g	525.0efg	910.7fgh	1189.0de
	Backcross	1/4M3/4E	166.1cd	403.2c	723.9cd	1026.7c
	Backcross	1/4L3/4M	238.0g	570.6h	1064.4i	1403.6f
	Backcross	3/4L1/4M	189.7e	452.7d	775.2de	1008.1c
	Backcross	3/4L1/4E	158.9bc	397.5c	673.6bc	902.5b
	Backcross	1/4L3/4E	151.1b	370.5ab	643.9ab	861.8ab
	Three-breed cross	1/2L1/4M1/4E	206.1f	493.2ef	879.1fg	1189.6de
	Three-breed cross	1/4L1/2M1/4E	221.8g	536.9gh	943.4h	1255.5e
	Three-breed cross	1/4L1/4M1/2E	177.9de	428.5cd	756.5d	1066.8cd
M	Pure breed	MM	225.9e	571.3de	1022.4d	-
	Pure breed	EE	190.4abc	461.1ab	795.4a	940.5a
	Pure breed	LL	157.3a	463.7abc	865.8abc	1156.3cde
	F_1 cross	ME	229.0e	559.4d	1015.4d	1195.0de
	F_1 cross	LM	221.6de	587.1de	970.8cd	1183.7cde
	F_1 cross	LE	175.9ab	427.9a	798.6a	1006.9ab

Table 4.2.2 cont. :

Sex	Type	Genetic group	Mean body weights at different ages (weeks)			
			4	8	12	16
M	Backcross	3/4M1/4E	277.2fg	605.9ef	1097.1def	1331.4ef
	Backcross	1/4M3/4E	201.9cd	473.9abc	828.3ab	1109.8bcd
	Backcross	1/4L3/4M	277.2g	678.0f	1188.8f	1457.1f
	Backcross	3/4L1/4M	219.3de	589.9de	1032.3de	1188.7cde
	Backcross	3/4L1/4E	188.2abc	486.1bc	845.7ab	1067.9bc
	Backcross	1/4L3/4E	180.9abc	455.9a	798.2a	994.6ab
	Three-breed cross	1/2L1/4M1/4E	230.4e	601.3e	1047.1de	1360.1f
	Three-breed cross	1/4L1/2M1/4E	247.7ef	641.7ef	1108.0ef	1332.1f
	Three-breed cross	1/4L1/4M1/2E	197.8bcd	515.7cd	917.3bc	1196.2de

* Means of the same trait and sex with no subscript letters in common are significantly different ($P < 0.01$).

less satisfactorily than its equivalent backcross involving the local breed as one of the parents (3/4L1/4M.). Furthermore it is interesting to note that whereas the half cross between the egg and the local breed was nearly always the smallest of all the genetic groups both the backcross to the local and that to the egg breed outperformed this genetic group.

In general it can be said that these results were in accordance with the expectations based on the additive theory of inheritance of characters. It is also apparent that the ranking of the genetic groups tended to be less clearly defined and less consistent in males than in females.

From the results in the Appendix Tables 1a and 1b it may be considered that inspite of the extreme values observed for all the genetic groups and for all the body size traits the variation in these groups was in most cases only moderate. For example the coefficients of variation for body weights of pullets or cockerels at 8, 12 and 16 weeks of age rarely exceeded 25% and was in most cases below 20%. It can be shown that with this level of variability, deviations of sample means of the order of 10% from their respective population means would be detectable with 95% level of confidence using only about 16 - 25 animals per genetic group. Thus it is suggestive that the extreme values observed in this case were far removed from the general distribution of the populations from which they were supposed to have been drawn.

The mean performance of the pullets with respect to egg production traits are summarized in Table 4.2.3. Also the table shows the parameters of variability for egg size. No such parameters were available for age at 50% egg production rate, nor for other egg production traits. As was previously mentioned, this was due to the fact that egg production was observed only on pen basis.

It is evident from the results in this table that nearly all the crossbred groups attained the 50% egg production record when they were between 29 and 30 weeks of age. However, it is surprising that none of the parental breeds had approached this level of production even at 32 weeks of age when the experiment was terminated. Whereas not much can be said about the local breed in view of the scarcity of documented information about the breed, the performance of both exotic breeds was certainly far below the expectation for such breeds. For example North (1972) has given performance data for standard egg-type and meat-type breeds which when interpreted accordingly lead to the conclusion that these breeds would be expected to lay at 50% rate when they are 25 to 26, and 26 to 27 weeks of age respectively. Despite the fact that the various crosses laid at about the same rate of 50% at 29 to 30 weeks of age pronounced differences among them were observed at the age of 32 weeks. Apparently the local breed out-performed the egg breed, while the meat breed had not yet come into lay at this time.

Table 4.2.3 : Egg production performance of pullets (material T_2)

Type	Genetic group	Age at 50% prod. (weeks)*	Egg prod. (%) at 32 weeks	Mean egg prod. (%)	Egg weight (g) **			
					Mean	Min.	Max.	CV
Pure breed	MM	-	0.0	0.0	-	-	-	-
Pure breed	EE	-	35.5	16.8	53.5h	47	64	7.9
Pure breed	LL	-	42.5	26.1	41.7a	33	66	12.8
F_2 cross	ME	29.8	69.3	35.3	51.4g	35	62	9.4
F_2	LM	29.8	52.5	33.7	48.6e	41	60	6.2
F_2 cross	LE	31.1	60.0	32.7	46.5cd	36	56	8.1
Backcross	3/4M1/4e	29.0	49.0	30.1	51.0fg	38	57	6.9
Backcross	1/4M3/4E	30.0	75.5	33.8	51.6g	-	63	7.5
Backcross	1/4L3/4M	29.3	73.3	48.9	51.1fg	38	59	8.5
Backcross	3/4L1/4M	30.2	65.0	40.3	45.6c	37	55	8.3
Backcross	3/4L1/4E	30.0	49.5	26.8	44.3b	37	66	9.6
Backcross	1/4L3/4E	30.3	53.0	27.0	48.7e	37	66	10.3
Three-breed cross	1/2L1/4M/1/4E	29.1	49.8	40.3	46.9d	38	57	6.9
Three-breed cross	1/4L1/2M1/4E	30.1	60.5	34.5	53.1h	42	65	7.6
Three-breed cross	1/4L1/4M1/2E	30.0	61.5	54.6	50.0f	40	64	8.2

* Based on pen production records

** Based on individual egg weights in each pen. The average number of hens per pen was 32.8

Mean egg weights with no subscript letters in common are significantly different ($P < 0.01$).

It is worth mentioning that the results for both age at 50% production and egg production rate at 32 weeks of age were subject to the differences in the number of hens observed among the genetic groups. This might have been the case especially with those groups with very few hens (i.e. the 3/4L1/4M, LM, 1/4L3/4M,3/4M1/4E and 1/4L1/4M1/2F). A more useful indicator of the relative egg production potential of the genetic groups would probably be the mean intensity from the first egg up to the age of 32 weeks when record collection was terminated. This measure may tend to favour the early beginners, but might also compensate late beginners with a high laying intensity.

However, under the conditions of the present study the mean laying intensity was considered to be able to reflect more clearly the relative merits of the groups even when some groups had fairly few hens. On the basis of this measure it is apparent that the three-breed cross with one half of its inheritance drawn from the egg breed (1/4L1/4M1/2E) had the best performance of all the genetic groups, followed by the 1/4L3/4M meat x local backross, and the 3/4L1/4M meat x local backcross. The mean laying intensity of these genetic groups (54.6, 48.9 and 40.3%,respectively) are considered to have been quite good when viewed against the figures 50% and 31% quoted for standard egg type and meat type breeds respectively at the same age (North, 1972). This result is difficult to reconcile with the observation that the birds in the present study attained the egg production rate of 50% at a much later age than reported for standard breeds. One possible expla-

nation for this discrepancy could be that whereas the laying intensity in the present study was calculated on the basis of hen-day or survivors' production the figures for the standard breeds are based on hen-housed production. Considerable differences between these two measures of egg production rate could arise if a flock is subjected to either substantial culling or mortality or both. Another explanation for the discrepancy could be that whereas in the management of standard breeds the onset of sexual maturity is deliberately delayed through feeding and lighting programmes, such control was not exercised in the present study. This might have favoured the birds in the present study relative to the standards with respect to the age at first egg. Although in most of the pens eggs were laid as early as the twenty-first week of age the age at sexual maturity could not be ascertained because of the lack of individual observations. The point at the 50% egg production rate could not be taken as the age of sexual maturity because this would not be valid with generally low production flocks.

With the exception of parental breeds and the backcrosses between the local and the egg breed the rest of the genetic groups seemed to compete favourably with each other.

As far as egg size was concerned the results in Table 4.2.3 reveal that the egg breed and the three-breed cross with one half heritage from the meat breed (1/4L1/2M1/4E) laid the largest eggs (53.5 and 53.1 g, respectively. These egg sizes are considered to have been quite satisfactory since the trait was measured a little too early.

Also satisfactory egg sizes were attained by the meat x egg breed F_2 and backcrosses (ME, 3/4M1/4E and 1/4M3/4E), as well as by the local x meat breed backcross to the meat breed (1/4L3/4M). These genetic groups laid eggs which weighed about 51g. The egg size (50 g) for the three-breed cross with one half heritage of the egg breed (1/4L1/4M1/2E) may be considered to have been acceptable. All genetic groups with one half or more heritage of the local breed produced rather small eggs (less than 49 g). Thus it may be said generally that egg size decreased with increasing proportions of inheritance from the local breed in the genetic groups. In the case of crosses of this breed it is apparent that those genetic groups with the meat breed as the second parent performed better than their counterparts in which the egg breed was the second parent. This was also true for backcrosses, i.e. the backcross 1/4L3/4M tended to lay larger eggs than the analogous cross 1/4L3/4E; the cross 3/4L1/4M performed better than the cross 3/4L1/4E, and the three-breed cross 1/4L1/2M1/4E appeared to be better than the three-breed cross 1/4L1/4M1/2E. One would be led to conclude from this trend that the heritage from the meat breed was more favourable than that from the egg breed with respect to egg size.

The figures for the coefficients of variation for this trait are low enough to suggest that the means shown for the different genetic groups in Table 4.2.3 would most likely be close to the means of the respective populations.

In order to facilitate the explanation of the observed phenotypic performances of the various genetic groups estimates for the component parts of performance were obtained as described in chapter 3. These estimates together with their standard errors are summarised in Tables 4.2.4a, 4.2.4b and 4.2.4c. The estimates for additive genetic components in Table 4.2.4a are deviations from the additive genetic means for the balanced population, which was defined in chapter 3 as one in which the germ plasm from all the parental breeds involved in the study was represented in equal proportions.

In each of the Tables 4.2.4a, 4.2.4b, and 4.2.4c the constant estimates were compared and the pooled standard errors of these effects were used to test the significance of differences between each pair of estimates. The 95% probability level was used in the tests. The appropriate degrees of freedom for the comparisons were computed as $n_1 + n_2$, as described by Alders and Roesler (1972), where n_1 and n_2 were the number of observations used in the estimation of the constant estimates being compared.

It is evident from the results in Table 4.2.4a that whereas the additive genetic estimates for the meat breed were always significantly different from those of the other two breeds with respect to body weights of pullets the trend was less clearly defined in the case of males. It is also apparent that there were either little or no additive genetic differences between the egg and the local breed with respect to body weights. As for egg size it is revealed that there were no additive genetic differences between the

Table 4.2.4a : Comparison between the additive genetic constant estimates for the meat type, egg type and local breed germplasm (material T_2)

Sex	Trait	Breed germplasms and their additive genetic constant estimates (g)*		
		Meat type breed	Egg type breed	Local breed
F	BW4	50.5 ± 12.2a	- 17.6 ± 3.6b	- 32.9 ± 4.8c
	BW8	73.9 ± 26.0a	- 23.2 ± 7.9b	- 50.7 ± 10.8c
	BW12	91.4 ± 40.1a	- 38.2 ± 12.4b	- 53.2 ± 17.4b
	BW16	130.4 ± 55.7a	- 84.2 ± 19.0b	- 46.1 ± 22.9b
	EGGWT	2.92 ± 1.28a	4.08 ± 0.11a	- 7.00 ± 0.54b
M	BW4	49.8 ± 20.1a	- 14.7 ± 0.0b	- 35.1 ± 14.9b
	BW8	72.6 ± 44.0a	- 42.4 ± 0.0ab	- 33.2 ± 32.6b
	BW12	124.4 ± 79.0a	- 99.3 ± 0.0ab	- 25.1 ± 58.6b
	BW16	72.9 ± 120.7a	-103.7 ± 0.0a	30.8 ± 73.3a

* Estimates were calculated according to the procedure described on page 37 to 44, using the performance data of the genetic groups of material T_2.

Estimates with no subscript letters in common in a row are significantly different ($P < 0.05$).

two exotic breeds, but the local breed was inferior with respect to this trait.

The results for heterosis differences (Table 4.2.4b) were very consistent for all the body weight traits in both females and males. It is apparent from Table 4.2.4b that the heterosis between the meat and the egg breed was in most cases higher than that between the meat and the local breed. However, these differences were statistically non-significant. Negative heterosis was observed between the local and the egg breed both for body weights and egg size. In the case of egg size negative heterosis was evident also between the meat and the egg breed.

The results for reciprocal effects in Table 4.2.4c need more care in interpretation. Whereas the tests for significant differences among these effects are valid the signs associated with some of the reciprocal effects do not suggest that the corresponding breeds have generally negative reciprocal effects. The negative signs were simply the consequence of the coding procedure used in the isolation of these effects where for a given mating type the contribution of reciprocal effects from the sires were coded +1 and those from the dams were given the code -1. Thus negative figures for reciprocal effects in the table simply indicate that it is disadvantageous to use the respective breeds as sires. Instead the breeds should be used on the maternal side and vice versa. On the basis of the results in this table it is imperative that the meat breed and its cross with the egg breed should be used

Table 4.2.4b : Comparison between the constant estimates for heterosis in crosses involving the meat type, egg type and local breeds (material T_2)

Sex	Traits	Constant estimates for heterosis (g) in different germ plasm combinations*		
		Meat x Egg breed	Local x Meat breed	Local x Egg breed
F	BW4	51.5 ± 17.5a	39.8 ± 10.3a	- 10.2 ± 10.3b
	BW8	129.3 ± 38.2a	112.5 ± 22.4a	- 63.8 ± 22.8b
	BW12	353.3 ± 59.4a	244.7 ± 34.7a	-109.4 ± 35.7b
	BW16	489.1 ± 82.5a	351.4 ± 48.2a	- 70.5 + 50.4b
	EGGWT	- 3.04 ± 1.49a	3.62 ± 0.88b	- 3.60 ± 0.84a
M	BW4	19.3 ± 24.3ab	31.4 ± 14.6a	- 18.9 ± 18.0b
	BW8	84.9 ± 53.5a	152.1 ± 32.0a	- 83.2 ± 39.3b
	BW12	237.3 ± 97.3a	208.0 ± 58.0a	- 88.4 ± 72.2b
	BW16	380.1 ± 14.6a	326.9 ± 80.8a	33.3 ± 90.2b

* The estimates were calculated according to the procedure described on page 37 to 44 . For each pair of parental breeds the heterosis in the F_2, backcrosses and three-breed crosses was used in the estimations. Estimates with no subscript letters in common in a row are significantly different ($P < 0.05$).

Table 4.2.4c : Comparison of constant estimates for reciprocal effects of the meat type, egg type and local breeds, and their crosses (material T_2)

Sex	Traits	Genetic groups and their constant estimate (g) for reciprocal effects*		
		Meat breed	Egg breed	Local breed
F	BW4	- 12.3 ± 7.9d	7.5 ± 5.5b	15.2 ± 2.4a
	BW8	- 31.3 ± 17.7d	14.9 ± 12.3b	38.7 ± 5.5a
	BW12	- 94.6 ± 27.6c	39.8 ± 19.3a	61.1 ± 8.8a
	BW16	-130.0 ± 39.6d	33.2 ± 26.1b	51.9 ± 12.5b
	EGGWT	1.42 ± 0.57a	- 0.73 ± 0.45cd	- 0.16 ± 0.13bc
M	BW4	- 1.9 ± 10.4ab	- 2.4 ± 8.6ab	14.4 ± 5.8a
	BW8	- 21.2 ± 22.7bc	15.8 ± 19.2ab	38.6 ± 12.6a
	BW12	- 50.3 ± 41.6bc	44.5 ± 34.5a	44.6 ± 23.2a
	BW16	- 66.2 ± 54.4bc	- 2.6 ± 45.8abc	34.8 ± 24.0ab
		Meat x egg breed	Local x meat breed	Local x egg breed
F	BW4	- 14.9 ± 4.9d	5.5 ± 5.8b	- 0.9 ± 5.7c
	BW8	- 40.6 ± 10.7d	32.6 ± 13.3a	-14.3 ± 8.8c
	BW12	79.4 ± 16.6a	89.5 ± 20.6a	-16.4 ± 13.7b
	BW16	- 73.8 ± 23.0d	132.6 ± 29.9a	-13.9 ± 19.0b
	EGGWT	- 0.08 ± 0.31bc	0.77 ± 0.40ab	-1.23 ± 0.20c
M	BW4	- 17.4 ± 5.9c	14.4 ± 9.9a	- 7.0 ± 9.1c
	BW8	- 37.1 ± 12.9c	26.4 ± 21.5ab	-22.5 ± 14.0bc
	BW12	- 66.1 ± 23.4c	37.2 ± 38.8a	- 9.8 ± 25.0b
	BW16	- 71.3 ± 30.6d	109.1 ± 50.4a	- 3.9 ± 30.1bc

* The estimates were computed according to the procedure described on page 37 to 44. Using the performance data of the genetic groups of material T_2.

Estimates with no subscript letters in common in a row are significantly different ($P < 0.05$).

as dams. The cross between the local and egg breed should also be used on the dam side. On the other hand the local and egg breeds as well as the cross between the local and meat breed should be used as sires.

Furthermore the results in the table provide evidence that not only did the reciprocal effects differ in direction but also in magnitude. Thus it is imperative that in evaluating cross-breeding programmes breed differences in reciprocal effects should be considered.

Tables 4.2.5a, 4.2.5b, 4.2.5c, 4.2.5d and 4.2.5e show the distribution of the various components of merit in different genetic groups with respect to body weights at 4, 8, 12 and 16 weeks of age respectively, as well as for egg production rate and egg size in that order.

Tables 4.2.5a to 4.2.5e also show the sum of all the components for the various genetics groups and for each trait observed in the study.

In view of the close similarity in the features of the data in Tables 4.2.5a to 4.2.5d it is only appropriate to consider these results together. One of the salient features of these results is that for all the body weight measurements and in both sexes the additive genetic component for the meat genetic group was significantly

higher than those of other genetic groups. Next in magnitude were the components for the backcrosses to the meat breed (1/4L3/4M and 3/4M1/4E), which did not differ significantly with one another. The F2 crosses with the meat breed as one of the parents (LM and ME), and the three-breed cross (1/4L1/2M1/4E), came third in the hierarchy whereas the backcrosses with only one quarter heritage from the meat breed came fourth. The three-breed crosses with one quarter of their heritage from the meat breed (1/2L1/4M1/4E and 1/4L1/4M1/2E) also tended to fall in this category. The egg and local breeds together with their crosses were genetically the smallest and often could not be distinguished from one another statistically. This pattern was not unexpected since it was only an arithmetic result. What was surprising, however, was the tendency for the genetic groups to be distinct from each other during the early growing period while there was much overlapping at 12 and 16 weeks of age. The overlapping was more pronounced in males and seems to have been in effect as early as the fourth week of age. The lack of clear-cut genetic differences among the cockerels of different genetic groups may lead one to consider that some factors which had a higher precedence than the additive genetic determination were operative. Such a prospect might indeed prevail when important genotype x environment interactions are existent. In the present study the environmental factors which could have been interacting with the genotypes might have been the feeding level (qualitative, quantitative or both) and heat stress. Since in all the genetic groups males had higher propensity to grow than females they would be more influenced by such limiting factors.

Table 4.2.5a : Reconstituted components of merit in different genetic groups of material T_2: Four-week body size

Sex	Type	Genetic group	Reconstituted components (g)*			
			Add. genetic	Hetero-sis	Recipro-cal	Sum
F	Pure breed	MM	224.1a	0.0c	0.0cd	224.1
	Pure breed	EE	156.0i	0.0c	0.0cd	156.0
	Pure breed	LL	140.81	0.0c	0.0cd	140.0
	F_2 cross	ME	190.1c	25.7b	0.0cd	215.8
	F_2 cross	LM	182.4e	19.9b	0.0cd	202.3
	F_2 cross	LE	148.4k	-5.1c	0.0cd	143.3
	Backcross	3/4M1/4E	207.1b	25.7b	2.7bcd	235.5
	Backcross	1/4M3/4E	173.0f	25.7b	-22.4e	176.3
	Backcross	1/4L3/4M	203.3b	19.9b	17.7a	240.9
	Backcross	3/4L1/4M	166.6i	19.9b	9.7bc	191.2
	Backcross	3/4L1/4E	144.6k	-5.1c	16.1ab	155.6
	Backcross	1/4L3/4E	152.2j	-5.1c	8.4bc	155.5
	Three-breed cross	1/2L1/4M1/4E	165.4h	14.8b	30.1a	210.3
	Three breed cross	1/4L1/2M1/4E	186.3d	45.6a	-11.4cde	220.5
	Three breed cross	1/4L1/4M1/2E	169.2g	20.3b	-14.0de	175.5
M	Pure breed	MM	255.0a	0.0bc	0.0bc	255.0
	Pure breed	EE	190.4fgh	0.0bc	0.0bc	190.0
	Pure breed	LL	170.0h	0.0bc	0.0bc	170.0
	F_2 cross	ME	222.7bc	9.6b	0.0bc	232.3
	F_2 cross	LM	212.5de	15.7ab	0.0bc	228.2
	F_2 cross	LE	180.2gh	-9.5c	0.0bc	170.7
	Backcross	3/4M1/4E	238.8b	9.6b	15.5abc	263.9
	Backcross	1/4M3/4E	206.5e	9.6b	-15.0c	201.1
	Backcross	1/4L3/4M	233.7bc	15.7ab	16.3abc	265.7
	Backcross	3/4L1/4M	191.fg	15.7ab	0.1bc	207.0
	Backcross	3/4L1/4E	175.1gh	-9.5c	21.5ab	187.1
	Backcross	1/4L3/4E	185.3fgh	-9.5c	4.6abc	180.4
	Three-breed cross	1/2L1/4M1/4E	196.3f	6.2b	31.8a	234.2
	Three-breed cross	1/4L1/2M1/4E	217.6de	25.3a	5.1abc	248.0
	Three-breed cross	1/4L1/4M1/2E	207.1e	7.9b	-10.4c	204.6

* Figures with no subscript letters in common within column and sex are significantly different ($P < 0.05$).

Table 4.2.5b: Reconstituted components of merit in different genetic groups of material T_2 : Eight-week body size

Sex	Type	Genetic group	Reconstituted components (g)*			
			Add. genetic	Hetero-sis	Recipro-cal	Sum
F	Pure breed	MM	486.3a	0.0c	0.0cd	486.3
	Pure breed	EE	389.2h	0.0c	0.0cd	389.2
	Pure breed	LL	361.6l	0.0c	0.0cd	361.6
	F_2 cross	ME	437.7c	64.6b	0.0cd	502.3
	F_2 cross	LM	423.9e	56.2b	0.0cd	480.1
	F_2 cross	LE	375.4j	-31.9c	0.0cd	343.5
	Backcross	3/4M1/4E	462.0b	64.6b	9.3bc	555.9
	Backcross	1/4M3/4E	413.5e	64.6b	-55.6e	422.5
	Backcross	1/4L3/4M	455.1b	56.2b	63.9a	575.2
	Backcross	3/4L1/4M	392.8h	56.2b	6.2bcd	555.2
	Backcross	3/4L1/4E	368.5k	-31.9c	53.0a	389.6
	Backcross	1/4L3/4E	382.3i	-31.9c	29.2b	379.6
	Three-breed cross	1/2L1/4M1/4E	399.7g	24.4b	79.3a	503.4
	Three-breed cross	1/4L1/2M1/4E	430.8d	120.9a	-17.1de	534.6
	Three-breed cross	1/4L1/4M1/2E	406.7f	44.5b	-26.3de	424.9
M	Pure breed	MM	574.6a	0.0bc	0.0cde	574.6
	Pure breed	EE	459.6e	0.0bc	0.0cde	459.6
	Pure breed	LL	468.9e	0.0bc	0.0cde	468.9
	F_2 cross	ME	517.1d	42.5b	0.0cde	559.6
	F_2 cross	LM	521.7bc	76.1ab	0.0cde	597.8
	F_2 cross	LE	464.2e	-41.6c	0.0cde	422.6
	Backcross	3/4M1/4E	545.8b	42.5b	15.9bcd	604.2
	Backcross	1/4M3/4E	488.3de	42.5b	-53.0e	477.8
	Backcross	1/4L3/4M	548.1ab	76.1ab	47.6abc	671.7
	Backcross	3/4L1/4M	495.3d	76.1ab	12.3bcde	583.6
	Backcross	3/4L1/4E	466.5e	-41.6c	61.1ab	486.1
	Backcross	1/4L3/4E	461.9e	-41.6c	38.3abc	458.6
	Three-breed cross	1/2L1/4M1/4E	493.0d	34.5b	75.8a	603.2
	Three-breed cross	1/4L1/2M1/4E	519.4cd	118.5a	1.3cde	639.2
	Three-breed cross	1/4L1/4M1/2E	490.7d	38.5b	-14.7de	514.4

* Figures with no subscript letters in common within column and sex are significantly different ($P < 0.05$).

The net effect of such influence would be to mask any differences in the genetic potential of the groups, and hence detection of genetic differences among the genetic groups would be rendered difficult.

As regards heterosis it is revealed that the three-breed cross owing one half of its heritage to the meat breed (1/4L1/2M1/4E), had consistently higher heterosis advantage than the other groups. The crosses and backcrosses involving the meat breed appear to have had comparable amounts of heterosis acredited to them. The three-breed crosses with only quarter meat breed heritage (1/2L1/4M1/4E and 1/4L1/4M1/2E) also seem to have had a considerable beneficial heterosis advantage. However, in the case of the F_2 cross and backcrosses between the egg and local breeds the heterosis effects were either not significantly different from zero or were negative. Thus with respect to this component these crosses were disadvantaged.

The ranking of the genetic groups with respect to reciprocal effects had a pattern similar to that of additive genetic effects (i.e. the groups were more distinct from each other in early life growth than in the latter growth period). Furthermore the overlapping among the genetic groups was more pronounced in males than in females. In general the meat x local backcross to the meat breed (1/4L3/4M) and the three-breed cross with one half of its heritage drawn from the local breed (1/2L1/4M1/4E) benefited from significantly higher reciprocal effects than the other groups. On the other hand the three-breed crosses with one half of the

Table 4.2.5c : Reconstituted components of merit in different genetic groups of material T_2 : Twelve-week body size

Sex	Type	Genetic group	Reconstituted components (g)*			
			Add. genetic	Hetero-sis	Recipro-cal	Sum
F	Pure breed	MM	786.1a	0.0e	0.0c	786.1
	Pure breed	EE	656.5fgh	0.0e	0.0c	656.5
	Pure breed	LL	641.5h	0.0e	0.0c	641.5
	F_2 cross	ME	721.3c	176.7b	0.0c	898.0
	F_2 cross	LM	713.8cd	122.3bc	0.0c	836.1
	F_2 cross	LE	649.0h	-54.7f	0.0c	594.3
	Backcross	3/4M1/4E	753.7b	176.7b	-17.2cd	913.2
	Backcross	1/4M3/4E	688.9de	176.7b	-119.2f	746.0
	Backcross	1/4L3/4M	749.9b	122.3bc	104.1a	976.3
	Backcross	3/4L1/4M	677.6efg	122.3bc	-28.4cde	771.5
	Backcross	3/4L1/4E	645.2h	-54.7f	77.5b	688.0
	Backcross	1/4L3/4E	652.7gh	-54.7f	56.2b	654.2
	Three-breed cross	1/2L1/4M1/4E	681.4ef	67.6d	140.5a	889.5
	Three-breed cross	1/4L1/2M1/4E	717.5c	299.0a	-78.2ef	938.3
	Three-breed cross	1/4L1/4M1/2E	685.1c	122.2bc	-63.0de	744.3
M	Pure breed	MM	1009.9a	0.0cd	0.0bcde	1009.9
	Pure breed	EE	786.1e	0.0cd	0.0bcde	786.1
	Pure breed	LL	860.4d	0.0cd	0.0bcde	860.4
	F_2 cross	ME	898.0d	118.6b	0.0bcde	1016.7
	F_2 cross	LM	935.2bc	104.0b	0.0bcde	1039.2
	F_2 cross	LE	823.3e	-44.2 d	0.0bcde	779.1
	Backcross	3/4M1/4E	954.0b	118.6b	15.8bcde	1088.4
	Backcross	1/4M3/4E	842.1de	118.6b	-110.6e	850.1
	Backcross	1/4L3/4M	972.5ab	104.0b	87.6ab	1164.3
	Backcross	3/4L1/4M	897.8d	104.0b	7.4bcde	1009.2
	Backcross	3/4L1/4E	841.8e	-44.2d	54.4ab	852.0
	Backcross	1/4L3/4E	804.7e	-44.2d	54.3abc	814.8
	Three-breed cross	1/2L1/4M1/4E	879.2d	59.8bc	110.7a	1049.7
	Three-breed cross	1/4L1/2M1/4E	916.6cd	222.7a	-40,5cde	1098.7
	Three-breed cross	1/4L1/4M1/2 E	860.6d	89.2b	-56.3de	893.6

* Figures with no subscript letters in common within colomn and sex are significantly different ($P < 0.05$).

Table 4.2.5d : Reconstituted components of merit in different genetic groups of material T_2 : Sixteen-week body size

Sex	Type	Genetic group	Reconstituted components (g)*			
			Add. genetic	Hetero-sis	Recipro-cal	Sum
F	Pure breed	MM	1057.9a	0.0c	0.0de	1057.9
	Pure breed	EE	843.4h	0.0c	0.0de	843.4
	Pure breed	LL	881.4g	0.0c	0.0de	881.4
	F_2 cross	ME	959.6de	244.5b	0.0de	1204.1
	F_2 cross	LM	969.6cd	175.7bc	0.0de	1145.3
	F_2 cross	LE	862.3h	-35.2d	0.0de	827.1
	Backcross	3/4M1/4E	1004.2bc	244.5b	-56.2ef	1192.5
	Backcross	1/4M3/4E	896.9fg	244.5b	-107.0fg	1034.4
	Backcross	1/4L3/4M	1013.7b	175.7bc	262.5a	1451.9
	Backcross	3/4L1/4M	925.5ef	175.7bc	-80.6fg	1020.6
	Backcross	3/4L1/4E	871.8h	-35.2d	65.8bc	902.4
	Backcross	1/4L3/4E	852.8h	-35.2d	47.0cd	864.6
	Three-breed cross	1/2L1/4M1/4E	916.0fg	140.5c	125.7b	1182.2
	Three-breed cross	1/4L1/2M1/4E	960.1de	420.2a	-116.1g	1264.2
	Three-breed cross	1/4L1/4M1/2E	906.5fg	192.5b	-59.9fg	1039.1
M	Pure breed	MM	1118.1a	0.0c	0.0b	1118.1
	Pure breed	EE	941.6c	0.0c	0.0b	941.6
	Pure breed	LL	1076.0ab	0.0c	0.0b	1076.0
	F_2 cross	ME	1029.8c	190.0b	0.0b	1219.9
	F_2 cross	LM	1097.1ab	163.5b	0.0b	1260.5
	F_2 cross	LE	1008.8c	16.7c	0.0b	1025.4
	Backcross	3/4M1/4E	1074.0bc	190.0b	5.0c	1269.0
	Backcross	1/4M3/4E	985.7c	190.0b	-68.7c	1107.1
	Backcross	1/4L3/4M	1107.6ab	163.5b	175.4a	1446.4
	Backcross	3/4L1/4M	1086.5ab	163.5b	-74.3c	1175.7
	Backcross	3/4L1/4E	1042.0bc	16.7c	1.3b	1059.9
	Backcross	1/4L3/4E	975.2c	16.7c	1.3b	993.1
	Three-breed cross	1/2L1/4M1/4M	1052.9bc	180.1b	106.1a	1339.2
	Three-breed cross	1/4L1/2M1/4E	1063.4bc	353.5a	-62.4c	1354.6
	Three-breed cross	1/4L1/4M1/2E	1019.3c	181.1b	-62.4c	1137.0

* Figures with no subscript letters in common within column and sex are significantly different ($P < 0.05$).

heritage from the egg or meat breed (1/4L1/2M1/4E and 1/4L1/4M1/2E) as well as the 1/4M3/4E meat x egg breed backcross received unfavourable reciprocal effects from their parents. For the rest of the groups reciprocal effects had little or no influence on their performance.

From the results in these tables it should be clear why the meat breed, which is expected to be far superior to other genetic groups with respect to growth and body size characters, was outperformed by some of its crosses. Those groups which appear to be superior to the meat breed had substantial heterosis effects or in some cases favourable reciprocal effects accredited to them. This also explains the observed departure of the relative performance of different genetic groups from the expectations based on the additive theory of inheritance of characters. It is evident from the results that if the contributions of reciprocal effects are ignored, then the three-breed cross with one half of its heritage from the meat breed (1/4L1/2M1/4E) would be the best of all the genetic groups as far as juvenile body weights were concerned. In fact this might be true as well even when reciprocal effects are considered. It should be noted that the magnitude of the reciprocal component in this genetic group was quite large especially for 12 and 16 week body weights. This component can be made to contribute favourably to the phenotype of this genetic group by simply reversing the mating arrangement of the parents. The next best group would be the backcross with one quarter of the inheritance from the local breed and three quarters from the meat breed (i.e.$1/_4L3/_4M$), followed by the

Table 4.2.5e : Reconstituted components of merit in different genetic groups of material T_2: Egg production and egg size.

Trait	Type	Genetic group	Recosntituted components*			
			Add. genetic	Heterosis	Reciprocal	Sum
Egg prod.(%)	Pure breed	MM	32.8	0.0	0.0	32.8
	Pure breed	EE	15.2	0.0	0.0	15.2
	Pure breed	LL	22.5	0.0	0.0	22.5
	F_2 cross	ME	24.0	13.7	0.0	37.7
	F_2 cross	LM	27.6	12.2	0.0	39.8
	F_2 cross	LE	18.8	15.4	0.0	34.2
	Backcross	3/4M1/4E	28.4	13.7	-15.8	26.3
	Backcross	1/4M3/4E	19.6	13.7	3.9	37.2
	Backcross	1/4L3/4M	30.2	12.2	6.0	48.4
	Backcross	3/4L1/4M	25.1	12.2	2.5	39.8
	Backcross	3/4L1/4E	20.6	15.4	-5.4	30.6
	Backcross	1/4L3/4E	17.0	15.4	-2.0	30.4
	Three-breed cross	1/2L1/4M1/4E	23.2	27.6	-7.3	43.5
	Three-breed cross	1/4L1/2M1/4E	26.6	26.0	-13.9	38.7
	Three-breed cross	1/4L1/4M1/2E	21.4	20.7	2.0	44.1
Egg weight(g)	Pure breed	MM	51.95ab	0.00bc	0.00c	51.95
	Pure breed	EE	53.12a	0.00bc	0.00c	53.50
	Pure breed	LL	42.03f	0.00bc	0.00c	42.03
	F_2 cross	ME	52.54a	-1.52cd	0.00c	51.02
	F_2 cross	LM	46.99de	1.81a	0.00c	48.80
	F_2 cross	LE	47.58d	-1.70d	0.00c	45.88

Table 4.2.5e cont.:

Trait	Type	Genetic group	Reconstituted components*			
			Add. genetic	Heterosis	Reciprocal	Sum
Egg weight (g)	Backcross	3/4M1/4E	52.24a	- 1.52cd	1.50ab	52.22
	Backcross	1/4M3/4E	52.83a	- 1.52cd	0.65bc	51.96
	Backcross	1/4L3/4M	49.47c	1.81a	-0.64cd	50.64
	Backcross	3/4L1/4M	44.51e	1.81a	-0.94cd	45.38
	Backcross	3/4L1/4E	44.80e	- 1.70d	1.06b	44.16
	Backcross	1/4L3/4E	50.35bc	- 1.70d	0.50bc	49.15
	Three-breed cross	1/2L1/4M1/4E	47.28d	0.11bc	-0.09cd	47.30
	Three-breed cross	1/4L1/2M1/4E	49.77c	0.29b	2.64a	52.70
	Three-breed cross	1/4L1/4M1/2E	50.06c	- 0.75cd	1.15b	50.46

* Figures with no subscript letters in common within column and trait are significantly different ($P < 0.05$).

backcross with one quarter of the inheritance from the egg breed and three quarters from the meat breed (3/4M 1/4E). The three genetic groups would be superior to most of the other genetic groups also with respect to egg size and egg production rate.

Discussion

The results from the present study indicate that all the traits studied were to a greater or less extent under the influence of additive genetic, heterosis and reciprocal effects. In such situations it becomes difficult to recognise prospective genotypes from the less prospective ones. However, it may be asserted that to some extent the general trend revealed by these data conforms to the expectations based on the current understanding of the determination of characters. The observed tendency for large body size to be associated with the proportion of heritage drawn from the meat breed is very much in line with the expectations since body size in chickens and in other animals as well is considerably influenced by additive genetic effects. Within populations body size is known to be highly heritable, with heritability coefficients normally exceeding 0.45 (King, 1961; Siegel, 1962; Merritt, 1968; Craig et al., 1969; Jaap, 1969; Nelson, 1969; Kolstad, 1972; Lien, 1973; Nordskog, 1974; and Aboud and Kolstad, 1979). However in crosses this parameter seems to decline in importance mainly due to the large non-additive genetic component resulting from the cross. Notwithstanding this fact still the additive genetic component (measured as the percentage variation due to general combining ability) appears to be considerably large even in crosses

(Eisen et al., 1966 and Kolstad, 1973). It is also evident from the results of the present study that the performances of different genetic groups were not necessarily directly proportional to the proportion of inheritance drawn from the superior parental breed, since considerable heterosis influences existed in most of the crosses. These influences were the main cause for the observed higher performance of some crosses of the meat breed compared to that of the pure meat breed. In some cases the additive genetic differences between two genetic groups were much smaller than the heterosis difference between them. For example despite the significant additive genetic difference between the meat breed and the three-breed cross owing only 50% of its heritage to the meat breed (1/4L1/2M1/4E), this component was much smaller than the difference in heterosis between these two groups for nearly all the body weight measurements, in pullets and cockerels. It is to be noted that the levels of heterosis estimated from the data of material T_2 (Table 12) were considerably large, especially those arising from the combination between the meat and the egg breed and between the local and the meat breed. Heterosis effects reported for body size from other studies are usually in the range of 3 to 13% (Nordskog and Ghostley, 1954; Eisen et al., 1966; Kolstad, 1972b; Gowe and Fairfull, 1982; and Abdou and Kolstad, 1984). Two explanations may be put forward to account for the departure of the results obtained in the present study from those reported from other studies. First, the general environmental conditions under which the present study was carried out were most likely much more inimical to the performance of the exotic breeds than those prevailing in other studies. It is widely speculated that heterosis

effects would assume much more importance under sub-optimal environments than in good environments (Orozco, 1974; Sheridan, 1981; and Cunningham, 1982). Secondly, it is considered that the material used in the present study were genetically more diverse than is usually the case in many crossbreeding experiment. According to the dominance theory as illustrated by Falconer (1960) and Cunningham (1982) the level of heterosis should be proportional to the degree of heterozygosity in the crossbred animals, and this would in turn depend upon the difference in gene frequencies between the parental breeds. The difference in gene frequency between any two populations depends upon the genetic distance between the two populations (Falconer, 1960). However in view of the diversity of the material used in some of these studies (e.g. Nordskog and Ghostley, 1954; Eisen et al., 1966; and Abdou and Kolstad, 1984) it is doubtful if this factor could account for a significant proportion of the deviation of the present results from those generally reported from other studies. Nevertheless it seems reasonable to assume that the joint effect of genetic diversity and the stressful environment which must have been partinent with the material of the present study would have far more pronounced effects on heterosis than any of these factors acting singly.

The negative heterosis observed for body size and egg size in the cross involving the local and egg breed does not render itself to easy explanation. In most of the investigations on heterosis this component has been found to be nearly always positive if not zero. The results of the present study, however, are in agreement with those reported by Abdou and Kolstad (1984) from a study in

which the material used can reasonably be said to have been quite similar to those in the present study. The occurence of negative heterosis seems to negate the theories that have been put so far to explain the phenomenon of hybrid viguor. According to the dominance and overdominance theories, crossbred animals are expected to supercede at least the midparent because they will be much more buffered against adverse environments than one or both of their parents (Falconer, 1960; Sheridan, 1982). However, according to the theory advanced by Kacser and Burns (1981, after Cunningham, 1982 and Sheridan, 1982) heterosis is explained by the non-linear responses to enzymatic doses as the dose level increases, so much that the phenotypic differences between active homozygote (one possessing positive genes) and its heterozygote, decreases. Sedcole's theory (1981, after Cunningham, 1982) that heterosis could arise from the reduced effectiveness of gene represo rs leading to higher enzyme levels in heterozygotes leaves room for speculation that with some crosses this mechanism may not be operative or may augment gene repression so that the heterozygote will have lower enzyme levels. Dobzhansky (1950) has made a distinction between two forms of heterosis which he ascribes to two completely distinct underlying phenomena. The first of these forms has been attributed to the masking effects of favourable genes over their unfavourable alleles in heterozygous individuals. The second form has been attributed to the adaptive polymorphism endowed in heterozygotes thus making them able to meet a host of environmental challenges. According to this contention it is possible to get heterozygotes that are less fit than the homozygotes. This is said to arise if the parental breeds have been adapted for survival in different environments.

However, it is doubtful if the degree of genetic differentiation within the same species of farm animals could be so large as to result in poor adaptability of crossbreds.

The existence of large reciprocal effects as observed for body weights in the present study causes some problems in interpreting results from crossbreeding experiments. As a consequence reciprocal crosses have to be represented in such studies. However, there are limitations to the use of reciprocates if the number of parental breeds involved in the test is large. With n parental breeds involved in the test there will be n^2 different genetic groups in the test, of which n(n-1) would be crosses. Rarely would there be adequate resources at one's disposal (space, funds, etc) to test more than a handful of breeds and crossbreds. Furtunately this problem can be got round by employing special statistical designs and analyses which exclude the necessity of having reciprocate animals. Yet it is important that these influences be estimated, for they are likely to be of considerable practical importance in some cases. For example in the present study reciprocal effects accounted for more than 10% of the mean body weights of some genetic groups and in a few cases up to 15% of the performance could be attributed to these effects. Conceptually reciprocal effects are recognized as maternal and sex linked influences. But the isolation of these effects as distinct components may be statistically difficult.

For n breeds there would be n additive genetic components to be estimated (one for each pure breed), in addition to the heterosis in $(n^2 - n)/2$ cross combinations, n sex-linked and n maternal constant estimates, i.e. the number of constant estimates to be made would be

$$(n^2 - n)/2 + 3n = n^2/2 + 5n/2 \quad - - - - \quad (28)$$

Since in the estimation process the number of degrees of freedom for the independent sources of information (i.e. genetic groups) is one less than the number of these sources, and since one degree of freedom would be expended in estimating the intercept, then the total number of independent sources of information that must be available has to exceed the number of estimates by 2, i.e. the number of genetic groups,

$$N = n^2/2 + 5n/2 + 2 \quad - - - - - \quad (29)$$

Therefore the total number of genetic groups that must be available to estimate all the required constants would be $(n^2 + 5n + 4)/2 = (n + 1)\ (n + 4)/2$.

From the above formula it is apparent that this can only be achieved with six or more parental breeds. The fewer the number of parental breeds involved the greater would be the necessity that each genetic group feasible with the given basic breeds be available for the complete estimation of all the components.

However exceptions may arise in cases where several genetic groups with graded proportions of inheritance from a particular breed are available.

The importance of reciprocal effects on body size of chickens has been indicated by a number of workers. Gowe and Fairfull (1982) considered that maternal influences would be quite important for early growth rates of chickens. These workers concluded that there was a need to include reciprocal crosses in cross performance tests in order to determine which breed combinations have best overall balance of performance. Similar views had been expressed by Goto and Nordskog (1959) who observed considerable reciprocal effects for eight week body weights of chickens. These workers pointed out that knowledge of the relative magnitude and sign of reciprocal effects would be advantageous in designating breeds as either sire or dam breeds. Important reciprocal effects for body size were also indicated in the study of King (1961); Jaap et al., (1962); and Eisen et al. (1966).

Despite the fact that reciprocal effects have been demonstrated in many studies it does not seem that the underlying factors or mechanisms of this phenomenon have been conclusively investigated for each trait in the fowl. Gowe and Fairfull (1982) have proposed that for traits expressed late in the life of the fowl reciprocal effects could be conditioned by genes located on the sex chromosome. However for early growth rate and mortality it has been proposed that maternal influences could be important.

Results from the studies by Warren and Moore (1956), Goto and Nordskog (1959), Nordskog and Philips (1969), and Nordskog and Pevzner (1977) indicated that crossbred chickens produced by heavy breed dams had lower mortality rates than those produced by light breed dams. The influence of the breed of dam seemed to persist even during the laying period of the daughters. It was suggested that heavy breed dams passed on antibodies through the eggs to their progeny, hence giving the progeny protection against diseases from their very early age. From this contention it appears reasonable to assume that the protective advantage endowed to the progeny of heavy breed dams would be reflected not only in the low mortality of these progenies but also in their early growth rates. Thus maternal influences could affect the growth rate of young birds in this way.

As far as egg production rate and egg size were concerned the interpretation of the results is subject to the fact that these traits were measured a bit too early in the present study . But of the two, egg production must have been the most affected by the period of measurement. Kolstad (1972a) has published findings demonstrating that egg production rate was both phenotypically and genetically negatively correlated with the age at sexual maturity and that the magnitude of the correlation coefficients increased with the earliness of termination of production records. This suggests that egg production records taken early in the production period would tend to favour early maturing birds in comparison with late maturing birds. The results of the present study might have been subject to such biases, thus giving the

impression that the egg breed had lower potential for egg production than both the meat and the local breed, a prospect that would be difficult to support with the current understanding of animal breeding theory. Therefore it is only reasonable to suppose that lower potential for egg production indicated for the egg breed was caused by late maturity in genetic groups with proportionately large heritage from this breed. Thus a longer recording period might have yielded a different picture. However, it is not understandable why the germplasm from the egg breed could have been associated with slower maturation rate. One could speculate that this trait was possibly under the influence of interactions between the genotypes and the environment. Since egg production stocks are usually highly selected for early maturation they would probably be more sensitive to genotype x environment interactions than stocks which have not been so highly selected for this trait.

For egg weight it could be safely assumed that the results obtained in this study reflected the true relative merits of the parental breeds as well as that of the crosses. Very little or no correlation between egg size and age of sexual maturity were discernible in the study by Kolstad (1927a). On the other hand this worker observed a genetic correlation of 0.82 between egg size at 270 and 518 days of age of the the pullets. Thus it is suggestive that egg weight records obtained early in the pullet's production period are quite good indicators of the subsequent performance for this trait. The observed trend for egg size to generally increase with the proportion of heritage from

the exotic breeds is not unexpected since this trait is known to be strongly influenced by additive gene actions, as indicated by the high heritability coefficients for the trait. In most studies the heritability coefficient of egg size has been found to lie between 0.45 and 0.60, although coefficients lower than 0.40 and higher than 0.7 have been obtained in some studies (King and Henderson, 1954; Hicks, 1958; King, 1961, Warring et al., 1962; Kiney et al., 1968; and Kolstad, 1972a). Despite the fact that the meat and the egg breed seem to have the same potential for egg size the crosses of these breeds with the local seem to behave differently. All the crosses between the meat and the local breed produced eggs that were heavier than those produced by corresponding crosses between the egg and local breed . This was mainly due to the high heterosis arising from the meat x local breed combination, as opposed to similar but opposite effects associated with the local x egg breed combination. That heterosis effects might be important for egg size were evident also in the finding reported by Gowe and Fairful (1982). However, results from other studies seem to indicate that general combining ability is much more important than specific combining ability for egg size (Goto and Nordskog, 1959; King, 1961; and Eisen et al., 1966).

The proportionately large heterosis component observed for egg production rate (also expressed in percentage in Table 4.2.6) was expected. Being a functional component of fitness this trait is expected to show heterosis on crossbreeding. In general heterosis effects are expected to be large for traits which are closely connected with fitness (Falconer, 1960).

Table 4.2.6 : Estimates of full heterosis* (%) for the three types of germ plasm combinations of material T_2

Sex	Traits	Meat x Egg breed	Meat x Local breed	Local x Egg breed
F	BW4	27.1	21.8	- 6.8
	BW8	29.5	26.5	-17.0
	BW12	49.0	34.3	-16.9
	BW16	51.0	36.2	- 8.2
	EGGWT	-5.8	7.7	- 7.1
	EP (%)	114.3	88.8	163.6
M	BW4	8.6	14.8	- 10.8
	BW8	16.4	29.2	- 17.9
	BW12	26.4	22.2	- 10.7
	BW16	36.9	29.8	3.3

* The estimates were obtained from the performance data of the F_2, backcrosses, and three-breed crosses of material T_2.

As for reciprocal effects on egg production and egg weight there seems to be a general agreement among a number of workers that these components need to be taken into account in crossbreeding work. Thus the findings from the present study are somewhat in line with those reported from other studies (e.g. Goodman and Jaap, 1960; Eisen et al., 1966; and Gowe and Fairful, 1982. King (1961) concluded that though maternal effects were small for the traits considered in his study (which included egg production and egg weight) these effects were very consistent.

In conclusion therefore it may be asserted that the results of this study have been demonstrative enough of the importance of all the factors considered in the study in the overall performance of various genotypes of animals. It has come to light that whereas the most logical way of achieving large body size of birds is to maximize the proportionate contribution of the meat breed in the desired genetic group this approach can be advantageous only up to a certain limit, beyond which other factors e.g. heterosis and reciprocal effects become paramount. Thus the best genotype with respect to juvenile body size is not one with the highest proportion of heritage from the meat breed per se, but rather the one with the highest proportion which is simultaneously pertinent with the highest heterosis level and highest parental effect advantage. Further it is apparent that with respect to egg production rate the best breed would not be one with the highest proportion of heritage drawn from the egg breed. Exclusion of the local germ plasm would not yield the most desirable genotype. It

appears that the best genotype would have to draw its heritage from all three of the basic breeds considered in this study. Utilization of heterosis would have to be an important aspect just as the optimization of additive genetic potential from the exotic breeds. As for egg size it is indicated that it would be most advantageous to maximize the proportion of heritage from the exotic breeds. The only heterosis effect that seems to be favourable for egg size is that between the meat and the local breed.

As regards the overall merit of the birds the results of the present study have indicated that the three-breed cross with 50% inheritance from the meat breed (i.e.1/4L 1/2M 1/4E) and the local x meat breed backcross with 75% inheritance of the meat breed were the best genetic groups. This emphasizes the need to maximize both the additive genetic contribution from the meat breed and heterosis in the composite breeds.

4.3 Performance of Egyptian and Norwegian Strains and their crosses (material E)

The mean performance of genetic groups constituting material E are summarised in Tables 4.3.1a and 4.3.1b. The variability of the material is indicated as minimum and maximum values, and as coefficients of variation in Appendix Table II in addition to the standard errors which are included in Table 4.3.1a. These results show that the Egyptian breeds were of about the same size when they started laying. These breeds were much smaller than both Norwegian lines at the onset of sexual maturity. However, there

Table 4.3.1a : Mean performance of Egyptian and Norwegian strains and their crosses : Body weights and age at sexual maturity

Type	Genetic group	Number of birds	Traits and performance levels*		
			BWSM (g)	ADBW (g)	AGESM (days)
Pure breed	FF	93	1256.8 ± 136.0ab	1354.3 ± 138.0ab	169.7 ± 8.0bc
Pure breed	BB	75	1230.7 ± 100.0a	1329.7 ± 117.5a	164.8 ± 16.4cde
Pure breed	L_2L_2	78	1331.0 ± 138.0cd	1518.5 ± 149.8e	167.9 ± 8.6de
Pure breed	L_7L_7	64	1372.0 ± 142.0e	1596.3 ± 127.0f	173.9 ± 9.3f
F_1 cross	FL_2	75	1250.0 ± 136.3ab	1381.5 ± 132.1bc	164.6 ± 13.9cd
F_1 cross	L_2F	51	1312.0 ± 129.8cd	1422.0 ± 131.0 cd	154.0 ± 12.5a
F_1 cross	FL_7	75	1233.2 ± 149.2a	1343.1 ± 153.9ab	159.0 ± 16.3b
F_1 cross	L_7F	67	1238.8 ± 141.0ab	1355.0 ± 135.9ab	160.3 ± 11.1b
F_1 cross	BL_2	49	1271.0 ± 125.0abc	1386.7 ± 139.1bc	161.2 ± 12.4bc
F_1cross	L_2B	50	1282.4 ± 135.6bc	1450.4 ± 109.8d	168.8 ± 17.0e
F_1 cross	BL_7	82	1268.4 ± 165.7abc	1469.4 ± 150.4d	150.9 ± 12.7a
F_1 cross	L_7B	78	1262.1 ± 145.1ab	1454.3 ± 141.0d	159.8 ± 12.4b

* BWSM, ADBW and AGESM refer to body weight at sexual maturity, adult body weight, and age at sexual maturity respectively.

Means within the same trait that have no subscript letters in common are significantly different ($P < 0.05$).

was no evidence that the Norwegian strains differed from each other with respect to body size at sexual maturity. Inspite of much overlapping the tendency was for the body weights of the crosses to fall in between those of the pure breeds. Except for one or two cases there did not seem to be important differences among the F_1 crosses with respect to body sizes at sexual maturity. The trend for adult body weights was somewhat similar to that for body weight at sexual maturity in some ways but was also different in other ways. The similarity was that in both traits the Egyptian breeds had the smallest body sizes and did not significantly differ from each other. Also for both traits the Norwegian stocks had the largest body sizes, with the genetic group L_7L_7 tending to be heavier than the genetic group L_2L_2. As was the case for body weight at sexual maturity the crosses tended to lie in between the purebreds with respect to adult body weights as well. However, in contrast with body weights at sexual maturity significant differences were evident between the two Norwegian stocks and also among some crosses with respect to adult body size. There was a discernible division of the crosses, with one group consisting of crosses between the Fayoumi and Norwegian stocks and the other consisting of crosses involving the Baladi and Norwegian stocks. Within each group the crosses tended to have similar adult body weights, which were significantly different from those of the other groups of crosses. The only exceptions were the Baladi x L_2 (i.e. BL_2) cross which appeared to have the same body size as the Fayoumi crosses, and the L_2 x Fayoumi (i.e. L_2F) cross which was not significantly different from the Baladi crosses. This trend was also apparent for body

Table 4.3.1b : Mean performance of Egyptian and Norwegian strains and their crosses: Egg production traits

Type	Genetic group	Traits *			
		EN 90	EN 5000	EP (%)	EGGWT (g)
Pure breed	FF	42.7 ± 10.3a	149.7 ± 32.6a	43.9 ± 9.1a	43.2 ± 6.3bc
Pure breed	BB	44.1 ± 16.4abc	150.6 ± 34.1a	44.8 ± 10.1a	40.3 ± 8.4a
Pure breed	L_2L_2	49.5 ± 10.6d	194.9 ± 41.4e	58.4 ± 11.8de	49.4 ± 5.9e
Pure breed	L_7L_7	47.1 ± 10.7bcd	180.9 ± 56.2bcd	55.0 ± 16.2e	51.1 ± 5.9e
F_1 cross	FL_2	48.6 ± 12.4cd	177.0 ± 42.8bcd	52.5 ± 12.3bcd	43.3 ± 6.1bc
F_1 cross	L_2F	46.8 ± 10.9cd	173.5 ± 36.8bc	50.0 ± 10.3b	45.5 ± 5.9d
F_1 cross	FL_7	46.8 ± 13.9cd	187.1 ± 40.3de	54.6 ± 11.0cd	44.6 ± 5.8cd
F_1 cross	L_7F	47.6 ± 12.1cd	183.8 ± 43.5cde	53.9 ± 8.7cd	44.7 ± 6.5cd
F_1 cross	BL_2	49.1 ± 10.2d	182.5 ± 32.8bcd	53.7 ± 9.6 cd	43.5 ± 6.6 bc
F_1 cross	L_2B	47.7 ± 13.7bcd	176.0 ± 40.6bcd	52.6 ± 11.4bcd	41.9 ± 5.0ab
F_1 cross	BL_7	43.8 ± 12.7ab	177.4 ± 36.4bcd	50.7 ± 10.2bc	43.9 ± 6.7bcd
F_1 cross	L_7B	46.8 ± 12.1bcd	167.8 ± 43.5b	49.2 ± 12.8b	43.9 ± 6.5d

* EN 90 refers to the number of eggs laid in 90 days beginning the date at sexual maturity; EN 500, EP and EGGWT refer to the number of eggs laid up to 500 days of age, survivors eggs production rate, and egg weight, respectively.

Means within same trait that have no subscript letters in common are significantly different ($P < 0.05$).

weights at sexual maturity, but there the separation among the crosses was not so pronounced. It is rather curious that the Baladi crosses superceded those of the Fayoumi while the pure Baladi breed was smaller than the Fayoumi breed. Also it is not quite understandable why the Baladi x L_2 cross performed significantly poorer than the other Baladi crosses while the reverse was true for the L_2 x Fayoumi cross. The results for age of sexual maturity reveal that, whereas the Egyptian breeds attained sexual maturity at about the same age the differences between the Norwegian lines with respect to this trait were statistically significant. The Norwegian lines tended to mature at a later age than the Egyptian breeds, though the difference between the the genetic group L_2L_2 and the Baladi breed was not significant. Also with respect to age of sexual maturity some curious feature was apparent. Whereas the genetic group L_7L_7 matured at a later age than L_2L_2, most of the crosses involving line L_7 matured much earlier than the crosses of line L_2. The only exception was the cross L_2F which, together with the BL_7 cross, matured significantly earlier than the rest of the genetic groups. The relative performance of genetic groups differed between the two egg production traits i.e. NE90 and EN500, so much that the best genetic groups with respect to the former trait were not necessarily the best for the latter and vice versa. The only exceptions were L_2L_2 and the Fayoumi which ranked first and last respectively, for both traits. For both egg production measures the Egyptian breeds had similar performance levels which were significantly lower than those of the other genetic groups. There was much overlapping among most, if not all crosses with

respect to both egg production measures. There was little evidence to suggest the existence of differences of any importance among the crosses. However, widely separated crosses in the rank were significantly different from each other. It is rather strange that despite the wide range of performance observed between some genetic groups these differences were not statistically significant. This suggests that random variation constituted a significant proportion of the total variation in the material investigated. Not withstanding this complication, some trend in the relative performance of the genetic groups was discernible for the ninety day egg production record, but not for the 500-day production record. The crosses involving line L_2 tended to do better than corresponding crosses involving line L_7, with respect to the ninety day egg production record. As for the 500 - day production record, both reciprocal crosses between Fayoumi and Line L_7 competed favourably with the genetic group L_2L_2. The relative performance of the genetic groups with respect to egg production intensity did not quite match with that of the 500 - day egg number. This may not be surprising, for the two traits relate to slightly different parameters. Whereas the egg production intensity measures just the average rate of laying for the whole year, the 500 - day egg number is a measure of both the age of sexual maturity and rate of egg production. The two measures would give the same result if differences in the age of sexual maturity were either absent or unimportant. Despite some differences in the two measures of full year egg production there is some relationship between them. The results in Table 4.3.1b show that there is some tendency for

genetic groups which are good with respect to one of the traits to perform well also with respect to the other trait. From these results it is evident that the Norwegian stocks laid at about the same intensity which was significantly higher than those for the other genetic groups. On the other hand the Egyptian breeds had similar laying rates which were significantly lower than those of the other genetic groups. The crosses were intermediate. However, the crosses between Fayoumi and line L_7 outperformed all the other crosses, though their differences from some crosses were not statistically significant.

As far as egg weight was concerned the Norwegian stocks were decidedly superior to the Egyptian breeds as well as to the crosses. Despite the fact that the genetic group L_7L_7 seemed to lay eggs that were larger than those of L_2L_2 the differences in egg sizes of these stocks were not significant. Though both Egyptian breeds were at the bottom of the egg size rank the Fayoumi breed laid significantly larger eggs than the Baladi. Similar to the trend for all other traits, the crosses fell in-between the pure breeds with respect to this trait as well. There was much overlapping among the performance levels of the crosses, the differences being significant only between crosses that were widely separated in the rank order.

The general feature for all traits considered was that the performance of the crosses were not exactly mid-way between those of the parental breeds. The crosses were found to be much smaller in size than the mid-parent both at sexual maturity and in adulthood.

Furthermore the crosses laid eggs which were much smaller than the mid-parent value. On the other hand the crosses were superior to the mid-parent with respect to age of sexual maturity and egg production traits. The deviation of the cross performance from the mid - parent value appeared to vary not only with traits but also with the type of cross.

It is apparent from the results in Appendix Table II that despite the wide range between the minimum and maximum values observed for body weights at sexual maturity and adult body size, the coefficients of variation for these traits were rather small in all the genetic groups. This suggests that the observed minimum and maximum values were extremes in the general distribution of the populations from which they were drawn. A similar inference may be made for age of sexual maturity.

However, variability seems to have been considerable for egg production rate and was moderate for egg size. The variability of a material has an important bearing on the reproduceability or reliability of the the information obtained from a sample of the material. In the present experiment the number of birds observed in the different genetic groups ranged from 49 to 93 with most groups having more than 60 birds (Table 4.3.1a). Since in most genetic groups the coefficients of variation rarely exceeded 25% there seems to be a ground for considering that the results presented in Tables 4.3.1a and 4.3.1b reflected fairly accurately the relative merits of the genetic groups studied.

Tables 4.3.2a, 4.3.2b and 4.3.2c show the additive genetic, heterosis, and reciprocal component estimates respectively, for Egyptian and Norwegian stocks and for crosses between them. The results for the additive genetic estimates in Table 4.3.2a reveal that there were no important differences between the Egyptian breeds, except for egg weight, in which case the Fayoumi was superior to the Baladi breed. However, there was a tendency for the Baladi to outperform the Fayoumi with respect to all measures of egg production, whereas the Fayoumi tended to have a larger body size and to mature earlier than the Baladi. The Egyptian breeds were genetically inferior to the Norwegian stocks for all traits considered except age at sexual maturity, for which the Egyptian breeds were superior. There was no evidence of important differences between the two Norwegian stocks with respect to body size at sexual maturity, part-year egg number, full year egg production rate, or egg size. However, significant genetic differences between these stocks were evident for age at sexual maturity, full-year egg number and adult body weight, the first two traits in favour of L_2L_2 and the third in favour of line L_7L_7.

The picture for heterosis resulting from crossbreeding between Egyptian and Norwegian stocks (Table 4.3.2b) is less clear than that for additive effects. Apparently there were no significant heterosis differences among the crosses with respect to part - year egg number and egg size. With respect to adult body size only the heterosis in the cross between the Fayoumi and line L_7 (i.e. the cross FL_7 and L_7F) was significantly different from the heterosis

Table 4.3.2a : Comparison between the additive genetic constant estimates of Egyptian and Norwegian stocks

Traits	Additive genetic constant estimates for different breeds*			
	GF	GB	GL_2	GL_7
BWSM (g)	- 40.8 ± 14.3b	- 66.9 ± 19.2b	33.4 ± 15.2a	74.4 ± 15.6a
ADBW (g)	- 95.4 ± 14.1c	- 120.0 ± 19.0b	68.8 ± 15.0b	146.6 ± 15.4a
AGESM (days)	- 6.1 ± 1.3c	- 2.0 ± 1.8bc	-1.0 ± 1.3b	7.1 ± 1.4a
EN 90	- 3.1 ± 1.2c	- 1.8 ± 1.60bc	3.7 ± 1.0a	1.2 ± 1.3ab
EN 500	- 19.3 ± 4.1c	- 18.4 ± 5.6c	25.9 + 4.4a	11.9 ± 4.5b
EP (%)	- 6.6 ± 1.3b	- 5.7 ± 1.6b	7.8 ± 1.3a	4.5 ± 1.3a
EGGWT (g)	- - 2.8 ± 0.6b	- 5.7 ± 0.9c	3.4 ± 0.7a	5.1 ± 0.7a

* Expressed as deviations from the general population mean ,

Estimates with no subscript letters in common within the same trait are significantly different ($P < 0.05$)

Table 4.3.2b : Comparison between the constant estimates for heterosis in crosses between Egyptian and Norwegian stocks

Traits	Constant estimates for heterosis in different crosses *			
	HFL_2	HFL_7	HBL_2	HBL_7
BWSM (g)	- 11.8 ± 15.2a	- 78.8 ± 15.7b	- 3.4 ± 16.8a	- 36.0 ± 18.5ab
ADBW (g)	- 34.7 ± 15.1a	-125.8 ± 15.6b	- 5.3 ± 16.6a	- 1.2 ± 18.4a
AGESM (days)	- 5.0 ± 1.4ab	- 7.6 ± 1.4b	- 1.3 ± 1.5a	- 14.0 ± 1.7c
EN 90	1.3 ± 1.3a	2.3 ± 1.3a	1.3 ± 1.4a	- 0.3 ± 1.6a
EN 500	3.0 ± 4.4b	20.2 ± 4.5a	6.0 ± 4.9b	6.8 ± 5.4ab
EP (%)	0.1 ± 1.3b	4.8 ± 1.3a	1.5 ± 1.4ab	0.0 ± 1.5b
EGGWT (g)	- 1.9 ± 0.7a	- 2.5 ± 0.7a	- 2.1 ± 0.3a	- 0.8 ± 0.8a

* HFL_2, HFL_7, HBL_2 and HBL_7 refer to the heterosis in the crosses between Egyptian and Norwegian stocks as suggested by the subscript symbols.

Estimates with no subscript letters in common within the same trait are significantly different ($P < 0.05$).

in all other crosses. As for body weight at sexual maturity the difference between the heterosis in the Fayoumi x L_7 crosses and that in the Baladi x L_7 crosses only approached the significant level, while the heterosis levels in the rest of the crosses were similar. An important heterosis difference was observed also between the cross Baladi x L_7 and all other crosses for age of sexual maturity. It is to be noted that heterosis effects were negative in sign with respect to body weight at sexual maturity, adult body size, age of sexual maturity and egg size. Thus the general feature was that the heterosis in the cross between Fayoumi and line L_7 had the most depressive effects for both body size traits and egg size whereas the heterosis between Baladi and line L_7 had the biggest influence in advancing the age at sexual maturity. On the other hand the heterosis in Fayoumi x L_7 crosses appeared to be significantly higher than that in other crosses (except the Baladi x L_7 cross) with respect to the total egg number up to 500 days of age of the pullets. This heterosis was also higher than that in other crosses (except the Baladi x L_2 cross), with respect to the full - year egg production rate.

The results in Table 4.3.2c reveal that there were no important differences among the breeds in their reciprocal effects for all the traits considered, except age at sexual maturity. For this trait it appears that the Fayoumi and line L_7 were favoured as sires with no significant differences between them, whereas the Baladi and line L_2 would be suited as dams. However, the reciprocal component of line L_2 was significantly lower in magnitude

Table 4.3.2c : Comparison between the constant estimates for reciprocal effects of Egyptian and Norwegian stocks

Traits	Constant estimates for reciprocal effects for different breeds*			
	RF	RB	RL_2	RL_7
BWSM (g)	- 12.4 ± 7.7b	4.1 ± 9.2ab	13.6 ± 6.0a	- 5.2 ± 6.7b
ADBW (g)	- 6.3 ± 7.7a	- 6.6 ± 9.1a	- 19.1 ± 0.6a	- 6.1 ± 6.6a
AGESM (g)	3.1 ± 0.7a	- 3.6 ± 0.8c	- 1.1 ± 0.5b	2.6 ± 0.6a
EN 90	0.1 ± 0.6a	0.0 ± 0.8a	- 1.0 ± 1.8a	0.6 ± 1.6a
EN 500	0.4 ± 2.2a	2.3 ± 2.6a	- 1.0 ± 0.5a	- 1.8 ± 1.9a
EP (%)	0.5 ± 0.6a	0.1 ± 0.8a	0.5 ± 0.3a	0.2 ± 0.6a
EGGWT (g)	- 0.5 ± 0.4a	0.2 ± 0.4a	0.0 ± 0.2a	0.3 ± 0.3a

* RF, RB, RL_2 and RL_7 stand for the reciprocal effects of the Fayoumi, Baladi, L_2L_2 and L_7L_7 stocks.

Estimates with no subscript letters in common within the same trait are significantly different ($P < 0.05$).

than that of the Baladi.

Despite the general impression obtained by comparing the components of merit due to different breeds or breed combinations, it is considered that the implications of the differences or similarities among these components may be better realized if they were pooled together into components of means for the different genetic groups investigated in this study. The procedure for pooling together the components from different breeds or breed combinations was briefly described in the foregoing section (pg 47) . The pooled or reconstituted components are shown for the various traits in Tables 4.3.3a, 4.3.3b and 4.3.3c.

The main feature for the additive genetic component (Table 4.3.3a) was that the Norwegian stocks were superior to the Egyptian breeds, and therefore also to the crosses with respect to all the traits considered (except age at sexual maturity). There was no evidence of genetic differences between the Norwegian stocks with respect to body weight at sexual maturity, egg number in 90 days after sexual maturity, full-year egg production rate and egg weight. Of course these results follow directly from those of Table 4.3.2a where the genetic merits of individual purebreds were compared. The genetic group L_7L_7 was genetically slower in attaining sexual maturity and was genetically heavier than L_2L_2 at sexual maturity. L_2L_2 on the other hand had a higher genetic potential for the 500 - day egg number, but not for the full - year laying intensity. The trend for the Egyptian breeds also was as described for Table 4.3.2a, i.e. There did not seem to exist any

Table 4.3.3a : Reconstituted merit components for body weights and egg size in Egyptian and Norwegian stocks and their crosses

Trait	Type	Genetic group	Reconstituted components (g)*			
			Add. genetic	Heterosis	Reciprocal	Sum
BWSM	Pure breed	FF	1257.2ef	0.0a	0.0b	1257.2
	Pure breed	BB	1231.1f	0.0a	0.0b	1231.1
	Pure breed	L_2L_2	1331.4ab	0.0a	0.0b	1331.4
	Pure breed	L_7L_7	1372.4a	0.0a	0.0b	1372.4
	F_1 cross	FL_2	1294.3cd	-11.8a	-26.0bc	1256.5
	F_1 cross	L_2F	1294.3cd	-11.8a	26.0a	1308.5
	F_1 cross	FL_7	1314.3abc	-78.8b	-7.2bc	1228.8
	F_1 cross	L_7F	1314.3abc	-78.8b	7.2ab	1243.2
	F_1 cross	BL_2	1281.3de	- 3.4a	-9.5bc	1268.4
	F_1 cross	L_2B	1281.3de	- 3.4a	9.5ab	1287.4
	F_1 cross	BL_7	1301.3bcd	-36.0ab	9.3ab	1275.1
	F_1 cross	L_7B	1301.3bcd	-36.0ab	- 9.3ab	1256.5
ADBW	Pure breed	FF	1354.3f	0.0a	0.0ab	1354.3
	Pure breed	BB	1329.7f	0.0a	0.0ab	1329.7
	Pure breed	L_2L_2	1518.5b	0.0a	0.0ab	1518.5
	Pure breed	L_7L_7	1590.3a	0.0a	0.0ab	1590.3
	F_1 cross	FL_2	1436.4de	-34.7b	12.9a	1414.6
	F_1 cross	L_2F	1436.4de	-34.7b	-12.9b	1388.8
	F_1 cross	FL_7	1475.3c	-125.8c	- 0.1ab	1349.4
	F_1 cross	L_7F	1475.3c	-125.8c	0.1ab	1349.6
	F_1 cross	BL_2	1424.1e	- 5.3ab	12.5ab	1431.3
	F_1 cross	L_2B	1424.1e	- 5.3ab	-12.5ab	1406.3
	F_1 cross	BL_7	1463.0cd	- 1.2ab	- 0.5ab	1461.3
	F_1 cross	L_7B	1463.0cd	- 1.2ab	0.5ab	1462.3

Table 4.3.3a cont.:

Trait	Type	Genetic group	Reconstituted components (g)			
			Add. genetic	Heterosis	Reciprocal	Sum
EGGWT	Pure breed	FF	43.2e	0.0a	0.0ab	43.2
	Pure breed	BB	40.3f	0.0a	0.0ab	40.3
	Pure breed	L_2L_2	49.4a	0.0a	0.0ab	49.4
	Pure breed	L_7L_7	51.1a	0.0a	0.0ab	51.1
	F_1 cross	FL_2	46.3bc	-1.9b	-0.5b	43.9
	F_1 cross	L_2F	46.3bc	-1.9b	0.5a	44.9
	F_1 cross	FL_7	47.2b	-2.5b	-0.8b	43.9
	F_1 cross	L_7F	47.2b	-2.5b	0.8a	45.5
	F_1 cross	BL_2	44.9d	-2.1b	0.2ab	43.0
	F_1 cross	L_2B	44.9d	-2.1b	-0.2ab	42.6
	F_1 cross	BL_7	45.7cd	-0.8ab	-0.1ab	44.8
	F_1 cross	L_7B	45.7cd	-0.8ab	0.1ab	45.0

*Estimates with no subscript letters in common within column and trait are significantly different ($P < 0.05$).

significant genetic difference between them for any trait except egg weight. Thus with respect to most of the traits considered in this study three categories of genetic groups were recognizable i.e. the Norwegian stocks, being genetically the most superior for almost all traits, the crosses and lastly the Egyptian breeds. There was so much overlapping in the additive genetic merits of the crosses that it was difficult to make a clear cut observation about these genetic groups. However, there was a tendency for crosses involving line L_7 to be heavier at sexual maturity and in adulthood than crosses involving line L_2. Also egg size tended to be larger in crosses involving line L_7 than in crosses of line L_2. On the other hand crosses of line L_2 were superior to those of line L_7 with respect to all egg production measures. Though there was some faint evidence suggesting the existence of genetic differences among widely separated crosses in the rank order, it is doubtful if such differences would be of much practical value.

The results in Table 4.3.3b show that heterosis levels were for most traits similar in all the crosses. Again the results for heterosis in Table 4.3.3b follow directly from those shown for the same component in Table 4.3.2b, thus there would be no need of restating them. It is only worth adding that the results in Table 4.3.3b show that for all the traits considered most heterosis effects were not only similar but also were not significantly different from zero. The only exceptions were the heterosis for body size, egg size, and egg production traits in the Fayoumi x L_7 cross and for age at sexual maturity in the Baladi x L_7 cross.

Table 4.3.3b : Reconstituted merit components for age at sexual maturity and egg number in 90 days after onset of sexual maturity in Egyptian and Norwegian stocks and their crosses

Trait	Type	Genetic group	Reconstituted components*			
			Add. genetic	Hetero-sis	Recipro-cal	Sum
AGESM (days)	Pure breed	FF	160.7e	0.0a	0.0d	160.7
	Pure breed	BB	164.8cde	0.0a	0.0d	164.8
	Pure breed	L_2L_2	165.8c	0.0a	0.0d	165.8
	Pure breed	L_7L_7	173.9a	0.0a	0.0d	173.9
	F_1 cross	FL_2	163.3de	-5.0bc	4.2ab	162.5
	F_1 cross	L_2F	163.3de	-5.0bc	-4.2fg	154.1
	F_1 cross	FL_7	167.3bcd	-7.6c	0.5cd	160.2
	F_1 cross	L_7F	167.3bcd	-7.6c	-0.5de	159.2
	F_1 cross	BL_2	165.3cd	-1.3ab	-2.5ef	161.5
	F_1 cross	L_2B	165.3cd	-1.3ab	2.5bc	166.5
	F_1 cross	BL_7	169.4b	-14.0d	-6.2a	149.2
	F_1 cross	L_7B	169.4b	-14.0d	6.2a	161.2
EN 90	Pure breed	FF	42.8e	0.0ab	0.0ab	42.8
	Pure breed	BB	44.1de	0.0a	0.0ab	44.1
	Pure breed	L_2L_2	49.6a	0.0a	0.0ab	49.6
	Pure breed	L_7L_7	47.1ab	0.0a	0.0ab	47.1
	F_1 cross	FL_2	46.2bcd	1.3a	1.1a	48.1
	F_1 cross	L_2F	46.2bcd	1.3a	-1.1b	46.4
	F_1 cross	FL_7	45.0cde	2.3a	-0.5ab	46.8
	F_1 cross	L_7F	45.0cde	2.3a	0.5a	47.8
	F_1 cross	BL_2	46.9bc	1.3a	1.0ab	49.2
	F_1 cross	L_2B	46.9bc	1.3a	-1.0ab	47.2
	F_1 cross	BL_7	45.6bcde	-0.3a	-0.6ab	44.7
	F_1 cross	L_7B	45.6bcde	-0.3a	0.6ab	45.9

* Estimates with no subscript letters in common within column and trait are significantly different ($P < 0.05$).

Table 4.3.3c : Reconstituted merit components for egg number at 500 days of age and laying intensity in Egyptian and Norwegian stocks and their crosses.

Trait	Type	Genetic group	Reconstituted components *			
			Add. genetic	Hetero-sis	Recipro-cal	Sum
EN 500	Pure breed	FF	149.7e	0.0b	0.0ab	149.7
	Pure breed	BB	150.6e	0.0b	0.0ab	150.6
	Pure breed	L_2L_2	194.9a	0.0b	0.0ab	194.9
	Pure breed	L_7L_7	180.9b	0.0b	0.0ab	180.9
	F_1 cross	FL_2	172.3bc	3.0b	1.4ab	176.7
	F_1 cross	L_2F	172.3bc	3.0b	-1.4ab	173.9
	F_1 cross	FL_7	165.3d	20.2a	2.2ab	187.7
	F_1 cross	L_7F	165.3d	20.2a	-2.2ab	183.3
	F_1 cross	BL_2	172.8b	6.0b	3.3ab	182.1
	F_1 cross	L_2B	172.8b	6.0b	-3.3ab	175.5
	F_1 cross	BL_7	165.8cd	6.8ab	-4.1b	176.7
	F_1 cross	L_7B	165.8cd	68ab	-4.1b	168.5
EP (%)	Pure breed	FF	43.9c	0.0b	0.0a	43.9
	Pure breed	BB	44.8c	0.0b	0.0a	44.8
	Pure breed	L_2L_2	58.3a	0.0b	0.0a	58.3
	Pure breed	L_7L_7	55.0a	0.0b	0.0a	55.0
	F_1 cross	FL_2	51.1b	0.1b	0.0a	51.2
	F_1 cross	L_2F	51.1b	0.1b	0.0a	51.2
	F_1 cross	FL_7	49.5b	4.8a	0.4a	54.7
	F_1 cross	L_7F	49.5b	4.8a	-0.4a	53.9
	F_1 cross	BL_2	51.6b	1.5ab	-0.4a	52.7
	F_1 cross	L_2B	51.6b	1.5ab	0.4a	53.5
	F_1 cross	BL_7	49.9b	0.0b	0.0a	49.9
	F_1 cross	L_7B	49.9b	0.0b	0.0a	49.9

* Estimates with no subscript letters in common within column and trait are significantly different ($P < 0.05$).

It is evident from the results shown in Table 4.3.3c that reciprocal effects were not an important factor of merit in the crosses. There was, however some faint evidence of reciprocal differences with respect to age of sexual maturity, but even in this case there was so much overlapping among the genetic groups that significant differences were detectable only between widely separated genetic groups in the rank order. It is doubtful if differences of this magnitude would be of much practical importance.

Table 4.3.4 shows the heterosis levels resulting from different crosses between Egyptian and Norwegian stocks. It is revealed by these results that heterosis effects were only moderate or low for nearly all the traits. The only heterosis level exceeding 10% was that for the 500 - day egg number in the Fayoumi x L_7 cross. Furthermore, as it has been pointed out earlier, negative heterosis was manifested for body size, egg size and age at sexual maturity, while egg production traits appeared to be positively affected by heterosis. It is worth noting that the negative heterosis for age at sexual maturity was in the desirable direction.

Discussion

The evidence obtained in the present study indicated that, except for age at sexual maturity the Norwegian stocks were superior to the Egyptian breeds for all the traits considered. This is rather surprising because the environmental conditions in which the Norwegian stocks had been selected are expected to

Table 4.3.4 : Heterosis in F_1 crosses between Egyptian and Norwegian stocks

Traits	Type of crosses and resultant heterosis (%)			
	Fayoumi x L_2	Fayoumi x L_7	Baladi x L_2	Baladi x L_7
BWSM	- 0.9	- 6.0	- 0.3	- 2.8
ADBW	- 2.4	- 8.5	- 0.4	- 0.1
AGESM	- 3.1	- 4.5	- 0.8	- 8.3
EN 90	2.9	5.1	3.3	- 0.7
EN 500	1.8	12.2	3.8	4.1
EP (%)	0.3	8.9	2.9	0.0
EGGWT	- 4.1	- 5.3	- 4.7	- 1.8

be quite different from those prevailing in Egypt. On the other hand the Egyptian breeds are expected to be well adapted to the environment of that region. Notwithstanding the recognition that the Norwegian stocks had been genetically improved for productive traits, one could still expect that the environmental differences between Norway and Egypt would be large enough to invoke important genotype x environment interactions. The effect of such interactions would be to mask or reverse any genetic differences existing between the two breed types. The comparative performance of the Norwegian lines in Norway (Kolstad, 1981) and in Egypt (material E) are shown in Table 4.3.5.

The data in this table indicate that the Norwegian lines matured sexually about three to four weeks later in Egypt than in Norway. However, the difference between the two lines with respect to this trait was about the same in both countries. It is also evident that the two lines reached about the same adult body weight both in Egypt and in Norway, and the difference between them was about the same in the two countries. It is somewhat difficult to comment on the comparative performance of these lines in the two countries with respect to egg production and egg size since these traits were measured at different periods of production in the two countries. However, it seems that the performance levels attained in Egypt were lower than those attained in Norway. The apparently lower performance of the Norwegian lines in Egypt than in Norway with respect to age at sexual maturity, egg production and egg size suggests that the environmental conditions in Egypt were probably

Table 4.3.5 : Comparative performance of Norwegian lines in Norway and in Egypt

Traits	Norway Kolstad (1981)		Egypt Present study*	
	Line L_2	Line L_7	L_2L_2	L_7L_7
Age at. sexual maturity (days)	140	150	167.9	173.9
Egg number in 90 days after Sexual maturity	-	-	49.5	47.1
Egg number at 42 weeks of age	121	109	-	-
Adult body weight (g)	1513	1666	1518.5	1596.3
Egg weight at 38 weeks of age	-	-	49.5	51.1
Egg weight at 42 weeks of age	54.3	58	-	-

* L_2L_2 and L_7L_7 were renamed from line L_2 and line L_7 respectively.

not as suitable for these lines as those prevailing in Norway. One possible environmental stress which these lines might have suffered from in Egypt could have been high ambient temperatures. But also disease problems might have had some influence. However, the fact that the Norwegian lines outperformed their Egyptian counterparts may be an indication that the experimental conditions in Egypt were still conducive to superior genotypes to express their merit. This is further indicated by the observation that the differences between the two Norwegian stocks were in the same direction in both countries. Such a result may not be surprising when birds are managed under well controlled environmental conditions, with well insulated and ventilated shelters, balanced rations and sound disease control programmes.

The lack of significant differences between the Egyptian breeds for nearly all traits considered is not surprising in view of the fact that these breeds had not been subjected to intensive and persistent artificial selection for productive traits.

Despite the extreme overlapping in the mean performances of the crosses, widely separated genetic groups in the rank order were in most cases significantly different from each other. The overlapping among the genetic groups was mainly due to the small genetic differences between the Norwegian stocks and also between the Egyptian breeds. Also as a consequence of the small genetic gap between the Norwegian stocks and also between the Egyptian breeds the mean performance of nearly all the crosses was to be found in between those of the two types of breeds.

For most of the traits considered heterosis and reciprocal differences among the crosses were either unimportant or non-existent.

In the present study considerable heterosis was observed only in the Fayoumi x L_7 cross, for body size and egg production traits and in the Baladi x L_7 cross, for age of sexual maturity. It is not clear why other types of crosses did not show as much heterosis as the above crosses.

Also it is not understood why the Fayoumi x L_7 cross should exhibit considerable heterosis only for body size and egg production traits while the Baladi x L_7 cross exhibited pronounced heterosis only for age of sexual maturity and not for other traits. The genetic distances between the parents forming the different cross combinations were expected to be the same. Generally it appears that line L_7 performed better in crosses than line L_2, but the two Egyptian breeds were equally suitable as the second parental breeds in crosses with the Norwegian lines.

That special effects peculiar to certain breed combinations exist had been also demonstrated for age at sexual maturity and part - year egg production in the study of Wearden et al. (1967). But these workers had noted that the superiority of heterosis arising from certain breed combinations could not be predicted on the basis of pure strain or average performance of a strain in crosses. However, Gowe and Fairful (1982) concluded

from their study that superior crosses generally had above average parents. These workers, however, have emphasized the importance of testing parental breeds in all possible combinations to find those which combine best.

The observed tendency in the present study for the crosses to have smaller body weights and to produce smaller eggs than the respective mid - parent values indicates the existence of negative heterosis with respect to these traits. The occurrence of negative heterosis for these traits was discussed in the foregoing section. To add to the list of speculations one could postulate that the negative heterosis observed for body weight and egg size might have been the result of a positive heterosis for a trait or traits which are phenotypically (or genetically) negatively correlated to body size and egg size. For example it may be reasoned that the reduction in age at sexual maturity resulting from heterosis would be associated with a reduction in the body weights of the birds at sexual maturity. Early attainment of sexual maturity might also cause nutritional or physiological strains to be imposed on the pullets hence reducing their adult body size. In the same way it may be contended that the increase in the rate of egg production due to heterosis would have a depressive effect on egg size. There is considerable literature on the association (both environmental and genetic) between age at sexual maturity, body weight at sexual maturity, adult body size, laying intensity and egg size (King, 1961; Jaap et al., 1962; Merritt, 1968; Kolstad, 1972a; Lien, 1973; Nordskog et al., 1974). Whereas in the majority

of the studies a negative genetic correlation was indicated between egg laying intensity and egg size, and a positive genetic correlation was indicated between age at sexual maturity and adult body weight, environmental correlations between these traits were usually either small or positive. At present there seems to be a scarcity of literature on the correlated response to heterosis effects. In the present study the most important heterosis effects for age at sexual maturity were expressed in the Baladi x L_7 cross whereas the most important heterosis for body weight at sexual maturity, adult body size, egg production and egg size were demonstrated in the Fayoumi x L_7 cross.

The lack of significant differences among the reciprocal effects of the breeds investigated in this study was in some way contrary to the findings reported from other studies. In the present study some evidence of important breed differences in reciprocal effects were demonstrated only for age at sexual maturity. In most of the studies aimed at detecting these components evidence of their existence was demonstrated to a large or small extent. Gowe and Fairful (1982) observed significant reciprocal effects for unrelated strain crosses of chickens with respect to body weight, age at sexual maturity, egg production and egg size. These effects were important for many other traits included in their study. These workers, however, were able to note that reciprocal effects were absent in related strain crosses. Wearden et al (1967) considered that maternal influences were important only for adult body size, but not for egg production traits.

This was contrary to the findings reported by Goto and Nordskog (1959) who had observed important maternal effects for egg production traits. Consistent, but small, maternal effects for egg production traits had also been reported by King (1961).

The general picture revealed for material E is that the additive genetic effects were the most important determinant of performance both in the pure breeds and in the crosses. Heterosis effects were large only in crosses between Fayoumi and L_7, and for one trait (age at sexual maturity) in the Baladi x L_7 crosses. It is considered that larger heterosis effects than observed in the present study could have been manifested if the test conditions in Egypt had been more severe. It is generally conceded (e.g. Orozco, 1974; Sheridan, 1981; and Cunningham, 1982) that heterosis effects would be manifested more in adverse environments than in optimum or near optimum conditions.

Despite the fact that the Egyptian breeds had lower egg production and egg size potential than the Norwegian stocks, it is worth noting some of the characteristics of economic importance in these breeds. The birds had smaller body size, and hence would have lower maintenance requirements than the Norwegian stocks. As the body weights of the crosses appeared to fall below the mid - parent value, they would be a good starting point for selection to improve egg production and egg size while keeping body size at a constant level. Secondly, as has been pointed out by Abdou and Kolstad (1984), much would be gained

by incorporating the adaptive qualities of the Egyptian breeds to the environment of that region, in the development of highly productive strains. Some evidence is available (Nordskog and Philips, 1960; Briggs and Nordskog, 1973; Pevzner and Nordskog, 1975; and Nordskog and Pevzner, 1977) to suggest that the Fayoumi breed (and possibly the Baladi as well) is genetically highly resistant to some diseases to which exotic breeds succumb easily.

Marder et al . (1974, after Arad et al., 1975) have published findings to indicate that the Bedouin fowl, native to the desert areas of Israel and the Sinai peninsula, were exceptional in their ability to regulate body temperature, metabolic rate and acid base metabolism when exposed to high (37 - 48^{o}C) ambient temperatures. Arad et al. (1975) were able to demonstrate that the cross between the White Leghorn and the Bedouin breed was efficient both in egg production and its physiological mechanisms in regulating body temperatures under conditions of severe environmental heat. These findings indicated the possibility of combining adaptive and productive qualities in a single stock. It is most likely that the Egyptian breeds have similar adaptive qualities to heat stress as was demonstrated for the Bedouin breed. The importance of incorporating adaptive qualities in breeding programmes have been stressed by a number of workers (e.g. Alberro, 1982; Barker, 1982; Frisch and Vercoe, 1982; and Gregory et al., 1982).

CHAPTER 5

GENERAL CONCLUSIONS AND THEIR APPLICATION TO CHICKEN IMPROVEMENT IN TANZANIA

The main findings from the experiments constituting the present study may be summarized as follows:-

First, the superiority of the exotic germplasm to that of the indigenous chickens was generally demonstrated for nearly all the traits considered in the study.

The differences among the various breeds were shown to be due to mainly their differences in their additive genetic merits. However, there was some evidence to suggest that the differences among the breeds would be less pronounced in stressful than in stress-free environments. This view stems from the observed differences in the relative performance of the exotic and indigenous chickens between the two experiments in Tanzania (i.e. material T_1 and T_2). As it has been pointed out earlier (in chapter 3) the environmental conditions to which the birds of the second year experiment (material T_2) were exposed were generally less favourable than those to which the birds of the first year experiment (i.e. material T_1) were exposed. This resulted in the narrowing of the gap between the exotic and the indigenous chickens, as well as that between the two exotic breeds in traits for which each had been specially selected (i.e. growth rate in the meat type and egg production in the egg type breed).

Furthermore, whereas under good management conditions of experiment T_1 the performance in a particular trait increased with increasing levels of inheritance from the exotic breed which had been developed specifically for the trait the trend was rather obscure under the relatively poor conditions of experiment T_2. These results are consistent with Cunningham's (1981) contention that the additive genetic differences among breeds would be expected to vary with variations in the quality of the environment.

Secondly, the results of the study demonstrated that the differences between the indigenous breeds were very small relative to the gap between the indigenous and exotic breeds. A similar observation applied to similar-purpose lines of exotic breeds. This fact is evident from the results of Experiment E in which the differences between the Egyptian breeds as well as those between the Norwegian strains were found to be very small compared to the differences between the two genetically diverse groups of chickens. However, this was not surprising bearing in mind that very little selection pressure had been applied on the Egyptian breeds, whereas the Norwegian lines had been intensively selected for egg production rate and egg size.

The lack of persistent selection pressure in Egyptian breeds on one hand, and the common ancestry of the Norwegian lines on the other hand accounted for the close similarly observed within each of the two sources of chickens. These results suggest that as far as the additive genetic component of merit is concerned discrimination between unimproved strains of chickens or between similar-purpose improved breeds would not be of much value.

Thirdly, the results revealed that differences between the parental breeds with respect to their additive genetic values were the most predominant factor determining differences in the performance of genetic groups with various proportions of genes from the parental breeds. However heterosis effects also contributed significantly to the observed differences among the genetic groups, especially for juvenile body weights and egg production traits. Heterosis effects might have been responsible for the observed tendency of the superiority of the exotic germplasms to be manifested more strongly in the crosses of the stocks rather than in the purebred chickens. As a matter of fact some of the crossbreds outperformed the purebred exotic chickens. Therefore it appears that in any chicken improvement programme due consideration ought to be given to heterosis effects. In connection with this phenomenon, the results from material E revealed that considerable differences existed between the indigenous breeds with regard to their specific combining ability with the exotic breeds. A similar feature was revealed in respect of the Norwegian lines. This emphasizes the need to test breeds both for their general and specific combining abilities as one of the first stages in an improvement programme aimed at incorporating genes from both types of stocks.

The existence of negative heterosis, which was observed for body size and egg size in all three experiments of the present study may be attributed to a correlated response in these traits resulting from positive heterosis in egg production traits. Negative associations between body size and egg size on one hand, and egg production traits on the other hand, have been widely reported in literature

(e.g. King, 1962, Kinney, 1969 and Abdou and Kolstad, 1979 and 1984). An extensive treatment of the subject has been given by Manwell and Barker (1970).

Fourthly, evidence of important reciprocal effects was revealed for body size, egg size and egg production intensity.

There have been considerable agreement among workers that reciprocal effects could constitute an important component of chicken performance (Warren and Moore, 1958; Nordskog, 1959; Goto and Nordskog, 1959; Goodman and Jaap, 1960; Nordskog and Philips, 1960, King, 1961; Jaap et al., 1962; Eisen et al., 1966; Nordskog and Pevzner, 1977; Gowe and Fairfull, 1982; and Fairfull and Gowe 1986). The general conclusion from most of the studies has been that maternal influences (which together with sex-linked effects consititute the reciprocal effects) are important for traits expressed early in the bird's life (e.g. juvenile body weights and rearing livability), whereas sex-linked effects are important for traits expressed later in the bird's life (i.e. age at sexual maturity and egg size). Maternal influences are considered to manifest themselves through the protective role of maternal antibodies in the progeny (Goto and Nordskog, 1959; Nordskog and Philips, 1960; and Nordskog and Pevzner, 1977). Gowe and Fairfull (1982) have proposed that maternal influences could be manifested through the effect of vertically transmitted diseases such as lymphoid leucosis. Other workers (e.g. Goto and Nordskog, 1959) have suggested that the precursors of maternal influences could be maternal differences in quantity of nutrition (e.g. egg size) and quality of nutrition.

In the present study reciprocal effects tended to be more favourable when either a heavy breed or a crossbred genetic group was used on the maternal side and light breeds were used on the parternal side. These results were in line with the findings reported by Briggs and Nordskog (1973); Pevzner and Nordskog (1975); and Nordskog and Pevzner (1977). It was indicated in these studies that heavy breeds were more favourable as dams than light breeds. It was concluded from these studies that heavy breed dams transmitted antibodies through eggs to their progeny. On the other hand breeds of chickens indigenous to sub-optimal natural environments have been reported to be very resistant to diseases. For example Nordskog and Philips (1960); and Nordskog and Pevzner (1977) observed that the Fayoumi breed were very resistant to leucosis complex. This suggests that indigenous breeds may be a valuable source of disease resistance.

The existence of important reciprocal effects suggests that care ought to be exercised in designating breeds as sire breeds or dam breeds in crossbreeding programmes. This point has been stressed by Gowe and Fairfull (1982).

From the foregoing results it is to be concluded that although exotic breeds have been intesively selected for high performance in specific productive traits maximization of germplasm of these breeds may not necessarily yield the best results under less favourable environments. In such circumstances some adjustment in the gene content of the improved breeds would be valuable in order to adapt the breeds to local production conditions. The most prospective way

of achieving this is through crossbreeding between improved exotic breeds and indigenous breeds to form composite breeds. Further improvement could be made in the composite breed through selection for desired traits.

Furthermore it is imperative from the results of the study that in the formation of composite breeds due consideration would have to be given to the residual heterosis in the composite population. It appears in this case that the highest proportion of inheritance from the exotic breeds which would at the same time be consistent with high heterosis in the composite breed would be optimum. This can occur when intermediate proportions of inheritance from the contributing parental breeds occur in the composite breed.

On the basis of the information summarized above, as well as that which has been reported from other studies it is apparent that the chicken improvement strategy for Tanzania has to have a somewhat different outlook from the strategies persued in developed countries.

There have been arguments by some workers against the idea of developing breeds of animals to suit particular environments and in favour of adopting already improved exotic breeds to take advantage of the genetic potential for productive traits which has been accumulated in these breeds. However, the reasons for advocating the former strategy are three fold:-

First, there is a need for flexibility in animal production systems. This flexibility should include variability in the stocks, each selected for a different set of production conditions and objectives. This aspect has been pointed out by Cartwright (1982) Gregory et al. (1982), Hickman (1980); Rendel (1982) and Smith (1986).

Secondly, there have been considerable evidence to suggest that genotype x environment interactions in fowls could reach such magnitudes as to affect the performance of stocks developed in environments other than those in which they would be required to perform (Fox et al., 1960; Thornton and Whittett, 1960; Harms and Waldroup, 1962; Abplanalp et al ., 1962; Cook et al., 1963). In view of this difficulty there have been a general concesus among workers that breeds should be preferably developed in environments which as far as possible resemble those in which they would subsequently perform. The only conditions for which breed development in an exotic environment would be justifiable are, first when there exists a high genetic correlation in the characters to be improved between the two environments, and secondly, when the heritabilities of the traits in the exotic environment are considerably larger than those in the local environment and at the same time higher selection intensity is possible in the exotic environment than in the local environment (Falconer, 1960). However, in the absence of information about the absolute and relative magnitudes of these population parameters in different environments it seems most appropriate to opt for genetic improvement in the local environment.

Lastly, it has to be borne in mind that achievements derived from the betterment of the environment would be temporary, unless the improved environment is sustained for prolonged periods of time. The sustenance of improved environment requires considerable use of resources many of which may be beyond the reach of poor developing countries. On the other hand gains due to genetic improvement of stocks in their natural environment would be cummulative and of more permanent nature than environmentally derived gains.

Bowman (1981) has pointed out the need for animal breeders to form some views about the intermediate future structure and requirement of agriculture in order to determine what changes in livestock performance may be desirable and therefore for which to select. It is the author's view that the development of high performing local strains of chickens should go hand in hand with the improvement of the environment to exploit the genetic potential inherent in improved breeds.

With regard to growth performance of the birds it is clear from the results of the present study that the disired body weight of 1.5 kg for twelve week old cockerels could be attained much faster by optimizing the proportion of genes from the meat breed. Since the environmental conditions envisaged for the target breed would probably be too harsh for pure meat-type germplasm the maximization of genes from this breed in the composite breed might not yield the best results, as the results of the present study have demonstrated. This may be surprising in view of the fact that

meat type strains are highly selected for fast growth rate. But as Cunningham (1981) has pointed out, while the physiological limitations to performance in good environment could be those of additive genetic merit for production, in poor environments the limitations could be those of tolerance to stressful environment. In the present study crosses between the meat breed and other breeds appeared to offer better solutions. The most prospective genotypes would seem to be the backcross to the meat breed with 25% inheritance from the local breed (i.e. 1/4L3/4M) and the three-breed cross with 50% inheritance of the meat breed (1/4L1/2M1/4E).

For age of the birds at sexual maturity it may not be necessary to devote significant efforts toward the improvement of the trait. In the first year experiment in Tanzania (material T_1) the crosses between the indigenous and exotic breeds were found to attain sexual maturity at about the same age or earlier than the egg type exotic breed (Table 4.1.2a). This trend was also apparent from the results for materials T_2 (Table 4.2.3) whereby none of the pure breeds (including the exotic breeds) had reached the 50% egg production mark by the thirtieth week of age, while most of the crosses had reached this level at about this age or earlier. These results suggest that under the circumstances envisaged for future poultry production the crosses would be expected to perform better than the purebred exotic breeds with respect to the trait. Furthermore, the age at sexual maturity can be varied considerably through the manipulation of light regimes (Siegel et al., 1963; Siegel and Wood, 1964; and Skoglund et al., 1966 and Morris, 1967),

and also through feeding regimes (North, 1972; Olajumoke and Wood, 1982; and Wambeke, 1985).

If the short term egg production records of both experiment T_1 and T_2 are extrapolated it would seem that some crosses between the local and exotic breeds would be expected to lay up to 200 eggs per year. Such performance levels would be quite close to those envisaged for the improved local breed. However, selection for egg production intensity would have to be carried out in the compsite breed to further improve the trait and also to increase uniformity in the breed.

It has been contended by some workers (e.g. Alberro, 1982), that birds with above average performance in unfavourable environments would be expected to be more adapted to the local environment than poor performing birds. Therefore in such circumstances selection for high performance would reinforce natural selection for adaptation to stressful environments.

Egg size is another trait that would probably pose little difficulty in improving. The results from the present study revealed that a 12 - 20% improvement in egg size could be achieved through cross-breeding alone between local and improved exotic chickens. The egg size of 56 to 58 g usually desired in improved breeds would not be too far off from the mean egg size attained by most of the crosses. Furthermore, the usually high heritability of this trait, plus its highly positive genetic correlation with body size would facilitate genetic improvement in the trait through selection in the

segregating material following the cross between different parental breeds.

Reasonably large adult body size would be one of the desired characteristics of the target improved local breed. But it is considered that improvement in this trait would be achieved mainly as a correlated response to selection for juvenile body size and egg size. This expectation is based on the available evidence from various studies that highly positive genetic correlations exist between juvenile body weight, adult body weight and egg size (Clayton and Roberts, 1966; Wilson et al., 1968; Jaap, 1969 and Merritt, 1968 and 1974).

From the above considerations it is apparent that the most important traits to consider in the development of a local breed would be juvenile body weights and egg production intensity. It is considered that breeding efforts directed to the improvement of these traits would also result in the improvement of the overall efficiency of the birds.

In the endeavor to improve both body size and egg production traits in the same stock due attention would have to be paid to the genetic relationship between these two groups of traits. Research findings from some studies have revealed the existence of very small, but positive correlations between juvenile body weights and egg production intensity (Jaap et al., 1962 and Lien, 1973). However, Merritt (1968 and 1974) has reported findings in which small to

moderate negative correlations between juvenile body weights and egg production were indicated. On the other hand the results from selection studies by Nestor et al. (1967) and Nestor (1980) revealed both negative and positive moderate correlations between these traits, depending on the trait being selected for.

It seems that any relationship between juvenile body weights and egg production is mediated through the positive genetic correlation between juvenile and adult body weights on one hand and the negative correlation between adult body size and egg production rate on the other hand. Merritt (1974) has published findings from his selection studies suggesting that improvement in juvenile body size could be achieved without invoking a correlated increase in adult body size. Therefore it would seem that simultaneous improvement in juvenile body weights and egg production intensity is possible.

The best approach in the selection programme would be probably to select for juvenile (e.g. twelve week) body size in one line (to be designated as the sire line) and for egg production intensity in another line (the dam line). Restricted selection indices for juvenile body size and egg production would have to be used in each of the lines. The final product would be produced by crossing between the two lines. The value of this strategy in the simultaneous improvement of genetically opposed traits has been demonstrated by the findings from the studies by Liljedahl and Weyde (1980), Kolstad (1980) and Sørensen et al. (980).

It is therefore clear from the results of the present study and also from the findings reported in literature that there exist possibilities for developing breeds and strains of farm animals specifically for given environments. In this case there seem to exist a possibility of developing a dual-purpose breed of chickens by forming a composite breed possessing genes from the local breed, and improved meat-type and egg type breeds.

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Appendix Table 1a : Variability of genetic groups in material T_2 : Four and eight week body weights

Sex	Type	Genetic group	BW4			BW8		
			Min	Max	CV	Min	Max	CV
F	Pure breed	EE	67.3	267.8	26.5	206.9	656.2	22.6
	Pure breed	LL	55.2	210.6	22.2	170.7	624.7	22.2
	F_2 cross	ME	129.7	358.7	24.2	279.2	866.1	22.7
	F_2 cross	LM	84.8	353.8	30.3	268.6	768.3	22.1
	F_2 cross	LE	71.7	256.7	24.5	136.9	578.9	23.8
	Backcross	3/4M1/4E	105.3	373.8	33.9	305.1	761.9	24.7
	Backcross	1/4M3/4E	80.4	272.1	28.5	145.5	602.4	27.4
	Backcross	1/4L3/4M	100.9	360.9	30.3	272.0	831.6	24.9
	Backcross	3/4L1/4M	71.7	332.0	31.0	235.6	709.3	25.7
	Backcross	1/4L3/4E	70.2	251.1	26.1	123.9	643.3	26.7
	Backcross	3/4L1/4E	80.5	247.1	22.7	135.5	756.5	22.4
	Three-breed cross	1/2L1/4M1/4E	115.2	314.7	20.1	188.9	717.1	21.1
	Three-breed cross	1/4L1/2M1/4E	97.9	343.7	24.9	338.2	736.9	18.2
	Three-breed cross	1/4L1/4M1/2E	115.2	324.7	23.7	182.1	587.9	20.4
M	Pure breed	EE	95.9	261.0	16.6	147.9	625.5	18.4
	Pure breed	LL	123.2	198.7	15.0	346.9	566.2	13.7
	F_2 cross	ME	112.3	362.4	22.7	284.6	963.5	21.9
	F_2 cross	LM	126.3	307.4	24.3	446.2	829.3	18.0
	F_2 cross	LE	97.3	252.9	22.4	283.5	683.6	22.5
	Backcross	3/4M1/4E	165.7	398.7	24.6	403.4	854.2	22.3
	Backcross	1/4M3/4E	110.8	242.9	14.0	230.3	579.0	14.6
	Backcross	1/4L3/4M	158.2	459.1	29.8	477.8	946.7	19.5
	Backcross	3/4L1/4M	161.1	306.8	19.1	449.6	719.5	16.1
	Backcross	3/4L1/4E	130.6	364.5	22.2	244.8	867.7	19.9
	Backcross	1/4L3/4E	90.3	255.7	22.4	302.6	572.7	15.4

Appendix Table I.a cont.

Sex	Type	Genetic group	BW12			BW16		
			Min	Max	CV	Min	Max	CV
M	Three-breed cross	1/2L1/4M1/4E	137.8	359.4	23.0	372.6	786.7	19.4
	Three-breed cross	1/4L1/2M1/4E	158.4	361.2	19.2	294.7	907.8	21.8
	Three-breed cross	1/4L1/4M1/2E	125.0	282.5	22.7	385.1	686.1	16.5

Appendix Table Ib: Variability of genetic groups of material T_2 :Twelve and sixteen-week body weights

Sex	Type	Genetic group	BW 4			BW 8		
			Min	Max	CV	Min	Max	CV
F	Pure breed	EE	359.1	1180.7	22.2	502.2	1382.5	18.6
	Pure breed	LL	344.4	901.2	20.1	516.2	1227.2	16.4
	F_2 cross	ME	488.2	1451.2	21.7	785.1	1617.6	18.2
	F_2 cross	LM	350.5	1103.6	18.8	836.7	1450.3	13.7
	F_2 cross	LE	220.9	853.6	19.0	446.2	1108.7	15.0
	Backcross	3/4M1/4E	511.7	1240.9	18.5	633.5	1864.9	25.5
	Backcross	1/4M3/4E	340.7	974.0	20.4	580.8	1450.3	18.1
	Backcross	1/4L3/4M	670.9	1657.8	24.1	1055.9	1945.6	21.9
	Backcross	3/4L1/4M	272.1	1213.2	24.2	315.4	1692.8	24.6
	Backcross	3/4L1/4E	290.7	983.9	17.9	527.9	1214.3	15.5
	Backcross	1/4L3/4E	352.4	1119.9	22.1	422.4	1539.3	22.8
	Three-breed cross	1/2L1/4M1/4E	442.7	1234.8	17.7	803.6	1561.8	15.9
	Three-breed cross	1/4L1/2M1/4E	578.0	1393.9	17.2	633.5	1712.6	17.9
	Three-breed cross	1/4L1/4M1/2E	301.3	953.1	19.7	892.5	1372.7	11.7
M	Pure breed	EE	458.8	1238.8	17.2	680.8	1503.8	19.5
	Pure breed	LL	712.3	1030.2	12.2	1016.3	1312.2	7.5
	F_2 cross	ME	658.0	2069.3	25.1	839.4	1623.3	18.5
	F_2 cross	LM	577.6	1467.0	23.4	794.3	1815.4	23.1
	F_2 cross	LE	531.3	1931.9	29.0	629.5	1588.5	21.1
	Backcross	3/4M1/4E	712.4	1722.9	24.7	1049.2	1678.8	15.4
	Backcross	1/4M3/4E	504.5	1042.8	14.0	907.7	1361.6	10.4
	Backcross	1/4L3/4M	872.0	1492.6	17.5	1253.8	1734.2	11.6
	Backcross	3/4L1/4M	681.1	1202.9	13.6	1083.2	1361.6	8.6
	Backcross	3/4L1/4E	651.5	1165.7	13.4	873.7	1489.9	11.5
	Backcross	1/4L3/4E	484.0	1247.0	17.7	629.5	1154.2	13.0

Appendix Table Ib cont.

Sex	Type	Genetic group	BW12			BW16		
			Min	Max	CV	Min	Max	CV
M	Three-breed cross	1/2L1/4M1/4E	690.8	1376.5	16.6	848.6	1815.4	16.0
	Three-breed cross	1/4L1/2M1/4E	679.3	1526.9	20.9	894.9	1638.9	15.6
	Three-breed cross	1/4L1/4M1/2E	596.2	1218.4	17.0	833.0	1568.9	15.6

Appendix Table II : Variability in Egyptian and Norwegian stocks and their crosses

Type	Genetic group	BWSM (g)			ADBW (g)			AGESM (days)		
		Min	Max	CV	Min	Max	CV	Min	Max	CV
Pure breed	FF	1000	1700	10.9	1070	1790	10.1	144	180	5.0
Pure breed	BB	1000	1470	8.1	1120	1650	8.8	136	230	9.9
Pure breed	L_2L_2	1100	1705	10.1	1180	1840	9.9	150	191	5.1
Pure breed	L_7L_7	1135	1780	10.4	1340	1950	8.0	151	196	5.4
F_1 cross	FL_2	940	1670	10.9	1050	1760	9.6	136	192	8.5
F_1 cross	L_2F	1055	1700	9.9	1110	1775	9.2	122	186	8.1
F_1 cross	FL_7	950	1790	12.1	1030	1970	11.5	110	196	10.3
F_1 cross	L_7F	915	1600	11.4	1105	1705	10.0	139	187	6.9
F_1 cross	BL_2	970	1600	9.9	1100	1780	10.0	127	188	7.7
F_1 cross	L_2B	1015	1620	10.6	1240	1790	7.6	128	239	10.1
F_1 cross	BL_7	985	1760	13.1	1165	1905	10.2	127	185	8.4
F_1 cross	L_7B	1005	1655	11.5	1205	1820	9.7	120	187	7.8

Appendix Table II cont.

Type	Genetic group	EN 90			EN 500			EGGWT (g)			EP (%)		
		Min	Max	CV	Min	Max	CV	Min	Max	CV	Min	Max	CV
Pure breed	FF	22	70	24.8	77	217	21.8	31	60	14.5	24.9	61.9	20.8
Pure breed	BB	21	77	26.0	74	234	22.7	26	65	20.8	23.7	66.9	22.6
Pure breed	L_2L_2	19	74	21.4	95	285	21.2	39	63	11.9	29.7	84.1	20.2
Pure breed	L_7L_7	16	69	22.7	61	294	31.1	40	67	11.5	19.7	85.5	29.5
F_1 cross	FL_2	16	72	25.9	59	255	24.2	34	64	14.0	17.7	72.9	23.3
F_1 cross	L_2F	15	65	23.3	70	243	21.2	32	59	12.9	19.4	70.2	20.7
F_1 cross	FL_7	14	74	29.6	90	255	21.5	32	58	13.0	28.7	74.6	20.2
F_1 cross	L_7F	21	68	25.8	83	280	25.9	33	66	14.2	26.6	75.7	16.1
F_1 cross	BL_2	15	78	20.9	82	245	18.0	32	60	15.3	22.9	69.8	17.9
F_1 cross	L_2B	15	70	29.3	85	282	23.1	31	54	12.0	26.6	79.5	21.5
F_1 cross	BL_7	14	68	29.0	81	249	20.5	31	61	15.2	23.3	67.1	20.1
F_1 cross	L_7B	21	68	25.8	83	280	25.9	33	66	14.2	21.8	82.4	25.9