EFFECT OF INBREEDING ON THE BODY WEIGHT IN JAPANESE QUAIL

(Coturnix c. japonica)

ALAKH DEO NARAYAN

UNIVERSITY OF EDINBURGH

Postgraduate Regulation 2.4.9.

DECLARATION ON ACCESS TO A THESIS

[The following Declaration is designed to protect the Candidate while expediting the availability of his work to other scholars. Candidates should note that (i) the thesis may be consulted by registered users in Edinburgh University Library or in the libraries of other educational establishments but may not be issued for loan outside any library to individuals except academic staff of the University of Edinburgh; (ii) the Abstract of the thesis is the copyright of the University of Edinburgh. All applicants for consultation, loan or photocopy of the thesis have to sign an appropriate declaration.]

Full Names of Candidate (surname first) NARAYAN ALAKH DEO

Candidate for degree of M. Sc. Faculty of Science

Title of Thesis Effect of inbreeding on the body weight in Japanese quail (Coturnix c Japonica).

Please DELETE two paragraphs of 1–3 below, leave one of them undeleted, and sign the form. Save in exceptional circumstances, PARAGRAPH 1 is recommended.

~~1. I hereby give my permission to Edinburgh University Library to photocopy this thesis in whole or in part for use by individuals, on condition that each person for whom a copy is made signs the following declaration (which will be preserved in Edinburgh University Library and available there for inspection by me);~~

> ~~'I undertake fully to observe the author's copyright in this thesis, not to publish the whole or any part of it without the author's written permission, and not to allow any other person to use the copy made for me'.~~

OR

2. I wish all applicants for photocopies of the whole or any part of this thesis to be referred to me individually; but I recognise that if Edinburgh University Library cannot by reasonable enquiry discover my address the University Librarian will decide, after consulting my Head of Department, whether or not to make a photocopy on obtaining from the applicant a declaration as in 1 above.
Please delete the following sentence if desired: The bibliography/list of works consulted may be photocopied providing the applicant completes a declaration as in 1 above.

OR

~~3. If this paragraph is left undeleted, please ask your Head of Department to complete paragraph 4.
I request exceptionally that no access of any kind be permitted to this thesis, commencing when and if restriction is approved. I understand (i) that 'no access' means that not even I, my supervisor, nor my Head of Department will have access to the thesis; (ii) that at the end of the year the thesis will be made available to library users unless I make a request for the restriction to be extended for a further year. *This request is supported in paragraph 4 below by the Head of my Department.*~~

Signature of Candidate [redacted] *Date* 7/9/1973

4. Certificate by University of Edinburgh Head of Department (if appropriate: see 3, above):
I have read the full text of paragraph 3, above. I support the request for restriction of access for the following reason(s):–

Signature of Head of Department.. *Date*..................................

Pg.Dec.Th. 73/2000

EFFECT OF INBREEDING ON THE BODY WEIGHT IN JAPANESE QUAIL (*Coturnix c. japonica*)

by

ALAKH DEO NARAYAN
M.V.Sc. (Agra)
DIP.ANIM.GENET. (Edinburgh)

Thesis presented for the Degree of Master of Science
of the University of Edinburgh in the Faculty
of Science

October, 1972

SUMMARY

The usefulness of a slow rate of inbreeding achieved by double first cousin mating over a rapid rate achieved by full sib mating for preventing depression of characters on inbreeding is discussed in the present report. Estimations of parental and offspring inbreeding components were made. The experiment was conducted on two closed Japanese quail lines for six generations. The characters studied were body weights measured at day old, 7, 14, and 35 days, and daily gain from 1-14 and 14-35 days. It was observed that the depression of characters was more pronounced at the slow than the rapid rate. The underlying reason was the greater inbreeding of the parents in the slowly inbred lines compared with the rapidly inbred lines up to a given inbreeding coefficient of the progeny. The body weights taken at an earlier age showed greater depression due to parental inbreeding than the body weight taken near sexual maturity. Of the parental components, the maternal inbreeding component was more important than the paternal inbreeding component. The contribution of the maternal inbreeding to the depression of character was more pronounced on day old chicks. As the chicks grew older, the depression due to maternal inbreeding declined. On the 35th day i.e. near sexual maturity, depression in body weight due to maternal inbreeding was low and non-significant. Crossbred progenies obtained from inbred parents showed heterosis over inbreds and controls. Crossbred progenies of two controls did not show heterosis. At a constant inbreeding of the parents, the inbred individuals were significantly lighter than the non-inbreds in most of the cases. Genetic, phenotypic and environmental correlations were higher between successive body weight measurements. The correlations declined as the characters widened in age. Females were significantly heavier and had higher growth rate than males as early as the 14th day.

CONTENTS

INTRODUCTION

It is of considerable theoretical and practical importance to discover the factors governing the depression of a character on inbreeding. Partitioning the paternal, maternal and offspring inbreeding components and a study of their extent and relative importance on a character is an aid to discovering line differences, if any, in response to inbreeding. The bearing of such differences on the specificity of line combinations is of interest for academic and agricultural reasons. A study of inbreeding necessarily involves observations on performance of line crosses and non-inbred lines. The relationship between levels and rates of inbreeding with crossbred performance and specificity or otherwise of such crosses is of interest. Comparison of the performance of inbreds, line crosses, control populations and conventionally selected lines is of importance in elucidating the nature of the genetic variation governing the traits in question. Answer to these questions have a considerable bearing on the type of breeding programme which should be followed.

The quail has a pattern of performance similar to that of poultry. On account of a short generation interval, high fecundity and economy in rearing, the species may prove of value for reaching general conclusions on other avian species.

A rapid inbreeding induced by full sib mating leads to the extinction of the line at about 50 per cent F. Alternatively, a slow rate of inbreeding may be used for developing highly inbred lines because the slow rate may allow the elimination of recessives and lethals through natural selection. Reports on the usefulness of a slow rate of inbreeding over a rapid rate are meagre.

In the present experiment, an attempt has been made to compare the effectiveness of a slow rate of inbreeding over a rapid rate on the body weight and growth rate. The slow and rapid rate of inbreeding has been achieved by regular double first cousin and full sib mating systems respectively. The experiment has been performed on two closed quail lines maintained at the Institute of Animal Genetics, University of Edinburgh.

REVIEW OF LITERATURE

Hutt (1949) reviewed the reports on the body weight of poultry and factors influencing it. Inbreeding depressed body weight, though the extent of decline was low and in many cases non-significant (Table 1).

Table 1.

Regression of body weight per 1% inbreeding coefficient in poultry

Author & Year	b	Body Weight Measured at:
Shoffner, 1947	-0.004 ± 0.003 lb	300 days
Chung & Park, 1969	-0.595 g	8 weeks
	-2.576 g	Sexual maturity
	-6.023 g	300 days
	-4.260 g	500 days

Jull (1929, 1933) and Dumon (1930) reported that the extent of depression differed in different characters and in the same character studied in different populations. Their results were based on small number of observations and lacked comparison with a suitable contemporary control population. The environmental influence may be exaggerated in such a case reducing the reliability of the estimates of depression.

Shoffner (1947) made a detailed investigation of the effect of inbreeding induced by full sib mating on fertility, hatchability, chick viability, egg production, egg weight and body weight at 300 days of various strains and strain crosses of the chicken.

Relative change of the characters on inbreeding estimated by the formula, percentage relative change in the performance = $\frac{\text{Regression coefficient x 100\% Fx}}{\text{Mean performance of outbred}} \times 100$ ranked hatchability, egg production, sexual maturity, body weight and egg weight in descending order. The relative decline of hatchability and egg production was 8 times and increase of age at sexual maturity 4 times greater than the body weight change (-8.4%/100% F). The egg weight had the least relative decline (-0.8%/100% F). He concluded that with an attainment of homozygosity of 100%, a decline of 8% or lower in the body and egg weight is practically negligible. The overall relative decline of performance is based on an assumption of linearity of regression of characters on inbreeding considered at an F value of 100%. Reports of earlier workers and some of Shoffner's lines show wide variation in the effects of inbreeding on performance. For instance, some lines showed a more rapid decline at an early stage than at later stages and vice versa. In Shoffner's results chance selection of sires might have contributed to irregularity in the trend of performance in successive generations of inbreeding as the number of sires used was small.

In Japanese quail, Sittmann et al. (1966) observed a decline of 6 week body weight on inbreeding achieved by regular full sib mating. With a rise of 10% in inbreeding, a decline of 2 and 4g in the body weight of males and females respectively was noticed. The body weight at 6 weeks in female quail is influenced by developing eggs in the oviduct. He noticed delay in sexual maturity in inbreds as compared to outbreds. Delayed sexual maturity due to inbreeding might have exaggerated the decline in body weight of female at that age. The authors did not consider the relative importance of delayed sexual maturity and inbreeding. A 10% rise of maternal inbreeding depressed body weight by 1 and 3g in males and females respectively. The significance of the depression was not indicated. The depression in body weight on inbreeding may be a consequence of decrease in egg weight due to maternal inbreeding. The evidence suggests that egg weight exerts very little, if any, effect on mature body weight (Scott & Phillips, 1936 in turkey; and Henderson, 1953; Godfrey et al., 1953 and Godfrey & Williams, 1955 in broilers). Goodwin (1961), Tindell and Morris (1964) and Merritt and Gowe (1965) made careful study of the effect of egg weight and mature body weight and, though low, considered the effect of importance in broiler production.

Indirect evidence on the importance of egg weight on 31 week body weight of White Leghorn appears in the report of Goodwin et al. (1964). They set eggs from 1 and 2 year old mothers derived from 2 annual hatches from the same parent stock. The mothers of the two groups were mated to the same males reducing the genotypic differences of the progenies. The 31 week weight was significantly higher in the progenies of 2 year old mothers than that of 1 year olds. The differences in the two groups of progenies were thought to be due to the differences in egg weight. In a subsequent egg weighing trial it was observed that 2 year old hens laid on an average 2.5g heavier eggs than the pullets.

Shinjo et al. (1971) observed a non-significant decline of 16 weeks body weight ($b = -1.15g / 1\% F$ in Japanese quail), a non-significant figure roughly 4 times larger than observed by

Sittmann et al. (1966). The adult body weight of the material of the two experimenters was nearly equal (about 100g). Due to these differing results, further investigation on a larger sample size is needed.

MATERIALS & METHODS

The inbred lines for the present experiment were derived from the two separately bred and pedigreed base populations of Japanese quail (Coturnix c. japonica). The two base populations were called line 3 and line 7. Quail constituting line 3 were imported in 1963 from the University of California, Davis, and since then have been maintained on a cyclical mating system (Fig. a) with 20 pairs as the control and 20 pairs as reserve.

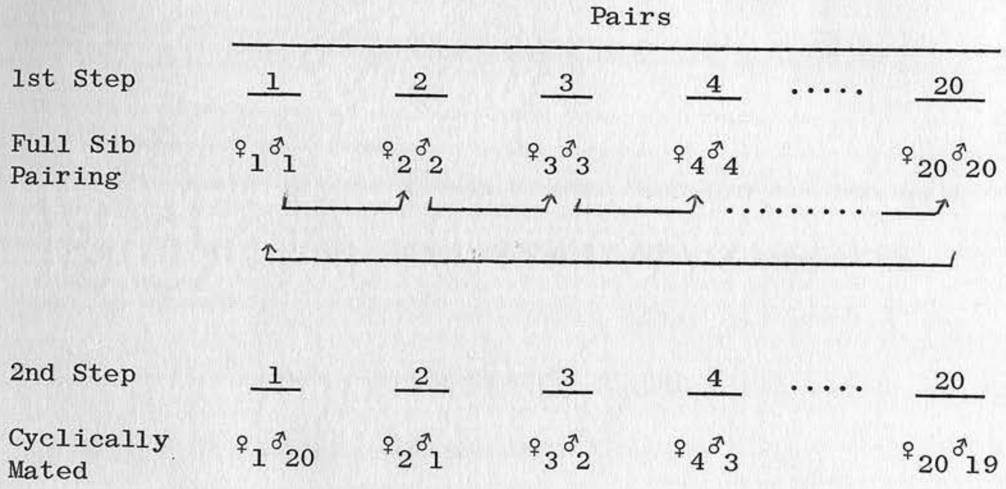


Fig. a. - Schematic diagram of cyclical mating system.

For convenience, the plan of the cyclical mating system can be illustrated in two steps. In the first step, full brothers and sisters belonging to numbered pairs are consectuvely caged in an ascending order. In the second step males are transferred to the next cage until the cycle is completed (Fig. a). The direction of the transfer of males (clockwise or anticlockwise) is kept constant in successive generations. If a particular control pair failed to reproduce, progenies of the corresponding pair from the reserve were used.

The inbreeding coefficient of line 3, computed by the method of Cruden (1949), was approximately 1% per generation. The average inbreeding coefficient at the 20th generation, from which the present inbreeding experiment was started, was 16.3%.

The line 7 is narrowly based. It was purchased from a flock-mated population and was mass selected for body weight. Line 7 has also been maintained on a cyclical mating system with 20 pairs as the control and 20 pairs as reserve for 6 generations. The inbreeding coefficient of the base generation was 6% with an increase of 1% per generation.

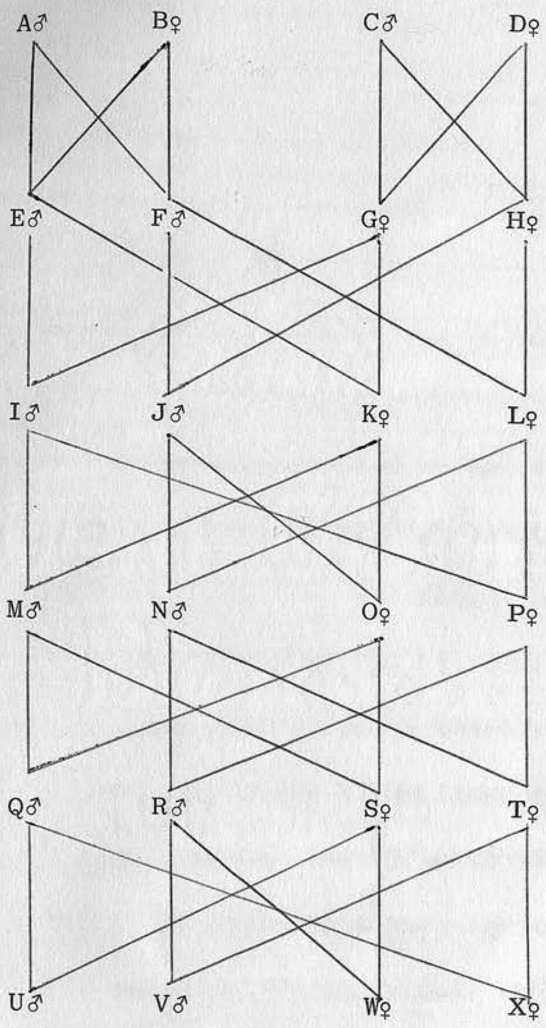
Double first cousin (Table 2) and full sib matings were employed to achieve the slow and rapid rate of inbreeding, respectively. The rate of inbreeding after 2-3 generations settles down to 8% per generation in double first cousin matings, compared to 19% in full sib mating.

The inbred lines obtained from the base generations of the two control quail lines were as follows.

Control Line	Inbred Lines
Line 3	Full sib line 20
	Double first cousin line 27
	Double first cousin line 35
Line 7	Full sib line 21
	Double first cousin line 28

Table 2.

Schematic diagram of double first cousin mating system with their inbreeding coefficients as compared to full sib line



Generation	Double first cousin mating system	F	Regular full sib mating F
t-3	A♂ B♀ C♂ D♀	0.0	0.0
t-2	E♂ F♂ G♀ H♀	0.0	0.0
t-1	I♂ J♂ K♀ L♀	0.0	0.25
t	M♂ N♂ O♀ P♀	0.125	0.375
t+1	Q♂ R♂ S♀ T♀	0.1875	0.50
t+2	U♂ V♂ W♀ X♀	0.25	0.594

Initially full sib line 20 and 21 comprised 22 and 23 sublines respectively, most of which had two replicates. In addition, line 20 had a few reserve full sib mated birds whose body weights were also included in the analysis. Line 28 was started with 20 sublines of double first cousin mated birds. Two pairs of birds per subline were needed to maintain a regular system of double first cousin mating. This makes a total of 20 x 2 = 40 single pair matings available for the observations.

The double first cousin line obtained from control line 3 was recorded as two separate lines (27 and 35). The difference in the two double first cousin lines 27 and 35 can be seen by comparing the theoretical inbreeding coefficients (Appendix 25). The grand parental generation of line 27 had two common grand parents, whereas that of line 35 had one common grand parent. In succeeding generations, both were maintained by regular double first cousin mating and therefore the inbreeding coefficient calculated from the base generation is identical in both lines (Appendix 25). Initially 9 and 11 sublines were available from line 27 and 35 respectively. Line 27 also had few reserve double first cousin mated birds whose data were included in the analysis. Besides, data were taken on 40 single pair matings from each of the two control populations in most of the cases.

Artificial selection for any character has not been practised. However, natural selection during inbreeding could not be avoided due to inequality of sexes and the minimum number of chicks required to constitute the next generation. Gradually sublines were lost (Table 3) and therefore to get a reasonable average body weight, the number of replicates per subline was increased.

Table 3.

Number of surviving sublines

	Lines						
Generation	20	27	35	45	46	21	28
1	22	9	11	19	15	23	20
2	20	8	11	16		16	9
3	14	7	7			8	7
4	2	3	3			-	6
5	1*	2	2			-	5
6	1	2	2			-	5

* Only one subline survived but was presented in the data as 5 sublines, as a result of further sublining.

For an estimation of the crossbred performance, the sublines belonging to a given line were crossed reciprocally among each other. The breeding plan with the identification of the crosses are presented in Figs. b, c, and d. To obtain a high level of inbreeding coefficient at 0 inbreeding of the parents, the crossbred progenies belonging to line 22 were full sib mated. Line 45 was obtained from crossbreds in generation 3 of full sib line 20, and thereafter maintained by regular full sib mating (Fig. b). Similarly, line 46 was obtained from full sib mating of crossbreds in generation 4 (Fig. b).

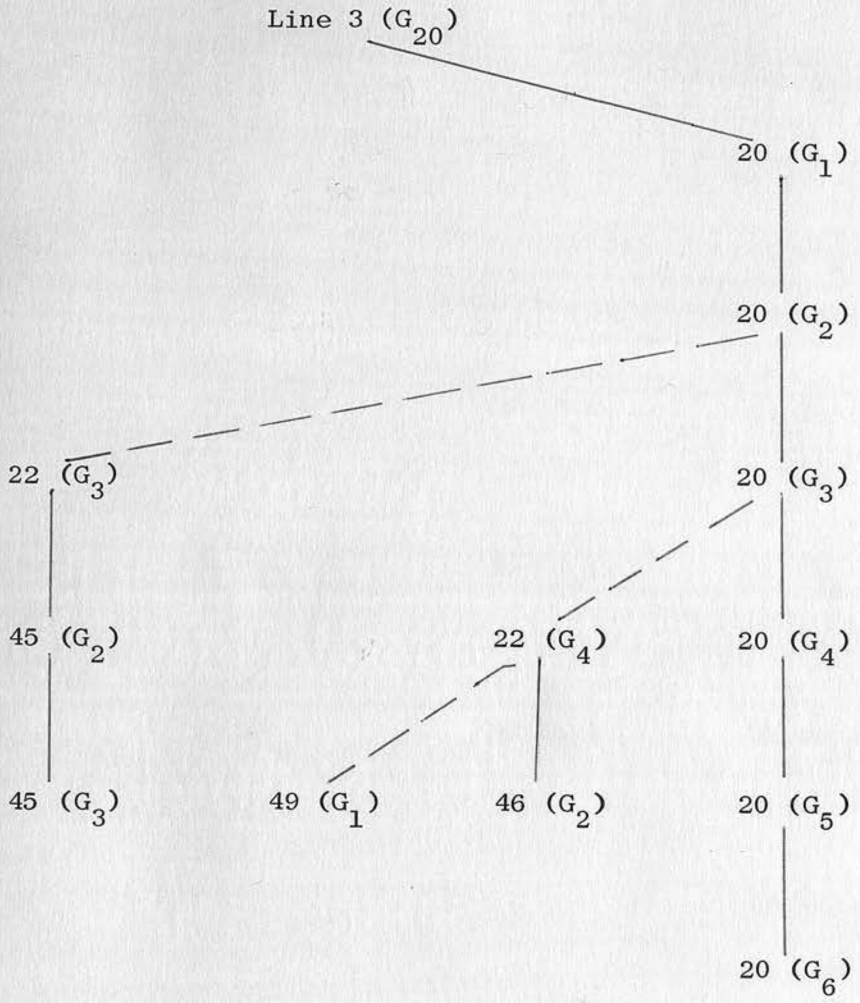


Fig. b. Schematic diagram of full sib lines and their crosses from control line 3.

G = Generation

(——) = Regular full sib line

(----) = Reciprocal crosses among sublines

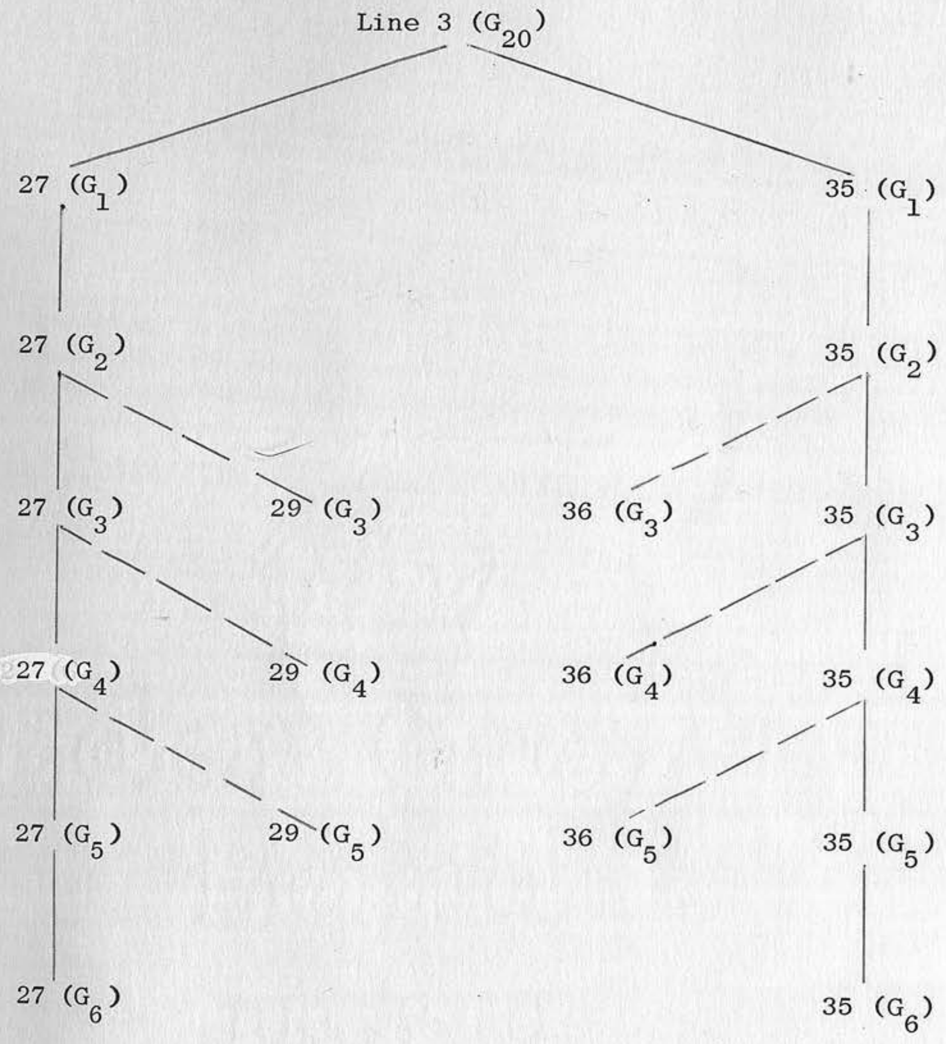


Fig. c. Schematic diagram of double first cousin lines and their crosses from control line 3.

G = Generation

(——) = Double first cousin lines

(----) = Reciprocal crosses among sublines

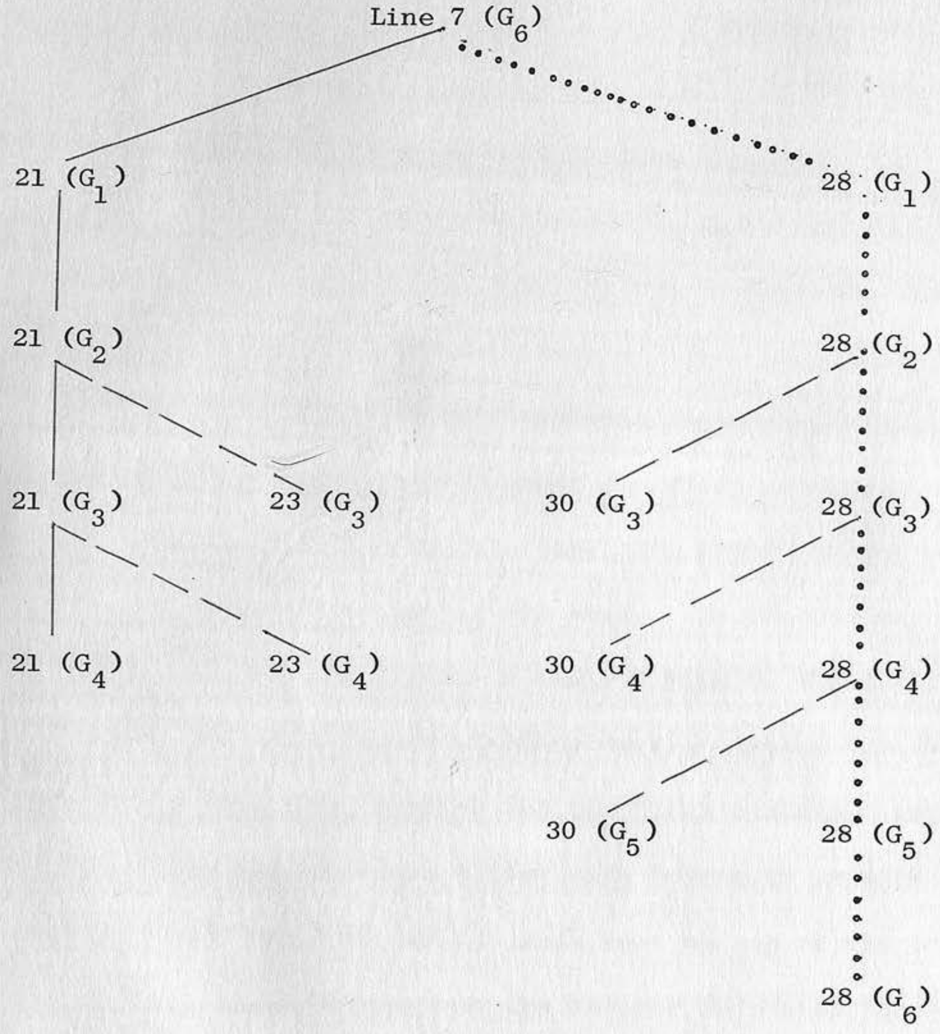


Fig. d. Schematic diagram of full sib and double first cousin lines and their crosses from control line 7.

G = Generation

(——) = Full sib line

(....) = Double first cousin line

(----) = Reciprocal crosses among sublines

Chicks were weighed on 3 consecutive hatching days in order to minimise the weakness and reduction in chick weight usually observed when early hatching chicks are delayed in the hatcher and removed at a time when most of the chicks have hatched. The present method, though laborious, provides the early and late hatching chicks, a fresh vigorous start in the brooder and helps in giving a true day old weight.

While hatching chicks adequate care was taken to prevent them from chilling. Immediately after banding, chicks were weighed and kept in insulated chick boxes. They were reared in the brooder room maintained at 70°F throughout the year. In the brooder room, chicks were maintained for 7 days on the top tier of the 4 tiered brooder. Two sets of 4 tiered brooders were available for the experiment. At any time, none of the top tiers contained more than 200 chicks. The brooders were fitted with hovers to provide heat. Extra radiant heat was provided by lamps kept on top of the brooder. Chicks uniformly spread throughout the brooder indicated that the remperature was not too low. Watering and feeding were ad-lib. The chicks were fed on a commercial turkey starter mash for up to 20 days of age. Thereafter, they were maintained on turkey starter crumbs. On the 7th day, the chicks were weighed and distributed in brooder tiers. Chicks from all the families were distributed equally in the brooders, in such a way that each brooder tier, at any one time, held an equal number of chicks. The maximum number of 7 day old chicks accommodated per brooder was 110. Chicks of two age groups were not mixed with one another. On the 14th day, the chicks were weighed and given their adult bands. They were sexed on or about the 28th day. On the 35th day, the birds were weighed, transferred to the battery room and pair mated. The records of their culling date and body weight were maintained. The date and cause of death of the birds failing to complete their record was noted.

The data on adult body weight were excluded from the analysis because they were limited to the unavoidably reduced samples used for propagating future generations, and the day of culling differed in different experiments. The body weights were measured to the nearest 0.1g. The two successive measurements of the daily gain in weight were calculated from hatch weight and 14 day weight, and from 14 and 35 day weight as follows:

$$\text{Daily gain} = \frac{\text{14 day weight - hatch weight}}{14} \;\&\; \frac{\text{35 day weight - 14 day weight}}{21}$$

Individuals providing four measurements (weight at day old, 7, 14 and 35 days) were included in the present analysis, except in earlier generations in which 7 day weight was not recorded. In the latter case, the remaining 5 variates were analysed.

The birds of the full sib and double first cousin lines obtained from the same base population were hatched and bred together. The available facilities did not permit the combined hatching and rearing of the birds from the control and inbred lines derived from both base populations, although all were reared and bred under feeding and managemental regimes kept as constant as possible. The experiment lasted $1 \frac{3}{4}$ years starting in June, 1970 and yielded observations on a maximum of 6 generations.

Statistical Methods

The body weights of both sexes were recorded in the present experiment. To meet the requirement of the future generations, quails from two or more hatches were reared in different brooder tiers. Significant effects of hatch date, tier and sex were observed in a preliminary trial. Therefore, adjustment for sex, hatch dates and brooder tiers were made by the method of Henderson (1953). Sex, hatch dates and brooder tiers were considered as fixed effects. The least square estimates of these fixed effects were made and the original data were adjusted for these estimates. Weighted analysis of variance and covariance was performed using the computer programme of Mr. Robin Thompson, Senior Research Officer, Institute of Statistics, University of Edinburgh.

RESULTS

The terms included in the analysis of variance tables are as follows:

(a) Sublines - Numbers alloted to unrelated full sib and double first cousin lines from a base population were referred to as sublines. The subline identifications were made in the first generation of the regular mating systems and thereafter remained constant in successive generations.

(b) Sub Sublines - The replicates of each subline were numbered and referred to as sub sublines.

Adjustment of the data improved the results by reducing the error variance. Therefore, the analysis of variance-~~covariance~~ after adjustment has only been presented in the present report. The reports can be classified in three categories according to the sources of variation. The model and the expected mean squares for the three categories are presented in Table 3A.

The three categories of analysis of variance tables are self explanatory and are as follows:

1. Category (a) includes analysis on the birds used for propagating future inbred generations.
2. Category (b) describes the result of crosses between sublines of various mating systems.
3. Category (c) presents analysis of the data on control birds in various generations and the first generation of full sib and double cousin matings where subline and sub sibline numbers were not assigned.

Table 3A.

(a)

Source	Expected mean square
Lines	$\sigma^2 e + K_4\sigma^2 SS + K_5\sigma^2 S + K_6\sigma^2 G$
Sublines/within lines	$\sigma^2 e + K_2\sigma^2 SS + K_3\sigma^2 S$
Sub-sublines/sublines/lines	$\sigma^2 e + K_1\sigma^2 SS$
Individuals/sub-sublines/sublines/lines	$\sigma^2 e$

$Yijkl = \mu + \alpha_i + S_{ij} + SS_{ijk} + e_{ijkl}$

(b)

Source	Expected mean square
Lines	$\sigma^2 e + K_4\sigma^2 R + K_5\sigma^2 C + K_6\sigma^2 G$
Crosses within lines	$\sigma^2 e + K_2\sigma^2 R + K_3\sigma^2 C$
Reciprocals within crosses within lines	$\sigma^2 e + K_1\sigma^2 R$
Individuals within reciprocals/ crosses/lines	$\sigma^2 e$

$Yijkl = \mu + \alpha_i + C_{ij} + R_{ijk} + e_{ijkl}$

(c)

Source	Expected mean square
Dams	$\sigma^2 e + K_1\sigma^2 D$
Individuals/dams	$\sigma^2 e$

$Yij = \mu + D_i + e_{ij}$

Adjusted means of the 6 traits with their standard errors belonging to different generations of the base line 3 and the full sib and double first cousin lines derived from it are presented in Appendix 25. Appendix 26 presents the means and standard errors of various generations of full sib and double cousin lines derived from, and of line 7. The last two pairs of columns figure the average inbreeding coefficient of the individuals of the particular generation (F offspring) and the average inbreeding coefficient of their parents. The first pair of the inbreeding coefficients have been calculated considering the base generation of the lines kept at zero inbreeding, whereas the last pair of figures give the theoretical inbreeding coefficient calculated from the inception of the population at the Institute of Animal Genetics, Edinburgh. Wright's inbreeding coefficient was calculated by the method of Cruden (1949). The original computer programme was altered to accommodate observations on 400 individuals. The means with the subheading "crosses" (Appendix 25, 26) come from the crossbred progenies of sublines in the previous generation and thus they are contemporary with the generation below which they have been entered.

To reveal any systematic seasonal or managemental change in various lines, the means were plotted on generations (Figs. 1, 2, 3). The graph of the mean hatch weight was parallel to the X-axis at 7 to 7.5g in different lines and their crosses (Figs. 1,2). This suggests that the character was insensitive to seasonal changes, different rates and levels of inbreeding and heterosis. Non-significant between line mean squares in different analysis of variance tables (Appendix 1 to 22) also supports this conclusion.

Body weight measured at 14 and 35 days showed a decline in the control as well as at slow and rapid rates of inbreeding. Very little information was available on the 7th day body weight of control birds. The decline of body weight at 7, 14 and 35 days was more pronounced in full sib than double first cousin lines in successive generations. The full sib and the two double first cousin lines obtained from base line 3 differed significantly in respect of 14, 35 day weight and growth rate from 1-14 day up to the 3rd generation (Appendix 1,2,3). From the 4th to 6th generation the differences in the body weights and growth rates of full sib and D.F.C. lines were non-significant (Appendix 4,5,6). The full sib line (21) obtained from base line 7 was significantly inferior to its contemporary double first cousin line (28) in respect of 7, 14, and 35 day weight and the two measures of growth rate (Appendix 8 to 11). The F test to detect the differences between lines is tentative and is biased upward. It can be seen by comparing coefficients of the expected mean squares. In most of the cases the between line coefficients (K_4 and K_5) are larger than the between sublines/lines coefficients (K_2 and K_3).

Fourteen and 35 day body weights of the crossbreds of full sib and double first cousin lines derived from control line 3 exceeded the control (Fig. 1). The differences in the mean body weights of crossbreds and the contemporary controls were tested for their significance by t test when $n_1 \neq n_2$ and $\sigma_1^2 \neq \sigma_2^2$, a method devised by Cochran (1964). The result is presented in Table 4. The 23rd generation of the control line 3 and 9th generation of control line 7 are the contemporary of the 3rd generation of crossbreds of full sib and double first cousin lines.

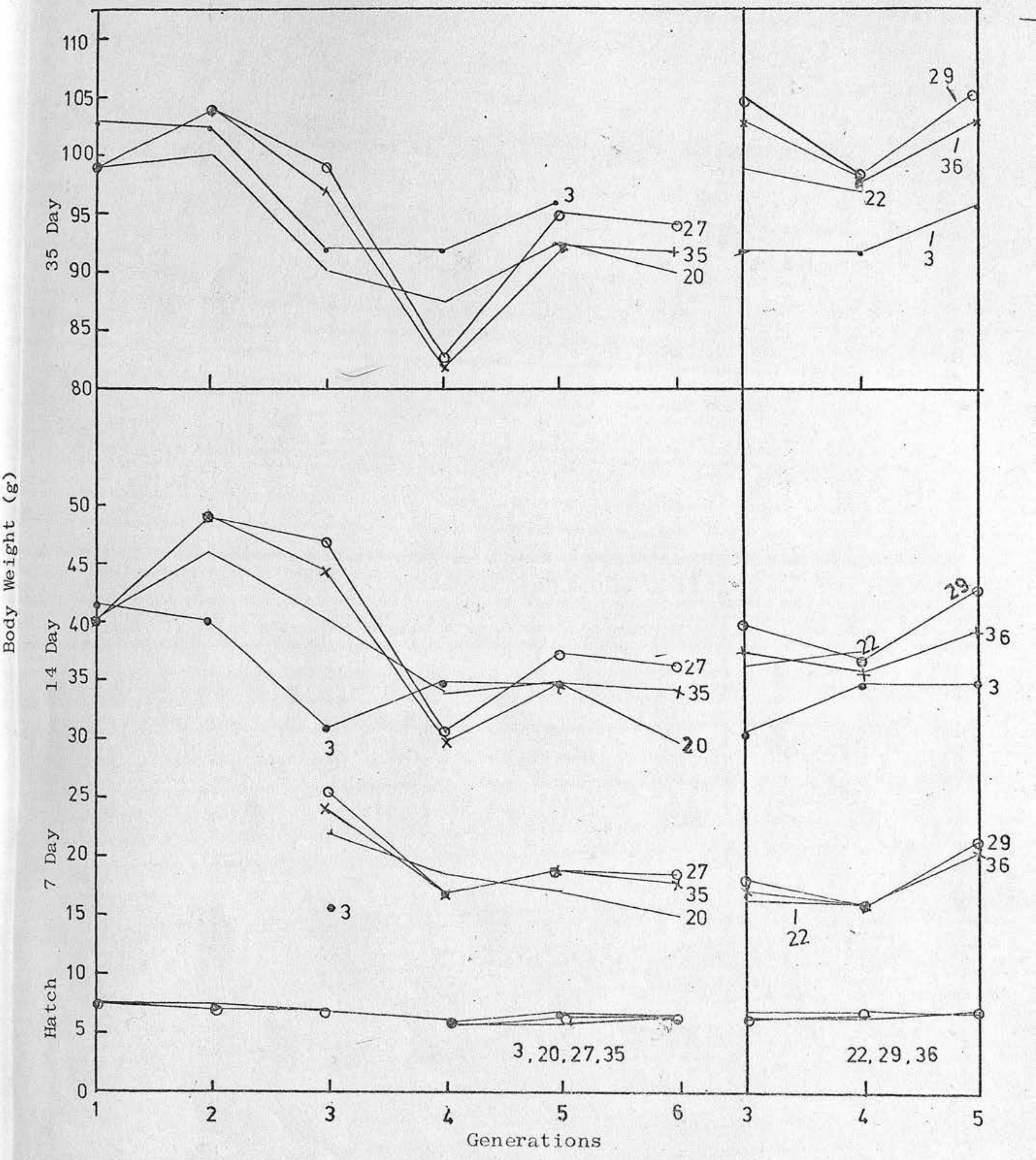


Fig. 1. Graph of Body Weight.

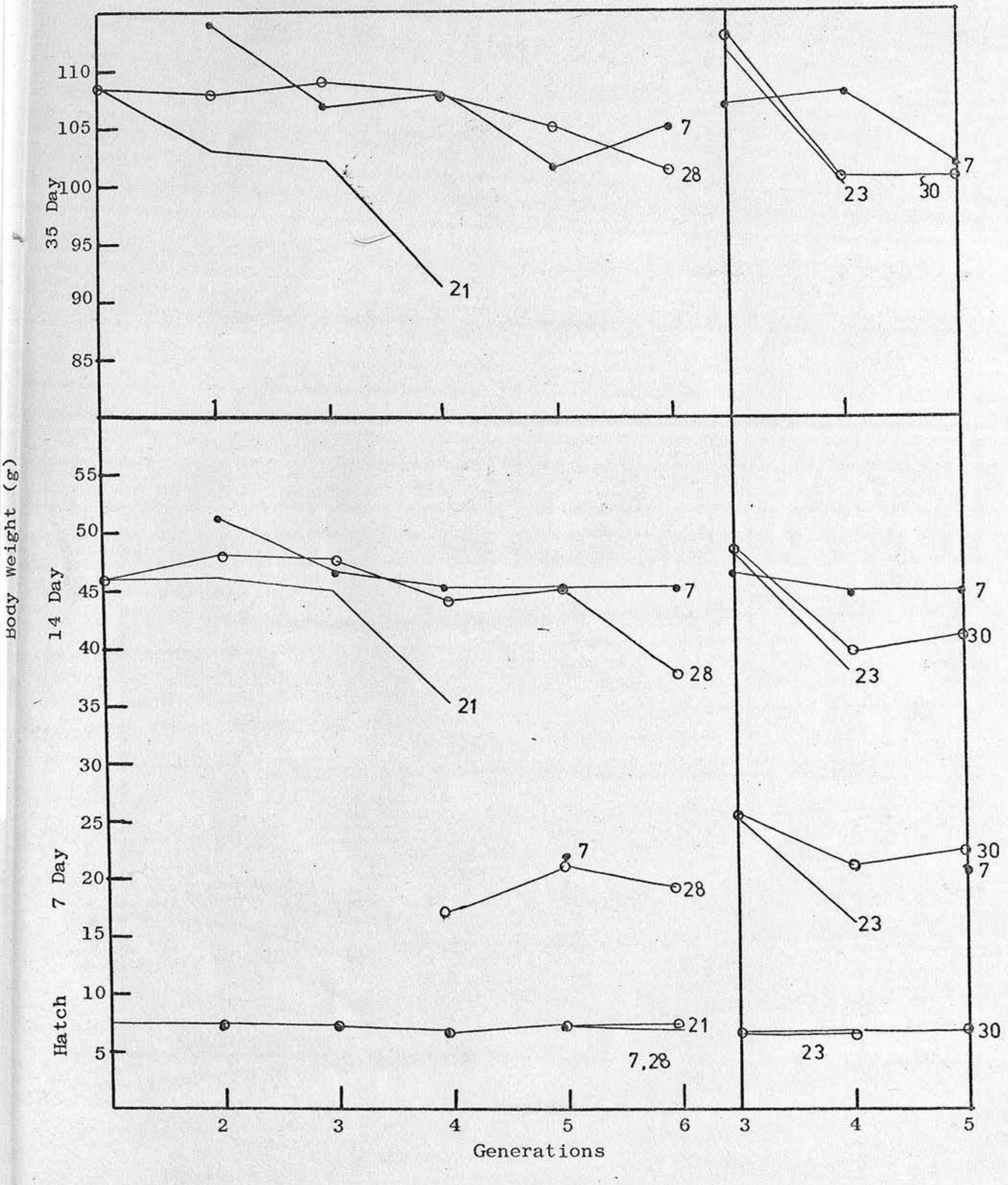


Fig. 2. Graph of Body Weight

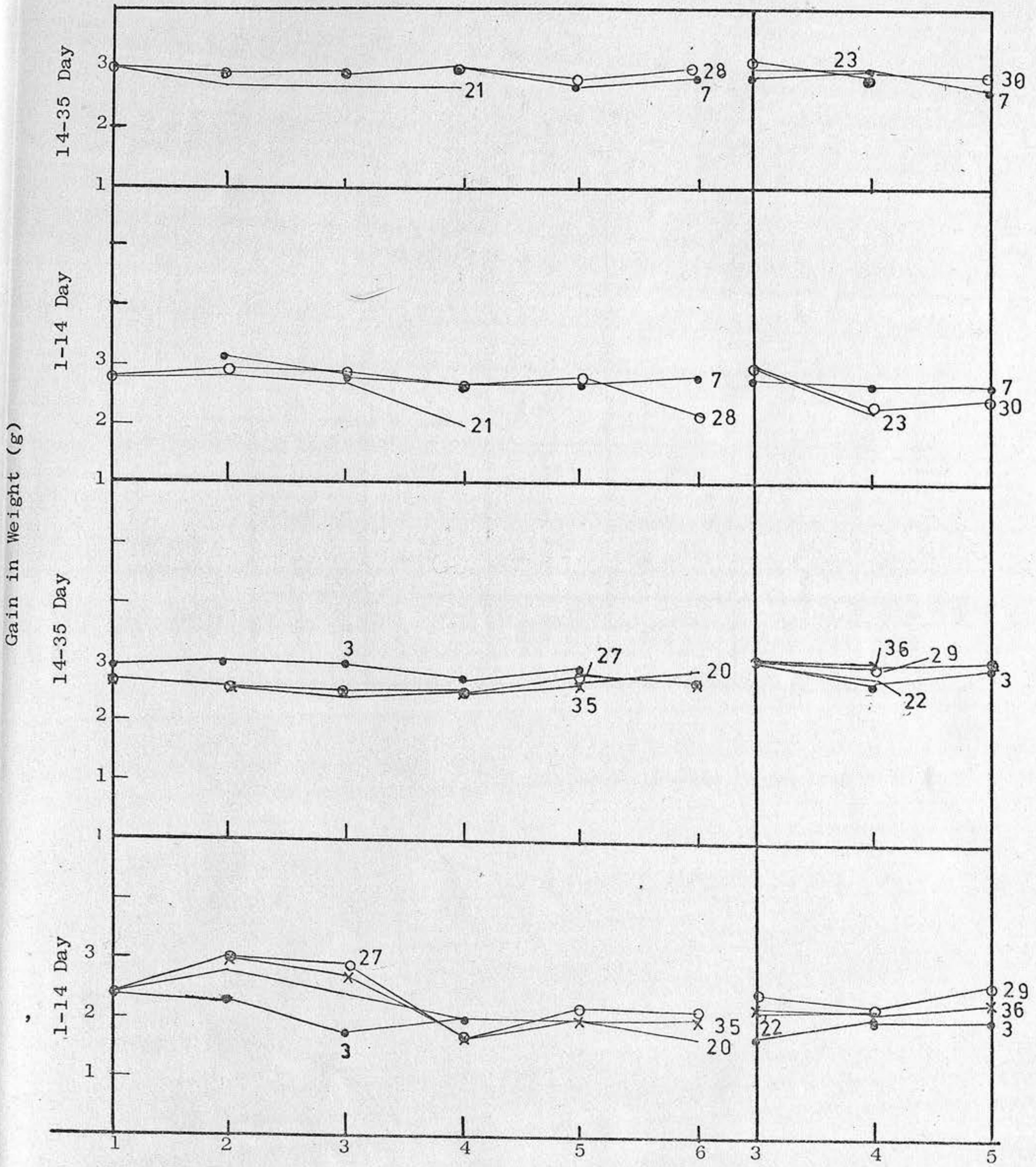


Fig. 3. Graph of Gain in Weight

Table 4.

Crossbred progeny from inbred parents as deviations from control (g)

Characters	Generation	Base line 3			Base line 7	
		Line 22	Line 29	Line 36	Line 23	Line 30
14 day weight	3	5.2***	8.6***	6.1***	1.3	2.0
	4	2.8*	2.2	1.4	-7.0*	-5.3***
	5	-	7.9***	4.4***	-	-3.8***
35 day weight	3	7.0***	12.7***	11.1***	4.8*	6.2***
	4	4.9***	6.6***	6.0**	-7.4*	-7.2***
	5	-	9.9***	7.1***	-	-1.1

*, **, *** $P < 0.05, 0.01, 0.001$

The differences of two means ($\bar{X}_1 - \bar{X}_2$) and the degrees of freedom for calculating t' were obtained from Appendix 25 & 26. σ_1^2 and σ_2^2 were adjusted crosses and dam variances of the crossbreds and controls respectively (Appendix 15-24). A significantly higher 35 day weight of the crosses over controls indicates positive heterosis. The means of the crossbreds from double first cousin lines (line 29 and 36) in the 4th generation were higher than the controls but not significantly different. The 14 day body weight of the crossbreds in the 3rd and 5th generation was significantly higher than those of controls showing positive heterosis. Crossbreds from double first cousin lines 27 and 35 showed higher 14 and 35 day body weights than that from full sib line 20 but these were not significantly different (Appendix 15, 16 & 17).

In the crossbreds 23 and 30, derived from the full sib and double first cousin lines 21 and 28 respectively, the situation was quite different (Fig. 2). In generation 3, body weight at 14 days was not significantly different from the control line 7, showing absence of heterosis; thereafter body weights were significantly lower than the control, showing negative heterosis. The 35 day weight of the crossbreds was significantly higher than the control in the 3rd generation; thereafter a significant negative trend was observed. Line 23 did not differ significantly from line 30 in respect to 7, 14 and 35 day body weight, though the former had lower body weight in all generations.

The plot of gain in weight per day measured at 1-14 days and 14-35 days has been shown in Fig. 3. Essentially the growth rates are measures of respective final body weights (14 and 35 day) because hatch weight was similar in all generations of various lines. This can be observed by comparing the curve of 14 day body weight and 1-14 day growth rate.

The comparison of the graph of two growth rates (1-14 day and 14-35 day) furnishes ample evidence of compensatory growth. Body weight at 35 days appears to be a target. The slow growing animals up to 14 days tried to speed up to reach a 35 day weight and vice versa. Full sib and double cousin lines and their crosses have shown such an anomaly to a lesser extent than the control lines, specially up to 3rd generation. This anomaly may be due to a recognisable managemental difference in the control line as compared with the inbreds and their crosses. The birds of the control line up to the 3rd generation remained crowded in the brooder tiers up to 14th day, in comparison with the inbreds and their crosses which were thinned on the 7th day.

In the control lines, body weight at 14 and 35 days and the two measures of growth rates showed an overall decline in successive generations, suggesting possible deterioration of the managemental conditions or an increase of inbreeding. To know the net effect of inbreeding, therefore, deviation from the control was taken (Fig. 4,5). Hatch weight did not differ in various lines and in successive generations. The information on 7 day weight of controls was inadequate. Therefore, a study of deviation of hatch and 7 day weight of inbreds from the control was unnecessary. The generation trends of deviations in most cases remained identical as in Fig. 1, 2 and 3, except for the graph of 14 day body weight of the inbred lines derived from control line 3 which showed increased variation. The probable

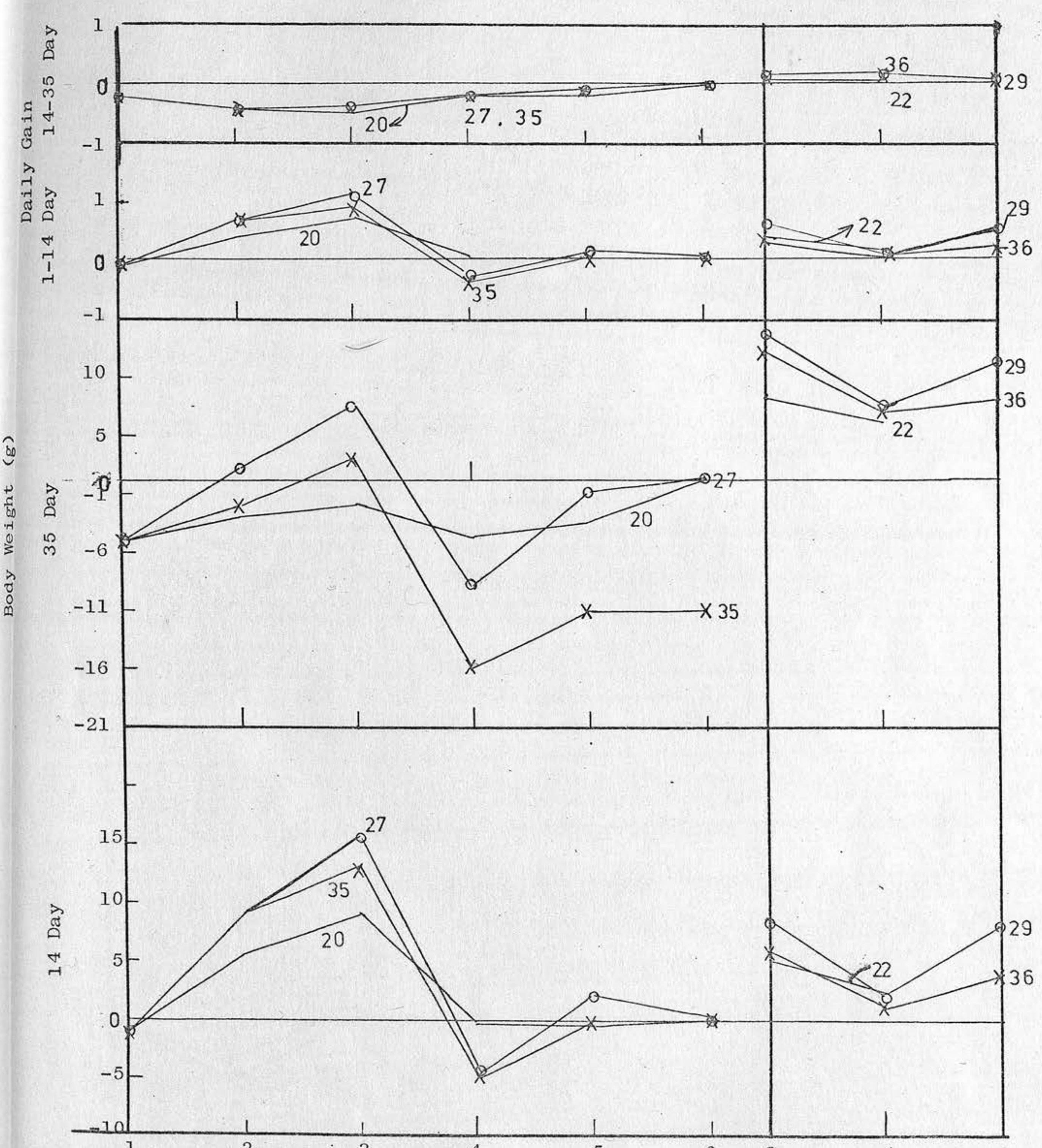


Fig. 4. Graph of Body Weight as Deviations from Control

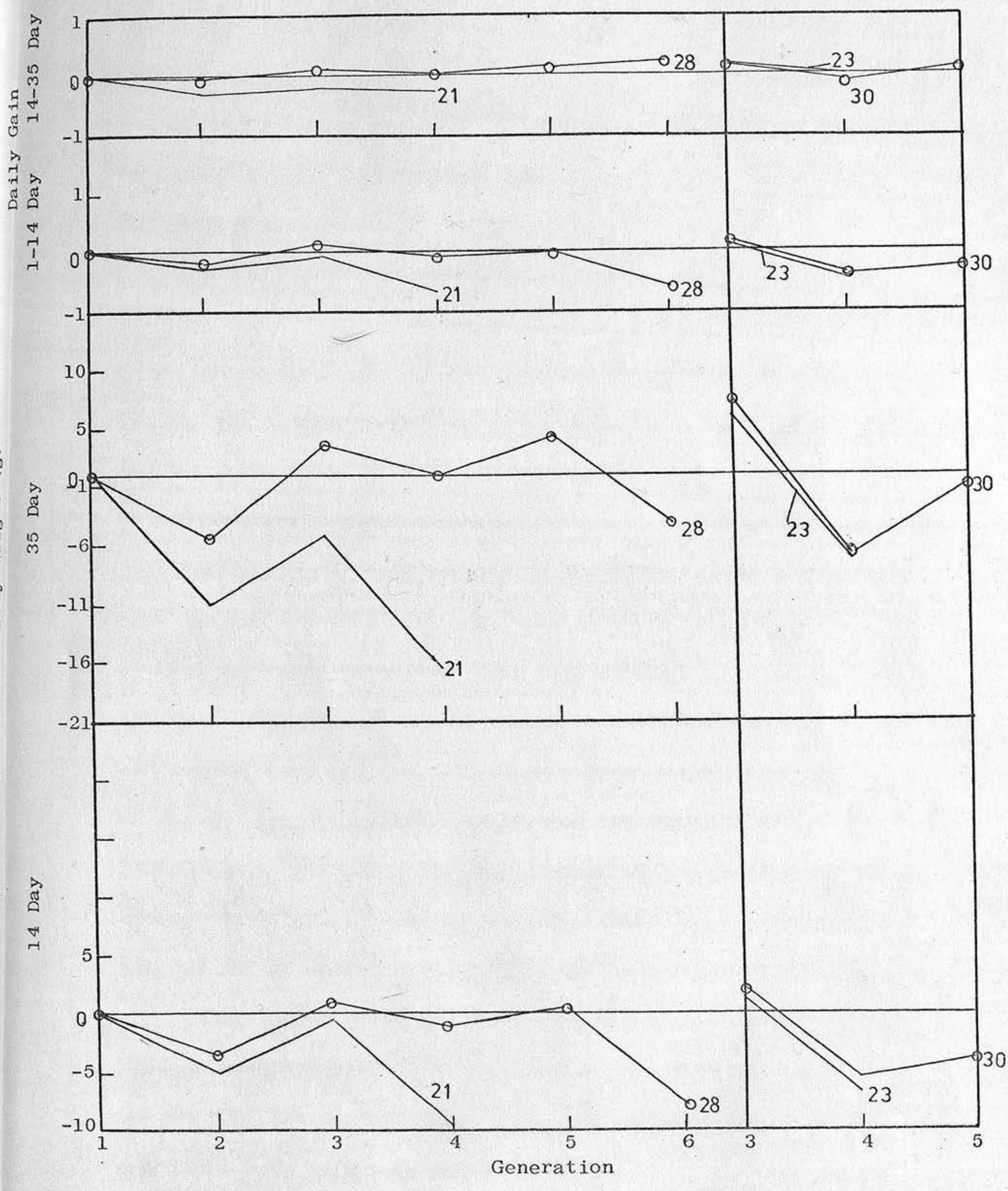


Fig. 5. Graph of body weight as deviations from control.

reason was an abnormally low 14 day body weight of the control line 3. Double first cousin lines were superior in all cases to their contemporary full sib lines.

The higher body weights and growth rates exhibited by double first cousin lines as compared with the full sib lines might be due to the low inbreeding coefficients of the former. In order to reveal this possibility, means were plotted on the inbreeding coefficients of the individuals and their parents (Figs. 6, 7 and 8).

Comparison of the graph of hatch weight on inbreeding coefficient (Figs. 6 and 7) suggests that in all cases, means of double first cousin lines were either equal or slightly lower than those of full sib lines. Birds were not weighed on the 7th day in the earlier generations of full sib lines resulting in unsuitability of the data for a valid comparison of the two systems of inbreeding.

Average 14 day body weights in the double first cousin lines were greater than in the full sib lines up to an inbreeding coefficient of 12.5 per cent; thereafter they were smaller. In respect of 35 day weight, the two mating systems behaved differently in the two stocks (line 3 & 7). The double first cousin line 28 maintained slightly higher weight than the contemporary full sib - line 21 up to 25% inbreeding coefficient of the progeny. Thereafter, the weight of line 28 was lower than that of line 21. Line 27 and 35 showed a similar trend in 14 day body weight.

Comparison of full sib and double first cousin lines at the same inbreeding coefficient can be made by comparing the graph at 25% F of the progeny (Fig. 6). The double first cousin lines had lower body weight in all cases except in 35 day body weight

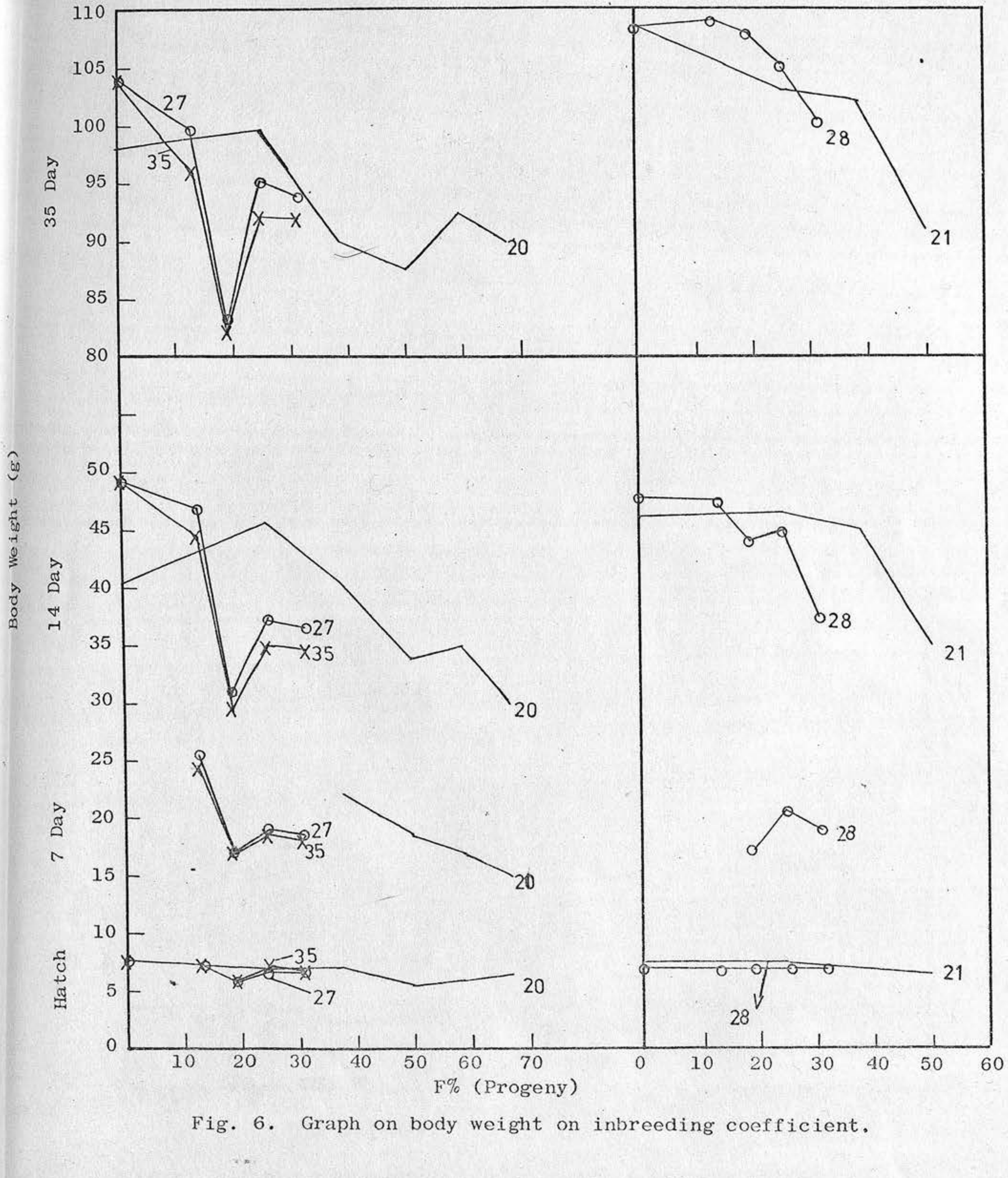


Fig. 6. Graph on body weight on inbreeding coefficient.

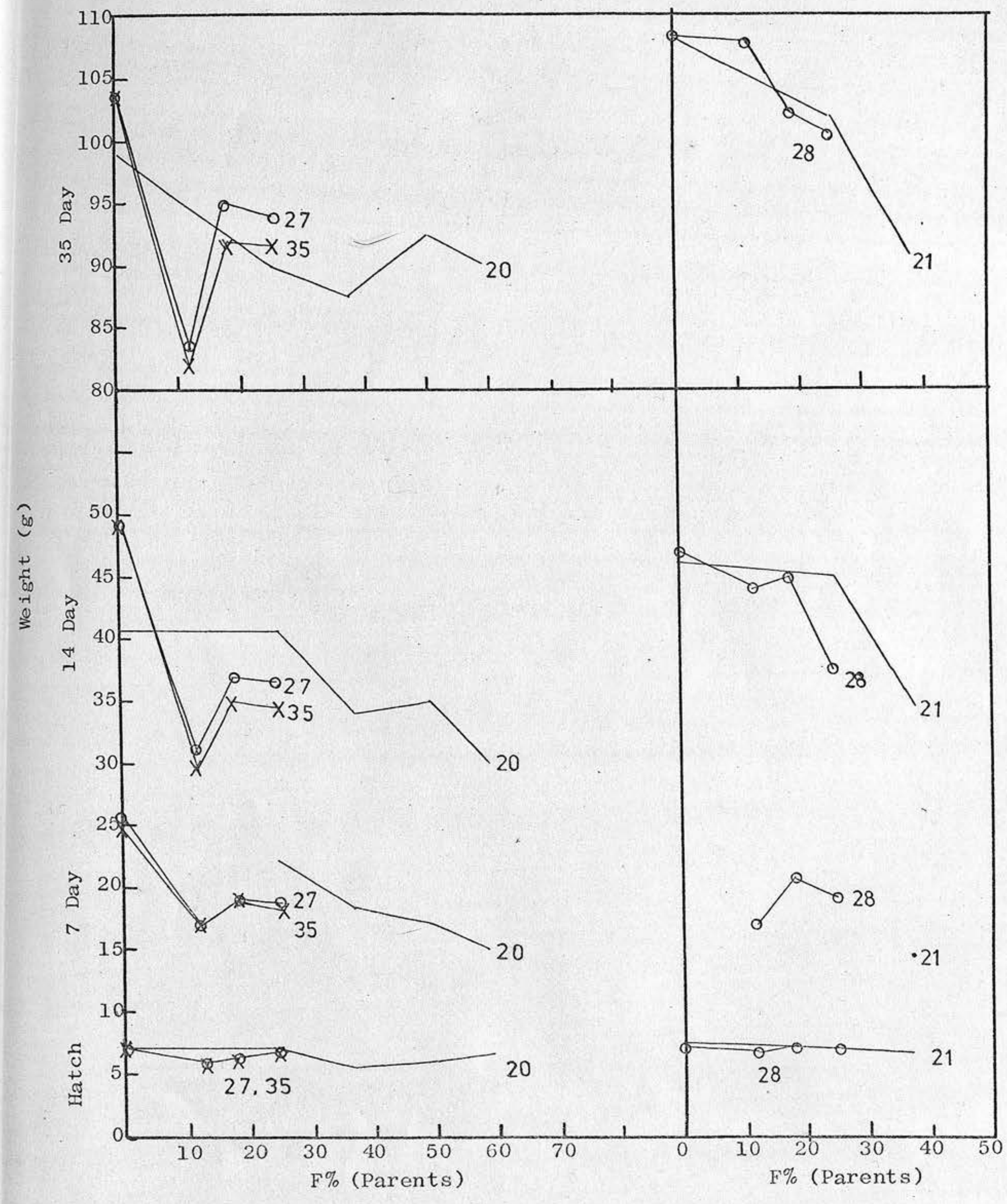


Fig. 7. Graph of body weight on inbreeding coefficient.

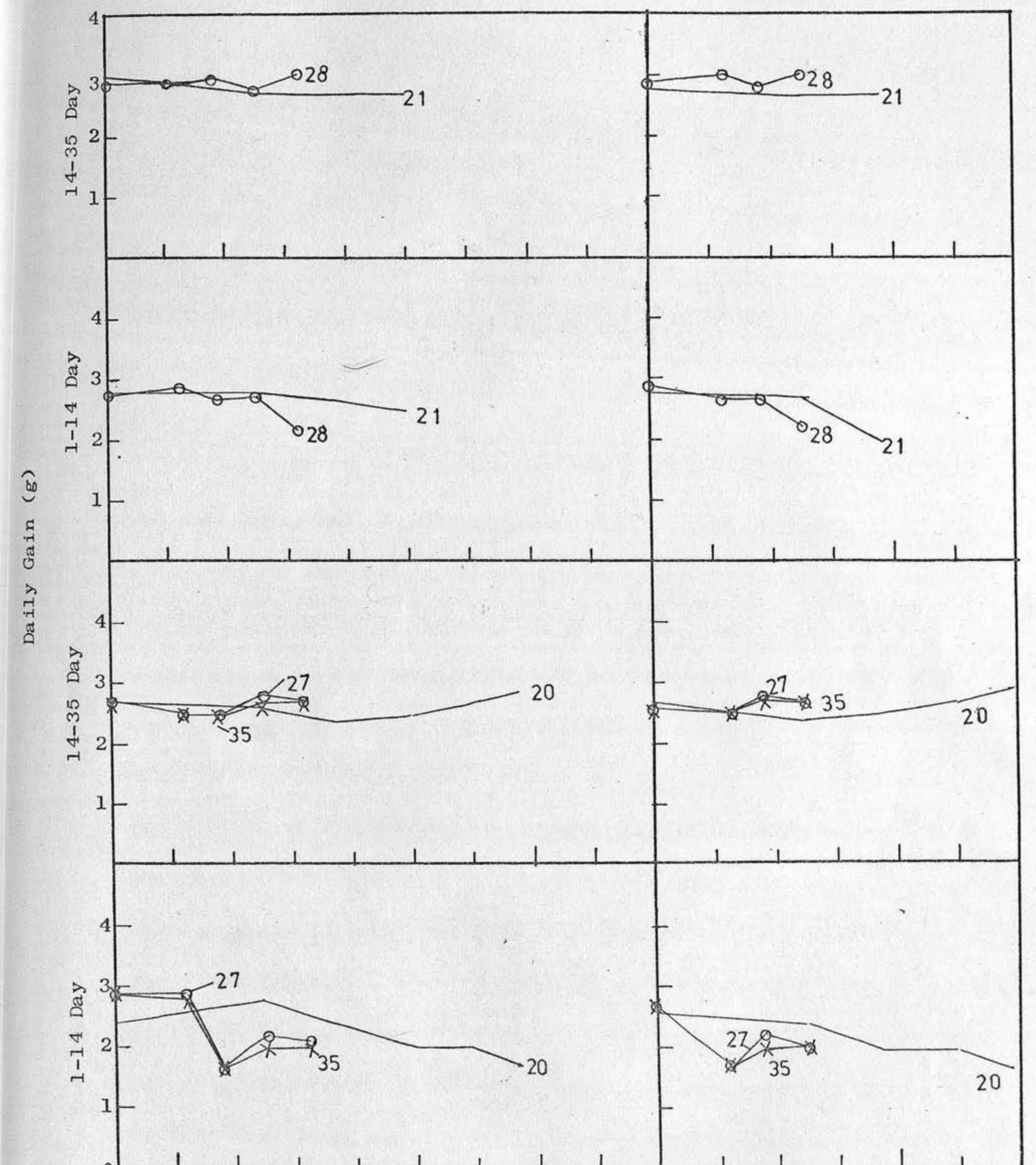


Fig. 8. Graph of gain in weight on inbreeding coefficient.

of line 28 where the difference was 2g. The trends of means plotted on the inbreeding coefficient of the parents were identical to those on F of progeny.

The daily gain from 1-14 days (Fig. 8) shows a similar trend to 14 day body weight. Due to compensatory growth, daily gain from 14-35 days shows an opposite trend as compared with 1-14 days. An overall greater decline of daily gain from 1-14 days than from 14-35 days, on inbreeding, suggests that the depressive effect of inbreeding is more profound at an earlier age and is exercised by depression of growth rate, since hatch weight is parallel to the X axis.

The slower rate of inbreeding increased the rate of depression over the rapid rate in the present report. The increased depression may be due to (a) decline of performance in successive generations due to a decline of environmental condition (Figs. 1,2,3), (b) higher parental inbreeding than the rapid rate in early generations and (c) sampling error. The deviation of means of inbreds from the means of their contemporary control was plotted on the inbreeding coefficient of the progeny to examine the first possibility (Fig. 9). The plot of deviations on the parental inbreeding coefficient has been omitted since it moves the curve one generation back without changing the trend (Figs. 4 & 5). A comparison of Fig. 9 and Fig. 6 in respct of 14 and 35 day body weight suggests that plotting deviations did not alter the trend of the inbred lines derived from the base line 3. On the other hand, deviations increased the variability as in Fig. 4. The double first cousin line 28 showed superiority over its contemporary full sib line 21 in maintaining high body weight. The

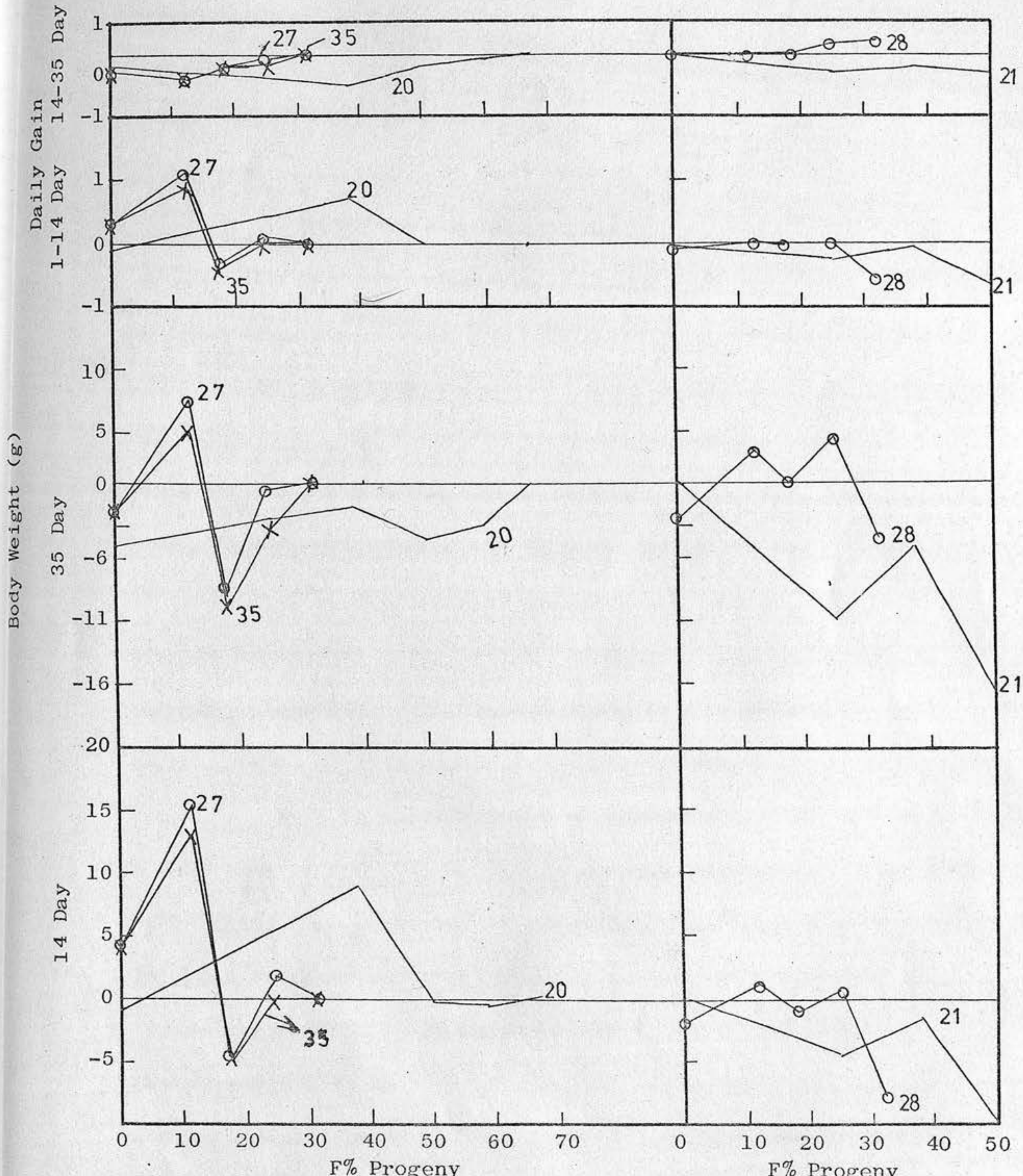


Fig. 9. Graph of body weight as deviations from control.

curves of two measures of daily gain in weight remained unchanged (Figs. 9 and 6). It may be inferred that decline of performance in successive generations was not responsible for the disadvantage shown by double first cousin lines.

The difference between two levels of inbreeding of individuals from parents of the same level of inbreeding provides an estimate of the effect of progeny inbreeding which is uninfluenced by parental inbreeding. The estimates for the two systems of inbreeding are presented in Table 5. The 2nd column of Table 5 (F offspring) presents the level of offspring inbreeding for which the differences of means were taken. For an example, the entry for line 20 at 25% F for hatch weight, is -0.5. This figure has been calculated from Appendix 25 by taking a difference of average hatch weights of generation 2 and 1 belonging to line 20. Columns16 and 17 give the inbreeding coefficientsof the parents and offspring. Subtraction of inbreeding coefficients of generation 1 from generation 2 of line 20 provides a value of 25% for progeny inbreeding and 0% for parents inbreeding. The result -0.5g is a reduction in hatch weight due to an increase in inbreeding coefficient of 25% of the progeny. Most of the estimates of Table 5 are negative, suggesting a reduction of body weight due to progeny inbreeding. The mean differences were regressed on inbreeding coefficient of the progeny in order to detect any trend or a possibility of difference in the two mating systems. Regressions for 7 day weight were not calculated due to absence of values. Regression coefficients (b) and the percentage of the variance of the body weights removed by regression for different characters is presented in Table 6.

Table 5.

Effects of inbreeding on individual (parents held constant)

Line	F% offspring	Hatch weight	7 Day weight	14 Day weight	35 Day weight	Daily gain 1-14 day	Daily gain 14-35 day
20	25.0	-0.5***	-	+5.2***	1.8	0.407***	-0.158**
	31.3	-0.7***	-	-3.9***	-10.5	-0.232***	-0.310***
	34.4	-0.8***	-	-4.1***	-9.4***	-0.238**	-0.252***
	34.4	0	-2.4***	-8.0***	-7.8***	-0.548***	-0.011
	37.5	0	5.3***	4.1**	-9.0***	0.297***	-0.630***
	50.0	-1.1***	1.7	-3.3	-9.2*	-0.163	-0.280*
27	12.5	-0.4*	-	-2.0	-4.9*	-0.118	-0.137*
	12.5	0.2	7.4***	7.1***	-6.0*	0.494***	-0.626***
	18.8	-0.7***	0.7	-6.5**	-15.4***	-0.419**	-0.419***
	25.0	-0.5*	-2.7***	-6.0***	-10.7***	-0.392***	-0.225**
35	12.5	-0.5**	-	-4.6***	-7.4***	-0.296***	-0.133*
	12.5	-0.2	7.3***	7.1***	-6.7*	0.524***	-0.659***
	18.8	-0.3	0.5	-6.5**	-15.7***	-0.440**	-0.438***
	25.0	0	-2.0***	-4.5**	-11.0***	-0.328**	-0.308***
21	25.0	-0.2	-	0.2	-5.6**	0.030	-0.273***
	37.5	0.3	-	-2.6	-9.4***	-0.212*	-0.322***
	50.0	0	-1.5	-2.8	-9.2*	-0.198	-0.305
28	12.5	-0.1	-	-0.1	0.9	0.008	0.049
	12.5	0.3	-	-1.0	-3.7*	-0.085	-0.127**
	18.8	0	-4.2***	4.5***	7.3***	0.321***	0.130**
	25.0	0.2	-1.3	4.3***	4.5*	0.300***	0.010

*, **, *** $P < 0.05, 0.01, 0.001$.

Table 6.

Regression of body weights (g) per 1% inbreeding of progeny and % of variance accounted for by regression

Lines	Df.	Hatch Weight		14 Day Weight		35 Day Weight		Daily gain 1-14 day		Daily gain 14-35 day	
		b	% variance removed	b	% variance removed	b	% variance removed	b	% variance removed		% variance removed
20	5	-0.0206	14.8	-0.189	9.2	-0.320	33.8	-0.0123	7.9	-0.0063	6.5
27	3	-0.0379	34.4	-0.755	51.5	-0.529	43.3	-0.0511	51.9	0.0108	8.8
35	3	0.0261	56.5	-0.532	26.3	-0.415	36.3	-0.0403	29.6	0.0058	2.4
Pooled	11	-0.0149	7.9	-0.364	20.1	-0.378	35.6	-0.0251	19.8	-0.0007	0.05
21	2	0.0080	15.8	-0.120	79.9	0.144	70.8	-0.0091	70.4	-0.0013	41.1
28	3	0.0058	3.6	0.427	78.6	0.557	49.3	0.0299	76.1	0.0061	11.5
Pooled	5	0.0074	10.2	0.020	0.5	0.2498	34.1	0.0009	0.2	0.0006	0.4

Pooled estimates of regression for the inbred lines derived from base line 3 (20, 27, 35) and from base line 7 (21, 28) have been obtained. All estimates of regression are non-significant, possibly due to small number of degree of freedom. In the inbred lines 20, 27 and 35 most of the regressions are negative. The values of the regressions in line 20 are lower than line 27 and 35 and consequently the proportions of variance removed by the regressions are also lower. Regression coefficients and percentage variability removed by regression of daily gain from 1-14 days are larger than from 14-35 days. This possibly reflects the role of compensatory growth in masking the effect of inbreeding of the progeny on the growth rate from 14-35 days. The inefficiency of a pooled estimate of regression is obvious from the low values of percentage of variance removed for each character.

The values of regression and percentage of variance removed by the regression in the case of lines 21 and 28 produce a different picture. Most of the regressions are positive and account for nearly 70% of the variability of 14 and 35 day body weight and daily gain from 1-14 days. The low variability removed in case of hatch weight is due to the stable nature of the character on inbreeding. The lower percentage of variability removed in daily gain in weight from 14-35 days by regression confirms the role of compensatory growth in masking the effect of inbreeding as noticed in inbred lines from base line 3. The atypical nature of the inbred lines derived from base line 7 may be due to the selection for body weight practiced earlier in that base line. Selection might have fixed desirable genes for body weight so that an increase in the inbreeding of the progeny is ineffective in depressing the body weight and growth rate. The increased uniformity in body weight in various generations of line 21 and 28 is also obvious from the high percentage of variability (70%) removed by regression. The percentage of variability removed by regression after pooling line 21 and 28 is lower than the average of the inbred lines suggesting inadequacy of pooling.

The contribution of the parental inbreeding to the depression of the characters has been removed from the data of Table 5. The regression of mean differences on the progeny inbreeding, therefore, is not expected to differ in double first cousin and full sib lines. The tests of heterogeneity of regressions were made for the lines derived from base line 3 and 7 separately due to differing response of the two lines. The result of analysis of variance is presented in Table 7. As expected, the regressions were homogeneous except in 14 day weight of line 21 and 28, where they were significantly different at the 5% level. This difference was due to negative regression in line 21 (b = -0.120g / 1% F) compared with positive regression in line 28 (0.427g / 1% F).

Relative Contribution of Parental and Offspring Inbreeding

The Averages of body weights and inbreeding coefficients presented in Appendix 25 and 26 were used for calculating the relative contribution of parents and offspring to the effect of inbreeding on the body weight. The theoretical inbreeding coefficient was used for the inbred lines derived from base line 3, i.e. for line 20, 45, 46, 27 and 35. The theoretical inbreeding coefficients

Table 7.

Analysis of variance for testing homogeneity of regressions of body weight on progeny inbreeding

Sources of Variation	d.f.	Mean Squares				
Line 20, 27, 35		Hatch Weight	14 Day Weight	35 Day Weight	Daily gain 1-14 day	Daily gain 14-35 day
Between Regressions	2	0.1246	14.97	1.92	0.0769	0.0148
Within Regression	8	0.1493	33.12	17.59	0.1595	0.0588
Line 21, 28						
Between Regression	1	0.0004	23.92*	13.66	0.1218	0.0043
Within Regression	3	0.0677	2.15	12.35	0.0137	0.0105

* $P < 0.05$

at the origin of the inbred lines 21 and 28, calculated from the base generation of line 7, had a mean of 6% and a range from 4 to 7%. Therefore, the inbreeding coefficient calculated from the base generation was used. Due to a difference of 10% in the inbreeding coefficient of the base generation of the line 3 and 7, the F obtained from the base generation was used for the combined data of line 3 and 7 in order to get more degrees of freedom. Estimates of correlation are presented in Table 8. Most of the correlations were negative and centered around 0.5. For hatch weight, 14 day weight and daily gain from 1 to 14 days, the correlations with the parental inbreeding were greater than those with the offspring inbreeding. Exactly the opposite situation was observed in the case of 35 day weight and daily gain from 14 to 35 days. This suggests a greater influence of parental inbreeding on early body weight than the offspring inbreeding and vice versa. A gradual decline of maternal effect with the advance of age may be the underlying cause.

The relative contribution of parental and offspring inbreeding to the changes in body weights and estimates of daily gain was calculated by partial regression (Table 9). Most of the regressions were negative suggesting decline of body weight with an increase of the parental and offspring inbreeding coefficient. Early body measurements (hatch, 14 day weight and daily gain from 1 to 14 days) showed greater depression due to inbreeding of the parent compared with the inbreeding of the offspring. The partial regressions on the inbreeding coefficient of the parents were significant whereas on the inbreeding of the offspring they were not significant. In the case of

Table 8.

Estimates of correlation coefficients between body weights and parental and offspring inbreeding coefficient

Characters	Line 3		Line 7		Line 3 + 7	
	F Parent	F Offspring	F Parent	F Offspring	F Parent	F Offspring
Hatch Wt.	-0.505**	-0.552**	-0.652*	-0.049	-0.541**	-0.469**
14 Day Wt.	-0.578**	-0.466*	-0.736**	-0.372	-0.571**	-0.485**
35 Day Wt.	-0.293	-0.640**	-0.661**	-0.590*	-0.373*	-0.594**
Daily gain 1-14 day	-0.576*	-0.462*	-0.716**	-0.384	-0.574**	-0.487**
Daily gain 14-35 day	0.220	-0.440*	-0.199	-0.632*	0.044	-0.444**
d.f.	26	26	12	12	40	40
r P.O.	0.5667**		0.4090		0.5838**	

*, ** $P < 0.05, 0.01$

r P.O. = Correlation between F of parents and F of offsprings.

Table 9.

Estimates of partial regressions of body weight on parental and offspring inbreeding

Characters	Base Line 3				Base Line 7				Base Line 3 + 7			
	$bF_p.F_o$	S.E.	$bF_o.F_p$	S.E.	$bF_p.F_o$	S.E.	$bF_o.F_p$	S.E.	$bF_p.F_o$	S.E.	$bF_o.F_p$	S.E.
Hatch Wt.	-0.0085	0.0058	-0.0092	0.0046	-0.0171^{**}	0.0053	0.0047	0.0043	-0.0096^{*}	0.0038	-0.0045	0.0031
14 Day Wt.	-0.1983^{*}	0.0830	-0.0686	0.0655	-0.2292^{**}	0.0727	-0.0227	0.0587	-0.1644^{**}	0.0592	-0.0704	0.0484
35 Day Wt.	0.0584	0.1049	-0.3120^{***}	0.0828	-0.2115^{*}	0.0919	-0.1299	0.0742	-0.0211	0.0845	-0.2485^{***}	0.0690
Daily gain 1-14 day	-0.0139^{*}	0.0058	-0.0047	0.0046	-0.0160^{*}	0.0055	-0.0021	0.0044	$-0,0116^{**}$	0.0042	-0.0050	0.0034
Daily gain 14-35 day	0.0118^{***}	0.0029	-0.0112^{***}	0.0023	0.0007	0.0025	-0.0051^{*}	0.0020	0.0065^{**}	0.0023	-0.0082^{***}	0.0019
Degree of Freedom		25		25		11		11		39		39

$*, **, ***$ $P < 0.05, 0.01, 0.001$

$bF_p.F_o$ = Regression of characters on parental inbreeding after removing the effect of progeny inbreeding.

$bF_o.F_p$ = Regression of chracters on offspring inbreeding after removing the effect of progeny inbreeding.

35 day weight and daily gain from 14 to 35 days the partial regressions on the inbreeding of the offspring are significant and greater than on the inbreeding of the parents as shown by the larger values of $bF_o.F_p$ than the $bF_p.F_o$. Due to small sample size in base line 7 the $bF_p.F_o$ of 35 day weight was significant at 5%.

Maternal and Paternal Inbreeding Components

In addition to genic contribution by sire and dam, body weight is influenced by maternal fitness; larger mothers tend to produce heavier offspring at birth by providing more intrauterine and postnatal nutrition in primiparous, and greater weight and better quality of eggs in oviparous species. Inbreeding depresses maternal fitness leading to depression in body weight of the progeny. The effect of inbreeding of the sire on the body weight of the progeny may be equally important if the maternal effect on a particular character is fairly low. A critical test to show the difference in the effect of inbreeding of the two sexes on the body weight and growth rate of the progeny, is to cross inbred individuals with non-inbreds reciprocally and compare the performance of their progeny. In the present experiment, 25% inbred individuals belonging to full sib line 20 and 21 were crossed reciprocally with their respective controls (line 3 & 7). The average body weights and growth rates of the crosses and comparable control lines with a measure of depression due to inbreeding of the mother (as difference) is presented in Table 10.

Subtraction of the average weight of progenies of inbred X

Table 10.

Estimates of maternal inbreeding components

	Source	Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain		No. of obser-vations	F of Parents		F of Offspring
						1-14 Day	14-35 Day		Female	Male	
LINE 3	Inbred ♀ x Control ♂	6.5	18.5	35.2	93.5	2.054	2.772	53	25	0	0
	Inbred ♂ x Control ♀	7.1	18.6	35.8	95.9	2.049	2.861	89	0	25	0
	Difference	0.6	0.1	0.6	2.4	-0.005	0.089				
	% Decline of Weight	8.5	0.5	1.7	2.5	-0.2	3.1				
	Control Line 3	6.8	15.1	31.3	92.2	1.752	2.898	199	0	0	0
LINE 7	Inbred ♀ x Control ♂	6.6	18.2	44.5	101.6	2.908	2.717	54	25	0	0
	Inbred ♂ x Control ♀	7.2	20.9	48.3	104.0	2.938	2.653	78	0	25	0
	Difference	0.6	2.7	3.8	2.4	0.030	-0.064				
	% Decline of Weight	8.3	12.9	7.9	2.3	1.0	-2.4				
	Control Line 7	6.8	-	44.8	107.8	2.716	2.999	172	0	0	0

control from those of control estimates the effect of maternal and paternal inbreeding if the contributions of the two sexes are additive. The argument may be presented as follows:

Control ♀ x Control ♂ - Inbred ♀ x Control ♂
≈ Control ♀ + Control ♂ - (Inbred ♀ + Control ♂)
= Control ♀ - Inbred ♀
= depression due to inbreeding of the female parent,

and

Control ♀ x Control ♂ - Inbred ♂ x Control ♀
≈ Control ♀ + Control ♂ - (Inbred ♂ + Control ♀)
= Control ♂ - Inbred ♂
= depression due to inbreeding of the male parent.

In the present experiment, progenies of control had a lower weight and inbred x control groups were reared separately explaining for the high average body weight of the latter in most of the cases as shown by negative depression of body weight due to inbreeding (Table 11).

Table 11.

	Depression due to inbreeding of:	Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain	
						1-14 Day	14-35 Day
Base Line 3	Female	0.3	-3.4	-3.9	-1.3	-0.302	0.126
	Male	-0.3	-3.5	-4.5	-3.7	-0.297	0.035
Base Line 7	Female	0.2	-	0.30	6.20	-0.192	0.282
	Male	-0.4	-	-3.5	3.8	-0.222	0.346

Progenies of inbred x control matings were hatched and reared together and are, therefore, directly comparable. Various body weights were higher in the progenies of inbred ♂ x control ♀ than its reciprocal suggesting greater effect of inbreeding of the dam in affecting body weight than that of the sire.

In the absence of selection, overall gene frequency in successive generations of inbreeding remains unchanged. Contribution of control and inbred males to the genotype of the progeny, therefore, may be supposed to be equal. The difference presented in Table 10 is equivalent to control ♀ - inbred ♀. On the assumption of equal genic contribution by inbred and control females, the difference represents the effect of depression in the fitness of the mother as follows:

	Composition
Control ♀	$G + M_C + E$
Inbred ♀	$G + M_I + E$

Where G = Genetic contribution of the mother;

E = Environmental effect on the progenies of two groups which are identical, and

M_C & M_I = Maternal effect of control and inbreds, respectively.

Progenies of inbred mothers had lower body weight at all the ages. Occurence of both negative and positive value in daily gain in weight was due to compensatory growth. The average body weight at various ages varied and therefore the relative percent decline in body weight per 25% inbreeding of the mothers was calculated by the formula:

Relative percent decline in the body weight of the progeny due to 25% inbreeding of the mother =

$$\frac{\text{Mean of inbred ♂ x control ♀} - \text{Mean of inbred ♀ x control ♂}}{\text{Mean of inbred ♂ x control ♀}} \times 100.$$

The result is presented in Table 10 as % decline in weight. A decline of 8% in hatch weight and 2% in 35 day weight of the progeny was noticed due to 25% rise in the inbreeding of the dam. The relative decline in 7 and 14 day weight differed in the birds of two populations. An unweighted average furnishes an estimate of 6.5 and 4.2% respectively for the two characters.

An analysis of variance (Tables 12 and 13) suggested that the differences between the average of inbred ♂ x control ♀ and its reciprocal were significant (P approx. $<$ 0.005) for hatch weight in the two base populations but not for 35 day weight. Reciprocal differences in 7 and 14 day body weights were significant in the birds coming from base line 7 (Table 13) but not from line 3 (Table 12). Variances between dams were significant for most of the traits. The F test employed here is approximate since it depends upon equal coefficient of the dam component in the two variances which is not the case as shown in E.M.S. Table 12 and 13. From the above finding it may be concluded that the depression in weight due to maternal inbreeding is in coordination with the maternal effect which gradually disappears as the progenies grow. The chicks approaching sexual maturity show negligible decline in body weight due to inbreeding of the dam.

Table 12.

Analysis of variance of crosses between inbred and control line 3

Brooder 4, 8 adjusted to 3

Characters / Sources of Variation	d.f.	Mean Squares						Coefficient of EMS	
		Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain		Comp. 1	Comp. 2
						1-14 Day	14-35 Day		
Reciprocals	1	**** 13.48	1.20	14.39	215.03	0.0001	0.268	66.18	4.07
Dams/Reciprocals	43	**** 1.37	**** 19.66	**** 48.29	**** 76.85	**** 0.220	*** 0.119		3.07
Individuals/Dams/ Reciprocals	94	0.17	8.08	18.01	33.77	0.086	0.050		

**** P < 0.005

*** P < 0.01

Table 13.

Analysis of variance of crosses between inbred and control line 7

Hatch date 282 adjusted to 270

Brooder 4, 7 adjusted to 2

Characters / Sources of Variation	d.f.	Mean Squares						Coefficient of EMS	
		Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain 1-14 Day	Daily Gain 14-35 Day	Comp. 1	Comp. 2
Reciprocals	1	10.96^{**}	214.42^{****}	436.86^{****}	178.24	1.578^{***}	0.129	62.46	6.57
Dams/ Reciprocals	29	1.49^{**}	11.32	36.40^{**}	105.13^{***}	0.173^{**}	0.132^{**}		3.94
Individuals/Dams/ Reciprocals	97	0.19	8.75	20.29	53.44	0.100	0.071		

*, **, ***, **** $P < 0.05, 0.025, 0.01, 0.005$.

Performance of Crossbreds Between Line 3 and 7

Average body weights of the base lines 3, 7 and their reciprocal crosses are presented in Table 14.

Table 14.

Average body weights and gain in weight of base lines 3, 7 and their crosses

Lines	Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain		No. of observations
					1-14 Day	14-35 Day	
Line 3	7.4	-	41.5	103.1	2.439	2.935	204
Line 7	7.5	-	51.3	114.0	3.129	2.987	222
Averages	7.45	-	46.4	108.6	2.784	2.961	
Line 34 (line 3♀ x line 7♂)	6.8	22.4	44.8	106.5	2.715	2.938	105
Line 24 (line 3♂ x line 7♀)	6.9	22.5	44.7	106.9	2.697	2.963	123
Average	6.85	22.5	44.8	106.7	2.706	2.951	
Difference (34-24)	-0.1	-0.1	0.1	-0.4	0.018	-0.025	

A comparison of the body weights and growth rates of line 3 and 7 suggests that line 7 had higher weights than line 3. The averages of the line 24 and 34 are near the averages of line 3 and 7, suggesting absence of heterosis.

The averages of line 24 and 34 do not differ significantly (Table 15). Between dam variances were significant for hatch, 14 day weight and daily gain from 1-14 days but not significant for gain in weight from 19-35 days. Dam variance was significant at 5% for 35 day weight.

Table 15.

Analysis of variance of the crosses between line 3 and 7

Hatch date 242 adjusted to 228

Brooder 7, 8 adjusted to 3

Source of Variation	Df.	Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain		E.M.S.
						1-14 Day	14-35 Day	
Reciprocals	1	0.88	0.84	0.75	13.48	0.017	0.047	$\sigma^2e+5.78\sigma^2D$ + $111.57\sigma^2R$
Dams/ Reciprocals	52	1.02^{***}	12.50^{***}	30.84^{***}	92.84^{*}	0.131^{***}	0.128	$\sigma^2e+4.08\sigma^2D$
Individuals/ Dams/ Reciprocals	171	0.22	5.65	12.46	55.22	0.059	0.092	σ^2e

$^{***}P < 0.005$

$^{*}P < 0.05$

Correlations Between Body Weights and Growth Rates

A representative sample of the estimates of genetic, environmental and phenotypic correlation between the body weights and growth rates is presented in Table 16. The genetic correlation estimated from between dam component, includes the effect of sire on account of single pair mating system. The environmental correlation was obtained from error mean square and product. The phenotypic correlation was estimated by summing error, dam and subline components. Birds furnishing these estimates were hatched

Table 16.

Estimates of correlation coefficients between various body weights and gain in weight

Environmental Correlation

	Characters	Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain	
						1-14 Day	14-35 Day
Genetic Correlation	Hatch Wt.		0.43	0.37	0.21	0.26	-0.05
	7 Day Wt.	0.26		0.87	0.53	0.85	-0.04
	14 Day Wt.	0.16	1.04		0.72	0.99	0.11
	35 Day Wt.	0.54	0.60	0.71		0.72	0.77
	Daily Gain 1-14 Day	-0.07	0.99	0.97	0.59		0.12
	Daily Gain 14-35 Day	0.61	-0.15	0.06	0.74	-0.08	
Phenotypic Correlation	Hatch Wt.						
	7 Day Wt.	0.42					
	14 Day Wt.	0.37	0.90				
	35 Day Wt.	0.32	0.67	0.80			
	Daily Gain 1-14 Day	0.25	0.88	0.99	0.79		
	Daily Gain 14-35 Day	0.14	0.16	0.26	0.79	0.25	

and reared together and belong to generation 3 of inbred line 20, 27 and 35. The degree of freedom for the error mean square and product was 309. Correlations obtained in other analysis follow similar patterns. The genetic, phenotypic and environmental correlations decreased as the measuring days became apart.

The phenotypic and environmental correlations between hatch weight and successive body weights ranged from 0.26 to 0.92. The genetic correlation between hatch weight and 35 day weight was 0.5. Hatch weight showed low genetic correlation with 7 and 14 day weight (0.26 and 0.16 respectively). The genetic correlation between daily gain from 1-14 day and 14-35 day was negative and non-significant.

Sex Difference in Body Weight and Growth Rate

Sexual dimorphism in the adult Japanese quail necessitated an adjustment of body weight of females to that of males. Adjustments between dam groups for various lines are presented in Appendix 27. The last two columns show the number of observations and degrees of freedom. Positive values of adjustments indicate that the average body weight of females was higher than that of males and vice versa. The standard error of the adjustments is calculated as follows:

$$S.E. = \sqrt{\sigma^2 e \times \text{coefficient}}$$

Where $\sigma^2 e$ = error mean square (Analysis of variance table - Appendix 1 to 23) and coefficient = inverse of number of dams and is presented in column 9 of Appendix 27. The ratio of adjustment and its standard error will be approximately distributed as a normal deviate due to large degrees of freedom. A significance of 5 and 1% was attached to the adjusted values if the ratios were larger than 1.96 and 2.58 respectively.

Difference in the hatch weight of males and females were mostly non-significant except for the crossbred 23 and 30 obtained from random crossing among full sib line 21 and double first cousin line 28. The crossbreds between full sib line 20 and control line 3 presented as line 25-26 (Appendix 27) also showed significant difference ($P < 0.05$) in the hatch weight of the two sexes. Comparatively fewer negative values of adjustments (9 out of 35) suggests a higher hatch weight of females in comparison to males. Large standard errors of the adjustments reveal the presence of significant variation in the hatch weight of the different dams; a fact which is also reflected in the analysis of variance table (Appendix 1 to 23).

Though 8 out of 22 values of adjustments of 7 day weight were significant at 5%, only 2 were significant at 1% level. This suggests that until the 7th day, marked difference in the body weight of the two sexes may not be observed and the outcome of different studies may differ.

Above 50% of the adjustments of 14 day weight were significant and many of the remaining have smaller standard errors. Females weighed 1 to 3g more than the males, though the adjusted body weights ranged from 0.19 to 5.03g. On the 35th day, the females were significantly heavier than males except in generation 3 of line 45 where, though the females were heavier, the standard error was large due to small size of 40. In various experiments females weighed 3.6 to 17.0g more than the males.

The sex difference in the daily gain in weight from 1 to 14 days and 14 to 35 days showed similar trends to those of 14 and 35 day body weights respectively.

A definite trend of the adjustments in successive generations of inbreeding is lacking which suggests that the difference in the female and male body weight did not decrease with the advance of inbreeding. One would expect a decrease of adjustments if the age at sexual maturity in control bird is near the 35th day and successive generations of inbreeding increase the age at sexual maturity which indirectly may reduce body weight at the 35th day. A large value of the adjustment in line 24-34 (crossbred between base line 3 and 7) is probably a reflection of the reduction in age at sexual maturity.

DISCUSSION

It is an important practical question whether the slow rate of inbreeding is advantageous in the formation of highly inbred lines over a rapid rate. The literature in poultry and other higher animals on this subject is lacking. In Drosophila melanogaster, Tantawy and Reeve (1956) observed a similar decline of body size in slowly and rapidly inbred lines at the same level of inbreeding. The body weight measured as wing and thorax length did not show any decline up to 50% F. From 50 to 80% F a slow decline independent of rate was observed which increased thereafter.

Slowly inbred lines in the present experiment showed a greater decline of 14 and 35 day body weight than the rapidly inbred lines up to an inbreeding coefficient of 31.5% and therefore the present result differs from the report of Tantawy and Reeve (1956). The cause of increased depression in the slowly inbred line in the present report was due to higher parental inbreeding in double first cousin lines than full sib lines. It can be observed from Table 3 that the first inbred generation in the regular full sib mating system is at t-1 generation with an F value of 25%. The regular double first cousin system takes t+2 generations to reach the same level of inbreeding. The parents of t-1 and t+2 generations are 0 and 18.8% inbred in full sib and double first cousin lines respectively. Due to long generation interval (3 $\frac{1}{2}$ months) in Japanese quail, it was not possible to reach beyond the 6th generation and therefore the effect of the two rates at higher inbreeding coefficient could not be known. If the inbreeding of the parents affect the body weight and the growth rate of the offspring to an appreciable degree one may expect the slowly inbred line showing greater depression than the rapidly inbred line up to 25% inbreeding coefficient of the progeny. The importance of parental and offspring inbreeding on the body weights was examined by partial regression. The results varied with the nature and control of the character. Parental inbreeding significantly depressed day old, 14 day weight and 1-14 day growth rate. The contribution of offspring inbreeding to these characters was also negative but lower than that of parental inbreeding and in most cases non-significant (Table 9). Exactly the opposite situation was observed in 35 day weight, where the partial regression on offspring inbreeding was higher and significant than parental inbreeding. Both parental and offspring inbreeding significantly depressed daily gain from 14-35 days. The value of the partial regression of the trait on offspring inbreeding however was higher than that of parental inbreeding. The present result clears the conflicting findings of the researchers evaluating maternal effect on body weight. Henderson (1953), Godfrey _et al_. (1953) and Godfrey and Williams (1955) in broilers observed that the mature body weights of the heavy breeds of chicken were not affected by the egg size. Observations made by Goodwin (1961), Tindell and Morris (1964) and Merritt and Gowe (1964) suggest that at 8 weeks of age the effect of egg weight is important on the body weight. Goodwin _et al_. (1964) showed that the effect of egg weight was observed on 31 week body weight of the White Leghorn. It appears from the above results that the maternal effect exercised via egg weight in poultry has a distinct effect on the early weight; the effect disappears as the individuals grow. The relative amount of depression due to parental and offspring inbreeding, as suggested by the present experiment, on a particular character depends on how the character is controlled.

The effect of paternal inbreeding in depressing body weight has been ignored in most of the reports (Shoffner, 1947 in poultry, and Sittmann et al., 1966 in Japanese quail). In the present experiment the effect of paternal inbreeding could not be assessed because the contemporary controls were reared separately and probably due to this reason had lower average body weight than inbred x control crosses (Table 10). However, from the study of paternal and maternal components it is obvious that the dam's inbreeding is more important than the sire's inbreeding. Assuming that the depression in the body weight of the progenies of inbred mothers as compared to non-inbred is mostly due to the depression in maternal quality of the former, it appears that such depression is more pronounced at an early age of the progeny than at a later age. The significant depression of hatch weight (-0.32% / 1% F) in both base lines, irregular depression in 14 day weight (in one population non-significant where as in the other significant (-0.32% / 1% F)), and the non-significant decline of 35 day weight in both base lines (0.08% / 1% F) suggests that the depression of maternal ability is an important factor in depressing early body weight of the quails. Shoffner (1947) also reported a decrease of 0.08% / 1% F in body weight of poultry measured at 300 days. The extent of depression in his material was similar to the results reported here.

Differences between the body weight of individuals at two levels of inbreeding born from the parents at the same level of inbreeding provides an estimate of progeny inbreeding uncomplicated by parental inbreeding. Most of the estimates were negative and significant suggesting a decline in the body weight due to progeny inbreeding (Table 5). The regression of these estimates on the difference in the inbreeding level of the progeny is non-significant (Table 6). The non-significant result is firstly due to the small degrees of freedom of the estimates and secondly because the individuals of different generations providing averages were reared separately.

In respect of hatch weight, crossbred offspring from the inbred parents had similar body weights to those of inbred offspring. (Figs. 1 & 2). The hatch weight is influenced by the egg size, a fact which is revealed by the significant dam variances in analysis of variance tables (Appendix 1 to 24). Inbred and crossbred offspring were born from the eggs of the same inbred mothers and are not expected to differ in respect to hatch weight because the two groups of eggs were collected at an interval of 7 days. Over such a short interval of time average egg weight remains fairly constant especially in mature animals.

In respect of 14 and 35 day body weight, crossbreds from the inbred parents of different inbred lines (20, 27, 35) obtained from base line 3, in most cases showed significant heterosis* over inbreds and controls (Table 4 and 11, Fig. 1). This result is in agreement with that of Robertson and Reeve (1955) on

---

* Heterosis can be defined as the superiority in the average weight of the crossbred offspring over the mid-parent value or contemporary control.

the body size in Drosophila melanogaster. They observed that the mean of crosses between inbred lines always exceeded the mid-parent value. Crossbred progenies of the inbred lines obtained from base line 7, on the other hand, showed significantly lower body weight than the control in many of the generations. This anomaly in crosses from full sib line 21 was due to small sample size (34 in 3rd and 17 in 4th generation). The crosses from the double first cousin line 28 did not show an increase of average body weight over inbreds and showed a significant decline in the 4th and 5th generation as compared with control. It seems that the crosses among inbred lines obtained from base line 7 did not show heterosis possibly due to the selection for body weight practiced earlier in the line. The non-significant between cross variances (Appendix 15 to 22) in most of the cases suggest that heterosis observed in the present experiment was not due to specific combining ability. Robertson (1957) has also shown that the genetic variance in body size of Drosophila melanogaster is largely additive in character.

Birds of control line 7 had higher body weight and growth rate than those of line 3. Crosses between two controls had intermediate body weights suggesting the additive nature of the characters (Table 14). Quite surprisingly reciprocal differences were not observed (Table 15). This result is in contrast to many published reports on breed crosses of poultry where reciprocal differences in the body weight of crossbreds were observed in favour of heavier group (Eisen et al., 1967).

The environmental and phenotypic correlations between different body weights (Table 16) suggest that the correlations are greater at closer ages. The correlations decline as the measuring days widen in age. The genetic correlation of hatch weight with other body weights did not suggest a trend, but between other body weights showed a similar trend to those of environmental and phenotypic correlations. In view of very small standard errors, (near 0.03), most of the estimates of correlations were highly significant except those of very low order (0.08). This suggests that the genes functioning at closer ages are more alike than at distant ages.

In poultry, males are heavier and grow at a faster rate than females. In Japanese quail the opposite holds true. Sexual dimorphism at prepubertal stage is still a matter of dispute. Stevens (1958) reported lighter body weight in female than in male quails up to 40 days of age. El-Ibiary et al. (1965) studied growth rate at weekly intervals up to 6 weeks of age in two random bred generations of Coturnix. The females were heavier at all measurements but not significantly different from males except after 6 weeks of age. In the present experiment, a non-significantly higher hatch weight of the females was noticed in 26 out of 35 groups of birds. On the 7th day, 8 out of 35 groups had significantly higher body weights of females. Females were significantly heavier than males on the 14th day in about 50% of the groups whereas the rest of the groups had low standard errors. The difference in the body weight of two sexes ranged from 1 to 5g. On the 35th day the females of all groups weighed significantly heavier than males. The difference in the weight of the two sexes ranged from 4 to 17g. Thus the results obtained here are in partial agreement to El-Ibiary et al. (1965) and in contrast to Stevens (1958). Non-significant difference in the body weight of males and females in the reports of earlier authors may be due to their small sample size (Appendix 27).

CONCLUSION

Inbreeding depression varies with the type of characters. Parental inbreeding and offspring inbreeding both depress the character. The relative depression due to parental inbreeding and offspring inbreeding depends on the magnitude of the parental effect and individuals own genotypic effect on the character. Early body weight and early growth rate are to a great extent depressed by maternal inbreeding suggesting the major control of character by maternal effect. The body weight taken near maturity is depressed mainly by individuals own inbreeding, suggesting that the maternal effect disappears as the animals grow. The disappearance of maternal effect is gradual with the ageing of animals as shown by 8, 6, 4 and 2% decline of day old, 7, 14 and 35 day body weight, respectively.

A slow rate of inbreeding has shown a greater depression of the characters than a rapid rate up to a given level of progeny inbreeding because of high parental inbreeding in the former as compared with the latter. The maternal component of inbreeding is more important than the paternal component. In estimating these components correction for environmental effects should be made as far as possible, since the outcome of any one experiment may be seriously affected by environmental fluctuations. The genetic, phenotypic and environmental correlations in successive body weights are fairly high; the correlation declines as the measurement becomes apart. Significant prepubertal sexual dimorphism in Japanese quail is noticed as early as 14 days, but not earlier.

ACKNOWLEDGEMENTS

I am grateful to my supervisor, Dr. G.A. Clayton, for suggesting the line of research, for his continued interest and advice, and for his critical reading of the manuscript.

I am also grateful to Professor D.S. Falconer for provision of facilities at the Institute of Animal Genetics.

The help provided in the statistical analysis of the data by Mr. Robin Thompson and in the computer programming and processing of the data by Mrs. J. Smith is gratefully acknowledged.

It is a pleasure to thank Miss N. Alexander and Miss E. Currie for introducing me to quail breeding techniques and their constant help in breeding and management of quails. My thanks are also due to Mrs. P. Hinde for the typing of the thesis.

This work was made possible by the award of a Commonwealth Scholarship for which grateful acknowledgement is made.

BIBLIOGRAPHY

Chung, S.B. & Park, Y.I. (1969) Effects of inbreeding on the economic traits in hens. Res. Rep. Off. rur. Dev., Suwon, Korea, 12 (4) : 5-8.

Cochran, W.G. (1964) Approximate significance levels of the Behrens-Fisher test. Biometrics, 20 : 191-195.

Cruden, D. (1949) The computation of inbreeding coefficients for closed populations. J. Hered., 40 : 248-251.

Dumon, A.G. (1930) The effects of inbreeding on hatchability. Report proc. 4th Wld's Poult. Congr. Crystal Palace, Lond., England. 1-5.

Eisen, E.J., Bohren, B.B., McKean, H.E. & King, S.C. (1967) Genetic combining ability of light and heavy inbred lines in single crosses of poultry. Genetics, 55, (1) : 5-20.

El-Ibiary, H.M., Godfrey, E.F. & Shaffner, C.S. (1965) Correlations between growth and reproductive traits in the Japanese Quail. Poult. Sci., 45 : 463-469.

Godfrey, G.F. & Williams, C. (1955) Unsuitability of the chick weight: egg weight ratio as an indicator of post natal growth. Poult. Sci., 34 : 164-166.

Godfrey, G.F., Williams, C. & Marshall, C.E. (1953) The relative influence of egg size, age at sexual maturity and mature body weight on growth to twelve weeks of age. Poult. Sci., 32 : 496-500.

Goodwin, K. (1961) Effect of hatching egg size and chick size upon subsequent growth rate in chickens. Poult. Sci., 40 : 1408.

Goodwin, K., Lamoreux, W.F. & Dickerson, G.E. (1964) Maternal effects in chickens: performance of daughters from dams of differing ages. *Poult. Sci.*, *43* : 1435-1442.

Henderson, E.W. (1953) Growth of twelve week old chickens not affected by size of eggs. *Quart. Bull. Mich. agric. Exp. Sta.*, *35* : 436-439.

Henderson, C.R. (1953) Estimation of variance and covariance components. *Biometrics*, *9* : 226-252.

Hutt, F.B. (1949) *Genetics of the Fowl*. McGraw Hill book Company. 1st Edn. p.590.

Jull, M.A. (1929) Studies in hatchability. II. Hatchability in relation to consanguinity of the breeding stock. *Poult. Sci.*, *8* : 219-229.

Jull, M.A. (1933) Inbreeding and intercrossing in poultry. The effects, on various characters, of close inbreeding and of intercrossing closely inbred lines of White Leghorns. *J. Hered.*, *24* : 93-101.

Merritt, W.S. & Gowe, R.S. (1965) Post embryonic growth in relation to egg weight. *Poult. Sci.*, *44* : 477-480.

Robertson, F.W. (1957) Studies in quantitative inheritance. XI. Genetic and environmental correlation between body size and egg production in *Drosophila melanogaster*. *J. Genet.*, *55* : 428-443.

Robertson, F.W. and Reeve, E.C.R. (1955) Studies in quantitative inheritance. VIII. Further analysis of heterosis in crosses between inbred lines of *Drosophila melanogaster*. *Z. indukt. Abstamm. -u. VererbLehre*, *86*, 439-458.

Scott, H.M. & Phillips, R.E. (1936) Egg size in relation to growth of Narragansett turkey. Poult. Sci., 15 : 435-438.

Shinjo, A., Mizuma, Y. & Nishida, S. (1971) Studies on inbreeding depression in Japanese Quail. Jap. Poult. Sci., 8 : 231-237.

Shoffner, R.N. (1947) The reaction of the fowl to inbreeding. Poult. Sci., 27 : 448-452.

Sittmann, K., Abplanalp, H. & Fraser, R.A. (1966) Inbreeding depression in Japanese Quail. Genetics, 2 : 371-379.

Stevens, V.C. (1958) Observations on the Reproduction and Development of the Coturnix Quail. M.S. Thesis, Ohio State Univ.

Tantawy, A.O. & Reeve, E.C.R. (1956) Studies in quantitative inheritance. ix. The effect of inbreeding at different rates in Drosophila melanogaster. Zeitchrift fur indukt. Abstammungs und vererbungslehre, Bd. 87, S : 648-657.

Tindell, D. & Morris, D.R. (1964) The effects of egg weight on subsequent broiler performance. Poult. Sci., 43 : 534-539.

ANALYSIS OF VARIANCE TABLES

Appendix 1.

Lines 20, 27, 35 generation = 1

Hatch date 313 adjusted to 300

Characters / Sources of Variation	Degree of Freedom	Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain		Coefficient of E.M.S. Comp (1)
						1-14 Day	14-35 Day	
Dams	74	1.71^{***}	x	88.08^{***}	171.78^{***}	0.416^{***}	0.143^{***}	5.45
Individuals/Dams	339	0.21	x	22.79	59.86	0.114	0.009	

Appendix 2.

Line 20, 27, 35 generation = 2

Hatch date 046 adjusted to 032

Brooders 3, 4, 6, 7, 8 adjusted to 2

Characters / Sources of Variation	Df.	Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain		Coefficient of E.M.S.		
						1-14 Day	14-35 Day	Comp(1)	Comp (2)	Comp (3)
Lines	2	5.06	x	909.09***	1394.96*	3.97***	0.12	217.64	20.37	10.28
Sublines/Lines	46	2.90	x	105.07***	334.47***	0.50***	0.33***		13.16	7.83
Sub-Sublines/Sublines/ Lines	45	2.98***	x	33.46*	104.58***	0.14	0.11			6.14
Individuals/Sub-Sub-lines/Sublines/Lines	570	0.57	x	21.17	58.67	0.10	0.09			

Appendix 3.

Line 20, 27, 35 generation = 3

Hatch date 123 adjusted to 137

Brooder 5, 7, 8 adjusted to 6

Characters / Sources of Variation	Df.	Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain		Coefficient of E.M.S.		
						1-14 Day	14-35 Day	Comp(1)	Comp(2)	Comp(3)
Lines	2	0.48	425.03***	1263.69***	2556.05***	6.207***	0.593*	132.79	11.45	6.70
Sublines/Lines	46	2.21*	40.76***	115.22***	290.98***	0.531***	0.168		7.83	4.95
Sub-Sublines/Sublines/Lines	39	1.25***	11.34	40.72**	95.28**	0.197**	0.106**			3.82
Individuals/Sub-Sub-lines/Sublines/Lines	309	0.31	9.22	22.76	55.16	0.108	0.061			

Appendix 4.

Line 20, 27, 35 generation = 4

Hatch date 228, 242 adjusted to 214

Brooder 6 adjusted to 7

Characters Sources of Variation	Df.	Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain		Coefficient of E.M.S.		
						1-14 Day	14-35 Day	Comp(1)	Comp(2)	Comp(3)
Lines	2	2.13	10.37	111.0	138.4	0.726	0.003	43.79	11.71	7.12
Sublines/Lines	15	0.90	26.38	88.4	250.0	0.415	0.255		7.46	3.88
Sub-Sublines/Sublines/ Lines	23	0.62^{***}	17.39^{*}	63.3^{***}	157.8^{*}	0.312^{***}	0.161			3.05
Ind./Sub-Sublines/ Sublines/Lines	111	0.16	8.86	27.1	80.9	0.136	0.115			

Appendix 5.

Line 20, 27, 35 generation = 5

Hatch date 319 adjusted to 333

Brooders 3, 4, 6, 8 adjusted to 2

Characters / Sources of Variation	Df.	Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain		Coefficient of E.M.S.		
						1-14 Day	14-35 Day	Comp(1)	Comp(2)	Comp(3)
Lines	2	9.88	43.17	120.1	238.3	0.642	0.071	75.32	47.84	10.87
Sublines/Lines	3	3.44	8.16	62.5	310.0	0.340	0.389^{*}		30.07	9.12
Sub-Sublines/Sublines/ Lines	23	1.15^{***}	15.41^{***}	51.5^{***}	108.1^{***}	0.230^{***}	0.127^{***}			7.57
Ind./Sub-Sublines/ Sublines/Lines	202	0.17	6.62	20.2	47.5	0.096	0.057			

Appendix 6.

Line 20, 27, 35 generation = 6

Characters Sources of Variation	Df.	Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain		Coefficient of E.M.S.		
						1-14 Day	14-35 Day	Comp(1)	Comp(2)	Comp(3)
Lines	2	0.09	126.46^{*}	320.5	93.1	1.605^{*}	0.207	25.81	11.73	4.23
Sublines/Lines	6	0.95^{*}	14.67	62.6^{*}	101.4	0.262^{*}	0.099		7.37	3.81
Sub-Sublines/Sublines/Lines	16	0.34^{***}	10.20	18.0	40.0	0.087	0.045			2.71
Ind./Sub-Sublines/Sublines/Lines	54	0.06	9.96	31.3	29.4	0.155	0.047			

Appendix 7.

Line 21, 28 generation = 1

Characters / Sources of Variation	Df.	Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain		Coefficient of E.M.S. Comp (1)
						1-14 Day	14-35 Day	
Dams	37	0.83***	x	53.4***	107.0***	0.271***	0.121**	2.47
Individuals/Dams	57	0.12	x	23.0	41.8	0.116	0.060	

Appendix 8.

Line 21, 28 Generation = 2

Hatch date 349, 362 adjusted to 335

Brooder 3, 4, 1 adjusted to 2

Characters / Sources of Variation	Df.	Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain		Coefficient of E.M.S.		
						1-14 Day	14-35 Day	Comp(1)	Comp(2)	Comp(3)
Lines	1	3.33	x	289.1	3307.8^{**}	1.808^{*}	3.721^{**}	175.05	13.55	7.64
Sublines/Lines	37	2.92^{***}	x	93.5^{*}	366.7	0.382	0.468		10.12	6.68
Sub-Sublines/Sublines/Lines	33	1.03^{***}	x	44.0^{***}	223.6^{***}	0.219^{***}	0.268^{***}			4.30
Ind./Sub-Sublines/Sublines/Lines	336	0.20	x	21.8	92.7	0.107	0.132			

Appendix 9.

Line 21, 28 Generation = 3

Hatch date 095 adjusted to 081

Brooder 4,7, 8 adjusted to 6

Sources of Variation \ Characters	Df.	Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain		Coefficient of E.M.S.		
						1-14 Day	14-35 Day	Comp(1)	Comp(2)	Comp(3)
Lines	1	0.34	x	315.3^{*}	2668.9^{***}	1.716^{*}	2.607^{***}	99.26	15.14	7.53
Sublines/Lines	20	2.03^{*}	x	58.4^{**}	184.2	0.298^{*}	0.185		11.09	4.91
Sub-Sublines/Sublines/ Lines	36	0.95^{***}	x	23.9	151.6^{*}	0.127	0.220^{*}			4.16
Ind./Sub-Sublines/ Sublines/Lines	204	0.20	x	29.6	99.7	0.139	0.123			

Appendix 10.

Line 21, 28 Generation = 4

Hatch date 193 adjusted to 179

Brooder 8 adjusted to 7

Characters / Sources of Variation	Df.	Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain		Coefficient of E.M.S.		
						1-14 Day	14-35 Day	Comp(1)	Comp(2)	Comp(3)
Lines	1	1.25	54.63	701.7***	2333.9***	3.284***	1.080*	16.84	4.64	1.65
Sublines/Lines	12	0.99	23.46*	44.8	36.4	0.229	0.143		12.36	3.86
Sub-Sublines/Sublines/ Lines	33	1.28***	8.90	29.8	96.6	0.164	0.121			3.80
Ind./Sub-Sublines/ Sublines/Lines	133	0.13	8.34	30.3	75.8	0.150	0.079			

Appendix 11.

Line 28 Generation = 5 and Line 45 Generation = 2

Hatch date 284, 298 adjusted to 270

Brooder 3, 4, 6 adjusted to 7

Characters / Source of Variation	Df.	Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain		Coefficient of E.M.S.		
						1-14 Day	14-35 Day	Comp(1)	Comp(2)	Comp(3)
Lines	1	0.75	877.19^{***}	4210.6^{***}	16404.2^{***}	20.9^{***}	9.054^{***}	104.46	16.90	6.24
Sublines/Lines	20	2.85^{***}	34.37^{*}	77.6^{*}	149.9	0.35^{*}	0.181		10.79	5.31
Sub-Sublines/Sublines/Lines	26	0.60^{***}	15.23	32.2	165.9^{**}	0.15	0.178^{***}			5.40
Ind./Sub-Sublines/Sublines/Lines	212	0.16	10.52	35.9	85.6	0.18	0.084			

Appendix 12.

Line 28 Generation = 6

Characters / Source of Variation	Df.	Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain		Coefficient of E.M.S.	
						1-14 Day	14-35 Day	Comp(1)	Comp (2)
Sublines	4	5.07*	64.22*	190.5*	415.3**	0.825*	1.254***	21.40	6.39
Sub-Sublines/Sublines	18	1.12***	20.40	53.8	89.3	0.232	0.131		4.65
Ind./Sub-Sublines/ Sublines	93	0.22	12.81	60.0	67.9	0.296	0.169		

Appendix 13.

Line 45 Generation = 3

Hatch date 017 adjusted to 003

Characters / Sources of Variation	Df.	Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain		Coefficient of E.M.S.	
						1-14 Day	14-35 Day	Comp(1)	Comp(2)
Sublines	12	0.46	4.05	42.1	152.1	0.191	0.200	2.77	2.40
Sub-Sublines/Sublines	3	0.57^{*}	9.21^{*}	91.7^{***}	246.4^{*}	0.401^{***}	0.088		1.59
Individuals/Sub-Sublines/Sublines	22	0.14	2.14	10.0	61.3	0.050	0.084		

Appendix 14.

Line 46 Generation = 2

Hatch date 361 adjusted to 010

Brooder 3 adjusted to 6

Characters / Sources of Variation	Df.	Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain		Coefficient of E.M.S.	
						1-14 Day	14-35 Day	Comp(1)	Comp(2)
Sublines	13	1.86^{*}	18.72^{*}	155.7^{***}	395.9^{***}	0.728^{***}	0.264^{**}	10.53	4.90
Sub-Sublines/Sublines	19	0.77^{***}	6.34	27.3	73.3	0.119	0.071		4.50
Individuals/Sub-Sublines/Sublines	123	0.18	5.24	27.5	62.9	0.133	0.075		

Appendix 15.

Lines 22, 29, 36 Generation = 3

Brooder 6 adjusted to 4

Characters / Sources of Variation	Df.	Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain		Coefficient of E.M.S.		
						1-14 Day	14-35 Day	Comp(1)	Comp(2)	Comp(3)
Lines	2	1.10	28.88	160.3	538.9	0.889	0.428	61.22	10.83	5.88
Crosses/Lines	19	2.19	16.75	55.8^{*}	294.4^{*}	0.284^{*}	0.362^{*}		8.36	4.82
Reciprocals/Crosses/ Lines	17	2.53^{***}	9.31^{*}	22.4	122.7^{**}	0.089	0.144			4.79
Individuals/Reciprocals/ Crosses/Lines	151	0.29	4.91	16.6	57.0	0.076	0.088			

Appendix 16.

Line 23, 29, 36 Generation = 4

Characters / Sources of Variance	Df.	Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain		Coefficient of E.M.S.		
						1-14 Day	14-35 Day	Comp(1)	Comp(2)	Comp(3)
Lines	2	1.86	1.00	20.3	40.0	0.106	0.022	32.36	6.38	4.32
Crosses/Lines	17	0.64	28.16	103.2	166.0	0.504	0.190		4.93	3.37
Reciprocals/Crosses/ Lines	12	0.55^{***}	19.04^{*}	64.0^{*}	201.2^{***}	0.331^{*}	0.235^{***}			2.76
Individuals/Reciprocals/ Crosses/Lines	72	0.19	9.00	32.7	65.1	0.157	0.058			

Appendix 17.

Line 29, 36 Generation = 5

Characters / Sources of Variation	Df.	Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain		Coefficient of E.M.S.		
						1-14 Day	14-35 Day	Comp(1)	Comp(2)	Comp(3)
Lines	1	1.21	21.70	300.5	196.4	1.345	0.025	51.05	28.74	15.36
Crosses/Lines	3	0.33	11.11	64.2	184.9	0.361*	0.075		14.74	8.70
Reciprocals/Crosses/Lines	4	0.78*	5.89	12.2	101.9	0.040	0.126			11.19
Individuals/Reciprocals/Crosses/Lines	94	0.29	5.35	11.2	62.4	0.049	0.108			

Appendix 18.

Line 23, 30 Generation = 3

Brooder 8 adjusted to 2

Characters / Sources of Variation	Df.	Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain		Coefficient of E.M.S.		
						1-14 Day	14-35 Day	Comp(1)	Comp(2)	Comp(3)
Lines	1	0.10	4.44	14.3	50.7	0.061	0.025	47.82	8.18	6.12
Crosses/Lines	17	1.37	38.61*	56.8	108.1	0.238	0.114		5.63	3.92
Reciprocals/Crosses/Lines	9	0.48*	9.69	31.7*	177.4*	0.165*	0.175			3.85
Individuals/Reciprocals/Crosses/Lines	86	0.19	6.12	15.2	73.6	0.073	0.105			

Appendix 19.

Line 22 Generation = 4

Hatch date 277 adjusted to 263

Characters / Sources of Variation	Df.	Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain		Coefficient of E.M.S.	
						1-14 Day	14-35 Day	Comp(1)	Comp(2)
Crosses	9	1.92	10.84	106.1	291.7	0.476	0.200^{***}	9.54	6.21
Reciprocals/Crosses	6	2.71^{***}	34.25^{***}	93.4^{**}	112.0^{*}	0.342^{*}	0.010		6.21
Individuals/Reciprocals/Crosses	88	0.21	9.58	27.1	38.8	0.125	0.05		

Appendix 20.

Line 30 Generation = 4

Hatch date 228 adjusted to 214

Brooder 3, 7, 8 adjusted to 4

Characters / Sources of Variation	Df.	Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain		Coefficient of E.M.S.	
						1-14 Day	14-35 Day	Comp(1)	Comp(2)
Crosses	8	2.36	15.79	31.4	57.9	0.134	0.117	9.74	5.95
Reciprocals/Crosses	7	0.85*	20.38	36.6	88.2	0.143	0.158		5.11
Individuals/Reciprocals/ Crosses	76	0.34	10.49	23.8	71.6	0.110	0.101		

Appendix 21.

Line 30 Generation = 5

Brooder 4, 8 adjusted to 3

Characters / Sources of Variation	Df.	Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain		Coefficient of E.M.S.	
						1-14 Day	14-35 Day	Comp(1)	Comp(2)
Crosses	8	0.55	22.75	66.1	184.5	0.315	0.113	7.12	5.22
Reciprocals/Crosses	5	1.68***	13.10	24.2	41.5	0.094	0.071		3.74
Individuals/Reciprocals/ Crosses	52	0.24	8.89	20.1	64.2	0.096	0.081		

Appendix 22.

Line 49 Generation = 1

Characters / Sources of Variation	Df.	Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain		Coefficient of E.M.S.	
						1-14 Day	14-35 Day	Comp(1)	Comp(2)
Crosses	9	1.04	18.97	90.7	241.2	0.409	0.187^{*}	10.37	6.68
Reciprocals/Crosses	9	1.94^{***}	14.02^{*}	47.3^{**}	93.1^{*}	0.190^{*}	0.038		4.17
Individuals/Reciprocals/ Crosses	86	0.18	6.67	17.5	33.2	0.083	0.055		

Appendix 23.

Control Line 3

Generation & Correction	Sources of Variation	Df.	Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain 1-14 Day	Daily Gain 14-35 Day	Coefficient of E.M.S.
Generation = 21	Dams	33	1.88^{***}	x	67.0^{***}	220.6^{***}	0.299^{***}	0.345^{***}	5.95
	Individuals/dams	169	0.19	x	16.6	59.6	0.083	0.120	
Generation = 22 Hatch date 147 adjusted to 133	Dams	27	4.40^{***}	x	85.5^{***}	129.2^{***}	0.327^{***}	0.156^{*}	9.79
	Individuals/dams	248	0.25	x	24.5	63.7	0.120	0.086	
Generation = 23 Hatch date 231 adjusted to 217 Brooder 4 adjusted to 2	Dams	38	1.59^{***}	8.72^{*}	41.1^{*}	100.0^{***}	0.182	0.120^{*}	4.97
	Individuals/dams	158	0.22	5.32	24.8	51.1	0.124	0.072	
Generation = 24 Hatch date 315 adjusted to 301 Brooder 7 adjusted to 2	Dams	53	0.64^{***}	x	32.4^{***}	87.9^{***}	0.146^{***}	0.118^{***}	3.20
	Individuals/dams	123	0.20	x	15.1	32.2	0.073	0.042	
Generation = 25	Dams	32	1.48^{***}	x	66.2^{***}	98.9^{***}	0.309^{***}	0.109^{*}	6.06
	Individuals/dams	169	0.17	x	26.1	44.7	0.130	0.065	

Appendix 24.

Control Line 7

Generation & Correction	Sources of Variation	Df.	Hatch Wt.	7 Day Wt.	14 Day Wt.	35 Day Wt.	Daily Gain		Expected Mean Square
							1-14 Day	14-35 Day	
Generation = 8	Dams	30	1.33***	x	52.0***	345.3***	0.248***	0.465***	6.95
Hatch date 021 adjusted to 007	Individuals/dams	189	0.16	x	22.9	98.9	0.110	0.133	
Generation = 9	Dams	26	1.68***	x	42.1***	132.8	0.195***	0.164	2.88
Hatch date 119 adjusted to 105	Individuals/dams	52	0.16	x	12.2	118.0	0.058	0.227	
Generation = 10 Hatch date 203 adjusted to 189 Brooder 4 adjusted to 2	Dams	29	0.98***	x	48.2	122.7**	0.244	0.166	5.61
	Individuals/dams	140	0.11	x	33.1	66.9	0.166	0.117	
Generation = 11 Hatch date 288 adjusted to 273 Brooder 8 adjusted to 2	Dams	31	1.29***	16.74	37.0	121.5*	0.163	0.153	5.06
	Individuals/dams	132	0.28	19.90	32.1	74.0	0.154	0.105	
Generation = 12 Hatch date 006 adjusted to 357 Brooder 4 adjusted to 2	Dams	29	1.10***	x	36.5	89.3	0.167	0.109	5.82
	Individuals/dams	147	0.18	x	24.5	74.5	0.120	0.111	

* $P < 0.05$
** $P < 0.01$
*** $P < 0.005$

Appendix 25.

Average body weights (g)

Line	Generations	Hatch Wt.	S.E.	7 Day Wt.	S.E.	14 Day Wt.	S.E.	35 Day Wt.	S.E.	Daily Gain				No. of Observations	F		Theoretical F	
										1-14 Day	S.E.	14-35 Day	S.E.		Parents	Offsprings	Parents	Offsprings
20	1	7.5	0.06	-	-	40.5	0.46	97.9	0.64	2.36	0.032	2.73	0.018	416	0	0	16	17
	2	7.0	0.10	-	-	45.7	0.61	99.7	1.08	2.76	0.042	2.57	0.034	284	0	25	17	37
	3	6.8	0.13	22.0	0.57	40.6	0.95	90.2	1.51	2.42	0.065	2.36	0.036	127	25	38	37	48
	X	6.8	0.16	16.7	0.44	36.5	0.81	99.2	1.85	2.12	0.057	2.99	0.065	86	25	0	37	16
	4	5.7	0.19	18.5	1.07	34.3	1.96	87.6	3.30	2.04	0.134	2.54	0.105	23	38	50	48	58
	X	6.8	0.14	16.8	0.32	37.6	1.00	96.8	1.66	2.20	0.067	2.82	0.043	106	38	0	48	16
	5	6.2	0.26	17.3	0.39	34.8	1.09	92.5	2.42	2.04	0.080	2.75	0.086	53	50	59	58	67
	6	6.6	0.17	14.9	0.67	30.0	1.38	90.3	1.75	1.67	0.089	2.87	0.055	33	59	67	67	74
45	2	6.8	0.16	16.8	0.57	36.6	0.86	87.4	1.19	2.13	0.057	2.42	0.041	106	0	31	16	42
	3	6.1	0.11	13.5	0.32	27.3	1.03	75.2	1.95	1.51	0.069	2.28	0.071	40	31	41	42	49
46	2	6.7	0.11	16.4	0.34	36.4	0.99	88.5	1.58	2.12	0.068	2.48	0.041	158	0	34	16	44
	X	6.7	0.10	18.8	0.42	44.0	0.93	96.3	1.51	2.67	0.062	2.49	0.042	106	0	0	16	19

X = Crosses

/Continued....

Line	Generations	Hatch Wt.	S.E.	7 Day Wt.	S.E.	14 Day Wt.	S.E.	35 Day Wt.	S.E.	Daily Gain 1-14 Day	S.E.	Daily Gain 14-35 Day	S.E.	No. of Observations	F Parents	F Offsprings	Theoretical F Parents	Theoretical F Offsprings
27	2	7.3	0.12	-	-	49.0	0.72	103.8	1.28	2.98	0.049	2.61	0.040	205	0	0	18	27
	3	6.9	0.13	25.6	0.57	47.0	0.96	98.9	1.52	2.86	0.065	2.47	0.036	126	0	13	27	33
	X	6.7	0.22	18.2	0.60	39.9	1.09	104.9	2.50	2.37	0.078	3.10	0.088	47	0	0	27	15
	4	6.2	0.12	17.1	0.63	30.5	1.16	83.1	1.95	1.74	0.079	2.51	0.062	66	13	19	33	38
	X	6.9	0.13	16.4	0.83	37.0	1.59	98.5	2.01	2.16	0.111	2.93	0.068	41	13	0	33	16
	5	6.7	0.20	18.9	0.31	37.1	0.86	95.0	1.91	2.17	0.063	2.76	0.068	85	19	25	38	43
	X	7.2	0.09	21.6	0.49	43.1	1.19	105.7	2.03	2.56	0.090	2.98	0.041	45	19	0	38	20
	6	6.6	0.22	18.6	0.86	36.5	1.77	94.1	2.25	2.14	0.114	2.74	0.070	20	25	31	43	47
35	2	7.3	0.13	-	-	49.1	0.76	104.0	1.36	2.99	0.053	2.61	0.043	181	0	0	18	23
	3	6.8	0.12	24.4	0.52	44.5	0.88	96.6	1.40	2.69	0.060	2.48	0.034	148	0	13	23	30
	X	7.0	0.19	17.1	0.53	37.4	0.97	103.3	2.23	2.17	0.069	3.14	0.078	59	0	0	23	18
	4	6.2	0.12	16.9	0.63	29.7	1.15	82.2	1.93	1.68	0.079	2.50	0.062	67	13	19	30	36
	X	6.5	0.12	16.4	0.77	36.2	1.48	97.9	1.88	2.12	0.104	2.94	0.064	47	13	0	30	16
	5	7.0	0.19	18.7	0.29	35.1	0.80	91.9	1.78	2.01	0.059	2.71	0.063	98	19	25	36	42
	X	7.0	0.07	20.7	0.43	39.6	1.04	102.9	1.77	2.33	0.078	3.01	0.036	59	19	0	36	13
	6	6.7	0.19	18.3	0.74	34.6	1.52	91.7	1.94	1.99	0.098	2.72	0.061	27	25	31	42	47

X = Crosses

/Continued....

Line	Generations	Hatch Wt.	S.E.	7 Day Wt.	S.E.	14 Day Wt.	S.E.	35 Day Wt.	S.E.	Daily Gain				No. of Observations	F		Theoretical F	
										1-14 Day	S.E.	14-35 Day	S.E.		Parents	Offsprings	Parents	Offsprings
3	21	7.4	0.09	-	-	41.5	0.57	103.1	1.04	2.44	0.038	2.94	0.041	204	0	0		
	22	7.6	0.13	-	-	40.1	0.55	102.5	0.68	2.32	0.034	2.97	0.024	278	0	0		
	23	6.8	0.09	15.1	0.20	31.3	0.45	92.2	0.71	1.75	0.030	2.90	0.024	199	0	0		
	24	6.4	0.06	-	-	34.8	0.43	91.9	0.70	2.03	0.029	2.72	0.026	179	0	0		
	25	6.5	0.09	-	-	35.2	0.57	95.8	0.70	2.05	0.039	2.89	0.023	203	0	0		

Appendix 26.

Average Body Weights (g).

Line	Generations	Hatch Wt.	S.E.	7 Day Wt.	S.E.	14 Day Wt.	S.E.	35 Day Wt.	S.E.	Daily Gain				No. of Observations	F		Theoretical F	
										1-14 Day	S.E.	14-35 Day	S.E.		Parents	Offsprings	Parents	Offsprings
21	1	7.5	0.09	-	-	46.2	0.75	108.5	1.06	2.77	0.053	2.96	0.035	96	0	0		
	2	7.3	0.12	-	-	46.4	0.69	102.9	1.37	2.80	0.044	2.69	0.048	195	0	25		
	3	6.9	0.17	-	-	45.3	0.90	102.2	1.60	2.74	0.064	2.71	0.051	72	25	38		
	X	6.6	0.20	25.3	1.06	47.9	1.29	111.6	1.78	2.95	0.084	3.03	0.058	34	25	0		
	4	6.4	0.33	14.5	1.61	35.0	2.23	91.2	2.01	2.05	0.159	2.68	0.126	9	38	50		
	X	6.4	0.19	16.0	1.29	37.8	2.46	100.4	3.12	2.24	0.172	2.98	0.106	17	38	0		

X = Crosses

/Continued....

Line	Generations	Hatch Wt.	S.E.	7 Day Wt.	S.E.	14 Day Wt.	S.E.	35 Day Wt.	S.E.	Daily Gain				No. of Observations	F		Theoretical F	
										1-14 Day	S.E.	14-35 Day	S.E.		Parents	Offsprings	Parents	Offsprings
28	2	7.0	0.12	-	-	47.7	0.65	108.4	1.29	2.91	0.042	2.89	0.046	219	0	0		
	3	6.9	0.10	-	-	47.6	0.55	109.3	0.97	2.91	0.039	2.94	0.031	194	0	13		
	X	6.6	0.13	25.6	0.69	48.6	0.83	113.0	1.15	3.00	0.054	3.07	0.037	82	0	0		
	4	6.7	0.08	16.9	0.37	44.0	0.51	107.9	0.46	2.67	0.036	3.04	0.029	173	13	19		
	X	6.7	0.16	21.1	0.41	39.5	0.57	100.6	0.78	2.34	0.037	2.91	0.035	96	13	0		
	5	7.0	0.13	20.7	0.46	45.3	0.70	105.0	0.97	2.74	0.047	2.84	0.034	159	19	25		
	X	6.8	0.09	22.0	0.57	41.0	0.98	100.5	1.64	2.44	0.068	2.83	0.040	69	19	0		
	6	6.9	0.21	18.9	0.74	37.5	1.28	100.7	1.88	2.19	0.084	3.01	0.103	117	25	31		
7	8	7.5	0.08	-	-	51.3	0.48	114.0	1.25	3.13	0.033	2.99	0.046	222	0	0		
	9	7.0	0.14	-	-	46.6	0.72	106.8	1.28	2.83	0.049	2.87	0.045	81	0	0		
	10	6.8	0.08	-	-	44.8	0.53	107.8	0.84	2.72	0.038	3.00	0.031	172	0	0		
	11	6.8	0.09	20.3	0.32	44.8	0.47	101.6	0.86	2.71	0.031	2.71	0.030	166	0	0		
	12	6.5	0.08	-	-	45.0	0.45	105.0	0.71	2.75	0.030	2.86	0.025	179	0	0		

X = Crosses

Appendix 27

Adjustments of female body weights

Lines	Generations	Hatch Weight	7 Day Weight	14 Day Weight	35 Day Weight	Daily gain in Weight 1-14 Day	Daily gain in Weight 14-35 Day	Coefficient	No. of Observations	Df. for MS.
3	21	0.121	-	3.77**	9.33**	0.2608**	0.2647**	0.0240	204	169
	22	-0.019	-	1.08	9.29**	0.0783	0.3911**	0.0158	278	248
	23	0.001	0.335	0.72	4.33**	0.0512	0.1719**	0.0253	199	158
	24	0.124	-	2.28**	6.83**	0.1539**	0.2167**	0.0320	179	123
	25	0.044	-	1.44	5.79**	0.0999	0.2070**	0.0231	203	169
7	8	0.011	-	2.17**	13.84**	0.1542**	0.5556**	0.0208	222	189
	9	0.037	-	2.08*	10.09**	0.1462*	0.3811**	0.0700	81	52
	10	0.072	-	1.09	8.37**	0.0726	0.3465**	0.0288	172	140
	11	-0.106	0.367	1.33	7.29**	0.1028	0.2836**	0.0322	166	132
	12	0.107	-	1.99*	10.99**	0.1347*	0.4288**	0.0259	179	147
20,27,35	1	-0.010	-	2.40**	9.31**	0.1724**	0.3290**	0.0113	416	339
	2	-0.003	-	1.84**	9.88**	0.1334**	0.3828**	0.0069	670	570
	3	0.013	1.216**	2.71**	7.57**	0.1925**	0.2314**	0.0126	401	309
	4	0.023	0.167	1.14	5.31**	0.0800	0.1986**	0.0373	156	111
	5	0.007	0.918*	1.50*	4.48**	0.1070*	0.1415**	0.0199	236	202
	6	-0.087	0.704	1.58	5.61**	0.1194	0.1918**	0.0759	80	54

Appendix 27 - continued.

Lines	Generations	Hatch Weight	7 Day Weight	14 Day Weight	35 Day Weight	Daily gain in Weight 1-14 Day	Daily gain in Weight 14-35 Day	Coefficient	No. of Observations	Df. for MS
21,28	1	0.042	-	2.73^{*}	7.09^{**}	0.1919^{*}	0.2076^{**}	0.0802	96	57
	2	0.005	-	1.49^{**}	13.37^{**}	0.1033^{**}	0.5657^{**}	0.0121	414	336
	3	0.088	-	1.24	10.50^{**}	0.0823	0.4412^{**}	0.0194	266	204
	4	-0.023	0.321	0.64	6.16^{**}	0.0476	0.2626^{**}	0.0298	186	133
28 & 45	5 & 2	-0.019	0.763	1.91^{*}	6.25^{**}	0.1381^{*}	0.2067^{**}	0.0186	265	212
28	6	0.037	0.619	5.03^{**}	13.27^{**}	0.3563^{**}	0.3928^{**}	0.0403	117	93
22,29,36	3	0.013	0.889^{*}	2.27^{**}	4.64^{**}	0.1609^{**}	0.1129^{*}	0.0282	192	151
23,29,36	4	0.155	1.623^{*}	4.12^{**}	8.98^{**}	0.2833^{**}	0.2313^{**}	0.0551	105	72
22	4	-0.120	-0.084	0.19	5.53^{**}	0.0219	0.2544^{**}	0.0457	106	88
29,36	5	0.037	0.070	1.35	6.79^{**}	0.0937^{*}	0.2589^{**}	0.0430	104	94
23,30	3	0.241^{**}	1.780^{**}	3.07^{**}	12.02^{**}	0.2017^{**}	0.4263^{**}	0.0437	116	86
30	4	0.228	0.558	1.55	11.26^{**}	0.0943	0.4623^{**}	0.0571	96	76
30	5	0.141	0.705	1.22	11.43^{**}	0.0772	0.4860^{**}	0.0661	69	52
45	3	-0.005	-0.281	1.27	2.87	0.0912	0.0762	0.1541	40	22
46	2	0.035	-0.068	0.79	5.17^{**}	0.0538	0.2089^{**}	0.0316	158	123

Appendix 27 - continued.

Lines	Genera-tions	Hatch Weight	7 Day Weight	14 Day Weight	35 Day Weight	Daily gain in Weight		Coeffi-cient	No. of Obser-vations	Df. for MS
						1-14 Day	14.35 Day			
49	1	-0.082	1.055*	1.59	5.71**	0.1197*	0.1962**	0.0413	106	86
25 - 26	4	0.197*	0.804	1.17	3.64**	0.0693	0.1179*	0.0435	142	94
37 - 38	4	0.016	1.419*	2.43*	10.17*	0.1722**	0.3689**	0.0416	132	97
24 - 34	1	0.119	0.684*	1.54**	17.10**	0.1013**	0.7411**	0.0208	228	171
Total									6776	

* $P < 0.05$

** $P < 0.01$