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Selection for Egg Production on Part Records

Part 1: Evaluation of Short Term Response to Selection

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Summary. Responses from four generations of index selection for egg production to 280 days of age in four White Leghorn populations have been presented. A pedigreed randombred population derived from one of the lines was reared with the selected lines to measure the environmental trend. The magnitude of total as well as average response although varying from population to population was positive in all the lines studied. Close correspondence between predicted and realized gains indicated that natural selection, genotype environmental interactions and environmental fluctuations were unimportant during the course of selection. Realized heritabilities agreed fairly well with the estimated heritabilities in at least three out of four populations studied. Probable reasons for variable and insufficient response were investigated.

Key words: Part period egg production – Realized and predicted response

Introduction

Part year record instead of total production derives its advantage as a selection criterion from the fact that loss in the accuracy of selection is more than compensated by a reduction in generation interval. Most of the selection experiments with chickens reported in the literature support the efficacy of the part record as a selection criterion for improving both part as well as annual egg production (Morris 1963; Abplanalp et al. 1964; Caceres 1967; Saadeh et al. 1968; Bohren et al. 1970; Kinney et al. 1970; Nordskog et al. 1974; Goher and McGibbon 1974; Gowe 1977; Poggenpoel and Erasmus 1978).

Classical formulae for prediction of genetic gain appear to be valid only if the population size is of the order of thousands (Robertson 1967). Since most of the experimental populations are small, there is need for greater knowledge concerning the validity of quantitative genetics theory in small populations for the expected selection response and the correspondence between expected and realized gains in selection experiments.

This paper reports results pertaining to the first four generations of selection based on a family index for increased egg production to 280 days of age in four White Leghorn populations.

Materials and Methods

Selected Lines

Four Single Comb White Leghorn populations (L33, L55, L77 and L99) which have been maintained as closed flocks since 1972 were utilized for this study. The history of the flocks prior to 1972 is not known. The chicks hatched from these populations during 1974 constituted the foundation stocks for the present experiment.

Control Population

From L55 during 1975 hatch year a sample of 30 cockerels and 240 pullets were randomly chosen to establish a pedigreed control population and was continued during 1976 hatching year. From then on it was continued with the sire base increased to 40 by random choice of 10 extra males and only 200 females, each male being mated to 5 females. In each of these years as far as possible each sire contributed a sire and each dam contributed a dam as breeders in succeeding generations to minimize genetic drift. To avoid inbreeding through matings of relatives sets of 5 daughters from each of the 40 sire families were kept intact in every generation. Matings were arranged in a rotational way so that a male from the sire family one of the previous generation is mated to the set 2 females in the next generation and the male from the sire family 2 was mated to the set 3 females in the next generation and so on. In this way it was expected that only after the 40th generation would there be a possibility of a related mating.

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Management

In all the generations birds were maintained in three tier individual cages in an open-type house and a standard method of feeding and management was followed. Chicks belonging to various lines were brooded together. Sexes were reared separately in grower houses. Management conditions were kept identical as far as possible for all the lines in each generation.

Natural matings in single sire breeding pens were initially used (S_0, S_1) but in the later three generations hens were artificially inseminated.

Selection Procedures

Selection was practised for the single trait, egg production (No. of eggs) up to 280 days of age. The criterion for selection was a combined selection in which pullets were selected on the basis of an index taking into consideration individual production and the sire and dam family averages. The cockerels were selected on the basis of an index constructed utilizing information on full and half sib averages only. The weighting factors for each of the components in the index were derived as per Osborne (1957a, b). The number of males and females selected in each generation within each line have been presented in Table 1. Matings were at random within the populations with the restriction that full and half sib matings were not permitted.

Statistical Methods

Since individuals in each generation were taken out in more than one hatch, data were corrected for hatch effects using least square constants as per Harvey (1966) when hatch effects were found to be significant. All the subsequent analyses were done on hatch corrected data.

The heritability estimates for the selected trait were computed within lines and generations using variance component analysis (King and Henderson 1954a). Pooled estimates of heritability over generations were obtained following the method of Enfield et al. (1966) by weighting individual estimates with the inverse of their respective variances. Standard errors of heritability estimates were calculated according to Dickerson (1960). Realized heritabilities were estimated from the regression of response on the cumulative selection differentials (Falconer 1960) and their sampling errors were estimated according to the procedure outlined by Hill (1972b). The deviations from control were taken for individual lines in each generation to obtain realized responses to selection and they were regressed over generation numbers to obtain the average realized response per generation. Predicted response was obtained in two different ways: (i) utilizing the formula as suggested by Kinney et al. (1970); and (ii) by computing the theoretical efficiency of index selection over mass selection from multiple correlations between breeding value of the individual and the criterion of selection (Nordskog et al. 1967). The phenotypic correlations among the various sources of information used in the latter method were derived from path coefficient technique (Li 1956).

Table 1. Population size and inbreeding

Line	Generation	No. of individuals	Breeders			
			Sires	Dams	Ne	ΔF
L33	S_1	538	30	134	98.05	0.0051
	S_2	797	36	186	120.65	0.0041
	S_3	787	40	177	130.51	0.0038
	S_4	770	40	192	132.41	0.0038
	Average	723.0	36.5	172.2	120.40	0.0042
					Total	0.0168
L55	S_1	713	30	131	97.64	0.0051
	S_2	960	36	186	120.65	0.0041
	S_3	1097	40	187	131.82	0.0038
	S_4	513	40	170	131.58	0.0038
	Average	820.7	36.5	168.5	120.42	0.0042
					Total	0.0168
L77	S_1	596	30	138	98.57	0.0051
	S_2	895	36	195	121.56	0.0041
	S_3	614	40	166	129.87	0.0038
	S_4	506	40	141	126.58	0.0039
	Average	652.7	36.5	160.0	119.14	0.0042
					Total	0.0169
L99	S_1	524	30	134	98.05	0.0051
	S_2	717	36	179	119.89	0.0042
	S_3	756	39	165	126.58	0.0039
	S_4	555	39	171	128.20	0.0039
	Average	638.0	36.0	162.2	118.18	0.0043
					Total	0.0171

Results and Discussion

Table 2 presents means, with their standard errors for egg production up to 280 days of age and the regression coefficients of the uncorrected means on generation numbers for both selected and control lines. It is evident that each of the lines improved substantially in their production performance over generations. The average phenotypic response per generation, although positive in all the selected lines, was significant only for L33. The control line presented considerable variation among generations. The regression of control means on generation numbers however was non-significant (Table 2) suggesting that the yearly fluctuations in the control were the random variation of the environment. Gowe et al. (1959) observed a similar positive environmental trend in their control population. That the control was effective in eliminating environmental trends was also confirmed from the comparison of two sets of regression coefficients estimated by using raw means (Table 2) as well as control deviations (Table 5) on generation numbers as suggested by Hill (1972d). It is, therefore, is assumed that the deviations of the selected lines from the control are unbiased estimates of genetic change resulting from selection.

Effective Population Number and Inbreeding

The number of progeny tested, the effective number of sires and dams and the effective number of parents are

Table 2. Mean egg production and phenotypic regression coefficients in control and selected lines

Year	Generation	Control	L33	L55	L77	L99
1974-75	S_0	58.54 ± 0.80 (319)	54.33 ± 0.85 (438)	58.54 ± 0.80 (319)	57.68 ± 0.80 (329)	62.19 ± 0.77 (360)
1975-76	S_1	64.51 ± 0.71 (339)	62.98 ± 0.62 (538)	69.07 ± 0.49 (713)	67.79 ± 0.53 (596)	74.26 ± 0.62 (524)
1976-77	S_2	76.57 ± 0.40 (663)	78.45 ± 0.55 (797)	80.34 ± 0.37 (960)	77.54 ± 0.39 (895)	83.11 ± 0.47 (717)
1977-78	S_3	59.20 ± 0.57 (669)	71.10 ± 0.62 (787)	71.30 ± 0.44 (1097)	71.04 ± 0.62 (614)	72.70 ± 0.57 (756)
1978-79	S_4	72.04 ± 0.57 (486)	81.97 ± 0.62 (770)	81.20 ± 0.56 (513)	78.38 ± 0.74 (506)	79.30 ± 0.66 (555)
b ± SE		2.17 ± 2.61	6.34 ± 1.89[a]	4.75 ± 1.98	4.46 ± 1.68	3.27 ± 2.2

Number of observations are shown in the parenthesis

[a] $p < 0.05$

Table 3. Expected and realized selection differentials

Line		Selection differential		Phenotypic standard deviation	Intensity of selection
		Expected	Realized		
L33	S_0	11.31	11.21	17.70	
	S_1	8.88	10.23	14.48	
	S_2	11.14	10.65	15.16	
	S_3	13.51	13.52	17.19	
	Average	11.21	11.41	16.13	0.707
L55	S_0	8.78	9.18	14.24	
	S_1	9.19	9.48	13.01	
	S_2	8.51	8.58	11.37	
	S_3	11.14	10.92	14.53	
	Average	9.40	9.54	13.29	0.717
L77	S_0	7.93	7.81	14.45	
	S_1	8.73	9.42	12.95	
	S_2	9.58	9.91	11.66	
	S_3	9.27	8.70	14.95	
	Average	8.88	8.96	13.50	0.663
L99	S_0	8.06	7.34	14.64	
	S_1	9.47	9.58	14.19	
	S_2	9.26	9.26	12.24	
	S_3	8.44	8.86	15.59	
	Average	8.81	8.76	14.16	0.618

shown in Table 1. The expected rate of inbreeding for an unselected random mating population of that size is also given. The cumulative expected inbreeding during four generations of selection ranged from 1.68 to 1.71% in the various lines. This is, however, an over-estimate since full and half-sib matings were avoided. The effective number of parents per generation ranged from 118 to 120 in the selected lines and was around 180 for the control. Average size of the tested population per generation varied from 638 to 820 in the selected lines and was 497 in the control line.

Selection Differentials

Expected and realized selection differentials and the phenotypic standard deviations are shown in Table 3. Comparison of the expected and the realized selection

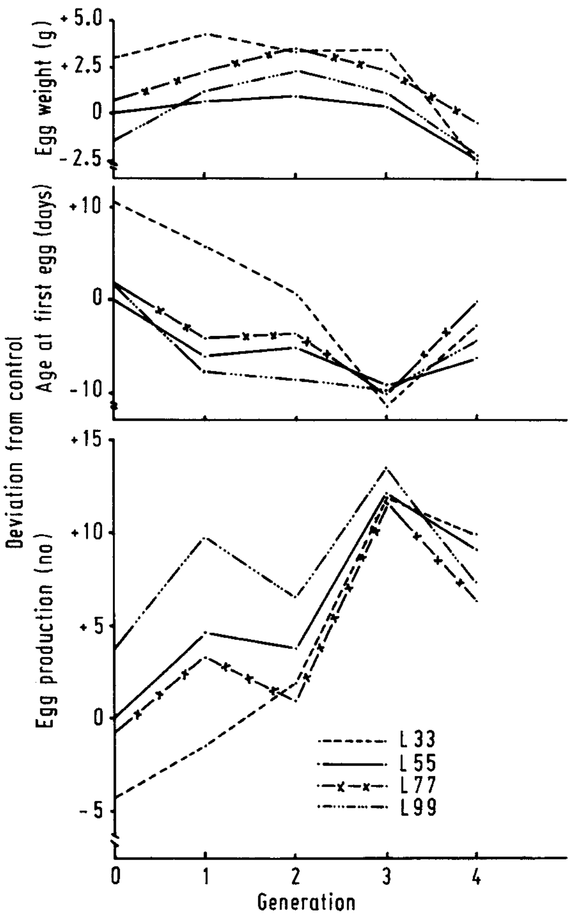

Fig. 1. Regression of response on generation number

differentials indicated that natural selection was unimportant during the course of selection. The selection intensity measured as average over both sexes ranged from 0.618σ (in L99) to 0.717σ (in L55).

Response to Selection

The total realized genetic progress from 4 generations of selection for egg number to 280 days of age was 14.14, 9.16, 7.20 and 3.61 eggs for L33, L55, L77 and L99 lines, respectively (Fig. 1). Average response per generation although positive in all the lines, was significant only for L33. Conspicuously the response in L99 was associated with a standard error of equal magnitude. Hill (1971, 1972a, b, c, d) showed that genetic drift, individual measurement sampling, genotype-environment interactions, time trends in environment and natural selection are the possible causes of variable response in a selection experiment. The drift variation (N/Ne) in the present study (obtained as suggested by Nordskog et al. 1974) was 6.0, 6.8, 5.5 and 5.4 times more important than the sampling variance among individuals tested for L33, L55, L77 and L99 lines, respectively. Since the number of individuals tested in each line per generation was more than adequate to reduce sampling error, the magnitude of drift variance in any particular line was also not high. The drift variance therefore may not be the principal reason for inadequate response in L99. The question of genotype-environment interaction becomes relevant whenever an unrelated control population is used. Since 3 lines, including L99, were not related to control, some genotype-environment interactions may have occurred and would be confounded with the actual sampling error estimates. The genotype environment interations could decrease or even halt selection progress even if the heritability were reasonably large. Dickerson (1955) suggested that interactions between breeding value and the environment in successive years could be responsible for lack of progress in a poultry flock. In the present study environmental trends were not found significant and natural selection was also unimportant.

Poggenpoel and Erasmus (1978) reported realized response of 3 eggs per generation for 275 days production from 7 generations of index selection in White Leghorns. Gowe et al. (1959) reported a significant regression of 3.71 eggs per generation in their Ottawa strain selected for egg production. When corrected for environmental trends by means of a control population, however, the regression dropped to 1.26 eggs per generation. Gowe et al. (1973) also reported results in 2 White Leghorn strains primarily selected for number of eggs to 273 days of age on an Osborne index. In about 20 generations the egg number increased from less than 70 to more than 105 in both the strains. Less than ten eggs of the difference was attributed by the authors to a positive trend in environment. Part of this increase was also attributed to over 20 days decrease of age at first egg and also to increase in rate of egg production in the lengthened first period of production.

Gowe (1977) reported genetic gains of 4.8, 3.7 and 12.4 eggs in hen housed egg number to 273 days of age from 5 generations of selection in three White Leghorn lines selected on the basis of an index that included individual, full sib and half-sib records. From the results of selection experiments presented above as well as those from this study it would appear that selection on part record has been effective to bring about improvement in egg production. The rate of improvement however would suggest that genetic improvement for egg production is a slow process.

Heritability

The heritability estimates for 280 days egg production, with their standard errors, are presented in Table 4. The

Table 4. Estimated and realized heritabilities for egg number 10 280 days of age

Line	Component	S_0	S_1	S_2	S_3	Pooled	Realized
L33	S	0.41 ± 0.18	0.59 ± 0.24	0.46 ± 0.16	0.21 ± 0.10	0.331	0.366 ± 0.091
	D	0.01 ± 0.18	0.48 ± 0.18	0.18 ± 0.12	0.11 ± 0.12	0.177	
	S + D	0.21 ± 0.20	0.53 ± 0.16	0.32 ± 0.11	0.16 ± 0.09	0.267	
L55	S	0.33 ± 0.19	0.23 ± 0.12	0.23 ± 0.10	0.12 ± 0.07	0.184	0.268 ± 0.099
	D	–0.11 ± 0.23	0.24 ± 0.13	0.20 ± 0.11	0.23 ± 0.11	0.223	
	S + D	0.11 ± 0.17	0.23 ± 0.10	0.21 ± 0.08	0.18 ± 0.07	0.195	
L77	S	0.10 ± 0.21	0.09 ± 0.08	0.25 ± 0.11	0.08 ± 0.11	0.127	0.254 ± 0.137
	D	0.68 ± 0.32	–0.05 ± 0.13	0.34 ± 0.13	0.42 ± 0.19	0.398	
	S + D	0.39 ± 0.23	0.02 ± 0.09	0.29 ± 0.10	0.25 ± 0.13	0.181	
L99	S	0.42 ± 0.23	0.42 ± 0.17	0.05 ± 0.09	0.21 ± 0.11	0.187	0.118 ± 0.167
	D	0.23 ± 0.23	0.05 ± 0.15	0.52 ± 0.18	0.17 ± 0.13	0.213	
	S + D	0.33 ± 0.19	0.24 ± 0.13	0.29 ± 0.10	0.19 ± 0.10	0.243	

estimates in different lines varied from moderate to low. In L33 and L99 the estimates from the sire component were consistently higher than the estimates from dam component. On the other hand in L77 the dam component estimates were higher than the sire component. The pooled estimates ranged from 0.127 to 0.331 for the sire component estimates and were comparable to the values reported in the literature (Shoffner and Sloan 1948; Lerner and Cruden 1948; King and Henderson 1954b; Oliver et al. 1957; Waring et al. 1962; Krause et al. 1965; Shibata 1965; Kinney and Shoffner 1965; Jaffe 1966; Bohren et al. 1970; Gowe et al. 1973; Gowe 1977 and Poggenpoel and Erasmus 1978). Realized heritabilities calculated as regression of response on cumulated selection differential are shown in Figure 2 and Table 4. Except for L99 the estimated standard errors of the realized heritability estimates were reasonaby low. Quite apart from whether it provides a valid estimate of heritability or not, realized heritability provides the most useful empirical description of the effectiveness of selection. Comparison of different experiments can be made even when the intensity of selection is not the same (Falconer 1960). The low realized heirtability estimate in L99 indicate that the selection was least effective in this line.

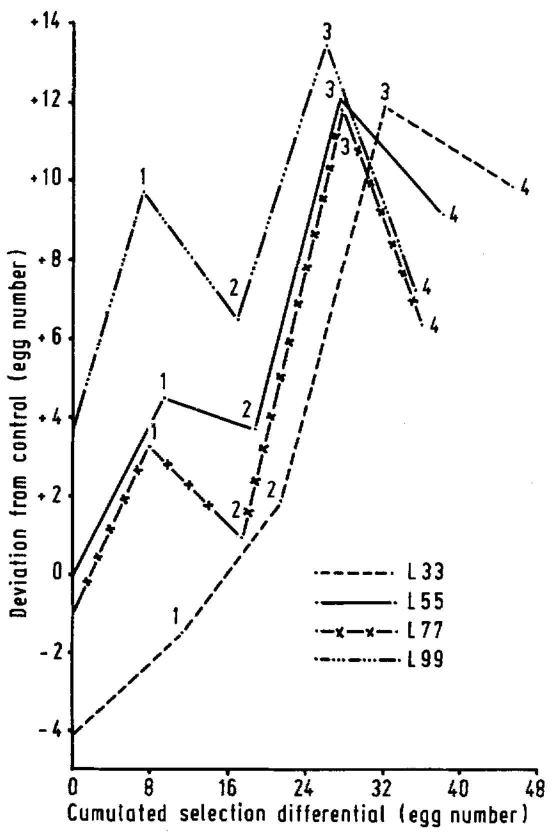

Fig. 2. Regression of response on cumulated selection differential

Comparison of Predicted and Realized Gains From Selection

The average realized and predicted genetic gains per generation to selection for egg number are presented in Table 5. The theoretical efficiency of the index that was

Table 5. Predicted and realized genetic gains

Lines	Predicted response		Realized
	Method 1	Method 2	response b ± SE
L33	3.944	4.715	4.171 ± 0.917[a]
L55	2.088	2.378	2.586 ± 0.881
L77	1.399	1.561	2.296 ± 1.252
L99	1.879	2.185	1.097 ± 1.194

[a] $P < 0.05$

used in obtaining predicted gain in method two was found to be 1.25 for L33, 1.356 for L66, 1.372 for L77 and 1.335 for L99. It is apparent that the expected gain derived from both the methods was not much different. The realized genetic gain exceeded the predicted gain in all the lines except L99. The difference between the two however was not significant statistically as seen from the standard errors associated with the realized response, indicating good agreement between the expected and realized response.

Barring the study of Poggenpoel and Erasmus (1978), there does not seem to be any report in the literature where the realized response to egg number selection has been compared with the predicted response. There are a few reports, however, where such comparisons have been made for rate of production (Nordskog et al. 1967; Kinney et al. 1970; Goher and McGibbon 1974). The trend in these reports has been that the realized genetic gains for rate of production did not measure up to the expectations. While Nordskog et al. (1967) reported negative realized gains against a positive predicted response, Kinney et al. (1970) and Goher and McGibbon (1974) reported a final ratio much less than unity for realized to predicted gain. Theoretical studies by Bohren et al. (1970) and Ayyagari et al. (1979) showed that egg number as selection criterion was 3 to 5 times more efficient in reducing the age at maturity than the percent production. Gowe et al. (1973) and Poggenpoel and Erasmus (1978) reported concomitant decrease in age at maturity and egg weight to the selection of part record egg number. Similar results were observed in the present study and are shown in Figure 1. The regression coefficients obtained from control deviations over generation numbers ranged from -1.009 to -3.273 days for age at maturity and from -0.16 gm to -1.2 gms for egg weight in different populations. None of these regressions were significantly different from zero. As the egg number was the criterion of selection in the present experiment the reduction in age at first egg and the egg weight in different lines might have contributed to the principal trait i.e. egg number, because of the increase in the number of functional days available. Prediction equations of selection response do not take account of this kind of concomitant change. Perhaps this could be a reason why the realized responses have exceeded the predicted responses, unlike the position in the rate of lay selection experiments. Nordskog et al. (1974) stated that the prediction equation of selection responses usually has fair accuracy in the short term. Since this report involves only four generations of selection a fair agreement between the predicted and the realized responses need not be unexpected. The results presented by Clayton et al. (1957), Reeve and Robertson (1953), Falconer (1955) and Roberts (1965) in a wide variety of other experimental materials also indicate that prediction of selection response remains fairly valid as long as selection lasts only a few generations.

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