Egyptian J. Anim. Prod., 33, Suppl. Issue, Nov. (1996): 379-388

SELECTION RESPONSES ACHIEVED FROM ONE- AND TWO-STAGE SELECTION INDICES IN CHICKEN LAYERS

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SUMMARY

Six selection indices (3 in one-stage and 3 in two-stage) were applied in NORFA chicken layers and their efficiencies were compared. Expected and realized selection responses of some egg production traits were estimated and discussed. The method of incorporating an index comprising early variables into another index involving late variables was applied.

Results showed that general selection index involving all five traits extracted from complete individual records of egg production was more efficient, but it required more effort and cost. Two-stage selection indices involving early variables in stage-one and late variables in stage-two had efficiencies equal to 78-85% relative to the general index. Therefore, two-stage selection indices in layers can be applied in improving some egg production traits. They have the advantage of reducing effort and cost due to discarding inferior individuals in early stage.

Keywords: Layers, egg traits, selection indices

INTRODUCTION

The breeding value of a laying hen depends on several variates achieved in different stages. Some of these variates can be estimated in early stage such as age, egg size and body weight at sexual maturity and egg number during the first ninety days of laying. Other traits of late stage need a longer time to be measured as egg and body weights at maturity (42 wks.) and a complete record of egg number (500 d.). Keeping all individuals till 500 days is costly and it needs more efforts. Therefore, alternative methods may be followed to save cost and efforts such as using partial records. The accuracy of the index involving partial records depends mainly on the magnitude of the genetic correlations between partial and complete records and genetic standard deviations of both of them. Other alternative method is to use two-stage index on which early variates are involved to evaluate all individuals in stage one and only superior individuals are kept till complete records at late stage.

Early trials of calculating two-stage index were done by several investigators. Dickerson and Hazel (1944) studied the effectiveness of selection on progeny performance as a supplement to earlier culling in livestock. The selection criterion was constructed in two-stage selection; early selection based on pedigree, individual or collateral relatives performance as stage one and the supplementary performance of progeny as stage two. Cohen (1950) estimated the mean and variance of normal populations from singly and doubly truncated samples. Finney (1956) dealt with the theory of two-stage selection and he suggested impracticable complicated formulas. Moreover, Falconer (1981) discussed the method of correcting partial records by calculating correlated response. Kolstad (1979) gave examples of applying this method on cocks.

Some investigators dealt with the problems of multi-stage selection (Jain and Ample, 1962 and Young, 1964). However, their methods were complicated and needed more calculations. Namkoog (1970) studied optimum allocation of selection intensity in two stages of truncation selection and he developed tabular solutions for bivariate truncation of genetically correlated traits. Although the method was mathematically simple, it needs extensive computation. Young (1972) studied the moments of a distribution after repeated selection with error.

Cunningham (1975) developed a simple method for two-stage selection by incorporating an index into another. The simplicity of the method is that the actual weighting factors of the two-stage index are the same and are not affected by prior selection.

The main advantage of two-stage index is to save cost and effort due to discarding the inferior individuals in early stage. Efficiencies of one- and two-stage selection indices were compared and discussed by several investigators (Cunningham, 1975; Abdou and Kolstad, 1979; Ayyagari *et al.*, 1985; Enab, 1991; Enab *et al.*, 1992 and Abdou and Enab, 1994).

The aim of the present study is to compare the genetic gains achieved in some egg production traits using one- and two-stage indices in Norfa pullets. Efficiencies of different selection indices were also compared and discussed.

MATERIALS AND METHODS

Experimental data and flock management

The experimental data were extracted from NORFA project initiated jointly between the Agricultural University of Norway and Faculty of Agriculture, Menoufyia University, Shebin El-Kom, Egypt. One day pedigreed chicks through two successive generations (*i.e.* 1994 as a base parental population and 1995 for the selected progeny individuals). All chicks were brooded and reared in a brooder supplied with a central heating system till 16 weeks of age. The pullets were transferred to individual laying cages, while cockerels were moved to individual cages in cocks' house. Artificial insemination was applied to get pedigree chicks. All the managerial conditions were almost the same as possible.

Traits studied

The studied traits were:-

I - Early traits:

BW_1: Early body weight in grams at sexual maturity.
EW_1: Early egg weight in grams of the first five eggs laid for each pullet.
EN_1: Early egg number in the first ninety days after sexual maturity.

II- Late traits:

EW_2: Late egg weight in grams of five eggs for each pullet during 38-40 weeks of age.

EN_2: Late egg number till 68 weeks of age.

Data analysis

Pedigreed data based on family means (Table 1) were analyzed using LSMLMW (Least Squares Maximum Likelhood and Mixed Model Program, Harvey, 1987). Economic values (v) were calculated according to Egyptian market quotations (1994-1995) using the method expressing the profit obtained by changing the individual trait for one unit (Kolstad, 1975). Enab (1982) illustrated this method of calculating the relative economic values in chickens.

One-stage selection indices:

The general selection index was calculated according to Hazel (1943) method after adjusting in matrix form for computer analyze (Cunningham, 1969). The general index equation is:

$Pb = Gv.$

to be solved to get weighting factors:

$b = P^{-1} Gv.$

where:-

P = the matrix of phenotypic variances and covariances.

G = the matrix of genetic variances and covariances.

v = a column vector of the relative economic values.

and b = a column vector of the weighting factors which will be solved.

Therefore, selection indices in stage one were as follows:-

$I_G = b_1 BW_1 + b_2 EW_1 + b_3 EN_1 + b_4 EW_2 + b_5 EN_2$

$I_1 = b_1 BW_1 + b_2 EW_1 + b_3 EN_1$

$I_2 = I_1 + b_4 EW_2 + b_5 EN_2$

In I_2 index the early variates (BW_1, EW_1 and EN_1) were replaced by their index I_1

Therefore, I_2 index was constructed by incorporating an index into another by applying the formula:

$M_y = E(\underline{I_1}, \underline{X_2}, \underline{Y'})(\underline{I_1}, \underline{X_2}, \underline{Y})$ Cunningham (1975)

The first element of this matrix is $\sigma^2 I_1$, while the remainder figures contain the covariances of I_1 with the elements of $\underline{X}_2$ and $\underline{Y}$ to get the matrices necessary for one-stage selection index containing I_1 EW_2 and EN_2.

Two-stage selection indices

Two-stage selection index was constructed according to the method described by Cunningham (1975) where the variates BW_1, EW_1 and EN_1 were available at early stage while BW_2 and EN_2 at late stage. The two-stage selection indices were as follows:-

$I_4 = I_1 + b_4 EW_2 + b_5 EN_2$

$I_5 = b_1 BW_1 + b_2 EW_1 + b_3 EN_1 + b_4 EW_2 + b_5 EN_2$

The main advantage of the method of Cunningham (1975) is that the actual index is the same whether or not prior selection on I_1 has taken place.

Two necessary steps should be done when constructing two-stage selection index. First step is to adjust the matrices of variances and covariances of the prior index (M_y) for the effect of selection on I_1 by applying the formula:-

$$M_y^* = M_y - T' TW \text{ (Cunningham, 1975)}$$

where M_y^*= the adjusted matrix, T= the average aggregate genotype W = $S/\sigma^2 I_1$

Before incorporating an index into another it is necessto define the selection intensity (i) in I_1. Accordingly the upper 38% layers were selected and this gave selection intensity of i=1 and implies truncation at point t = 0.305 σI_1. To estimate a combined selection parameters for I_4, the following equation was applied:

$S - i'(i'-t) = 1(1-0.305) = 0.695$ (Cunningham, 1975)

Comparison among these different indices needs to fix the final selection intensity (i), being 20% with a corresponding selection differential of 1.4. In I_G, I_1 and I_2, selection intensity was 20% with 1.4 σ. In I_3, I_4 and I_5 this selection intensity (20%) can be achieved in two stages using selection intensity table given by Becker (1975). In stage one upper 38% individuals (i=1) were selected on the basis of individual performance. Therefore, in stage two the best 52.6% (i=0.757) of the remaining individuals were selected according to full-sib performance to get final selection intensity equaled to 20%.

RESULTS AND DISCUSSION

Means of the studied traits and phenotypic variance and covariances together with the genetic parameters estimated for the present NORFA flock are shown in Table 1. It was noticed that heritability estimates of the studied traits, except for egg number till 68 weeks were low to medium. These findings agree with the estimates cited in the literature (Kinney, 1969). Heritability of late egg number was medium to high (0.42) and this may be due to the fact that this trait was estimated from complete individuals' records. Correlations among the studied traits were as expected. Negative correlations between egg number and both body and egg weights were noticed, while positive estimates between body weights and egg weights were found. Variations of the traits studied expressed as coefficients of variations were 13.4, 16.3, 19.0, 7.2 and 8.8% for BW_1, EW_1, EN_1, EW_2 and EN_2, respectively.

One-stage selection indices

Matrices necessary for constructing the general selection index (I_G) were solved to give the following general index (I_G):

$$I_G = 0.7544\, BW_1 + 0.2306\, EW_1 + 0.0673\, EN_1 + 0.0509\, EW_2 + 0.0274\, EN_2.$$

The variance of I_G index was 3.4176 and its correlation with the aggregate genotype was 0.4095. The value of each trait, expressed as the percent reduction in rate of genetic progress for aggregate genotype if the trait was dropped from the index was 16.61, 17.25, 7.64, 0.67 and 4.76% for BW_1, EW_1, EN_1, EW_2 and EN_2, respectively. It was clear that EW_1 had the highest value, while EW_2 had the lowest one.

The regression of the trait on the index depends mainly on measuring scale of the trait and it indicates that one unit of change in the general index is expected to produce genetic gain equal to the regression value. These regression coefficients were -0.2018, 0.5963 and 0.8616 for BW_1, EW_1 and EN_1, respectively.

The developed selection index I_G was applied to select the upper 20% individuals. It was expected by applying selection on I_G after one round of selection with 1.4 σ to achieve -0.22 g. in BW_1, 2.33 g. in EW_1, 3.97 eggs in EN_1, 1.84 g. in EW_2 and 14.77 eggs in EN_2 (Table 3). The actual genetic gains were -34.20 g. in BW_1, 0.10 g. in EW_1, 7.20 eggs in EN_1, 1.40 g. in EW_2 and 39.20 eggs in EW_2.

Data in Table 3 show that actual genetic gains of egg number trait was higher than the expected figure. This may be due to high selection pressure applied on egg number which was given high economic value. Other reason was due to the fact that NORFA layers have been selected for several generations for egg number. Although general selection index (I_G) was constructed for multiple traits, it seems that selection was focused mainly on egg number. King (1966) analyzed data from the USA Random Sample Testes and he stated that "eventhough breeders have multiple trait objectives in mind, their effort tends to be concentrated on a single trait".

To apply one stage selection index comprising all variaties, we should waiting till 52 weeks of age to record all the variates. Therefore, it is necessary to keep the individuals all the time to select finally the upper 20% individuals. In this case inferior individuals were also kept and this increases efforts and costs, although the I_G index had the highest efficiency (100%). Individuals can be selected on the basis of early variates (i.e BW_1, EW_1 and EN_1) using the following index:

$$I_1 = -0.6789\, BW_1 + 0.2199\, EW_1 + 0.0880\, EN_1$$

The variance of the index was 2.6188 and its correlation with the aggregate genotype was 0.3832. Its efficiency was 0.88 relative to the general index. Although the efficiency of I_1 index is lower than that of I_G (88 vrs. 100%), it has the advantage that it needs less time and efforts. It is necessary to balance between this advantage and its efficiency decreasing. This depends mainly on the breader's goal.

The regression of each trait on the index I_1 was -0.2203, 0.7846 and 0.8075 for BW_1 , EW_1 and EN_1 , respectively . It was expected to achieve genetic gains equal to -24 g. BW_1 , 3.06 g. EW_1 and 3.72 eggs in EN_1 , while the actual genetic gains were -34.20 BW_1, 0.10 g. EW_1 and 7.20 eggs in EN_1 (Table 3). It was clear that there was a big discrepancy between the actual and expected genetic gains. A reasonable explanation for this discrepancy between the actual and expected genetic gains in these early variates may be due to the way of calculating these variates. For example early body weight (BW_1) was recorded at firsrt egg laid and the average of the first five eggs after sexual maturity (EN_1) was also recorded. These two early variates depend on age at sexual maturity which is highly affected by environmental factors. Moreover, heritability estimates of sexual maturity are low to moderate. Efforts should be done to avoid the effect of variation in age at sexual maturity by correcting the date of sexual maturity prior to selection. Stability of other environmental factors such as time of hatching, lighting regime and other managerial conditions would be valuable to decrease the discrepancy between expected and actual genetic gains.

The index (I_2) was constructed through incorporating the index I_1 with another one involving late variates (i.e. EW_2 and EN_2). In this index the early variates (BW_1, EW_1 and EN_1) were replaced by their index. The efficiency of this index was 0.90 relative to the general index (I_G). However in one-stage indices (i.e. I_G, I_1 and I_2) all

Table 3. Comparison between expected and realized responses in the selection indices.

Index	Selection response	BW_1 gm.	EW_1 gm.	EN_1 egg	EW_2 gm.	EN_2 egg
$I_G = BW_1\ EW_1\ EN_1\ EW_2\ EN_2$	Expected	-22.250	2.3270	3.9685	1.8351	14.7747
	Actual	-34.200	0.1000	7.2000	1.4000	39.2000
	Act./Expect.	1.534	0.0400	1.8100	0.7600	2.6500
$I_1 = BW_1\ EW_1\ EN_1$	Expected	-24.300	3.0619	3.7193	-	-
	Actual	-34.200	0.1000	7.2000	-	-
	Act./Expect.	1.407	0.0300	1.9400	-	-
$I_4 = EW_2\ EN_2$	Expected	-	-	-	-0.8620	0.9431
	Actual	-	-	-	0.0010	24.5000
	Act./Expect.	-	-	-	0.0010	25.9800
$I_5 = BW_1\ EW_1\ EN_1\ EW_2\ EN_2$	Expected	-17.790	1.6800	2.4279	0.4091	4.7269
	Actual	-53.200	0.0010	4.3000	0.0010	24.5000
	Act./Expect.	2.990	0.0050	1.7700	0.0020	5.1800

Table 1. Heritability estimates (diagonal), phenotypic correlations (above diagonal), genetic correlations (below diagonal), means, phenotypic (σ_P) and genetic (σ_G) standard deviations and coefficients of variances (c.v).

Traits	BW_1	EW_1	EN_1	EW_2	EN_2	$\bar{X}$	σ_P	σ_G	v	C.V
BW_1	0.2200	0.7920	-0.1190	0.3200	-0.0200	1255.7	168.00	0.787	0.23	13.4
EW_1	0.2620	0.2400	-0.0580	0.4000	-0.1000	34.9	5.69	2.788	0.31	16.3
EN_1	-0.2700	-0.0600	0.2500	-0.4000	0.5500	55.7	10.58	3.290	1.00	19.0
EW_2	0.2300	0.2600	-0.0900	0.3400	-0.1200	52.2	3.77	2.198		7.2
EN_2	-0.0400	-0.3200	0.4500	-0.0170	0.4200	214.4	18.90	12.249		8.8

Early traits: BW_1= Body weight at sexual maturity.
Late traits: EW_2= Mature egg weight at 38-42 wks., EW_1= Egg weight at sexual maturity, EN_2= Egg number till 68 wks, EN_1= Egg number during 90 days.

Table 2. The weighting factors variance of the index as well as correlation of the index and aggregate genotype and the relative effectiveness of the five selection procedures.

Selection procedures	b values	i	$\sigma^2 I$	σI	rTI	Gain from selection Absolute	Gain from selection Relative
(1) One-stage I_G variates BW_1, EW_1, EN_1, W_2 and EN_2	b = 0.7544 BW_1 + 0.2306 EW_1 + 0.0673 EN_1 + 0.0509 EW_2 + 0.0274 EN_2	1.4	3.4176	1.8486	0.4095	2.5881	100
(2) One-stage I_1 variates BW_1, EW_1, and EN_1	b = -0.6789 BW_1 + 0.2199 EW_1 + 0.0880 EN_1	1.4	2.6188	1.6182	0.3832	2.2655	0.8753
(3) One-stage I_2 variates I_1, EW_2, and EN_2	b = 0.7958 I_1 + 0.0563 EW_2 + 0.0254 EN_2	1.4	2.7436	1.6563	0.4024	2.3188	0.8959
(4) Two-stage I_3 variates I_1, EW_2, and EN_2	b = 0.8681 I_1 + 0.3685 EW_2 + 0.0252 EN_2	0.966 0.798	2.6189 0.6285 3.2474	1.6183 0.7928	0.9343	1.5632 0.6326 2.1958	0.8484
(5) Two-stage I_4 variates EW_2, and EN_2	b = 0.0463 EW_2 + 0.0565 EN_2	0.966 0.798	2.6189 0.5608 3.1797	1.6183 0.7488	0.2606	1.5632 0.5975 2.1607	0.8348
(6) Two-stage I_5 variates BW_1, EW_1, EN_1, EW_2 and EN_2	b = 0.7544 BW_1 + 0.2306 EW_1 + 0.0673 EN_1 + 0.0509 EW_2 + 0.0274 EN_2	0.966 0.798	2.6189 0.3351 2.9540	1.6183 0.5789	0.7983	1.5632 0.4620 2.0252	0.7824

the individuals should be kept till the end of the experiment to evaluate them. In I_2 individuals were evaluated twice for early variates.

To avoid keeping inferior individuals all the time, two-stage indices were constructed to cull the inferior individuals in early age. This can be achieved by selecting the upper 40% layers according to early variates and this gave selection intensity of 0.966. Thereafter, selection was applied by using i=.798 to get finally the upper 20% individuals (i.e. 40 x 50 = 20%).

In two-stage selection index (I_3) the layers were selected according to early variates (BW_1, EW_1 and EN_1) and then re-evaluated by applying the index I_1 EW_2 EN_2 as follows: $I_3 = 0.8681\ I_1 + 0.3685\ EW_2 + 0.0252\ EN_2$. However, this method simplifies the calculation and application of two-stage selection without the need of calculating new weighting factors. The variance of the index is 3.25 and its accuracy is 0.9343.

Index I_5 can be designed involving only the late variates after selection has been applied on early variates. $I_5 = 0.7544\ BW_1 + 0.2306\ EW_1 + 0.0673\ EN_1 + 0.0509\ EW_2 + 0.0274\ EN_2$. The variance of this index is 2.95 nd it's accuracy is 0.7983.

Two-stage selection index can be constructed after evaluating variates (BW_1, EW_1 and EN_1) in stage one and late variates in stage two as follows:

$I_4 = 0.0463\ EW_2 + 0.0565\ EN_2$

The variance of the index is 3.180 and its accuracy is 0.7983.

In stage one, the most efficient selection index followed the general index (I_G) is I_2 (i.e. I_1 EW_2 EN_2) and its relative gain is 89.59% in relation to the general index (Table 2). This is expected due to replacing the variates BW_1, EW_1 and EN_1 by their index I_1. However, the less efficienct index (87.53%) is that procedure (I_1) involving only the early variates.

(I_3) is the oindex in stage two (Table 2) its relative efficiency is 84.84% in relation to the general index.

Although the results of the present study indicate that two-way indices were less efficient than the general index involving all traits in one stage, they have the advantage of reducing cost and efforts due to discarding inferior individuals in early stage. Therefore, poultry breeder should balance between this advantage and decreasing the efficiency of two-way index relatively to the general index.

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الإستجابات الإنتخابية المحققة من الأدلة الإنتخابية ذو المرحلة الواحدة وذات المرحلتين فى دجاجات النورفا البياضة

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طبقت ستة أدلة إنتخابية (٣ ذات مرحلة واحدة ، ٣ ذو مرحلتين) فى دجاجات النورفا البياضة وقورنت كفاءة كل دليل وتم تقدير ومناقشة الإستجابات المتوقعة والمتحققة لبعض صفات إنتاج البيض فى هذه السلالة. وتم تطبيق طريقة دمج دليل يشمل صفات إنتاج البيض المبكره بدليل آخر يشمل الصفات المتأخرة .

وقد حقق الدليل العام المحتوى على الخمسة صفات الإنتاجية المستخلصة من سجلات الأفراد أعلى كفاءة ولكنه إحتاج لكثير من الجهد والتكاليف .

والدليل الإنتخابى ذو المرحلتين والذى يشمل الصفات المبكرة فى المرحلة الأولى والصفات المتأخرة فى المرحلة الثانية قد حقق ٧٨-٨٥٪ من كفاءة الدليل الإنتخابى العام ولهذا فإنه يمكن تطبيقه بغرض تحسين بعض صفات إنتاج البيض والأدلة الإنتخابية متعددة المراحل ذات فائدة كبيرة تتلخص فى توفير المجهود والتكاليف ويرجع ذلك لإستبعاد الأفراد ضعيفة المستوى فى مرحلة مبكرة .