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Improving Laying Performance of Local Chickens Using Selection Index

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Abstract:
The recent experiment has been carried out at the Poultry research farm of the Faculty of Agriculture, Menoufia University, Shebin El-Kom, Egypt, during the period from 2018 to 2022 for three generations aiming to improve some egg production traits by using selection indices in Norfa chickens. Data on 1078 Norfa hens including: age at sexual maturity (ASM); body weight at sexual maturity (BWSM) and at maturity (BWM); egg weight at sexual maturity (EWSM) and at maturity (EWM); egg number during first 90 days of laying (EN90) and till 42 weeks of age (EN42) were individually recorded. Data computerized and selection applied by selection index method helping appropriate statistical and genetic analysis software programs.
Results showed that, in the last generation of the study selected line sexually matured earlier than control line by 1.99 days (P ≤ 0.01). In addition, either body weight or egg weight in selected and control lines didn't differed significantly in selected comparing to control line. Application of selection index method resulted in improving average EN90 in selected line comparing with control line by 7.32 eggs (with highly statistical importance). Moreover, application of selection index method resulted in highly significantly improvement of average EN42 in selected line comparing with control line by 7.92 eggs. The highest value of h2 (heritability) recorded by body weight (0.454 and 0.333 for BWSM and BWM, respectively). Moreover, the lowest heritability estimates detected for EN90 (0.154) and EWM (0.159) in studied flock of Norfa chickens. Moderate to high estimates (0.267, 0.327 and 0.391) of h2 were observed for EN42, EWSM and ASM, respectively, in current study.
Results showed that using general index in selection for one generation resulted in improving egg production traits under investigation. The actual genetic gains for ASM, BWSM, BWM, EN90, EWSM, EWM and EN42 were -1.990 days, +27.850 g, +13.820 g, +7.324 eggs, +0.024 g, -0.059 g and +7.924 eggs, respectively. It can be concluded that applying selection indices including the main egg laying traits (i.e., EN42, EWM and BWM) leads to improve laying performance of Norfa hens regardless of the negative correlations detected between some traits at a multi-trait selection method.
***Key Word**: Laying performance, Chickens, Selection index.*

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I. Introduction

Local chicken breeds and strains considered as one of the most important parts in Egyptian agricultural resources, there are many advantages of the local chickens such as adaptation with the Egyptian environment conditions as well as the unique and favorable taste of their meat and eggs. In addition, local Egyptian strains produce high quality eggs, but egg production still need to be improved. So, we should take the responsibility to improve the productivity of the local chicken breeds by applying effective breeding plans.

The Norfa chicken is a synthetic, white layer strain developed at the Faculty of Agriculture, Menoufia University, Egypt, by crossing exotic breeds with local egg breeds (White Leghorn, Fayoumi and Baladi) and kept as a closed flock. The birds have white feathers, single comb, white eggs, and are adaptable to harsh environments and resistant to diseases.

Improving the laying performance of chickens is considered very essential topic to help developing countries meeting the nutritional needs of their growing populations. The aggregate genotype value of a layer hen relay mainly on many traits which must be considered when building a breeding plan, such as, body weight, number of eggs produced and weight of egg. It is already indicated previously by many workers that, when improving multiple traits is desired, selection index considered as the efficient method to evaluate the total breeding values of candidates (Devi *et al.,* 2011; Oleforuh-Okoleh, 2013 and Elnoomany 2015). Various selection indices (i.e. general, reduced, restricted, multi-source and two-stage indices) were applied (Ben Naser, 2007; Abou Elewa, 2010; Elnoomany, 2015) in Norfa strain using multiple economic traits, and the results of previous studies were auspicious. The current study's main goal is to genetically evaluate some economically important egg production traits, and to improve the production performance of Norfa chicken by applying selection index.

II. Material And Methods

The present investigation has been carried out at the poultry farm of the Faculty of Agriculture, Menoufia University, Shebin El-Kom, Egypt, throughout the period of 2018 to 2022 for three generations to investigate the possibility of genetic improvement of some egg production traits in chickens

Mating System: In the current study, Norfa chickens (local strain) were used. Artificial insemination was applied as a mating system during the experimental period. The semen was collected from cocks and inseminated fresh and undiluted into dams. Each sire artificially inseminated three dams in each line each generation. Relatives mating was avoided. Insemination started one week before collecting hatching eggs, each dam was inseminated twice a week. Fertile eggs were collected daily for two weeks and stored in a prepared storage room, where the storage temperature was 55°F and the relative humidity was 85-90%.

Management procedures: The stored fertile eggs were moved to hatching room one day night before incubation and then they were set in a full-automatic force draft incubator. After 18 days of incubation, the eggs transferred to the hatching compartment. At hatching, all chicks were wing banded and pedigreed. Chicks were brooded in floor brooder watered continuously and fed *ad libitum* during brooding period a starting diet containing 19.43 % crude protein and 2916 ME/kg. kcal, then at 16 weeks the ration was changed by a layer ration containing 17.1% crude protein and 2760 ME/kg. kcal. The compositions of the two rations are given in Table (1).

Cockerels were separated from pullets in brooding house at the 8^{th} week of age and at 14^{th}week cockerels moved to individual cages in cocks' house while pullets were moved to individual cages in laying house at 16^{th} week of age. A "step down-step up" lighting program was used during brooding, rearing and production periods. The photoperiod was 24 h/d during the first week, which decreased to 19 h/d during the second week. Thereafter, the photoperiod was decreased half an hour per a week until the 15^{th} week of age. Starting from the 16^{th} week of age, the photo period was increased by 20 minutes per week up to 14-16 h/d.

Table (1): Compositions and calculated analysis of the experimental at layer and starter diet

Ingredients	Starter ration	Layer ration
Ground yellow corn (8.9%)	62.35	61.31
Soybean meal (44%)	20.25	15.02
Gluten yellow (55%)	7.89	8.01
Wheat bran (11%)	5.82	5.18
Limestone, ground	1.80	7.85
Di-calcium phosphate	1.14	1.93
Vitamin and mineral premix(1)	0.31	0.30
L. lysine	0.10	0.06
Sodium chloride (salt)	0.34	0.34
Total kg	100	100
Calculated Value(2):		
Crude protein	19.43	17.10
ME/kg. Kcal diet	2916	2760
C/P ratio	150	161
Calcium%	0.99	3.46
Total Phosphorus%	0.53	0.68

(1) Vitamin and Mineral mixture: at 0.30% of the diet supplies the following / of the diet:Vitamin A 1200 IU, V.D3 2500 IU, V.E 10mg, VK3 3mg, V.B1 1mg, V.B2 4mg, BIOTIN 0.05 mg, Niacin, 40 mg, VB6 3mg, VB12 20mg, CHOLINE Chloride 400, Mn. 62 mg, fe 62mg, Zn 56 mg, CU 5mg and Se 0.01 mg.
(2) Calculated according to NRC (1994).

Studied traits: Age at sexual maturity (ASM); Body weight at sexual maturity (BWSM); Body weight at maturity (BWM): At 36 weeks of age birds will be weighted individually and data will be recorded; Egg weight at sexual maturity (EWSM): The first 5 eggs after maturity were weighted individually and the mean of egg weight at sexual maturity was calculated for every laying hen; Egg weight at maturity (EWM): The first 5 eggs at maturity (36 weeks of age) weighed individually and the mean of egg weight at maturity will calculated for every laying hen; Egg number in first 90 days (EN90) and egg number till 42 weeks of age (EN42) were recorded individually.

Statistical analysis: The statistical analysis was performed using general linear models procedure of the IBM-SPSS (IBM- Statistical Package for Social Science) program version 21 (2012). Different models were assumed according to the traits studied. Duncan's new multiple range tests were used to compare every two means of different traits studied (Duncan, 1955). The following two models were utilized:
Model (1):

$$Y_{ij} = \mu + L_i + e_{ij}$$

Where:
Y_{ij} : Observation of j^{th} hen;
μ : General mean;
L_i : Fixed effect of i^{th} line (i = selected and control);
e_{ij} : Residual effect.

Model (2):

$$Y_{ijk} = \mu + L_i + G_j + (L \times G)_{ij} + e_{ijk}$$

Where:
Y_{ijk} : Observation of k^{th} hen;
μ : General mean;
L_i : Fixed effect of i^{th} line (i = selected, control);
G_j : Fixed effect of j^{th} generation (j = first, second, third);
$(L\times G)_{ij}$: Effect of interaction $(L\times G)_{ij}$;
e_{ijk} : Residual effect.

The least squares and maximum likelihood general purpose program – mixed model LSMLMW (Harvey, 1990) was used to estimate the values of heritability, phenotypic and genetic correlations for the studied flock of Norfa Strain. The general random model (2) utilized by (LSMLMW) was as follow:

$$Y_{ijk} = \mu + S_i + D_{ij} + e_{ijk}$$

Where:
Y_{ijk} = Observation of the K^{th} progeny of the i^{th} sire and j^{th} dam.
μ = Common mean
S_i = Random effect of i^{th} sire
D_{ij} = random effect of j^{th} dam within i^{th} sire.
e_{ijk} = Random error assumed to be normally distributed with zero mean and variance σ^2e.

General selection index (I_G): The general index was obtained in terms of heritability, phenotypic and genetic correlations among the studied traits by solving the following equations given in matrix expression according to Cunningham (1969):

$$Pb = Gv \quad \text{to give} \quad b = P^{-1} Gv$$

Where:
P = Phenotypic variances and covariances matrix.
G = Genetic variances and covariances matrix.
V = Economic weights column vector.
b = Weighting factors column vector, which is going to be solved.

Furthermore, according to Cunningham (1969) the other different properties of the selection index were calculated as following:

The standard deviation of the index $=\sigma_I = \sqrt{b'Pb}$
The standard deviation of aggregate genotype = $\sigma_T = \sqrt{v'Gv}$
The correlation between the index and the aggregate genotype =

$$(r_{TI}) = {}^{\sigma_I}/_{\sigma_T} = \sqrt{{}^{b'Pb}/_{v'Gv}}$$

$$\text{value of each trait in the index} = V_T = 100 - \sqrt{\frac{b'pb - b_i^2/W_{ii}}{b'pb}} \times 100$$

Where,
W_{ii} is a diagonal element of p^{-1}

Expected and actual genetic gain:

- The expected genetic change (Δ_G) in each trait after one generation of selection on the index (i = 1) was obtained by solving the following equation:

$$\Delta_{Gi} = b_{GiI}\ i\ \ \sigma_I$$

Where
i = Selection differential in standard deviation units.
σ_{Gi} = Genetic standard deviation of the trait.
b_{GiI} = Regression of the trait on the index.
σ_I = Standard deviation of the index.

- Actual genetic gain and correlated responses was calculated as deviation from the control line performance by equation given by Hill (1972) as follows: $\Delta G = (S_t - C_t)$

Where: S and C are the means of selected and control lines in generation number (t).

The relative economic values (v): The economic values were calculated by estimating the change of the difference between cost and income per unit change in the trait according to the Egyptian market (Kolstad, 1975). According to the Egyptian market quotations in 2018 the relative economic values were: - 0.008, 1.110 and 1.000 for -1 gram in body weight at maturity, +1 gram in egg weight at maturity and + 1 egg in egg number till 42 weeks of age.

III. Results and Discussion

Means of studied traits:

Results represented in Table (2) showed the means ± S.E of different studied traits from current research. After one generation of selection using selection index method selected line differed significantly (P≤0.01) with average 175.87 days of ASM comparing to control (177.86 days). It is common that selection to improve egg production traits leads to decrease the ASM (Soltan, 1991 and Elnoomany, 2015). In the last generation of the study selected line matured sexually earlier than control line by 1.99 days. Recent study results fully agreed with those early found by Enab *et al.*, 2000; El-Hadad, 2003; Elnoomany, 2015. However, earlier ASM have been detected in Norfa chickens (170.9d) by many authors (Abdou and Enab 1994); 154 d (Zatter, 1994) and more recently by Abou Sada 2019 (162.5 d). On the other hand, Norfa chickens sexually matured later than current study as noticed by Abdou *et al.*, 2017 (201.2 d at the third generation of their experiment).

Body weight at sexual maturity (BWSM): After one generation of selection using selection index method selected line didn't differed significantly (P=0.072) with average 1131.01 g of BWSM comparing to control (1103.16 g) as shown in Table (2). According to the reviewed literature body weight at sexual maturity of Norfa bullets fluctuated between 919.2 g (Enab *et al.*, 2015) and 1496.7 g (El-Weshahy, 2010). Results of current experiment fall within the range previously reported and fully agreed with those noticed by many authors (El-Wardany, 1987; El-Wardany *et al.*, 1992 and more recently Enab, *et al.*, 2012 and Abou Sada, 2019). Effect of interaction between line and generation during the hole experimental period on BWSM was not significant (P=0.111). Significant differences between generations had been reported by Enab *et al.,* 2015 in their work aimed to improve the performance of Norfa chickens.

Body weight at maturity (BWM): At the third experimental generation selected line (1231.40 g) didn't differed significantly (P=0.417) comparing to control (1217.58 g) with overall average BWM of 1227.02 g as shown in Table (2). At the last generation of the study average of BWM in selected line was heavier than control line by 13.82 g. Current study results of Norfa mature body weight are in good agreement with those found by researchers over-time. From the reviewed articles, Norfa chickens body weight at maturity ranged from 1007.8 g (El-Wardany *et al.*, 1992) and 1549.0 g (Abou El-Ghar, 2003).

Egg weight sexual maturity (EWSM): At the final experimental generation selected line (36.41 g) didn't differed significantly (P=0.942) comparing to control (36.39 g) with overall average EWSM of 36.41 g as shown in Table (2). Egg weight at sexual maturity had been investigated for different local Egyptian chicken strains, it is very common that egg weight positively correlated to body weight, so, the heavier strain laid the heavier eggs and vise versa. Regarding Norfa chickens, EWSM ranged between 30.7 g (Enab, 1991; in control line) to 44.2 g (El-Weshahy, 2010; in selected line for body weight). Results from the recent work are consistent with previous findings by Ben Naser (2007), Abou-Elewa (2010), Enab *et al.* (2015) and Abou Sada (2019) for the base populations of Norfa hens. Slightly higher or lower estimates of EWSM had been recorded by many authors according to the experimental conditions for each reviewed study.

Egg weight at maturity (EWM): Egg weight at maturity wasn't affected significantly by either line (L) or interaction effect (L×G) in the current experiment. However, generation effect was highly significant (P≤0.01) for EWM; the trait significantly affected by generation effect according to ANOVA results. After one generation of selection by index method, the average of EWSM in selected line was heavier than control line by only -0.06 g (with negligible importance). At the final experimental generation, EWM in selected line (46.46 g) didn't differed significantly (P=0.858) comparing to control (46.52 g) with overall average EWM of 46.48 g as shown in Table (2). The lowest egg weight at maturity that reported from previous studies on Norfa strain was 38.9 and 39.1 g after one generation of selection for selected and control lines, respectively, as recorded by El-Sakka (1999). On the other hand, the highest estimate of EWM was noticed by Abou El-Ghar (2003) as 53.2 g for the birds that selected for high egg weight. Our results fall in the previously recorded estimates of EWM, heavier or lighter weights of eggs at maturity affected by many factors, mainly body weight of the laying hen.

Egg number during the first 90 days of laying (EN90): At the end of experiment (third generation), EN90 in selected line (48.28 eggs) differed significantly (P≤0.01) comparing to control (40.96 eggs) with overall average EN90 of 45.96 eggs as shown in Table (2). Higher average number of eggs were produced during the first 90 days of production cycle according to El-Weshahy, 2010 (70.6 eggs), Enab, 1991 (62.7 eggs), Sherif, 1991 (57.8 – 61.3 eggs) and El-Salamony, 1996 (62.0 – 64.8 eggs) than those found in current study. Moreover, lower average of EN90 were observed by many authors (Enab *et al.*, 2000; Abou Sada, 2007; Ben Naser, 2007 and Abou Sada, 2019). The lowest EN90 for Norfa strain reported by Abou El-Ghar (1994) for the selected line for body weight (27.5 eggs in average). For whole experiment (3 generations) egg number during first 90 days of production highly and significantly affected by line (L), generation (G) and interaction effect (L×G) in current experiment. Application of selection index method resulted in improving EN90 average in selected line comparing with control line by 7.32 eggs (with high statistical importance).

Egg number at 42 weeks of age (EN42): Highly significant differences ($P \leq 0.01$) were detected in EN42 according to line effect (within generation); selected line hens produced 62.21 eggs in average comparing to control hens (54.29 eggs) with overall generation average EN42 of 59.70 eggs as shown in Table (2). Results from current work are similar to those reported by reviewed literature (El-Hadad 2003: after two generations of selection for general immune response, Abou-Elewa, 2004; Abou Sada, 2007 and Abou-Elewa, 2010). Higher estimates of EN42 had been recorded by many authors in Norfa chickens ranged between 63.6 to 110.9 eggs (El-Hadad, 2003; Enab, 1991; Abdou and Enab, 1994; Abou El-Ghar, 1994; El-Weshahy, 2010 and Abou Sada, 2019). The lowest egg number produced till 42 weeks of age in Norfa chickens recorded by Enab *et al.*, 2015, that equal to 33.4 eggs during the first experimental generation of their study. During the whole experimental period (3 generations) average of egg number produced by hen till 42 weeks of age highly and significantly affected by line (L), generation (G) and interaction effect (L×G) in current experiment. Application of selection index method resulted in highly significant improvement of EN42 average in selected line comparing with control line by 7.92 eggs.

PHENOTYPIC AND GENETIC PARAMETERS:

Heritability: Heritability estimates (calculated from both maternal and paternal components of variance) for the studied traits are shown in Table (3). Results showed that estimated values of heritabilities for different characteristics in recent research fall in the normal biological rang (0.00 to 1.00). The highest value of h^2 (heritability) recorded by body weight (0.454 and 0.333 for BWSM and BWM, respectively). Moreover, the lowest heritability estimates detected for EN90 (0.154) and EWM (0.159) in studied flock of Norfa chickens. Estimates of h^2 from the studied flock for all traits are agreed with the observed values by previous workers (Abou-Elewa, 2010; Elnoomany, 2015 and Abou Sada, 2019)

It is widely accepted that heritability estimates for different characters of selfsame strain and/or breed might bear no resemblance due to the variation of the genetic making, selection plans applied and history of it, accordingly values of h^2 among reviewed literature in addition to current study exhibit different values for the same trait (Elnoomany, 2015 and Abou Sada, 2019).

Phenotypic and genetic correlations: Trustworthy evaluation of phenotypic and genetic relations (correlations) is essential to conduct different genetic improvement plans of the productivity of chickens especially that needs to construct selection indices (Hazel, 1943 and Enab, 1991). These correlations lead to cause changes in traits that correlated phenotypically or genetically to the selected trait (in either positive or negative direction). Consequently, all types of relations (phenotypic and genetic) between the studied traits that included in improvement plans have to recognized and considered to evade the unfavorable changes in some productive traits when applying selection plans for particular trait/traits.

Results recorded in Table (3) represent the estimated values of phenotypic and genetic correlations between different studied traits Moderate to high phenotypic correlations either positive or negative were noticed between EN42 and other traits under investigation. Phenotypically, EN42 positively correlated with EN90 and EWM, however, this relation was negative with other studied traits (i.e., ASM, BWSM, BWM and EWSM). The same trend was observed regarding the genetic correlation between EN42 and traits under investigation in current study.

Table (2): Means of different studied traits as affected by line, generation and interaction effects ($\bar{X} \pm S.E.$).

Generation	Line	ASM	†Line effect	BWSM	†Line effect	BWM	†Line effect	EWSM	†Line effect	EWM	†Line effect	EN90	†Line effect	EN42	†Line effect
1	Control	182.09±0.73^{a}		1086.01±10.48^{ab}		1228.06±10.83		37.28±0.25^{a}		45.58±0.24^{b}		43.24±0.48		54.15±0.69	
	Selected	182.18±0.66^{a}	NS	1071.28±8.15^{b}	NS	1194.48±8.28^{b}	*	37.01±0.21^{ab}	NS	46.11±0.20^{b}	NS	43.48±0.41^{b}	NS	54.24±0.58^{b}	NS
	Overall	182.14±0.49^{a}		1077.64±6.48		1208.98±6.68		37.13±0.16		45.88±0.15		43.38±0.31		54.20±0.45	
2	Control	183.77±2.68^{ab}		1058.59±15.32^{b}		1198.82±13.09		38.06±0.37^{a}		46.73±0.38^{a}		42.08±0.86		53.39±1.39	
	Selected	184.74±1.76^{a}	NS	1071.02±8.97^{b}	NS	1227.41±7.64^{a}	NS	37.21±0.26^{a}	NS	46.85±0.24^{a}	NS	43.05±0.38^{b}	NS	53.80±0.84^{b}	NS
	Overall	184.50±1.48^{a}		1067.93±7.74		1220.31±6.62		37.42±0.21		46.82±0.20		42.81±0.36		53.69±0.72	
3	Control	177.86±1.58^{b}		1103.16±14.27^{a}		1217.58±15.66		36.39±0.29^{b}		46.52±0.28^{a}		40.96±1.47		54.29±2.10	
	Selected	175.87±1.03^{b}	**	1131.01±8.15^{a}	NS	1231.40±9.01^{a}	NS	36.41±0.18^{b}	NS	46.46±0.18^{ab}	NS	48.28±0.66^{a}	**	62.21±0.95^{a}	**
	Overall	176.50±0.86^{b}		1122.18±7.19		1227.02±7.90		36.41±0.15		46.48±0.15		45.96±0.67		59.70±0.95	
Line effect		NS		NS		NS		NS		NS		**		**	
Generation effect (G)		**		**		NS		**		**		*		**	
Interaction effect (L*G)		NS		NS		**		NS		NS		**		**	

ASM = Age at sexual maturity; BWSM = Body weight at sexual maturity; BWM = Body weight at maturity; EWSM = Egg weight at sexual maturity; EWM = Egg weight at maturity; EN90 = Egg number during first 90 days of laying; EN42 = Egg number till 42 weeks of age; NS = non-significant; * = significant; ** = highly significant; a,b,c means of specific line have the same superscript didn't differed significantly according to generation effect; † = Line effect within generation.

Table (3): Heritability (on diagonal), genetic (above diagonal) and phenotypic (below diagonal) correlations between traits:

Traits	ASM	BWSM	BWM	EN90	EWSM	EWM	EN42
ASM	**0.391**	0.352	0.088	-0.770	0.636	-0.443	-1.007
BWSM	0.246	**0.454**	0.357	0.275	0.685	0.587	-0.210
BWM	0.164	0.664	**0.333**	0.501	0.184	0.717	0.091
EN90	-0.472	0.006	0.084	**0.154**	0.075	1.077	0.712
EWSM	0.627	0.462	0.320	-0.245	**0.327**	0.278	-0.521
EWM	-0.460	0.182	0.248	0.301	-0.035	**0.159**	0.622
EN42	-0.849	-0.166	-0.063	0.755	-0.527	0.421	**0.267**

THE GENERAL INDEX (I_G):

Regarding egg production type of chickens, body weight, egg number and egg weight must be taken into consideration when constructing section index. General selection index (I_G) considered as the fundamental index because of its attributes, general index assumed to include all traits under selection without any reduction or restriction. In current study, general selection index (I_G) was constructed for Norfa layers according to the formal method according to Cunningham (1969), the weighting factors acquired by solving the equation ($b = P^{-1} GV$) in matrix expression. Results in Table (4) shows the elements of P-, G-, P^{-1}- matrices which used to construct the general index. Weighting factors, values of traits in the index and genetic gain were recorded in Table (5). The equation of general index was:

$$I_G = 0.3008\ EN42 + 0.0801\ EWM + 0.0075\ BWM$$

The variance of this index was (17.26) and its correlation with the aggregate genotype was (0.5302). The expected genetic change which would be gained by applying this index were + 3.556 egg, + 0.638 g, and + 13.711g for EN42, EWM and BWM (Table 5). These results were in good agreement with those found by Abdou and Enab (1994), Barwal *et al.* (1994), Ben Naser (2007), El-Gazar (2012) and Elnoomany (2015).

Table (4): P-, G- and P^{-1} matrices elements were used to construct the applied selection indices in current experiment:

Matrix elements		Matrices in second generation		
J	K	P	G	P^{-1}
1	1	173.186	46.335	0.00728
1	2	20.743	6.330	-0.01191
1	3	-100.342	43.987	0.00014
2	2	14.018	2.235	0.09549
2	3	112.376	76.118	-0.00081
3	3	14647.780	5042.563	0.00008

Table (5): Weighing factors, value of each trait and the expected genetic changes of general index.

Variate	**General Index (I_G)**		
	b	V_T	ΔG
EN_{42}	0.3008	47.07	3.556
EW_M	0.0801	0.19	0.638
BW_M	0.0075	2.16	13.711

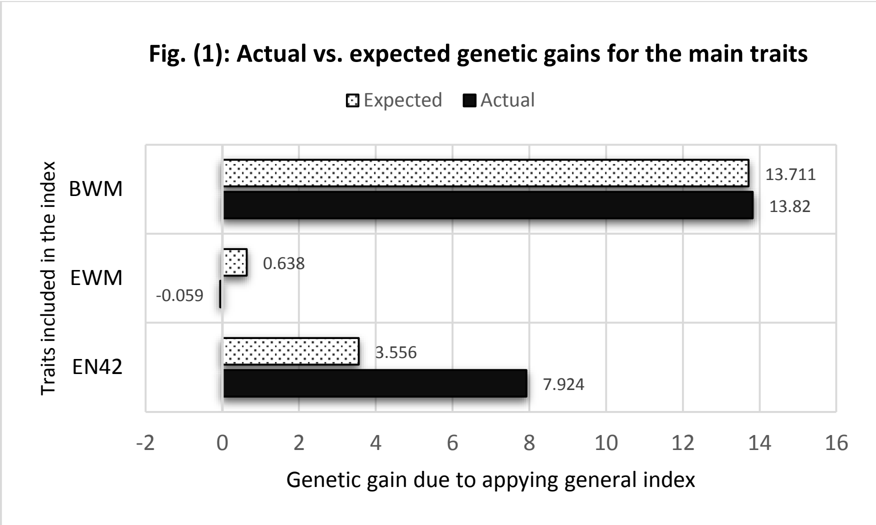
EN_{42wk} = egg number up to 42 weeks of age; EW_M = the average weight of 5 eggs during 35-38wk of age; BW_M = body weight at 36 weeks of age, b = economic weighing factor, V_T = value of the trait, ΔG = expected genetic gain.

Results indicated in the current study are in good agreement with those previously recorded by much research works on selection indices to improve laying performance in chickens. Expected genetic gains were 4.55 eggs (EN), 0.91 g (EW)and -33.2 g (BW) after one generation of selection as noticed by Abdou and Kolstad (1979). By construction of an index including EN, EW and BW in White Leghorn chickens, Das *et al.* (1982) found that after one generation of selection the genetic change was 9.99 eggs, 0.27 g and 99.4 g in egg number, egg weight and body weight, respectively. Moreover, Ben Naser (2007) reported that actual applying selection indices (26-indices in his study) leads to improve EWM and EN42 more than expected (in the second generation of his study) in two lines (light and heavy) of Norfa chickens. It can be concluded that applying selection indices including the main egg laying traits (i.e., EN42, EWM and BWM) leads to improve laying performance of Norfa hens regardless of the negative correlations detected between some traits at a multi-trait selection method.

Actual genetic gain from general selection index: Data represented in Table (6) and Figure (1) show the actual genetic gain and correlated responses that realized in selected line by applying selection using general selection index equation obtained previously in recent study. Results showed that using general index in selection for one generation resulted in improving egg production traits under investigation. The actual genetic gains for ASM, BWSM, BWM, EN90, EWSM, EWM and EN42 were -1.990 days, +27.850 g, +13.820 g, +7.324 eggs, +0.024 g, -0.059 g and +7.924 eggs, respectively.

Table (6): Selection differential and actual genetic gains for different traits in current study achieved by applying general selection index

	ASM	BWSM	BWM	EN90	EWSM	EWM	EN42
Selection Differential	-21.054	-13.909	9.580	3.731	-2.022	1.566	12.472
Genetic Gain	-1.990	27.850	13.820	7.324	0.024	-0.059	7.924



Generally, results from recent work revealed that applying general index (I_G) including three traits in Norfa chickens was effective in improving laying performance of Norfa chickens.

IV. Conclusion

It can be concluded that applying selection indices including the main egg laying traits (i.e., EN42, EWM and BWM) leads to improve laying performance of Norfa hens regardless of the negative correlations detected between some traits at a multi-trait selection method.

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