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R.Sh, Abou El-Ghar [α], O.M. Aly [σ], Hanan H. Ghanem [ρ] & Hedaia M. Shalan [ω]

Abstract - The present investigation was undertaken to study the combining ability for egg production traits using the line x tester mating design. Four local male lines (Baheij, Bj; Matrouh, Mt; Silver Montazah, SM and Golden Montazah, GM) and two commercial female testers (Lohman Brown, LB and Lohman Selected Leghorn, LSL) were used in this study. Combining ability estimates are important genetic attributes to chicken breeders in predicting improvement via hybridization and selection programs. The magnitude of specific combining ability (SCA) variance was evident from mean squares, indicating that egg production traits had been controlled by non-additive genes. However, among the four male lines, Silver Montazah (SM) showed maximum general combining ability (GCA) effects for number of eggs at 90 d., of laying (EN1), number of eggs at 180 d., of laying (EN2), number of eggs at 240 d., of laying (EN3), number of eggs till 52 wks., of laying (EN4), average egg weight at 52 wks., of laying (EW4) and egg mass throughout 52 wks., of laying (EM) studied traits. The second high GCA scoring parent for EN1, EN2, EN3, EN4, EW4 and EM was GM parental line. While the male lines Golden Montazah (GM) and Matrouh (Mt) were good general combiners for age at sexual maturity (ASM) -34.3 and -30.0, respectively. Moreover, GM parental line was the best general combiner for average egg weight through the 1st 90 d., of laying (EW1), average egg weight at 180 d., of laying (EW2) and average egg weight at 240 d., of laying (EW3) traits. Regarding the experimental testers, LSL represented higher estimates of GCA effects for ASM, EN2, EN3 and EN4, while LB tester represented higher estimates of GCA for EW1, EW2, EW3 and EW4 traits. The GCA and SCA mean squares estimates suggested that all the studied traits could be improved through hybridization. However, the hybrids SM x LB and Bj x LSL exhibited maximum SCA effect for annual egg production. Consequently, the priority should be given to parents SM and Bj lines and LB and LSL testers for improving egg production yield.

Keywords : line x tester analysis, combining ability estimates, local strains of chicken.

I. Introduction

The effectiveness of crossing for genetic improvement of quantitative characters in the fowl remains a controversial issue. Determining good characteristics of various lines is possibly exploit heterosis during hybridization, and may evolve more favorable genes to their progenies. The concept of combining ability helps to identity desirable combiners that may be utilized to exploit hybrid vigorous. It is especially useful in testing the ability of parents to attain high performance when crossed with different testers. Tester is common to be inbred or outbreed lines even single cross tester, which is considered a rabid method for developing the best 3-way and/or double cross combination. Oldemeyer *et al.*, (1968) stated that good tester varieties must be chosen with of different origin than the material being tested, relatively broad genetic base and inherently poor in performance. One of the methods used to estimate the variance components and effects due to general and specific combining ability is line x tester mating design (Kempthorne, 1957). Two types of combining ability, general and specific, have been recognized in quantitative genetics. General combining ability was found to be important for almost all traits (Fairfull *et al.*, 1983; Singh *et al.*, 1983 and Gupta *et al.*, 2000; Szydlowski and Szwaczkowski 2001 and Abou El-Ghar *et al.*, 2009). However, specific combining ability was more widely important than has been reported elsewhere (Fairfull and Gowe, 1990; Wei *et al.*, 1991 a, b; Wei and van der Werf, 1993; Abou El-Ghar *et al.*, 2003 and Abou El-Ghar and Abdou, 2004). The objectives of this study were to estimate the combining ability effects, to estimates the additive and dominance mean squares and to estimate the contribution of various genetic variance components to the total variance for egg production yield. These estimates would provide guidelines to the fowl breeders to launch effective breeding strategies.

II. Materials and Methods

The current experiment had been carried out at El-Sabahiah Poultry Research Station, Animal Production Research Institute, Agriculture Research Center, Egypt.

a) Experiment Stock and Design

The progenies of eight F1 hybrids developed from line x tester mating design by crossing four local developed strains, used as male (*Lines*) in this study. They include: Baheij (Bj), Matrouh (Mt), Silver Montazah (SM) and Golden Montazah (GM) chickens together with females of two genetic stocks of commercial laying hens (*Testers*) i.e. Lohman Brown (LB) and Lohman Selected Leghorn (LSL), used in this experiment. Table 1 reflects the genetic stock designation of the four local strains as 295, 60, 180 and 60 dams for Baheij, Matrouh, Silver Montazah and Golden Montazah, and 100 and 100 dams of each of Lohman Brown and Lohman Selected Leghorn, respectively. The crossing plan of this

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experiment was that each line (10 males) was crossed to each of the two testers (20), thus we have 8 crosses. These crosses along with 6 parents, i.e., 4 lines and 2 testers, total entry being 14. The observations were recorded on 1195 hens, (595 lines, 200 testers and 400 lines x testers hybrids) were tested in a Randomized Complete Block Design with 5 replicates for providing information about the general combining ability of a line and expected to show good performance in specific combining ability in hybrid combinations.

Table 1 : Reflects the genetic stock designation and the crossing plan obtained

Lines	♀	♂	Testers	
			LB (♀)	LSL (♀)
Bj	295	10	20	20
Mt	60	10	20	20
SM	180	10	20	20
GM	60	10	20	20
Total	595	40	100	100

Bj = Baheij, Mt = Matrouh, SM = Silver Montazah, GM = Golden Montazah, LB = Lohman Brown and LSL = Lohman Selected Leghorn.

b) Management Conditions

All managerial practices were similar as possible as throughout the experiment for all replicates. Artificial insemination was applied by assigning 4 females per each male. Two hatches in each mating combination were used. For each hatch eggs were collected throughout 7 d and incubated in full-automatic draft machine. At hatch, all chicks were wing-banded and weighed to the nearest gram. The chicks were fed *ad libitum* commercial starter ration (19 % CP and 2800 KCal) up to 8 weeks of age, then the ration was changed by commercial grower ration (15 % CP and 2700 KCal) up to 20 weeks of age. During the production period the pullets were fed a commercial layer ration (16.5 % CP and 2750 KCal) and they were housed in individual cages and received 16 hr day light. At the onset of lay, eggs were recorded and weighed daily during the first 90 (d.) of production, then twice a week till the end of experiment.

The Studied Traits: 10 egg production traits were studied; i.e.

Age at sexual maturity (A.S.M)

Number of eggs at 1st 90 d. of laying (EN1),

Average egg weight through the 1st 90 d. of laying (EW1),

Number of eggs at 180 d. of laying (EN2),

Average egg weight at 180 d. of laying (EW2),

Number of eggs at 240 d. of laying (EN3),

Average egg weight at 240 d. of laying (EW3),

Number of eggs at 52 wks of laying (EN4),

Average egg weight at 52 wks of laying (EW4) and

Egg mass throughout 52 wks of laying (EM).

c) Statistical Analysis

The data derived from 8 crosses along with 6 parental lines were firstly analyzed in conventional analysis of variance for all characters prior to combine analysis to test the significance among the different genetic groups using the following linear model of SAS program (SAS Institute, 2000):

$$Y_{ijk} = M + G_{ij} + r_k + e_{ijk}$$

Where:

Y_{ijk} is the kth observation, M is the overall mean, G_{ij} is the effect of ith genotype, r_k is the effect of k^{th} replication and e_{ijk} is the random error. The procedures followed are possible to partition genotype source of variation into variations due to crosses, parents and parent vs. crosses. If these differences are found significant, line x tester analysis is done. Similarly, the line x tester analysis was partitioned into variations due to lines, testers and line x tester. Estimate of GCA of a tester (females) was obtained in terms of its performance in F1 hybrid combinations with all possible lines (male). Likewise, GCA of a line was determined in terms of its performance in F1 hybrid combinations with all possible testers. The lines and testers were considered as fixed effects. GCA and SCA effects were determined for each trait following (Kempthorne, 1957) as follows:

GCA lines (L) = *X* j – *Y*

GCA tester (T) = *X* i - *Y*

SCA (L x T) = *X* ij - *X* j - *X* i - *Y*,

Where:

***X* j** = the mean of hybrid with a given line (male) averaged over all replications and testers (females),

***X* i** = the mean of hybrid with a given tester (females) averaged over all replications and lines (males),

***X* ij** = the mean of a given hybrid (L x T) averaged over replications,

Y = the experimental mean.

Standard errors (*SE*) for general and specific combining ability were calculated as follows:

SE for GCA of lines = (Me/r*l) ½, SE for GCA of tester = (Me/r*t) ½ and SE for Line x Tester = (Me/r) ½,

Where:

Me, is the respective mean square of line x tester error divided by number of

If the absolute effect of GCA or SCA is greater than the C.D, it is considered significantly different from zero. The critical difference (C.D) was calculated as follows: C.D = SE x t (tabulated).

III. Results and Discutions

a) Performance of genetic groups

Results of crossing Baheij, Matrouh, Silver Montazah and Golden Montazah local sire lines with two testers dames Lohman Brown and Lohman Selected Leghorn in line x tester mating design given in Table 2, reveals superiority of Silver Montazah (SM) parental line means in most of the studied traits i.e. number of eggs at 90 d., of laying (EN1), number of eggs at 180 d., of laying (EN2), number of eggs at 240 d., of laying (EN3), number of eggs till 52 wks., of laying (EN4), average egg weight at 52 wks., of laying (EW4) and egg mass throughout 52 wks., of laying (EM) traits 48±11 egg, 80±16 egg., 128±22 egg, 155±25 egg, 53.5±2 g., and 8±1.3 kg., respectively, while Matrouh (Mt) parental line was ranked second in EN1 42±5 egg, EN2 77±7 egg, EN3 100±9 egg and average egg weight at 240 d., of laying (EW3) 52.9±1 g., respectively. Contrarily, the parental line Golden Montazah (GM) had the earliest age at sexual maturity (A.S.M) 184±4 d., among all parental lines and it was superior in average egg weight at 90 d., of laying (EW1) 51.9±3 and average egg weight at 180 d., of laying (EW2) 52.4±3 g., traits. Regarding the experimental testers results showed that Lohman Brown (LB) was ranked first in most of traits studied 151±14 d. (A.S.M), 50±7 egg (EN1), 58.1±3 g. (EW1), 98±18 egg (EN2), 59.2±2 g. (EW2), 153±26 egg (EN3), 59.7±3 g. (EW3), 192±37 egg (EN4), 61.1±3 g. (EW4) and 12±2.7 Kg. (EM), while the other tester Lohman Selected Leghorn (LSL) was ranked second for the corresponding traits 153±8 d., 50±9 egg, 52.4±3 g., 91±10 egg, 55.7±3 g., 116±19 egg, 55.7±2 g., 168±25 egg, 56.4±2 g., and 11±2.7 Kg., respectively. Thus, the former results showed clearly that Silver Montazah and Golden Montazah local sire lines of chicken are considered to be fitting parental lines that play an important role in improving both egg number and egg weight traits, respectively. These findings agreed with those reported by (Kosba and Abd El-Halim, 2008 for egg number and egg mass at 90 d., of production, Abou El-Ghar *et al.*, 2009&2010 for egg weight and most of egg production traits and Iraqi *et al.*, 2012).

The results of tester's performance revealed that the testers Lohman Brown (LB) and Lohman Selected Leghorn (LSL) were gained either high or low egg production yield, respectively. It may conclude that they have either high or low frequency of favorable alleles for these traits. The same conclusion was reported by Lopez-Perez (1979). Furthermore, results of lines x testers analysis showed that the single cross Bj x LSL was the earliest hybrids in reaching sexual maturity (A.S.M) 184 d., while the single cross SM x LSL had better means of EN1 EW1, EN2, EN4 and EM (40, 119, 210 egg and 11 kg., respectively). Moreover, the single cross GM x LSL showed superiority in average egg weight at all laying periods studied (EW1 53.8 g., EW2 54.1 g., EW3 54.5 g., and EW4 54.2 g., as well as, the same hybrid (GM x LSL) had a higher means of annual egg number (EN3) and annual egg mass (EM) 153 egg and 11 kg., respectively. The same trend was found in lines x LB hybrids in Table 2, where the single cross SM x LB showed superiority means of EN1, EN2, EW2, EN3, EW3, EN4, EW4 and EM i.e. 41 egg, 117 egg, 53.7 g., 153 egg, 55.0 g., 209 egg, 55.8 g., and 12 kg., respectively. While, GM x LB single cross had the heaviest egg weight at the first 90 d. of laying (EW1 53.5 g.) and egg weight at 180 d. of laying (EW2 53.7 g.). Generally, the lines x tester (LSL) single crosses were achieved higher estimates for A.S.M 186 d., and 39, 114, 148, 201 eggs and 11 Kg., for EN1, EN2, EN3, EN4 and EM traits than the corresponding traits in lines x LB hybrids. Contrarily the lines x LB hybrids had the heaviest egg weight at different laying periods studied EW1, EW2, EW3 and EW4 52.7, 53.0, 53.4 and 53.7 g., respectively. It could be concluded that from the former results the lines x LSL single crosses were found to exhibit an outstanding higher egg production yield than the corresponding lines x LB hybrids, which has been associated with increased egg weight at different laying periods studied. The same finding was reported by Oldemeyer *et al.*, (1968) who stated that good tester varieties must be chosen with of different origin or relatively broad genetic base than the strains being tested. Also the former results showed clearly that there was a correlation between egg number and egg mass at the different periods of production, since egg mass could be affected mainly by the large proportion of variations in egg number trait. The same finding was reported by Abou El-Ghar *et al.*, (2010).

b) Phenotypic Variations

The differences among lines, testers and line x tester in Table 3 revealed that all egg production traits studied were statistically differ significantly (P<0.01) in between replicates except for egg number till 180 d., of laying (EN2), this finding indicating enough genetic variations for the genotypes and necessity of genetic analysis. In addition, the variations in between genotypes, between total parents and between hybrids were highly significant (P<0.01) for all egg production traits revealing the parents chosen were diverse and with a different genetic background. Moreover, the differences among lines and testers were insignificant with respect to all ten egg production traits. It also appears from Table, 3 that the interaction affects of hybrids vs. parents was highly significant differences (P<0.01) for all of the studied traits. On the other hand, the line x tester interaction was highly significant differences (P<0.01) except for all egg production traits, which indicating the presence of heterosis. These findings agreed with some Egyptian studies (Sheble *et al.*, 1990 and Iraqi, 2008) they reported that the possibility of improving the most of native breeds through crossbreeding could be evidenced. Generally, the findings of variations for egg production traits were agreed the previous estimates of means of the different genetic groups; moreover, significant mean square of parents vs. hybrids noted that the non-additive genetic effects may control most of the studied traits. These findings were in agreement with those reported by (Fairfull and Gowe, 1990; Wei *et al*., 1991 a, b; Wei and van der Werf, 1993; Abou El-Ghar *et al*., 2003 and Abou El-Ghar and Abdou, 2004).

c) General and specific combining ability effects

Estimated general combining ability (GCA) effects determined in line x tester mating design were presented in Table 4. It was noticed that the negative values denote to desirable values for age at sexual maturity (ASM). Results presented in Table 4 showed that from the studied parental lines three showed significant negative GCA values -30.0, -12.4 and -34.3 for Matrouh (Mt), Silver Montazah (SM) and Golden Montazah (GM), respectively, while the parental line Baheij (Bj) gave insignificant positive GCA value 76.7 of ASM trait. These results indicate that the parental lines Mt, SM and GM had desirable genes for early sexual maturity and considered good combiners for breeding to age at sexual maturity. Among testers, the Lohman Selected Leghorn (LSL) tester gave a significant negative GCA -33.0 effects on ASM. Conversely, Lohman Brown (LB) tester gave insignificant positive effect of GCA 33.0 on the same trait. Fairfull *et al*. (1983); Singh *et al*. (1983) and Huang and Lee (1991) cited that GCA was significant for ASM.

Concerning specific combining ability (SCA) effects, data obtained in Table 5 revealed that of the studied eight F1 crosses four showed significant negative SCA value -95.4, -29.9, -23.3 and -42.2 in the crosses Bj x LSL, Mt x LB, SM x LB and GM x LB, respectively. Although the insignificant positive SCA values were detected in four crosses, their values ranged from 95.4 in the cross Bj x LB to 23.3 in the cross SM x LSL. These results were in agreement with those reported by Fairfull *et al*., (1983) who found that general combining ability and specific combining ability effects were important for sexual maturity. Regarding egg number at the first 90 d., of laying (EN1) results obtained in table 4 revealed significant positive estimates of GCA effects 20.4 and 3.3 for SM and GM parental lines, respectively, these significant values indicated that the parental lines SM and GM were the best combiners for egg number during the first 90 d. of production. Unlikely, the insignificant GCA effects -6.2, -17.5, -2.0 and 2.0 were given by Bj, Mt parental lines and LB and LSL testers, respectively. These results agreed with those obtained by (Verma *et. al*., 1987 and Farghaly and Saleh, 1988). On the other hand, the estimated SCA effects in Table 5 showed that six crosses gave insignificant SCA values ranged from 4.2 to -8.6. On the other hand, a highly significant positive SCA value ($P<0.01$) was given by the cross Mt x LSL (8.6), while the significant SCA value ($P<0.05$) 6.1 was reflected by the cross SM x LB. These results agreed with those obtained by Verma *et al*., (1987). On the topic of GCA effects on egg production traits, the parental line SM showed the best significant positive GCA values of EN2, EN3 and EN4 traits 74.4, 59.8 and 142.1, respectively (Table 4). The parental line GM was ranked second among the parental lines, which reflects the significant positive values of GCA effects on EN2, EN3 and EN4 traits 17.2, 46.1 and 41.8, respectively. The same trend was found for LSL tester, which exhibits significant positive values of GCA effects on EN2, EN3 and EN4 i.e. 35.1, 22.7 and 51.0, respectively. The two parental lines Bj and Mt along with LB tester gives insignificant negative GCA values for the same traits, respectively. Therefore, the line SM as will as the tester LSL were considered the most superior genotypes for improving egg number at different laying periods. Moreover, estimates of specific combining ability effect values for egg number at different laying periods were presented in Table 5. Out of eight hybrid combinations, four had good estimates of positive specific combining ability (SCA) since they showed significant effects on EN2 i.e. 18.7, 23.3, 24.4 and 17.7 for Bj x LSL, Mt x LSL, SM x LB and GM x LB, respectively. For egg number at 240 d., of laying (EN3), three hybrids showed significant positive estimates of SCA were 19.0, 19.6 and 33.5 for Bj x LSL, Mt x LSL and SM x LB, respectively. Only two crosses reflected significant positive SCA effects on EN4 these values were 39.1 and 43.1 for Bj x LSL and SM x LB, respectively.

Concerning general combining ability effects on egg weight, Table 4 showed that the parental line GM had a significant higher GCA effect ($P<0.01$) of egg weight at different laying periods studied EW1, EW2 and EW3 12.2, 11.4 and 10.8, respectively. In addition, the parental line SM had the highest significant GCA effects ($P<0.01$) in egg weight at 52 wk., of laying EW4 (10.9). Therefore, the parental lines GM and SM were the most superior parental lines under this study. At the same time as, the LB tester was considered as good combiners for egg weight at different laying periods, it gains the significantly higher positive GCA values 2.4, 2.1, 3.1 and 5.7 for EW1, EW2, EW3 and EW4, respectively. Unlikely, the tester LSL showed the lowest negative insignificant GCA values -2.4, -2.1, -3.1 and -5.7 for EW1, EW2, EW3 and EW4, respectively. Therefore, it could be concluded that the parental lines Bj, Mt and LSL tester were not promising for egg weight traits. Generally, estimates of SCA effects listed in Table, 5 showed that the SCA effects in F1 crosses for EW1 being significant ($P<0.01$) 13.7, 4.1, 5.3 and 4.3 in Bj x LB, Mt x LSL, SM x LSL and GM x LSL F1 crosses, respectively. Moreover, the crosses Bj x LB, Mt x LSL, SM x LB and GM x LSL showed significant positive SCA effect values 4.1, 3.2, 3.3 and 4.2 in EW2 trait, respectively. Additionally, EW3 showed significant positive SCA effect values 3.4, 9.8 and 7.0 for Bj x LSL, SM x LB and GM x LSL, respectively. The same significant and positive direction of SCA effects on EW4 were 4.2, 10.1 and 7.3 given by Bj x LSL, SM x LB and GM x LSL F1 crosses, respectively. Similar results for egg weights were obtained by Fairfull *et al.*, (1983); Verma *et al.*, (1987) and Farghaly and Saleh (1988).

Further discussion of the results of GCA effects on annual egg mass (EM) in table 4, that the parental line SM achieved the highest significant estimate of GCA effects on EM trait 9.8, while the corresponding estimate of GCA effects 3.8 was achieved by GM parental line. In addition, negative estimates of GCA for EM trait were -9.6 and -4.0 achieved by Bj and Mt parental lines, respectively (Table 4). The insignificant estimates of GCA on the bases of the testers were -1.4 and 1.4 for LB and LSL, respectively. Otherwise, the estimates SCA effects (Table 5), revealed that the single crosses SM x LB and Bj x LSL had significant ($P<0.05$) positive estimates of SCA effects for EM trait 4.3 and 2.8, respectively. And insignificant estimate of SCA effects on EM trait were given by the crosses Bj x LB, Mt x LB, Mt x LSL, SM x LSL, GM x LB and GM x LSL i.e. -2.8, -0.6, 0.6, -4.3, -0.9 and 0.9, respectively. From the previous results, it is concluded that the parental lines SM and Bj could be favored in GCA for EM trait. These results agreed with those reported by Fairfull *et al.*, (1983) and Gupta *et al.*, (2000) they found significant ($P<0.01$) effect of GCA for egg production traits, while, Hill and Nordskog (1958) cited that the SCA effects is more importance for egg production traits.

d) Components of Genetic Variance

The estimates of genetic variance components were presented in Table 6, results showed that the variances of GCA for lines (σ^2GCA_{Lines}) were higher than those for testers (σ^2GCA_{Tester}) for all characters studied. The SCA mean squares for egg production traits were about more than two times greater than the GCA mean square of lines and more than four times greater than GCA mean square of tester. Thus, the results of SCA (variances due to lines x testers) implied that non-additive type of variations was controlling all egg production traits, yet non-additive genes were more important than the additive genes because variance due to SCA was higher than that of GCA. These results agreed with those obtained by Hill and Nordskog (1958) who reported that the SCA is more importance for hen-day egg production. Also these observations were in agreement with (Wearden *et al.*, 1965; Amrit, 1980; Fairfull *et al.*, 1983; Huang and lee, 1991 and Shebl, 1991). Moreover, results regarding the magnitude of additive σ^2A and dominance σ^2d mean square components of genetic variance in Table 6 indicated that dominance mean square component (σ^2d) play an important role in the inheritance of all the characteristics measured. However, the dominant mean square σ^2d was larger than additive components σ^2A for ASM, EN1, EW1, EN2, EW2, EN3, EW3, EN4, EW4 and EM4 traits. Consequently, it could be concluded that the nature of gene effects were dominant for these traits. Similar to the findings of Fairfull and Gowe, 1990; Wei *et al.*, 1991 a, b; Wei and van der Werf, 1993; Abou El-Ghar *et al.*, 2003 and Abou El-Ghar and Abdou, 2004 obtained higher magnitude of σ^2d over σ^2A for number of egg production traits. On the other hand, Table 7 shows that the contribution of lines was greater than that of testers for all egg production traits studied, while the contribution of line x tester was greater than that of lines or testers for all characters of egg production traits.

IV. Conclusion

The results of SCA mean squares were about more than two to four times greater than the GCA mean squares of lines and testers, suggests the importance of non-additive variances for all egg production traits studied. The parental line Silver Montazah demonstrates the ability to distinguish the merit of the male lines. However, the higher GCA effects of male line SM and female tester LB for most of egg production traits indicate that both these parents may be preferred for hybridization programs. On the other hand, the SCA effects reveal that, for hybrid egg yield development, crosses SM x LB and Bj x LSL could be the better choice for improving egg production yield.

Table 2 : Means and S.E of some egg production traits from line x tester analysis in laying hens

Genotypes	Traits									
	A.S.M	EN1	EW1	EN2	EW2	EN3	EW3	EN4	EW4	EM
Baheij (Bj)	194±5	41±3	45.7±1	57±5	45.8±1	82±12	45.7±1	148±9	45.0±4	7±0.7
Matrouh (Mt)	187±12	42±5	47.2±1	77±7	51.4±1	100±9	52.9±1	110±12	53.4±1	6±0.6
Silver Montazah (SM)	190±9	48±11	47.4±3	80±16	49.9±2	128±22	52.3±2	155±25	53.5±2	8±1.3
Golden Montazah (GM)	184±4	35±5	51.9±3	67±9	52.4±3	89±13	52.1±3	135±19	52.2±3	7±1.0
Total lines (L)	191±8	43±8	47.0±3	67±15	48.2±3	99±25	49.1±4	145±21	49.2±5	7±1.2
Lohman Brown (LB)	151±14	50±7	58.1±3	98±18	59.2±2	153±26	59.7±3	192±37	61.1±3	12±2.7
Lohman Select. Leghorn (LSL)	153±8	50±9	52.4±3	91±10	55.7±3	116±19	55.7±2	168±25	56.4±2	11±2.6
Total Testers (T)	152±11	50±8	55.3±4	95±15	57.5±3	134±29	57.7±3	180±34	58.7±4	11±2.7
Total Parents	181±19	44±9	49.1±5	74±19	50.6±5	108±31	51.3±5	154±29	51.6±6	8±2.5
Bj x LB	209±22	38±4	52.4±2	101±5	52.3±2	136±12	52.1±2	172±16	52.3±2	9±1.0
Bj x LSL	184±2	38±6	49.2±3	112±13	51.0±8	145±18	52.2±6	190±18	52.0±6	10±1.5
Mt x LB	186±9	36±4	52.5±3	99±8	52.3±2	137±13	52.7±2	185±14	52.9±2	10±0.8
Mt x LSL	184±7	38±5	49.2±2	112±5	51.0±2	145±14	52.2±2	190±16	52.0±2	10±0.9
SM x LB	189±3	41±6	52.4±3	117±14	53.7±1	153±8	55.0±1	209±25	55.8±1	12±1.4
SM x LSL	187±13	40±5	52.9±3	119±10	52.6±3	151±15	52.4±3	210±21	52.7±3	11±1.3
GM x LB	185±4	39±4	53.5±2	110±10	53.7±2	149±9	53.8±2	196±11	53.9±2	11±0.8
GM x LSL	186±8	39±4	53.8±4	114±8	54.1±4	153±7	54.5±4	204±14	54.2±4	11±0.7
Total hybrids	189±13	39±5	52.4±3	110±12	52.8±4	146±14	53.1±3	195±21	53.2±3	10±1.3

A.S.M = age at sexual maturity, EN1= egg number at the first 90 d., of laying, EW1 = early egg weight at the first 90 d., of laying, EN2= egg number at 180 d., of laying, EW2 = egg weight at 180 d., of laying, EN3 = egg number at 240 d., of laying, EW3 = average egg weight at 240 d., of laying, EN4 = egg number till 52 wk. of age, EW4 = average egg weight till 52 wk. of age, EM = egg mass till 52 wk. of age

Table 3 : Test the significance of source of variations from line x tester analysis for some egg production traits

S.O.V	d.f	Traits									
		A.S.M	EN 1	EW 1	EN2	EW 2	EN3	EW3	EN 4	EW 4	EM
Bet. Rep.	4	**	**	**	NS	**	**	**	**	**	**
Bet. Genotypes	13	**	**	**	**	**	**	**	**	**	**
Bet. Total Parents	5	**	**	**	**	**	**	**	**	**	**
Bet. Total Hybrids	7	**	**	**	**	**	**	**	**	**	**
Parents vs. Hybrids	1	**	**	**	**	**	**	**	**	**	**
Bet. Lines	3	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Bet. Testers	1	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Bet. Line x Tester	3	**	**	**	**	**	**	**	**	**	**
Error MS	1177	69	36	6	98	6	209	4	337	6	2

A.S.M = age at sexual maturity, EN1= Egg number at the first 90 d., of laying, EW1 = early egg weight at the first 90 d., of laying, , EN2 = egg number at 180 d., of laying, EW2 = average egg weight at 180 d., of laying, EN3 = egg number till 240 d. of laying, EW3 = average egg weight till 240 d. of laying, EN4 = egg number till 52 wk. of age, EW4 = average egg weight till 52 wk. of age, EM = egg mass till 52 wk. of age.

Table 4 : General combining ability effects (GCA) of lines and testers for some egg production traits

Parents	Traits									
	A.S.M	EN 1	EW 1	EN2	EW 2	EN3	EW3	EN 4	EW 4	EM
Lines (Males)										
Baheij (Bj)	76.7 NS	-6.2 NS	-16.2 NS	-39.5 NS	-11.0 NS	-56.5 NS	-9.5 NS	-143.8 NS	-10.2 NS	-9.6 NS
Matrouh (Mt)	-30.0**	-17.5 NS	1.8*	-52.1 NS	-4.1 NS	-49.5 NS	-7.8 NS	-40.0 NS	-9.6 NS	-4.0 NS
Silver Montazah (SM)	-12.4**	20.4**	2.1**	74.4**	3.7**	59.8**	6.5**	142.1**	10.9**	9.8**
Golden Montazah (GM)	-34.3**	3.3*	12.2**	17.2**	11.4**	46.1**	10.8**	41.8**	8.9**	3.8**
S.E. GCA Lines	1.8	1.3	0.5	2.2	0.5	3.2	0.4	4.1	0.5	0.2
Testers (Females)										
Lohman Brown (LB)	33.0NS	-2.0 NS	2.4*	-35.1 NS	2.1*	-22.7 NS	3.1**	-51.0 NS	5.7**	-1.4 NS
Lohman Select. Leghorn (LSL)	-33.0**	2.0 NS	-2.4 NS	35.1**	-2.1 NS	22.7**	-3.1 NS	51.0**	-5.7 NS	1.4 NS
S.E. GCA Testers	2.6	1.8	0.7	3.1	0.7	4.5	0.6	5.8	0.7	0.4

A.S.M = age at sexual maturity, EN1= Egg number at the first 90 d., of laying, EW1 = early egg weight at the first 90 d., of laying, , EN2 = egg number at 180 d., of laying, EW2 = average egg weight at 180 d., of laying, EN3 = egg number till 240 d. of laying, EW3 = average egg weight till 240 d. of laying, EN4 = egg number till 52 wk. of age, EW4 = average egg weight till 52 wk. of age, EM = egg mass till 52 wk. of age, S.E. = stander error for general combining ability, *, ** = Significant at 0.05 and 0.01 probability level respectively. NS. = Non-significant at 0.05 probability level.

Table 5 : Specific combining ability (SCA) estimates for some egg production traits from line x tester analysis

F1 Hybrids	Traits									
	A.S.M	EN 1	EW 1	EN2	EW 2	EN3	EW3	EN 4	EW 4	EM
Bj x LB	95.4NS	-1.7 NS	13.7**	-18.7 NS	4.1**	-19.0 NS	-3.4 NS	-39.1 NS	-4.2 NS	-2.8 NS
Bj x LSL	-95.4**	1.7 NS	-13.7 NS	18.7**	-4.1 NS	19.0**	3.4*	39.1**	4.2**	2.8*
Mt x LB	-29.9 **	-8.6 NS	-4.1 NS	-23.3 NS	-3.2 NS	-19.6 NS	0.5 NS	-14.2 NS	1.4 NS	-0.6 NS
Mt x LSL	29.9NS	8.6**	4.1**	23.3**	3.2*	19.6**	-0.5 NS	14.2 NS	-1.4 NS	0.6 NS
SM x LB	-23.3 **	6.1*	-5.3 NS	24.4**	3.3*	33.5**	9.8**	43.1**	10.1**	4.3*
SM x LSL	23.3NS	-6.1 NS	5.3**	-24.4 NS	-3.3 NS	-33.5 NS	-9.8 NS	-43.1 NS	-10.1 NS	-4.3 NS
GM x LB	-42.2 **	4.2 NS	-4.3 NS	17.6**	-4.2 NS	5.2 NS	-7.0 NS	10.2 NS	-7.3 NS	-0.9 NS
GM x LSL	42.2NS	-4.2 NS	4.3**	-17.6 NS	4.2**	-5.2 NS	7.0**	-10.2 NS	7.3**	0.9 NS
S.E.	3.7	2.6	1.0	4.4	1.0	6.4	0.9	8.2	1.1	0.5

A.S.M = age at sexual maturity, EN1= Egg number at the first 90 d., of laying, EW1 = early egg weight at the first 90 d., of laying, , EN2 = egg number at 180 d., of laying, EW2 = average egg weight at 180 d., of laying, EN3 = egg number till 240 d. of laying, EW3 = average egg weight till 240 d. of laying, EN4 = egg number till 52 wk. of age, EW4 = average egg weight till 52 wk. of age, EM = egg mass till 52 wk. of age, S.E. = stander error for specific combining ability, *, ** = Significant at 0.05 and 0.01 probability level respectively. NS. = Non-significant at 0.05 probability level.

Table 6 : General combining ability variances (σ^2GCA) from lines and testers, specific combining ability variance (σ^2SCA) from line x tester, additive ($\sigma^2 A$) and dominance ($\sigma^2 d$) mean squares for some egg production traits

Traits	σ^2GCA Lines $_{(L)}$	σ^2GCA Testers $_{(T)}$	σ^2SCA $_{(L \times T)}$	$\sigma^2 A$	$\sigma^2 d$
A.S.M	-3814420.6	-1907045.0	7629911.2	-3051470.4	30519644.7
EN 1	-159873.6	-79960.9	319842.9	-127908.5	1279371.6
EW 1	-293454.1	-146738.6	586963.2	-234767.9	2347852.9
EN 2	-1301886.1	-650787.1	2605100.1	-1041446.5	10420400.4
EW 2	-297264.5	-148639.9	594565.8	-237814.7	2378263.2
EN 3	-2283164.3	-1141754.4	4567802.1	-1826600.3	18271208.5
EW 3	-300680.2	-150346.5	601401.2	-240546.7	2405604.9
EN4	-4088800	-2044832.7	8183431.3	-3271213	32733725
EW4	-301570.7	-150785.3	603193.0	-241256.5	2412772.2
EM	-11580.8	-5796.9	23190.5	-9267.2	92762.0

σ^2GCA Lines = general combining ability mean square from lines, σ^2GCA Testers = general combining ability mean square from testers, σ^2SCA $_{(L \times T)}$ = specific combining ability mean square from line x tester analysis, $\sigma^2 A$ = additive genetic variance, $\sigma^2 d$ = dominance variance, A.S.M = age at sexual maturity, EN1= Egg number at the first 90 d., of laying, EW1 = early egg weight at the first 90 d., of laying, , EN2 = egg number at 180 d., of laying, EW2 = average egg weight at 180 d., of laying, EN3 = egg number till 240 d. of laying, EW3 = average egg weight till 240 d. of laying, EN4 = egg number till 52 wk. of age, EW4 = average egg weight till 52 wk. of age, EM = egg mass till 52 wk. of age.

Table 7 : Contribution of lines, testers, and lines x testers mean squares to the total variance for some egg production traits

Traits	Contribution (%)		
	Lines	Testers	Lines x Testers
A.S.M	0.014	0.008	99.98
EN 1	0.032	0.001	99.97
EW 1	0.010	0.001	99.99
EN 2	0.05	0.03	99.92
EW 2	0.0064	0.0004	99.99
EN 3	0.033	0.006	99.96
EW 3	0.007	0.001	99.99
EN4	0.07	0.02	99.91
EW4	0.009	0.003	99.99
EM	0.126	0.005	99.87

A.S.M = age at sexual maturity, EN1 = Egg number at the first 90 d., of laying, EW1 = early egg weight at the first 90 d., of laying, , EN2 = egg number at 180 d., of laying, EW2 = average egg weight at 180 d., of laying, EN3 = egg number till 240 d. of laying, EW3 = average egg weight till 240 d. of laying, EN4 = egg number till 52 wk. of age, EW4 = average egg weight till 52 wk. of age, EM = egg mass till 52 wk. of age.

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