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≪Research Note≫

Heritablity Estimates of Some Clutch Traits in the Laying Hen

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Oviposition time of 419 hens from a White Leghorn population of two lines divergently selected for high and low yolk-albumen ratio was observed at four stages of egg production period for a duration of about 30 days in each stage. A total of 1,498 records were used in the analyses of this study. The clutch traits for heritability estimation include ; Intra-clutch mean lag of oviposition time (LAG), mean delay of pause day between clutches (DELAY), the rate of internal laying (IP), the number of clutches (CN), the average length of clutches (CL), and the average size of clutches (CS). LAG and DELAY were estimated by the multiphasic model (Luc *et al*., 1995). Heritabilities of these clutch traits were estimated by a sire-dam nested model and intra-sire regression of daughter on dam.

Means of LAG were 1.04 hours and 1.32 hours for high and low lines, respectively. Corresponding heritability estimates were 0.41, 0.32, 0.62, and 0.55, 0.51, 0.62 for sire component and combined components of sire and dam, and intra sire regression coefficient of daughter on dam, respectively. Heritability estimates of DELAY were not different from zero in both lines using the two methods. Medium and high heritability estimates of CN, CL and CS were found for both high and low lines in the two methods, except for regression estimates in the high line. Heritability estimates in the low line were higher than that in the high line for most traits, except for DELAY and IP.

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Key words : clutch traits, multiphasic model, heritability, laying hen

Introduction

Egg production in laying hen strongly exhibits the cyclic process in which eggs are laid at the interval of about 24-27 hours or more, depending mainly on laying performance and age. This cyclic pocess results in the formation of the clutches. A mathematical model has been developed by using the approach of multiphase of egg laying to describe this phenomenon (Koops and Grossman, 1992 ; Luc *et al*., 1995). In the multiphasic model, egg production is treated as clutches, in which clutch consists of the eggs laid in consecutive days and internally laid eggs, and is terminated by one pause day. The model may be written as follows :

$$Y_t \quad 1-\frac{t-\delta(c-1)}{24+\lambda} \quad -i \qquad \text{[1]},$$

where Y_t is cumulative number of eggs at time t (in hour) ; λ is intra-clutch mean lag

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of oviposition time in hour (LAG) ; $\delta > 0$ is mean delay of pause day between clutches in hour (DELAY) ; c is the sequence number of the clutch (c = 1, 2, 3, ...) ; and i is cumulative number of internally laid eggs. Equation [1] reveals that the prolific hens lay eggs in one or a few clutches without internal laying, the production of these hens primarily depends on lag of oviposition time of subsequent eggs, and partly depends on delay of pause day between clutches. The hens with one clutch egg production, undoubtedly, the number of eggs is determined by the length of lag of oviposition time.

Several selection experiments have been practiced to increase the rate of lay on the principle of reducing the ovulation interval by using the measurable trait of oviposition interval within sequences (McClung *et al.*, 1976 ; Sheldon *et al.*, 1984). The oviposition interval within sequences in the selected lines was significantly decreased in the selected generations. It is concluded from the above experiments that the rate of lay in the population with relatively high egg production can be improved by reducing the oviposition interval. Heritability estimates for oviposition interval within sequences were reported to be medium (McClung *et al.*, 1976 ; Yoo *et al.*, 1988 ; Naito *et al.*, 1989 ; and Lillpers and Wilhelmson, 1993). However, heritabilities of other clutch traits such as clutch size, clutch length, number of clutches as well as intra-clutch lag of oviposition time and delay of pause day between clutches have not been reported so far.

The purpose of this study was to search for the genetic variations of LAG and DELAY obtained from equation [1], and other clutch traits of egg production as mentioned above.

Materials and Methods

Data of oviposition time were obtained from a White Leghorn population of two lines divergently selected for high and low yolk albumen ratio. This population has been founded since 1970, and relaxedly selected from 1983 (Mitsumoto and Miyoshi, 1989). The hens were housed in individual cages at an age of 150 days with the light-dark regime about 14hr/10hr. Oviposition time of individual hens was recorded at four stages during April, June, August and October 1993, and April, May, June and October 1994. Observation duration in each stage was about 30 days. Oviposition time was observed every one hour from 5 : 30 A.M. to 6 : 30 P.M. and recorded to the nearest half hour. Hens with no egg laid in the observation stage were excluded from the data set.

Clutch traits in this study were defined as intra-clutch mean lag of oviposition time (LAG), mean delay of pause day between clutches (DELAY). These traits were estimated by the multiphasic model [1]. Other clutch traits including the number of clutches (CN), the average length of clutches (CL), and the average size of clutches (CS) were calculated from the data of oviposition time. The rate of internal laying (IP) was estimated as the percentage between the number of missing eggs and the number of days in the observation stage. These missing eggs were determined based on the time of oviposition as described by Luc *et al.* (1995).

Statistical analyses were separated by lines. The number of sires, dams, hens and records in each line used in the estimation of variance components are presented in

Table 1. Number of sires, dams, hens and records in two lines selected for high and low yolk-albumen ratio

Year	High line				Low line			
	Sire	Dam	Hen	Record	Sire	Dam	Hen	Record
1993	18	33	131	464	18	31	119	416
1994	16	31	81	293	17	30	88	325
Total	34	64	212	757	35	61	207	741

Table 1. Variance components were obtained by the REML method of VARCOMP in SAS (SAS Institute, 1985) with a sire-dam nested model as follows :

$$Y_{ijklm} = \mu + G_i + P_{ij} + S_{ik} + D_{ikl} + e_{ijklm} \quad \cdots\cdots [2],$$

where Y_{ijklm} is the observation on LAG, DELAY, IP, CN, CL, and CS ; μ is the overall mean ; G_i is the fixed effect of the i^{th} year of data collection ($i=1, 2$) ; P_{ij} is the fixed effect of the j^{th} observation period within i^{th} year ; S_{ik} is the random effect of the k^{th} sire within i^{th} year; D_{ikl} is the random effect of the l^{th} dam mated with k^{th} sire within i^{th} year; e_{ijklm} is the residual effect. These random effects are assumed to be normal, identical and independent distributions with the variances of σ^2_{sire}, σ^2_{dam} and σ^2_e, respectively.

Data of dams used in analysis of regression were obtained from stages 1, 2 and 4 of egg production period in 1993. Data of daughters were obtained from stages 1, 3, and 4 of egg production period in 1994. Intra sire regression coefficients of daughter on dam for each trait were estimated from 203 and 207 records of daughters corresponding to 86 and 76 pairs of dams' families in high and low lines, respectively.

Results and Discussion

Means and standard deviations with the skewness of their distributions are presented in Table 2. Because clutch traits are mirror images of egg production traits, most of clutch traits had positively skewed distributions except for DELAY in both high and low lines and CN in the low line with negative skewed distributions. LAG and CN showed closely to the normal distribution. LAG is a continuous variable, while CN is a discrete variable. However, no transformations and truncations were applied for any trait.

Means of LAG were 1.04 hours and 1.32 hours, corresponding the oviposition intervals of 25.04 hours and 25.32 hours for high and low lines, respectively. These results are comparable to the values of oviposition interval within sequence reported by LILLPERS and WILHELMSON (1993). Means of DELAY were similar values for both high and low lines ; 17.50 hours in the high line and 17.40 hours in the low line. Average length of the clutches (CL) and size of the clutches (CS) in the high line were significantly larger than that in the low line ; 178.48 hours and 6.21 eggs, and 153.47 hours and 5.30 eggs for CL and CS in the high and low lines, respectively. Accordingly, the number of clutches (CN) in the high line was 4.92, was smaller than CN of 5.49 in the low line. However, the rate of internally laid eggs (IP) was higher in the high line of 9.73% compared with the low line of 7.64%. These results agree with the previous

Table 2. Means, standard deviations and skewness of some clutch traits

Trait	High line			Low line			Comparison between lines[1]
	Mean	SD	Skewness	Mean	SD	Skewness	
LAG	1.04	0.76	0.98	1.32	0.90	0.81	**
DELAY	17.50	4.53	−2.59	17.40	3.78	−2.11	NS
IP	9.94	11.93	1.89	7.75	11.55	2.73	**
CN	4.92	1.94	0.11	5.49	2.01	−0.03	**
CL	178.48	125.78	2.80	153.47	100.36	3.35	**
CS	6.21	5.34	2.88	5.30	4.29	3.52	**

[1]** : $p<0.01$; NS : No significant.

Table 3. Heritabilities with standard errors fo the clutch traits estimated by the sire-dam nested model and intra-sire regression of daughter on dam

Line and Trait	$h^2_S \pm SE$	$h^2_{S-D} \pm SE$	$h^2_{OP} \pm SE$
High line			
LAG	0.41±0.18	0.32±0.09	0.62±0.30
DELAY	0.08±0.07	0.04±0.08	−0.03±0.16
IP	0.07±0.11	0.12±0.06	0.14±0.15
CN	0.43±0.22	0.43±0.11	0.12±0.20
CL	0.49±0.23	0.49±0.12	0.28±0.20
CS	0.43±0.23	0.45±0.12	0.19±0.21
Low line			
LAG	0.55±0.27	0.51±0.13	0.62±0.19
DELAY	0.02±0.05	0.01±0.03	0.05±0.14
IP	0.03±0.18	0.33±0.10	−0.02±0.14
CN	0.68±0.39	0.83±0.18	0.55±0.17
CL	0.50±0.37	0.84±0.18	0.57±0.16
CS	0.60±0.38	0.87±0.19	0.62±0.14

report of LEE *et al.* (1995) for the clutch traits obtained from the data only in 1993. The IP for both high and low lines in present study was higher than that (2.6%∼4.4%) for the commercial strains that were introduced into our laboratory (unpublished).

Heritability estimates of the clutch traits were obtained from sire component of variance, the combination of sire and dam components of variance of the sire-dam nested model, and from the intra-sire regression coefficient of daughter on dam (Table 3). Heritabilities of LAG were 0.41, 0.32 and 0.62, and 0.55, 0.51 and 0.62 for sire and combined components, and regression in the high and low lines, respectively. In this study, heritability of LAG estimated by the sire-dam nested model, and by regression in both high and low lines is within the range of the previous estimates for intra-sequence mean of oviposition intervals with values of 0.47-0.66 estimated by YOO *et al.* (1988), 0.28-0.29 by NAITO *et al.* (1989) and 0.42-0.55 by LILLPERS and WILHELMSON (1993). Moreover, realized heritability for oviposition interval estimated from a selection experiment for reducing oviposition interval was 0.39 (MCCLUNG *et al.* (1976)). It would be expected that LAG has the same interpretation of egg laying with intra-clutch mean of oviposition intervals. However, LAG in this study was estimated by equation [1] in consideration of the internal laying and the delay of pause day.

Heritability estimates of DELAY were not different from zero in both high and low lines of the two methods. Heritability estimates of CN were 0.12–0.43 and 0.55–0.83, and that of CL were 0.28–0.49 and 0.50–0.84 for high and low lines, respectively. A similar trend in heritability estimates was also found for CS with the values of 0.19–0.45 and 0.60–0.87 for high and low lines, respectively.

Heritability estimates in the high line were lower than that in the low line in both estimation methods for the traits of LAG, CN, CL and CS except for LAG in the regression estimation. The difference between the two lines in the heritability estimates seems to be caused by the difference in the skewness of their distributions especially for CL and CS. The other possibility is that the selection for high yolk-albumen ratio may result in increasing the rate of ovulation in the high line. Thereafter, the reduction in genetic variation for clutch traits of the high line may occur. Because selection criterion in this population was not for the rate of lay, the rate of abnormally laid egg was higher in the high line than in the low line (Table 2). It is also in accordance with the previous report of Luc *et al.* (1995) that although LAG in the high line was significantly shorter than that in the low line, egg production in the high line was not higher than that in the low line, because of the higher rate of internal laying associated with high line.

This study was conducted in a small population thus, a profound interpretation is not much desired. However, the results of the estimates of heritability showed some trend in genetic variations among the clutch traits. The further estimation of the directly additive genetic variation by the animal model using all relationships in the pedigree is needed to increase the accuracy of the estimates.

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産卵鶏におけるクラッチ形質の遺伝率

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卵黄・卵白比の高および低方向に選抜育種された二系統の490羽を用い，放卵時間を4つの時点（各々，約30日間）で調査し，1,498個の記録を本研究で用いた。クラッチ内の放卵時刻のずれの平均（LAG）およびクラッチ間の休産日の遅れの平均（DELAY）はmultiphasicモデル（Luc *et al.*; 1995）で推定した。分析に用いた他のクラッチ形質は卵産率（IP），クラッチ数（CN），クラッチ長（CL）およびクラッチサイズ（CS）である。遺伝率はsire-dam nestedモデルによる分散分析および父親内母娘回帰から推定した。

LAGの平均は，高系統で1.04時間が推定され，低系統の1.32時間より有意に短いものであった。また，LAGの遺伝率は高系統で父親成分から0.41，全きょうだい成分から0.32および回帰から0.62が推定された。低系統では，それぞれ，0.55，0.51および0.62が推定された。一方，DELAYの遺伝率は両系統で零に近い値が推定された。また，DELAYとIPを除き，推定された遺伝率は低系統が高い傾向にあった。

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キーワード：クラッチ形質，miltiphasicモデル，遺伝率，採卵鶏

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