Phenotypic Traits Variance and Their Impact on Egg Production in Magelang Ducks: Implications for Breeding Programs

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Abstract. Variance in phenotypic traits plays a crucial role in determining duck egg production. This study investigated the onset of egg-laying and egg production in Magelang ducks up to 36 weeks of age and their correlation with body size. One hundred 10-week-old ducks were placed in individual battery cages for 26 weeks. Body measurements (body weight, body length, shank length, beak length, neck diameter, and neck length) were obtained before duck in, and egg data were collected daily. The significant variability in phenotypic traits suggests that selective breeding effectively improves Magelang ducks. Correlation analysis revealed no significant relationship between body size and egg productivity. However, the age at first egg was significantly correlated with egg number at 36 weeks of age ($P<0.0001$) with r -0,63, following the regression model $Y = -0,5144*X + 60,93$ where Y is egg number and X is age at first egg in days. The laying onset age showed a significant correlation, suggesting that breeding programs should focus on selecting ducks with an earlier laying onset rather than larger body size to improve egg production efficiency.

1 Introduction

Phenotypic variation plays a crucial role in duck egg productivity [1]. Phenotypic variation results from differences in genetics, environmental factors, and developmental processes [2]. This variation refers to observable differences in the physical characteristics and traits of individual ducks within a population. Previous research has shown that phenotypic variation observed in indigenous chickens in Indonesia could provide valuable information for the design of selection and genetic improvement programs [3]. In the context of egg productivity, phenotypic variance can manifest in various aspects such as egg size, shell quality, laying frequency, and overall reproductive performance, including the onset of laying egg age and egg production. Egg production traits are affected by genetics, nutrition, disease, heat stress, water restriction, and sex hormones [4]. Identifying and selecting ducks with desirable phenotypic traits related to egg production and implementing appropriate breeding programs will enhance the egg yield [5].

Egg productivity is a crucial factor in the success and profitability of duck farming. High egg production rates directly affect a farm's output, revenue, and overall efficiency. Ducks with superior laying capabilities can significantly increase the number of eggs available for sale or hatching, improving farmers' economic returns. The factors influencing egg productivity include genetics, nutrition, housing conditions, and management practices [6].

Magelang ducks, one of Indonesian local ducks native to the Magelang region of Central Java, Indonesia, are a distinctive breed with unique characteristics and adaptability. Refers to Decree of the Minister of Agriculture Republic of Indonesia, No. 701/Kpts/PD.410/2/2013 (issued on February 13, 2013) Magelang ducks typically weigh between 1,8 and 2,5 kilograms, with a distinctive upright posture and a slightly curved neck with a white necklace width of 1-2 cm. They are primarily raised for their meat and egg production and are capable of laying up to 200 eggs annually [7]. This breed is well-suited to the climate of Indonesia. Magelang ducks have become an important part of the local genetic resources, contributing to both the agricultural economy and rural livelihoods in the region.

Understanding phenotypic variance is essential for duck breeders and farmers to optimize their egg productivity. This research will provide an overview of phenotypic diversity in the body size of 10-week-old Magelang duck and its relationship with the egg yield of 36 36-week-old duck. It also provides valuable insights into the phenotypic and genetic variance of duck's body sizes and egg production. This research can enhance the overall flock performance and increase Magelang duck's egg yield.

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2 Materials and Methods

2.1 Experimental design

This study examined the body size of Magelang ducks at 10 weeks of age and their egg production at 36 weeks. It investigated the relationship between the age at which egg-laying begins and egg production up to 36 weeks in Magelang ducks housed in individual cages and how these factors correlate with their body size at 10 weeks.

2.1.1 Battery cage setup

The battery cage was set up using bamboo materials for 100 ducks at Kelompok Tani Bina Mandiri, a farmers' group located in Kalangan, Ambartawang, Mungkid, and Magelang Central Java. Individual compartments were created for each duck, approximately 25 cm × 35 cm × 45 cm (width × depth × height) with a height of two tiers. Design of sloped cage floors for eggs to roll to the front for easy collection. Install individual feed troughs for each cage, made from split PVC pipes, and position the troughs at the front of each cage for easy access and refilling. Nipple drinkers were used as the watering systems. A main water line was installed along the top of each tier and connected to the individual nipple. Ensure that the water supply is clean and consistent (*ad libitum*). Uniform conditions were ensured across cages.

2.1.2 Duck selection criteria.

The ducks were selected randomly based on certain criteria. The duck selection criteria were the Magelang female duck, which was laid at the same time so that the age of the duck could be accurately recorded. A hundred of 10 weeks duck selected must be healthy and have no defects.

2.1.3 Body size measurements

Body size measurements were conducted before the duck entered the battery cage, including body weight, body length, shank length, beak length, neck diameter, and neck length. Body weight was measured using a digital hanging scale, while the others were measured using a measuring tape.

2.1.4 Age at first egg measurements

The cage was observed daily to record whether the duck had laid eggs. The day when the first egg was observed was recorded as the onset of egg-laying and marked as the age at the first egg.

2.1.5 Egg numbers at 36 months of age measurements.

The 10 weeks aged ducks were observed for 26 weeks, and egg production was recorded daily. Thus, the total egg production at the end of the period represents egg production at 36 months of age. Samples of minimum and maximum total egg production were dissected to observe the weight of the reproductive track.

2.2 Data analysis

Data were analysed using descriptive statistics, Pearson correlation test, and simple linear regression by GraphPad Prism 10.2.3 software. Descriptive statistics were used to analyse the phenotypic variance of Magelang ducks based on body size, onset of egg laying, and egg production. A data normality test was performed, and abnormalities were corrected before analysing the normalised data using Pearson's correlation test, which evaluates the linear relationship between two variables with a normal distribution. Independent variables that had a significant correlation with the dependent variable were then analysed for regression using simple linear regression analysis. In this study, the dependent variable was egg production at 36 weeks of age, whereas the other variables were independent variables.

3 Result

3.1 Descriptive statistics of body size and egg productivity.

The following Table 1 provides a comprehensive depiction of the distribution of the phenotypic traits obtained in this study.

Table 1. Distribution data of phenotypic traits

Variable	Range	Min	Max
Body Weight /BW (g)	655	630	1285
Body Length /BL (cm)	9	18	27
Shank Length /SL (cm)	3	5	8
Beak Length /BKL (cm)	3	5	7
Neck Diameter ND/ (cm)	3	7	9
Neck Length NL/ (cm)	9	11	20
Onset Laying Age/ OLA (days)	93,00	157	250
36 Week Egg Production/ EP (number)	83,00	1	84

The mean, standard deviation, and Coefficient Variation were analysed to provide a comprehensive understanding of the data, and the results of this analysis

are presented for further examination and interpretation in the table. 2 below.

Table 2. Mean, Standard Deviation and Coefficient of Variation

Variable	Mean	Standard deviation (SD)	Coefficient of Variation (CV)
Body Weight /BW (g)	1012,70	123,18	12,16
Body Length /BL (cm)	21,10	1,84	8,72*
Shank Length /SL (cm)	7,35	0,76	10,34
Beak Length /BKL (cm)	5,76	0,58	10,07
Neck Diameter ND/ (cm)	7,65	0,54	7,06*
Neck Length NL/ (cm)	16,56	1,89	11,41
Onset Laying Age/ OLA (days)	195,84	21,08	10,76
36 Week Egg Production/ EP (number)	31,93	22,94	71,84

* : The value under 10%

The body weight was 1012.70 ± 123.17 g, which is lower than the standard specified in Keputusan Menteri Pertanian No. 701/Kpts. PD. 410/2013 dated February 13, 2013. While according to the previous study shows that the body weight of Magelang duck at layer phase was 1,54 ± 0,14 kg [8]. This was possible because the measurements were conducted when the duck was in the growth phase and not in the layer phase. While the EP is 31,93±22,94. The minimum and maximum EP reproductive track weights were 15 g and 64 g, respectively, with normal reproductive tracks weighing more than the abnormal tracks. The onset laying age was 195,84 ± 21.08 days or 5,8-7,2 months. This was later than that mentioned at Keputusan Menteri Pertanian No. 701/Kpts. PD. 410/2013 that Magelang duck sex maturity age at 5-6 months. These findings are consistent with previous studies indicating that native Indian ducks reach sexual maturity within 145-223 days, or 4,8 to 7,4 months.[9]. When analysing the Coefficient of Variation (CV) of the traits, it was observed that the values exceeded 10%, except for body length and neck diameter, which were 8,72% and 7,06%, respectively.

$$CV = \left(\frac{Standard\ deviation}{Mean}\right) x\ 100\%$$

CV is a value used to determine the distribution of data within a sample and to assess how closely the data points are clustered around the mean. A larger CV indicates greater diversity and more deviation from the mean, whereas a smaller CV suggests that values are more similar and closer to the mean, reflecting lower variance. CV greater than 10 percent indicates high variability within the dataset. This implies that the data points are widely spread out from the mean, reflecting significant variance among the phenotypic traits. This indicates that breeding programs focused on selection for genetic quality improvement in Magelang duck still have considerable potential for development.

3.2 Correlation between body size and egg productivity

The visualization of scatter plot between body size and egg production data is shown in Fig 1. bellow:

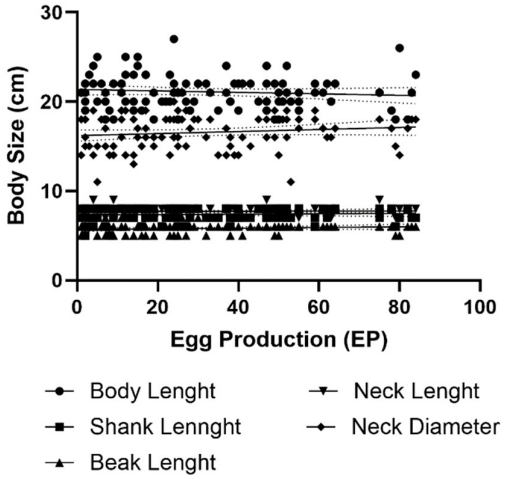

Fig. 1. The Scatter plot body size and egg production

The scatter plot shows a random pattern, with no clear trend between body size and egg production, indicating that the two variables are unrelated. Visualisation of the relationship between body weight and egg production is shown in Fig. 2, which also shows that there was no clear trend between body weight and egg production.

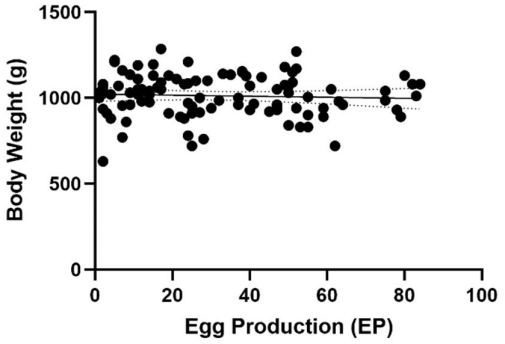

Fig. 2. The scatter plot between body weight and egg production

Correlations were analysed using Pearson's correlation on normalised data. The correlation between phenotypic traits was then visualised using the matrix, as shown in Fig. 3. The correlation between body size at 10 weeks of age and egg productivity at 36 weeks of age appeared weak because of the faint colouration of the matrix.

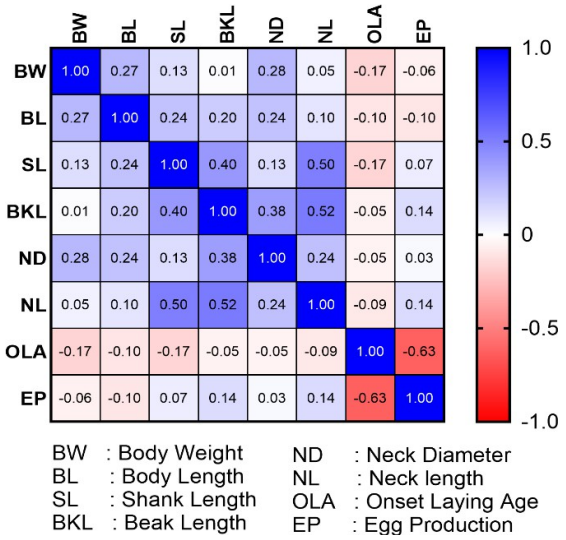

Fig. 3. Matrix of Correlation among phenotypic traits

However, the onset laying age was significantly correlated with egg productivity at 36 weeks of aged -0,63. The matrix of correlations among the variables is shown in Fig.1. The blue colour shows a positive correlation, whereas the red colour shows a negative correlation. A darker colour indicates a stronger correlation between variables. The darkest red colour indicates a significant negative correlation between the onset laying age and egg production.

3.3 Correlation between age at first egg and egg number at 36 weeks aged

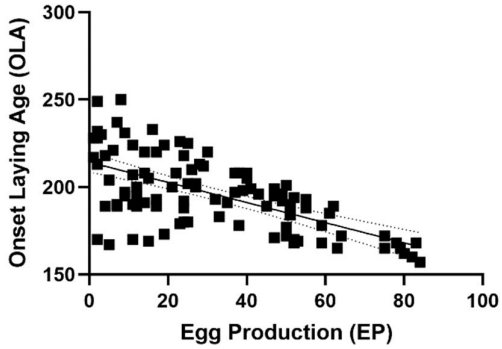

Fig. 4. The scatter plot between onset laying age and egg production

The relationship between the onset laying age and egg production is shown in Fig 4. The graph clearly shows a correlation between the age at onset of laying and egg production.

The correlation coefficient between the age at first egg and the number of eggs produced by 36 weeks of age was -0.63, indicating a moderate to strong negative relationship. A simple linear regression analysis was subsequently conducted, and the resulting mathematical model, which describes the relationship between the age at which the first egg was laid and the total number of eggs produced by the time the ducks reached 36 weeks of age, was determined as follows:

$$Y = -0,5144*X + 60,93$$

Y: egg number at 36 weeks of age; X: Onset laying egg age.

4 Discussion

4.1 Interpretation of correlation results

There was no correlation between body size at 10 weeks and egg productivity 36 weeks aged ducks. This means that body size during the grower phase could not be a predictor of egg production. It is tempting to assume a direct relationship between physical attributes and reproductive output because reality is often more complex. Factors influencing egg productivity in ducks can be multifaceted, and include genetics, nutrition, environmental conditions, and overall health [10]. Body size at 10 weeks of age may not be a reliable predictor of future egg-laying capacity as ducks continue to grow and develop beyond this point. Furthermore, egg production is heavily influenced by hormonal factors and reproductive system maturity, which may not be directly linked to body size. This corroborates the results of previous research on duck post-hatching period [11]. However, we were able to predict the number of eggs produced by the onset of egg laying. The Pearson Correlation was significant between OLA and EP.

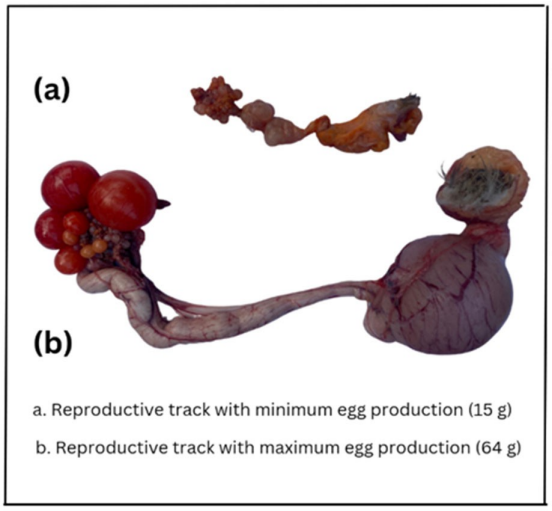

Fig. 5. The comparison of Magelang duck reproductive track

The minimum and maximum reproductive track weights of the egg production sample ducks were 15 and 64 g, respectively. Fig. 52 shows the differences between ducks with normal egg laying and ducks with one egg laying at the same age in this study. The upper panel (a) shows that improperly developed reproductive tracts represent a smaller size than the normal one in the lower (b). This clarifies the assumption that egg productivity may be more affected by the reproductive track

size than duck body size. The size of the reproductive tract may be affected by several factors.

4.2 Implications of the negative correlation between age at first egg and egg number

The correlation between OLA and EP is -0,63. A simple linear regression (SLR) curve between OLA and EP is shown in Fig. 6. The slope of the OLA curve decreased slightly when the number of eggs increased.

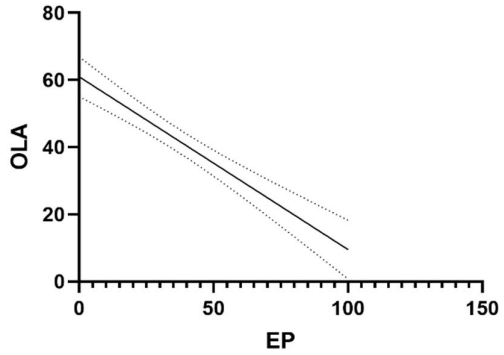

Fig. 6. The curve of Simple Regression Linier of OLA (Onset Laying Age) and EP (Egg Production)

The negative correlation between the age at which ducks lay their first egg and their total egg production has significant implications for poultry management and breeding strategies, suggesting that ducks which begin laying eggs earlier in their lifespan generally produce a greater cumulative number of eggs throughout their productive years. This relationship is consistent with findings from previous studies conducted on different species, such as chickens, which also demonstrated that early onset of egg-laying is associated with higher total egg output [12]. Given these insights, duck farmers could use this information to refine their flock management practices and breeding selection criteria, potentially prioritising ducks that reach sexual maturity sooner to maximise overall egg production. By selecting for an earlier onset of egg-laying, farmers might be able to enhance the efficiency and productivity of their flocks, leading to improved outcomes in egg production. These findings could inform decisions regarding flock management and selection criteria for breeding programs for poultry farmers. Selecting ducks for earlier sexual maturity may lead to increased overall egg production.

5 Conclusion

The variance of phenotypic traits demonstrated significant variability, indicating that a selective breeding program is well suited for enhancing the egg production trait of Magelang ducks. There was no correlation between body size during the grower phase and the egg production of ducks when they reached 36 weeks of age, indicating that the physical growth metrics observed earlier in their development do not have a direct impact on their egg-laying output at this particular stage. However, the age at which ducks begin laying their eggs does show a significant correlation with their overall egg production, suggesting that earlier onset of egg-laying is associated with higher egg yields. This observation suggests that egg production is influenced by a range of factors other than body size during the growth phase. Consequently, it is tempting to consider egg production as a multifaceted trait that is potentially influenced by a complex interplay of genetic, physiological, and environmental factors. The laying onset age showed a significant correlation, suggesting that breeding programs should focus on selecting ducks with an earlier laying onset rather than larger body size to improve egg production efficiency.

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The data supporting the findings of this study are available from the corresponding author upon reasonable request.
The authors' contributions are as follows:
Z. Ulfah conceptualized the study, collect and record data, analyses and interprets the result and wrote the manuscript.
D. Maharani contributed to the interpretation of results and revised the manuscript critically for important intellectual content.
H. Sasongko contributed to the design experiment and revised the manuscript critically for important intellectual content

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