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Original Article

On-Farm Evaluation of Genotype by Environment Interaction on Egg Production Traits of Exotic Chicken at Selected Zones of Amhara Region, Ethiopia

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Abstract

The current study was conducted in the Awi and West Gojam zones of the Amhara region with the main objective of evaluating genotype by environment interaction on egg production traits of exotic chicken. The districts of Banja and Fageta Lekuma from Awi and South Achefer district from West Gojam zone were selected purposively. Age at first egg, egg laid/week/hen and egg weight data were obtained from the ACGG project. Factorial analysis of variance using R software was used. Based on these study results, G*E interaction revealed a significant effect on average egg number per week per hen and age at first egg, whereas it was non-significant on hen day egg production (HDEP) and egg weight traits. All breeds scored a statistically similar number of eggs/week/hen within all districts during the 20-72 week egg laying period. The highest and lowest total collected eggs per year were observed by Koekoek (215) in South Acheferand by Kuroilor (133) in Fagta Lekoma district, respectively. Sasso laid the first egg earlier in Banja. In comparison to the other chicken breeds, Kuroiler and S-RIR in Fagta Lekoma and Koekoek in South Achefer district laid the first egg earlier. All breeds scored a higher %HDEP in Banja than in Fagta Lekoma during 20-72 weeks. At this age, all breeds except Koekoek exhibited higher egg weight in Fagta Lekoma than in Banja. Overall, the current study found that Koekoek was more productive and should be used for egg production to increase chicken production potential at scavenging with little supplementation in a small-holder production system.

Keywords: *Chickens, Eggs, Environment, Exotic, and Genotype*

Introduction

In Ethiopia, traditional poultry plays a dominant role in total poultry production and represents an important part of the national economy (Fisseha *et al.*, 2010; Aberra and Tegene, 2011). Farmers, for whom it may be the only form of savings and their own consumption, raise most of the chickens under the traditional management system.

Family poultry production is the means of livelihood for the household and is one part of integrated and complementary farming activities that contribute. Family chickens were a source of income for households and produced meat and eggs for home consumption (Abdo *et al.,* 2016). Nonetheless, local chicken (more than 95% of the total) and exotic chicken strains (less than 5% of the total) face traditional chicken production policy and strategy challenges in developing countries (Addis et al., 2014). Further, local chicken provides a major income-generating activity from the sale of birds and

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eggs. Women can meet their household expenses because the income generated from live bird and egg sales is used and managed by women family chickens (Aklilu et al., 2007).

The African Chicken Genetic Gain project introduced some superior tropically adapted chicken breeds as a result of the low productivity of African indigenous chicken genotypes. Since management under station would be different from extensive management (on-farm), this project distributed those introduced breeds to small households to study genotype by environment interaction (G*E) as on-farm conditions. Then it tried to quantify the significant effect of G*E interaction on the performance of introduced chicken breeds. This is accomplished by estimating interaction effects for multiple breeds and environments. Knowing the magnitude of the G*E interaction effect under a particular production system could help to determine strategies that can reduce such problems (Mulder and Bijma, 2005; Nauta, 2009).

Identification of environmental factors and genotypes that could fit into specific agro-ecology would help producers to make an optimal decision regarding chicken production systems (Williams *et al.,* 2012). Indigenous chickens in Ethiopia are characterised by an average flock of six to ten mature birds per household, which lays only 30-60 eggs per hen per year. Those local chickens have got little to no additional inputs except shelter for the night (Solomon *et al.*, 2013). As a result, modern poultry production started in Ethiopia in the early 1950s, mainly in colleges and agricultural research stations (Avery, 2004). Such institutions introduced pure exotic chicken breeds into the country and distributed them to the farming population along with management. And also, some on-farm studies involving the crossing of local chickens with exotic cocks have been performed (Tadelle and Ogle, 2001). Moreover, the performance of local chickens and their crosses with exotic chicken breeds were evaluated in on-station experiments using controlled high and low environmental conditions (Aberra *et al.*, 2011). As a result of unreliable supply and high costs of acquiring and maintaining exotic breeding cocks, this programme was unsustainable (Tadelle *et al.,* 2000; Udo *et al.,* 2006).

Due to a possible G*E interaction effect, the results of pure exotic chicken and their crosses with local breeds observed on station site did not translate into a similar response under village conditions. Therefore, evaluation of different improved chicken breeds' performance under on-farm conditions at different agro-ecological zones is important to know the significance of G*E interaction. Because our chickens have low genetic potential, previous attempts at either introducing exotic chickens to be used on their own or crossbreeding failed due to poor adaptation and the need for continuous multiplication. The ACGG programme introduced tropically adapted and more productive strains that could be tested across the country's various agro-ecological zones. Five districts, namely Banja, Fagita Lekoma, South Achefer, Gonderzuriya, and Kalu district, were selected from Amhara regional state by the project. As variation in the environment affects the performance of the strains, it is important to know which chicken strains perform well in a certain environment.

Chicken production practise in the study area is a traditional type, just like a family based in which producers rear a small number of chickens. Production is for home consumption, with a small percentage and seasonal marketable surplus. Even if evaluation of G*E interaction is mandatory to know the significant effect of the environment on the performance of the introduced chicken breeds, studies involving those breeds are rare.

This study was carried out with the main objective of evaluating genotype by environment interactions on the egg production performance of introduced chickens under on-farm conditions in selected zones of the Amhara region.

Materials and Methods

Description of the Study Area

The study was carried out in the western part of Amhara regional state (i.e., in Awi and West Gojam zones). Three rural districts (Banja, Fagta Lekoma, and South Achefer districts) were selected to carry out this study.

Banja district is found one hundred twenty-two kilometres away from Bahir Dar, the regional city, and 447 kilometres away from Addis Ababa, the capital city of the country. It is bordered by Guanga district on the west side; by Fagta Lekoma district on the north side; by Guagusa Shikudad district on the east; and by Ankasha Guagusa district on the south. Its altitude is 2560 metres above sea level and its average annual rain fall score is about 1300 mm. The average annual temperature of the district reaches 18.5°C. The agro-ecology of the district falls under cool and humid. Teff, wheat, barley, finger millet, faba bean, field pea, and lupine are crops mainly grown in the area. In this district, around 64,014 cattle, 6,305 sheep, 4,009 goats, 1,420 donkeys, 23,465 horses, 1,811 mules, and 36,106 chickens are found (BDARO, 2017).

Fagta Lekoma district is located 98 kilos away from Bahir Dar and is bordered with Guanga district on the west, with Banja district on the south, and with West Gojjam Zone in the north and east directions. The elevation falls within the range of 1800 to 2800 metres above sea level. The district's average annual rainfall in the fall ranges from 2379 to 2768 millimeters, and the average temperature ranges from 11 to 25 degrees Celsius. This district is known to have two agro-climatic zones; cool and sub-humid regions were covered by 55% and 45%, respectively. Mixed agriculture is practised in all parts of the district. Teff, barley, wheat, faba bean, pea, and lupin are the main crops grown in the area. In this district, around 127,800 cattle, 59,853 sheep, 13,721 goats, 6,439 donkeys, 15,346 horses, 2,221 mules, and 134,376 chickens are found (FDARO, 2017).

Bahir Dar town is 60 kilometres away from Bahir Dar town. It is bounded to the north by North Achefer district, to the south and west by Awi zone, and to the east by Mecha districts. Its elevation ranges from 1,500 to 2,500 metres above sea level. The average annual rainfall ranges from 1365 to 1623 millimeters, and the average temperature ranges from 11.8 to 28.4 degrees Celsius. Mixed farming is practised in all parts of the district and by each of the households in the community. Maize, *teff*, finger millet, wheat, chickpea, beans, niger seed, and cabbage are the major crops grown in the district. About 221,167 cattle, 121,041 sheep and goats, 26,911 equines, 16,721 bee colonies, 166,974 chickens, and 16,684 other domestic animals are found (SDARO, 2017).

Evaluated Chicken Breeds

African chicken genetic gain project introduced four exotic chicken breeds (Koekoek, Kuroiler, Sasso, and S-RIR).

Sampling Method

In this study, three districts (one district from West Gojam zone and two districts from Awi zone) were selected purposively based on the availability of introduced chicken breed performance data from the ACGG project. Even if three *kebeles* (lower administrative unit of the country) were selected in each district during the ongoing on-farm study by the project, due to the absence of complete data, only eight *kebeles* were included in this study. During the project's on-farm evaluation, 32 households from each kebele were chosen, and each household received 25 six-week old chickens. The project started chicken distribution in August 2016 and finished data collection in January 2018.

Experimental Design

The study was conducted in the experiment carried out by the ACGG project, which selected four exotic chicken breeds which are adaptive to sub-Saharan African environmental conditions (Koekoek, Kuroiler, Sasso, and S-RIR). While delivering chicken breeds by the project, 32 households were selected from each *kebele* and out of them, 8 households took similar breeds, and each household received 25 similar breeds aged forty-two days of one breed. Each breed was randomly assigned to a household with a factorial arrangement in a completely randomised design (CRD) by taking *kebeles* as replication in each selected district. Two factors (breed and location) with a 43 factorial were used to evaluate the effect of G*E interaction on chicken production performance. All breed data was taken out of the selected *kebeles*.

Type and Methods of Data Collection

Quantitative data (number of eggs collected per week/chicken, age at first egg, HDEP starting at 20 weeks of age up to 72 weeks of age, and egg weight laid in each breed) were collected for the G*E interaction study. This data was secondary data and was used to design and implement a retrospective study. Agro ecology data and other environmental parameters such as temperature, altitude, rain fall, cultivated land and crops, and distance away from the centre of the town were considered for this study, and the information was obtained from the study district agriculture office.

Evaluation was done by taking group egg number data collected every two weeks starting from 20–72 weeks of age. Data was retrieved by categorising egg-laying stages into three categories: initial (20-32 weeks), peak (33-52 weeks), and declining (53-72 weeks). Also, the full period of 52 weeks of egg laying time data from 20-72 weeks was taken. This classification was undertook based on the statement stated by Prabakaran (2003) that the egg layer-type chicken starts egg laying at about 20 weeks of age and continues to lay at a good rate for another 52 weeks (a total of 72 weeks). Three variables (i.e., age at first egg, number of eggs per week/hen, and average egg weight) were taken from the source directly. whereas the total number of eggs per hen per year was also extrapolated by multiplying the average number of eggs/week/hen of the entire age range from 20 weeks to 72 weeks by 52. HDEP was determined by using the formula:

$$\% \text{ HDEP} = \Sigma \frac{\text{Numberofeggs laid inthatday}}{\text{Number of hens available inthatday}} * 100$$

Methods of Data Analysis

Before data entry for analysis, data cleaning was undertaken by using R software version 3.6.1 for the G*E study by giving a command to exclude the irrelevant data from the analysis. So, egg weight data scores of less than 30 and greater than 75 g were excluded from the analysis. All egg weight data in the South Achefer district was excluded from the analysis as a result of being above 75 and below 30 g. So, egg weight was evaluated only in two districts (i.e., Banja and Fagta Lekoma districts). Similarly, the number of eggs produced per week/hen data record above seven and the HDEP value above one were not considered in the analysis. Sasso-RIR in Fagta Lekoma and Sasso-Chicken in South Achefer districts had no egg performance data during the 20-32 week egg laying period. There was no egg number data for Koekoek chicken in all districts and Sasso in South Achefer district during the 53-72 week egg laying period from the data source. The growth performance of male Kuroilor chickens in Fagta Lekoma district was not evaluated due to the unavailability of its performance data in this area. Generally, all the necessary things were done during data clearing to be clear and relevant to evaluate genotype by environment interaction effects on exotic chicken.

The model applied for data analysis was a generalised linear model, and the software used was R software. The effects considered in the model were breed, location, and breed-location interaction. Multiple means comparison was conducted by using Tukey's Multiple Comparison Test. The model equation used during the analysis looks:

$y_{ijk} = \mu + a_i + b_j + (a \times b)_{ij} + e_{ijk}$ where

y_{ijk} = observation of k^{th} variable in the i^{th} breed and j^{th} district/location

a_i = effect due to i^{th} breed of chickens (Koekoek,Kuroiler, Sasso and S-RIR);

b_j = effect due to j^{th} district/location (Banja, FagtaLekoma and South Achefer district)

$(a \times b)_{ij}$ = effect due to interaction between i^{th} breed and j^{th} district/location;

e_{ijk} = random residual error where:

$\Sigma a_i = \Sigma b_j = \Sigma (a \times b)_{ij} = 0$

Results and Discussion

Effects of Breed, District and Their Interaction on Egg Number per Week/Hen

The least square means for the average egg number per week/hen in the consecutive egg laying phases of four chicken breeds across three districts are given in Table 1. Except from week 20-32, all egg production periods showed significant interaction effects between district and breed. This indicated the genetic sensitivity of those breeds to environmental factors for each trait in the study area. This result is consistent with the result obtained by Wondmeneh *et al* (2016), who conducted under on-station and on-farm conditions and stated that there was a significant effect of breed, location, and breed*location interactions on chicken production traits (p> 0.001).

The average egg number per week/hen was significantly different within the Fagta Lekoma district among breeds during the 20-32 and 20-72 week egg laying periods. As compared to other breeds, Sasso (3.80.1) scored the higher average egg number/week/hen and Koekoek and S-RIR scored an intermediate number of eggs during the full time study period. The current study result was agreed with the finding reported by Tadelle (2017) that Sasso (160 eggs/year/hen) and Kuroiler (154 eggs/year/hen) produced more eggs than indigenous chicken by 255 and 242% per year when egg production in the 23 weeks after the start of egg laying was extrapolated to 52 weeks of laying in Ethiopia. On the contrary, Habtie (2018) stated that S-RIR breeds laid a higher number of eggs per week than Koekoek, Kurioler, and Sasso at the 28^{th}, 36^{th}, and 44^{th} week egg laying points. Both in South Achefer and Banja district, there was no statistically significant average egg number per week/hen difference among breeds in all egg laying periods.

Only Koekoek during 20-32 weeks and Kuroiler during 33-52 weeks of the egg laying period had a significant average egg number per week/hen difference across districts. Koekoek dropped higher eggs in Fagta Lekoma (5.40.4) and South Achefer district (5.10.5) than in Banja at 20-32 weeks, and Kuroiler laid higher eggs/week/hen in Banja than in Fagta Lekoma district at 33-52 weeks of the egg laying period. At this period, the performance of Kuroiler in South Africa was intermediate. However, other breeds had no significant differences across districts during all phases of the egg laying period.

And also, the present study noted the significantly highest total collected eggs/year in Koekoek (215) in South Achefer and the lowest in Kuroilor (133) in Fagta Lekoma district as compared with the other interactions. The superior performance achieved by Koekoek in South Achefer seems to be attributed to it being favoured and adapted to the South Achefer environment over the other breeds, and the lowest performance of Kuroilor in Fagta Lekoma indicated it was difficult to adapt to the situation found in the district as the other breeds could. The current study result is comparable with the finding of Tadelle and Fasil (2016), who noted that the Koekoek breed produces 196 eggs/hen/year. Desalew (2012) also noted a comparable result, that the Koekoek breed yields 187.04 eggs/hen/year. On the other hand, the total collected eggs/year of this study was higher than Adami-Tulu research centre (159.910.7) as Tesfa *et al* (2013) reported; the watershed area of North Ethiopia (144 6.97) as Abraham and Yayneshet (2010) reported; and then at Chittagong Government Veterinary College, Pahatali (140.7) as Khan *et al* (2006) reported. And also, the current result was higher than the result reported by Serkalem *et al.*(2018) as annual egg production of local chicken, Sasso, Bovans brown, and Koekoek were 53.7 10.8, 137 20.2, 144 20.0, and 148 29.0, respectively at mid-land agro-ecology.

The interaction pattern on egg production per week/hen was depicted in Figure 2. In the figure, the number of eggs/week/hen of Koekoek increased sharply from Banja to Fagta Lekoma district and continued in the same pattern in South Achefer district during the full time egg laying period. On the other hand, Kuroiler reduced its egg production sharply in Fagta Lekoma and increased in a slow manner in the South Achefer district. From this interaction combination, Koekoek was favoured in South Achefer and Fagta Lekoma than in Banja, whereas Kuroiler was favoured in Banja more than the other two districts. Besides, Sasso slightly increased its performance in Fagta Lekoma and South Achefer than in Banja, while S-RIR decreased from Banja to Fagta Lekoma and South Achefer. From

this interaction combination, it is possible to conclude that S-RIR was favoured in Banja and Sasso in Fagta, Lekoma, and South Achefer districts.

Table 1: Least square mean (± SE) of number of eggs/week/hen in different egg laying period

Egg laying period	Breed	District			Sources of variation		
		Banja	Fagta Lekoma	South Achefer	Breed	District	District* Breed
20-32	Koekoek	3.5^{j} ±0.6	5.4^{ai}±0.4	5.1^{i}±0.4	<0.001	<0.001	0.07976
	Kuroiler	3.0 ±2.4	NA	4.4±1.1			
	S-RIR	2.7±1.4	NA	3±1.1			
	Sasso	2.6±0.4	3.4^{b}±0.3	NA			
33-52	Koekoek	3.2±0.2	3.3±0.1	3.5±0.3	0.21030	<0.001	<0.01
	Kuroiler	3.8^{i}±0.1	2.7^{j}±0.1	3^{ij}±0.6			
	S-RIR	3.8±0.1	3.2±0.1	4.1±0.4			
	Sasso	3.3±0.1	3.2±0.1	3.2±0.3			
53-72	Kuroiler	2.9±0.1	2.3±0.1	2.5±0.3	0.08796	0.29487	<0.001
	S-RIR	2.6±0.1	3.0±0.1	2.4±0.3			
	Sasso	2.7±0.3	1.6±0.4	NA			
20-72	Koekoek	3.3±0.2	3.8^{ab}±0.1	4.1±0.2	<0.001	0.0799	<0.001
	Kuroiler	3.4±0.1	2.6^{b}±0.1	2.8±0.3			
	S-RIR	3.2±0.1	3.1^{ab}±0.1	2.9±0.2			
	Sasso	3.1±0.1	3.1^{a}±0.1	3.2±0.3			
TEC/year /hen						over all mean	
	Koekoek	160	198	215	194		
	Kuroiler	174	133	146	151		
	S-RIR	168	163	150	160		
	Sasso	163	163	165	164		

Super scripts ^{abcd}= among breeds, ^{ijk}=among districts comparison during each egg laying period, TEC= Total Collected Eggs, NA= Not Available

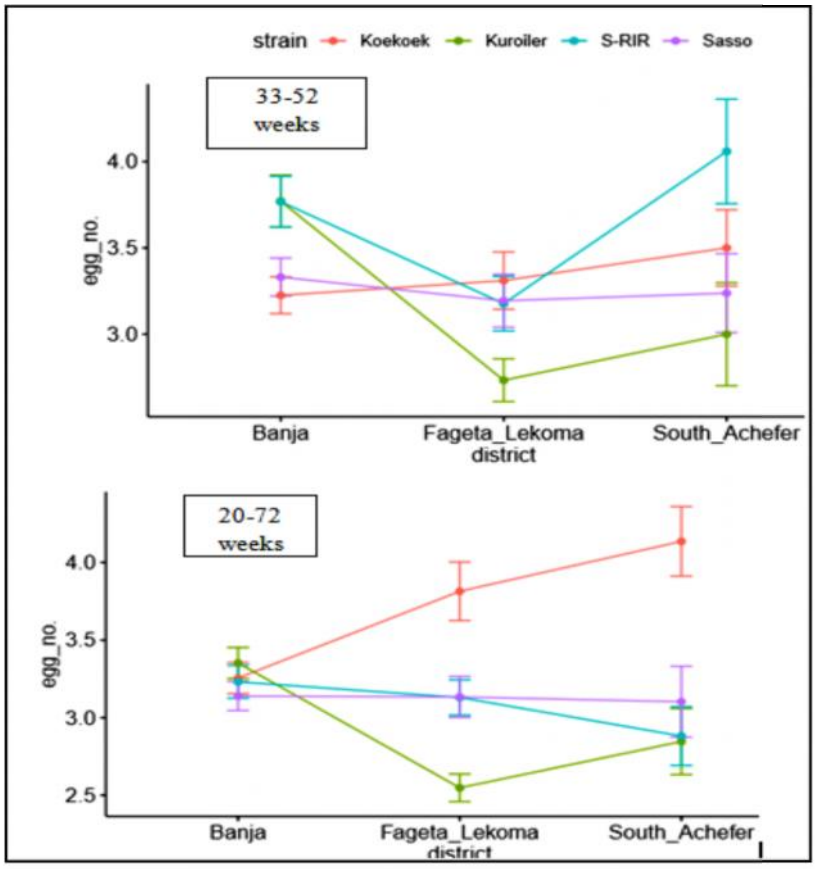

Figure 1: Interaction pattern of average number of eggs/week/hen during the peak and full egg laying periods

During the peak period of the egg laying stage of 33–52 weeks, S-RIR decreased its egg laying in Fagta Lekoma but increased sharply in the South Achefer district. On the other hand, Koekoek increased in a shallow manner from Banja to Fagta Lekoma and to South Achefer district. This implies that S-RIR was favoured in Banja and South Achefer than in Fagta Lekoma and the highest performance was encountered by this breed in the South Achefer district as compared with the other combinations. Kuroiler, on the other hand, was the least performer in the Fagta Lekoma district from these interaction combinations.

Effect of Breed, District and Their Interaction on Age at First Egg Trait

Least square mean of average age at first egg for four chicken breeds across districts is presented in Table 2. All source of variation (district, breed and district*breed interaction) had highly significant effect on age at first egg. The current result finding is supported by the findings conducted by Alem (2014) that stated breed and environment had significant effect (P<0.05) on sexual maturity of chicken performance.

From Banja district Sasso (179±7) and Koekoek (197±10) laid the first egg earlier followed by Kuroiler and S-RIR was late. This finding agreed with the result of Serkalem *et al* (2018) that stated the Sasso chickens reared at Boricha district in Sidama zone of southern Ethiopia had a shorter age at maturity when compared to the other exotic chicken genotypes. The observations may be partly explained by their enhanced adaptability to the studied agro ecologies, thereby favoring them over the other genotypes of chickens included in this study. Koekoek (155) started egg laying earlier followed by Kuroiler and S-RIR. Whereas, Sasso (239) took longest time to reach sexual maturity and drop the first egg in South Achefer district. The current study result was incomparable with the result obtained by Chali (2018) indicated that SasoT44 (157.58) pullets laid egg earlier age than Koekoek (163.66) and Dominant Red Barred (181.33) under farmers management. And also, the current result is much higher than the findings of Wondmeneh *et al* (2016) conducted in Ada district that commercial layers, crossbred and improved chickens started egg laying at 146.5±0.83, 155.5±0.35 and 159.5±0.59 days of age respectively.

To compare average age at first egg among districts, all breeds except Sasso took longer time to start egg laying in Banja district. Koekoek and Sasso in South Achefer district showed the lowest and highest age at first egg.

Table 2: (LSM± SE) of chicken age at first egg (in days)

Breed	District			Sources of variation		
	Banja	Fagta Lekoma	South Achefer	Breed	District	District* Breed
Koekoek	197^{ci}±10	173^{ij}±3	155^{cj}	<0.001	<0.001	<0.001
Kuroiler	225^{bi}±3	198^{j}±3	202^{bj}±5			
S-RIR	226^{ai}±4	198^{j}±5	192^{bj}±8			
Sasso	179^{cij}±7	190^{j}±4	239^{ai}			

Super scripts ^{abcd} = among breeds, ^{ijk}=among districts comparison

The least square mean of the average age at first egg for four chicken breeds across districts is presented in Table 2. All sources of variation (district, breed, and district*breed interaction) had a highly significant effect on the age at first egg. The current finding is supported by Alem's (2014) findings, which stated that breed and environment had significant effects (P 0.05) on sexual maturity of chicken performance.

The age at which a hen begins to lay eggs affects the total egg production in its life cycle. The interaction effect pattern on average age at first egg is presented in Figure 3. It showed that the age of all breeds except Sasso was significantly decreased in Fagta Lekoma however Koekoek continued in a decrement direction where as Sasso age at first egg became much higher in South Achefer district than Banja. On the other hand Koekoek decreased from Banja to Fagta Lekoma and highly reduced in South Achefer district. From this interaction Koekoek in South Achefer was the earliest age at first egg. This implies that Koekoek was highly favored in South Achefer than Banja and Fagta Lekoma district. And also average age at first egg of S-RIR was increased in Banja and decreased in

Fagta Lekoma district that indicated it was favored in Fagta Lekoma and South Achefer districts than Banja. Koekoek was also favored in South Achefer district.

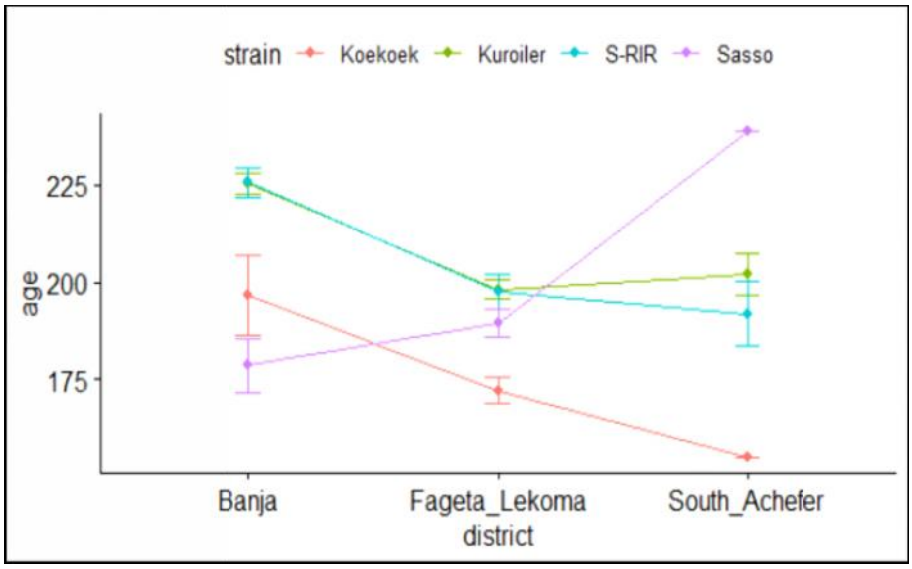

Figure 2: Interaction pattern of age at first egg in the study area

Effect of Breed, District and Their Interaction on HDEP

The least square means for HDEP of the egg laying period for four introduced chicken breeds across two districts (Banja and Fagta Lekoma) are given in Table 3. Except for the egg laying period from 53-72 weeks, all phases had no significant breed*district interaction effect. According to the findings of this study, breed and district had a significant impact on HDEP at all stages of the egg laying period except the 20-32 week egg laying period.

During the egg laying period of 33–52 weeks, both Kuroilor and S-RIR scored higher HDEP than Koekoek and Sasso in Banja district. In this period, Kuroiler and Koekoek laid with the highest and lowest rates of lay, respectively, in Fagta Lekoma district. In this district, HDEP of S-RIR was higher than in Sasso and also in Kuroiler, HDEP was intermediate during the 53-72 week egg-laying period. Higher HDEP in Kuroilor and S-RIR over the other breeds in both Banja and Fagta Lekoma districts during 33-52 weeks and S-RIR in Fagta Lekoma during 53-72 weeks. This result indicated that those breeds had greater adaptive ability than the other breeds and were favoured by the area. The current result is agreed with the finding revealed by Dawud (2019) that the commercial layer differed in % lay, especially during the 25-32 age in weeks, with Novogen Brown leading with an average of 67.4 %, followed by Novogen Color (60.4%), while Dominant Sussex (47.2%) was the lowest, whereas Lohmann Brown Classic, Koekoek, and Dominant Red Barred were intermediate with an average of 51% lay during the 25-32 age in weeks.

During the 33-52 week egg laying period and the full study time, all breeds scored higher HDEP in Banja than in Fagta Lekoma district. The value scored in all breeds was agreed with the result of Kassa and Saba (2016), who reported that Koekoek laid eggs with a 52% laying rate during the first phase of production (45 weeks of age) but that it grew to 79.4% in the case of the peak production stage in Jimma zone, southern Ethiopia under farmers' management. On the other hand, the current result is lower than the previous result reported by Birhan *et al*. (2021) in the current study area where the highest and lowest hen-day egg production percentage were recorded for Sasso (94.175.97) and Kuroiler (92.947.62) in South Achefer and for Kuroiler (94.244.82) in Banja districts at week 36 and for Sasso (57.215.08) in Fagita Lekoma district at week 44, respectively. The implication of lower HDEP in this study could be that the current study evaluated HDEP by classifying egg laying periods by phases instead of age points.

Table 3 also showed that all breeds showed a significant increment in HDEP from Banja to Fagta Lekoma district. But there was no breed that showed a significant HDEP reduction from Banja to Fagta Lekoma district during all the egg laying period. Based on this, it is possible to conclude that all breeds are preferred in the Fagta Lekoma district over Banja during all stages of egg laying.

Table 3:(LSM ± SE) of HDEP at different egg laying phases

Traits	Breed	District		Sources of variation		
		Banja	Fagta Lekoma	Breed	District	Breed*District
20-32	Koekoek	58±6	65±4	0.1853	0.3782	0.0808
	Sasso	76±4	67±3			
33-52	Koekoek	72^{bi}±2	51^{cj}±2	<0.001	<0.001	0.552
	Kuroiler	82^{ai}±2	69^{aj}±2			
	S-RIR	84^{ai}±2	66^{abj}±2			
	Sasso	73^{bi}±2	58^{bcj}±2			
53-72	Kuroiler	73^{i}±2	58^{abj}±3	<0.05	<0.001	<0.05
	S-RIR	68±2	63^{a}±2			
	Sasso	64^{i}±5	36^{bj}±8			
20-72	Koekoek	70^{abi}±2	54^{bj}±2	<0.001	<0.001	0.786
	Kuroiler	79^{ai}±2	64^{aj}±2			
	S-RIR	77^{abi}±2	65^{aj}±2			
	Sasso	72^{bi}±2	58^{abj}±2			

Super scripts ^{abcd}= among breeds, ^{ij}= between districts comparison during each egg laying period

Effect of Breed, District and their Interaction on Egg Weight

The least square means for average egg weight in the consecutive egg laying phases of four introduced chicken breeds across three districts are given in Table 4. Except during the 20-32 week period, at all phases, district*breed interaction effects weren't significant. However, the district showed significant differences during all phases except during the 20-32 week egg laying time. The breed also showed a significant difference during 20-32 and 33-52 weeks of egg laying time.

To compare the least square means of egg weight of four breeds with in Banja, the lightest average egg weight was recorded in S-RIR (510.4g) hens among Koekoek(540.5g) and Sasso (540.5g), but also Kuroilor (52.30.5g) dropped intermediate weighed eggs during 33-52 week egg laying time. This result was similar to that with egg weight for Lohmann (60.1g), which was reported by Jana *et al.* (2014) and for Lohmann Silver (52.9g) by Dawud *et al.* (2011). Desalew *et al.* (2015) also reported a lower egg weight for Koekoek (47.8g) than this finding with similar age periods. However, during the other laying period, all breeds laid statistically similar weighed eggs in the Banja district.

Within the Fagta Lekoma district, all breeds dropped similar weighted eggs during the 53-72 and 20-72 week egg laying periods. During the 20-32 and 33-52 week laying periods, both the Koekoek (550.6g) and Sasso (560.5g) breeds laid lighter eggs than the Kuroiler (550.5g) and S-RIR (530.5g). The results of this study agreed with the result of Gutu *et al.* (2021) who stated the average egg weight for Sasso at 28, 32, 36, 40, and 44 weeks was 48.0, 51.0, 52.7, 60.6, and 55.7 grammes respectively. The findings of Yonas *et al.* (2019) also supported the current finding by giving a conclusion stating that egg weight varied among breeds and also within breeds (among locations) in which local chicken eggs weighed 45.205.53 and 39.304.04 g, while Sasso eggs weighed 56.407.07 and 56.007.2 g, whereas Bovans brown eggs weighed 57.807.22 and 60.705.98 g at Hawassa and Yirgalem towns, respectively.

With regard to district comparison Kuroilor and Sasso chickens laid heavier eggs in Fagta Lekoma district, but there was no district difference in egg weight of Koekoek and S-RIR during the egg laying period of 33-52 weeks. Except Koekoek chicken, which laid similar weighed eggs in both districts, all breeds exhibited higher egg weight in Fagta Lekoma than in Banja district during 20-72 week egg laying time. The implication of higher egg weight exhibited in Fagta Lekoma district could be favourable environmental conditions and proper provision of supplementary feed in a regular manner, which could be a factor for high egg weight. The current result also showed a significant egg weight increment in Kuroiler and Sasso during the 33-52 and 20-72 week periods from Banja compared to

Fagta Lekoma district. And also, the egg weight of Koekoek and S-RIR was increased in Fagta Lekoma district compared to Banja. However, no decrease in egg weight was observed in all breeds when looking from Banja to Fagta in the Lekoma district during all phases of the egg laying period. This implies that all the above described breeds were favoured in the Fagta Lekoma district than Banja, which means that there was no specific selective breeding for a specific district.

Table 4: Least square mean (± SE) of egg weight (g) in different egg production period

Traits	Breed	District		Sources of variation		
		Banja	Fagta Lekoma	Breed	District	District*Breed
20-32	Koekoek	50±1.6	54^{b}±1.3	<0.001	0.10012	<0.01
	Kuroiler	50±6.3	72^{a}±2.8			
	S-RIR	67±6.3	69^{a}±3.6			
	Sasso	53±1.2	52^{b}±1.0			
33-52	Koekoek	54^{a}±0.5	54^{b}±1.3	<0.001	<0.001	0.178
	Kuroiler	52^{abj}±0.5	72^{ai}±2.8			
	S-RIR	51^{b}±0.4	69^{a}±3.6			
	Sasso	54^{aj}±0.5	52^{bi}±1.0			
53-72	Kuroiler	54±0.5	55±0.5	0.2807	<0.001	0.0813
	S-RIR	53^{j}±0.5	57^{i}±0.6			
	Sasso	53±1.0	52±3.1			
20-72	Koekoek	53±0.5	55±0.6	0.070	<0.001	0.9721
	Kuroiler	53^{j}±0.3	55^{i}±0.4			
	S-RIR	52^{j}±0.3	55^{i}±0.4			
	Sasso	53^{j}±0.4	55^{i}±0.4			

Super scripts ^{abcd} = among breeds, ^{ij}= between districts comparison during each egg laying period

Conclusion

The current study found that G x E interactions had a significant effect on egg number and age at first egg traits but had no effect on HDEP and egg weight traits. The present study noted the significantly highest total collected eggs/year by Koekoek (215) in South Achefer, both Kuroiler (174) and S-RIR (168) in Banja district. All breeds except Sasso took a longer time to start egg laying in the Banja district. Koekoek and Sasso in the South Achefer district showed the lowest and highest age at first egg. Except Koekoek chicken, which laid similar weighed eggs in both districts, all breeds exhibited higher egg weight in Fagta Lekoma than in Banja district during 20-72 week egg laying time. Based on this result, Koekoek was recommended for South Achefer and both Kuroiler and S-RIR for Banja district to enhance egg production at scavenging with little supplementation of small-holder production systems of the study area and similar environments.

Conflict of Interest

The authors declare that there is no conflict of interest.

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