



**EVALUATION OF GENOTYPE BY ENVIRONMENT INTERACTIONS ON
GROWTH AND EGG PRODUCTION TRAITS OF TROPICALLY ADAPTED
CHICKEN BREEDS UNDER SMALLHOLDER PRODUCTION SYSTEMS IN TWO
DISTRICTS OF TIGRAY REGIONAL STATE, ETHIOPIA**

MSc THESIS

BISRAT TSEGAYE TEKLU

HAWASSA UNIVERSITY

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EVALUATION OF GENOTYPE BY ENVIRONMENT INTERACTIONS ON GROWTH
AND EGG PRODUCTION TRAITS OF TROPICALLY ADAPTED CHICKEN BREEDS
UNDER SMALLHOLDER PRODUCTION SYSTEMS IN TWO DISTRICTS OF TIGRAY
REGIONAL STATE, ETHIOPIA

BISRAT TSEGAYE TEKLU

MAJOR ADVISER: PROF. ABERRA MELESSE (PhD)

CO-ADVISER: DR. TADELLE DESSIE (PhD) AND DR. WONDMENEH ESATU (PhD)

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The thesis entitled “**Evaluation of Genotype by Environment Interactions on Growth and Egg Production Traits of Tropically Adapted Chicken Breeds under Smallholder Production Systems in Two Districts of Tigray Regional State, Ethiopia**” will be approved by School of Animal and Range Sciences for partial fulfillment of the Degree of Master of Science in Animal and Range Sciences (Specialization: Animal Breeding and Genetics).

Submitted by:

Bisrat Tsegaye _____

Student Name Signature Date

Prof. Aberra Melesse (PhD) _____

Name of Major Advisor Signature Date

Dr. Tadelle Dessie (PhD) _____

Dr. Wondmeneh Esatu (PhD) _____

Name of Co-advisors Signature Date

School head Signature Date

SGS Coordinator Signature Date

EXAMINER’S APPROVAL SHEET-II
SCHOOL OF GRADUATE STUDIES
HAWASSA UNIVERSITY EXAMINER’S APPROVAL SHEET-2
(Submission sheet-3)

As members of the Board of Examiners of the final Master’s degree open defense, we certify that we have read and evaluate the thesis prepared by Bisrat Tsegaye Teklu under the title **“Evaluation of Genotype by Environment Interactions on Growth and Egg Production Traits of Tropically Adapted Chicken Breeds under Smallholder Production Systems in Two Districts of Tigray Regional State, Ethiopia”**, and recommended that it be accepted as fulfilling the thesis requirements for the degree of Master of science in school of animal and Range sciences with specialization animal Breeding and Genetics.

Name of Internal Examiner-I	Signature	Date
Name of Internal Examiner-II	Signature	Date
Major Advisor	Signature	Date
(DGS/SGC)	Signature	Date
SGS	Signature	Date

Signature and stamp of the Department/School

Signature and stamp of SGS

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DEDICATION

I dedicate this thesis manuscript to my father, Tsegaye Teklu and my mother Atsede G/Micheal, who passed away without seeing any of my achievements.

DECLARATION

I hereby declare that this MSc thesis is my original work and has not been presented for a degree in any other university and all sources of materials used for this thesis have been duly acknowledged.

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Signature: _____

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Name: _____

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ABBREVIATIONS

ACGG	African Chicken Genetic Gain
ADG	Average Daily Gain
AEW	Average Egg Weight
AEZ	Agro Ecological Zone
AFE	Age at First Egg
ANOVA	Analysis of Variance
BMGF	Bill and Melinda Gates foundation
BOARD	Bureau of Agriculture and Rural Development
CSA	Central Statistics Agency
DZARC	Debre Ziet Agricultural Research Center
FAO	Food and Agriculture Organization of the United Nations
GEI	Genotype by Environment interaction
GLM	General Linear Model
HDEP	Hen Day Egg Production
HHEP	Hen Housed Egg Production
ILRI	International Livestock Research Institute
MASL	Meters Above Sea Level
MOARD	Ministry of Agriculture and Rural Development
SD	Standard deviation
SNNPS	Southern Nations Nationalities and Peoples Region
S-RIR	Sasso-RIR
USAID	United States Agency for International Development

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Evaluation of Genotype by Environment Interactions on Growth and Egg Production Traits of
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Bisrat Tsegaye Teklu

Major adviser: Prof. Aberra Melesse (PhD)

Co-adviser: Dr. Tadelle Dessie (PhD) and Dr. Wondmeneh Esatu (PhD)

ABSTRACT

The aim of the study was to evaluate genotype by environment interactions (GEI) on growth and egg production traits of tropically adapted chicken breeds under smallholder production systems. The study was conducted in Kelte-Awlaelo and Seharti-Samre districts of eastern and south eastern zones of Tigray region, Ethiopia. Improved Horro, Kuroiler, Koekoek, Sasso and S-RIR chickens were used as experimental animals. Two Villages per district were purposively selected. From each Village, 40 households (HHs) were involved in the experiment and each HHs received 25 birds of a randomly selected breeds. The data were analyzed using the GLM procedure of R v.3.6.1 running on RStudio version 1.2.5001. Sasso chickens had higher ($P < 0.001$) weight at 90, 120 and 150 days while, Kuroiler were superior ($P < 0.001$) at 180 days and ADG than the other breeds. District significantly ($P < 0.05$) affected the body weight of chickens only at certain ages. Male chickens performed better ($P < 0.05$) than females across all ages. Among the male chickens, Kokekoek and Horro were inferior ($P < 0.05$) in body weight at all ages. Sasso and S-RIR chickens reared in Seharti-Samre district performed better ($P < 0.001$) than Kelte-Awlaelo in most of the body weight measurements. Koekoek chicken had higher ($P < 0.001$) HDEP% to 30 weeks as compared to Horro and Sasso chickens reared in Kelte-Awlaelo district. Except for S-RIR, Horro chicken had higher ($P < 0.05$) HHEP% to 30 weeks than the rest breeds reared in Saharti-Samre district. Sasso chickens had lower ($P < 0.05$) mean AFE as compared with the other breeds reared in Kelte-Awlaelo district. Chickens reared in Kelte-Awlaelo district were superior ($P < 0.001$) than those in Seharti-Samre on egg production traits. Except for Sasso and Horro all chicken breeds attained earlier maturity in Seharti-Samre district than in Kelte-Awlaelo. All chicken breeds had higher ($P < 0.01$) HDEP% and HHEP% (except S-RIR) to 30 weeks in Kelte-Awlaelo district than Saharti-Samre. Significant difference was observed for breed by environment/district interaction on the studied growth and egg production traits. The three-way interactions between breed, district and sex factors were found to be significant only for the growth trait of ADG. Sasso followed by Kuroiler breeds are the best options to improve meat productivity of both districts, while Koekoek and S-RIR are preferable breeds to enhance egg productivity in Kelte-Awlaelo and Seharti-Samre districts, respectively.

Key words: Age at first egg, Egg weight, Growth trait, Hen-day and hen-housed egg production

1. INTRODUCTION

Per capita consumption of animal products in developing countries is still meaningfully lower than in the developed world but there is significant potential for increasing per capita consumption of livestock products in these regions (FAO, 2009). Poultry is an important source of animal protein, which can be raised almost in every country around the world with limited feed and housing resources (FAO, 2010) and it may act as “starters” in a development practice in contrast to larger animals (Dolberg, 2001). Worldwide more than 300 breeds of the domestic chicken species exist, that can ‘convert’ a scavenged feed resource base into animal protein (FAO, 2010).

Indigenous chicken breeds which make up to 90% of the total poultry population in developing countries contribute significantly to poultry meat and egg production and consumption (Besbes, 2009). Smallholder poultry production affects the livelihoods of the majority of the rural population in most developing countries, and its role as a nutritional resource cannot easily be substituted by other kinds of animal production (FAO, 2010), economically as starter capital, as source of income, as means to recover from disasters and nutritionally as protein source and for other socio-culturally and spiritual purposes (Asgedom, 2007). Meat and egg from scavenging chicken present one of the most environmentally efficient sources of protein for village production systems (Melesse, 2017).

In Ethiopia, village poultry production system is characterized by no or few inputs and a low output level, chicken mortality at early ages and plays a major role in rural household economy, providing ready available protein (Tadelle, 2003) and contribute to 98.5% and 99.2% of the national egg and chicken meat production, respectively (Aleme and Mitiku,

2015). The overall chicken population of the country is estimated to be 48.96 million and out of these, 81.71% are indigenous, 10.86% hybrid and 7.43% exotic chicken (CSA, 2020). Similarly, in Tigray Region there are about 6.32 million chickens of which 67% indigenous, 11.4% hybrid and 21.6% exotic and accounts 12.52% of the total national indigenous chicken populations which contribute 15% of the total annual national egg and poultry meat production (CSA, 2020). Demeke (2008) indicated that the rural areas constitute about 81% of the total regional chicken population while the urban areas constitute 19%.

According to Addisu (2013) even though indigenous chickens have many desirable features, they have low production and reproductive performance. Matawork (2016) indicated that because of the low production performance of indigenous chicken (36 to 60 eggs per year per hen with an average weight of 38g), exotic chicken has been introduced to rural settings of the country. Alemneh and Getabalew (2019) reported that due to the fact that the smallholder production system is dominant, the contribution of exotic chicken to the Ethiopian economy is still significantly lower as compared to the other African countries. Because of negative genotype by environment interaction most of the time imported exotic chicken breeds performed below expected (Lozano-Jaramillo *et al.*, 2019).

Additional genetic gain does not necessarily mean additional profit (Lin and Togashi, 2002). In the environment where the smallholder production system is dominant, genetic and environmental variation can be large (Dri *et al.*, 2007), and this large variation causes the loss of productivity due to genotype by environment interaction (Montaldo, 2001). Since the possibility of adjusting the environmental conditions to the requirements for the preferred breed is very low (Mathur, 2003) and hence, availability of appropriate breed is significant for the development of smallholder poultry (Bamidele *et al.*, 2020).

If GEI exists, it is very important to inform the smallholder farmers about which breed performs best in which part of Ethiopia (Kinderen *et al.*, 2020). Thus, the adaptability and economic importance of newly placed populations should be assessed (Montaldo, 2001). The adaptability of particular breeds to particular environments can be determined by the interaction effects between breed and location (Dunlop, 1962). Zaman *et al.* (2004) reported that due to the fact that GEI commonly exists in the environment where the smallholder production system is dominant, the egg production performance of new chicken breeds should be assessed at different locations. Similarly, Dri *et al.* (2007) reported the existence of GEI on growth traits between the selection and production environments. According to Lozano-Jaramillo *et al.* (2019) environmental variables have strong influence on body weights across ages of the imported tropically dual-purpose chicken breeds. Tropically adapted dual-purpose exotic chicken breeds particularly Koekoek, Kuroiler, Sasso, S-RIR and the improved local Horro were introduced to selected districts of Tigray region under smallholder production systems by African chicken genetic gain (ACGG) project. For future chicken dissemination, performance testing under different environmental conditions is important, so it is essential to evaluate the effect of GEI on growth and egg production performance traits in the study areas.

1.1. General Objective

To evaluate the genotype by environment interactions on growth and egg production traits of tropically adapted chicken breeds under smallholder production systems in two districts of Tigray region.

1.2. Specific Objectives

- To evaluate growth and egg production performance of different chicken breeds under farmers' management conditions in the two districts.
- To determine the interaction effects of breed by district on egg traits and the interaction effects of breed, district and sex factors on growth traits of tropically adapted chicken breeds.

1.3. Hypothesis

Question: was there any difference in growth and egg production performance among the five chicken breeds in which they were introduced?

HO1= There is no any significant difference in Growth and egg production performance among the five chicken breeds

HO2= GEI have not any effect on the production performance of the different chicken breeds and sex of the breed has not also any effect on production performance.

2. LITERATURE REVIEW

2.1. Productive Performance of Chickens

In scavenging chicken production systems, growth and egg production performance traits plays a significant role in the household economy (Dana *et al.*, 2010). According to Yakubu *et al.* (2019) in selecting breeding stock, body size, egg number, egg size, and meat taste are reported to be traits of economic importance that appeared constantly. A study conducted by Teshome (2018) in southwest Ethiopia indicates that egg production, body weight and adaptability are the 1st, 2nd and 3rd preferred traits by farmers across all agro-ecologies. According to Jacob *et al.* (2014) egg production can be affected by different environmental factors like feed consumption (quality and quantity), water intake, intensity and duration of light received, parasite infestation, diseases, and management practices.

2.1.1. Production performance of indigenous chickens

Indigenous chicken breeds show lower advantage in growth and egg production traits as compared to the exotic chickens in both lowland and midland agro-ecologies (Assefa *et al.*, 2018). Despite their low production performance, the products (meat and egg) of indigenous chickens are much preferred by the consumers and make additional prices compared with commercial breeds (Gueye, 1998). A study conducted by Matawork *et al.* (2019) in Gena Bossa District of Dawro Zone indicated that productive and reproductive performance of indigenous chickens under smallholder management condition is low, which needs improvement both on their management (disease control, housing and feeding) and genetic potential through selection and cross breeding.

Indigenous chickens are characterized by small sized eggs, slow growth rate, late maturity, longer age at first mating, small clutch size, extended brooding period and high mortality of chicks (Addisu, 2013).

2.1.1.1. Egg production performance of indigenous chickens

Under farmer's management condition, annual egg production performance of indigenous chickens per hen is 60, 53 and 54 for Bure, Fogera and Dale districts, respectively (*Fisseha et al.*, 2010). According to Assefa et al. (2018) the annual egg production performance, age at first egg (AFE), number of eggs/clutch and length of clutch of local chicken is reported to be 54 eggs, 252 days, 14 eggs and 29 days respectively, in midland agroecology at Sidama southern Ethiopia. Wondmeneh *et al.* (2015) also reported, improved local Horro breed can produce up to 171 and 149 eggs per year under on-station and on farm performance evaluation, respectively. According to Fasil *et al.* (2016) the egg production traits HHEP percentage of improved Horro breed (8th generation) is reported to be 48.7 and 43.46% on station and farm levels, respectively. According to Dana *et al.* (2010) and Tadesse (2014) the AFE for the Horro chicken is reported to be on average 190 days. While, Aman *et al.* (2017) reported 217 days AFE for local breeds. Another study by Matawork (2016) indicates that the average egg weight (AEW) of local chicken is 38g under village management conditions.

2.1.1.2. Growth performance of indigenous chickens

Meat production potential of indigenous chickens is limited and is measured based on growth performance (FAO, 2010). Growth rate of the indigenous chicken is low, with an adult females weighing about 1kg and males seldom more than 2kg (Gueye, 1998). The live weights for matured male and female indigenous chickens at farm gate is 1.58kg and 1.30kg,

respectively (Gebre-Egziabher, 2007). The live weight of local male chickens at 6 months of age is reported to be 1.5kg and for female chickens is about 30% less (Bogale, 2008). Indigenous male chickens are heavier and taller than females and body weights of adult male range from 1411 (Konso) to 1700 g/bird (Horro) and female chicken from 1011 (Konso) to 1517 g/bird (Sheka) (Dana *et al.*, 2010). The body weight at 20 weeks of age for improved and unimproved female Horro chicken is reported to be 964g and 685g on station respectively, (Fasil *et al.*, 2016). In Ethiopia, the average weight of female Horro chicken is reported to be 56.3%, 46.2%, 44.6% and 52.4% of the weight of Koekoek, Kuroiler, Sasso and S-RIR, respectively (Solomon *et al.*, 2019).

2.1.2. Production performance of exotic chickens

Assefa *et al.* (2018) indicates that exotic chicken breeds show a superior advantage over the indigenous chickens in egg production traits as well as body weight in both lowland and midland agro-ecologies. Matawork (2016) reported that although management problems involved in rearing poultry, the exotic breed chickens are appreciated for their more egg and meat production. A study conducted by Mekonnen *et al.* (2017) and Getu *et al.* (2017) reveals that exotic chicken breeds show better production performance under the existing smallholder management systems.

2.1.2.1. Egg production performance of exotic chickens

According to Assefa *et al.* (2018) the average number of eggs per hen per year for Sasso breed is reported to be 134 under farmer production system. Dessie (2017) reported 110 eggs per year for Koekoek chicken while 180-240 reported by Shumuye *et al.* (2018) for the same breed.

Arega (2019) reported that the age at first egg for Kuroiler, Sasso, Sasso RIR and Koekoek is reported to be 6, 5.9, 5.7 and 6 months respectively, while 4.7, 5.5 and 6 months for White leghorn, Rhode Island Red and Koekoek is reported by Getu *et al.* (2017), in their respective order. Similarly, the studies conducted by Biratu and Hailu (2018), Shumuye *et al.* (2018) and Desalew (2012) has revealed the age first egg of the Koekoek chicken breed is to be 220, 180 and 153.57 days, in their respective order.

According to Arega (2019) hen-day egg Production percentage (HDEP%) at 36 weeks of age is reported to be 83, 72, 95 and 80% for Kuroiler, Sasso, Sasso RIR and Koekoek respectively, and the hen-housed egg Production (HHEP%) at 36 weeks of age is to be 69, 65, 87 and 74% in their respective order. Similarly, Yakubu *et al.* (2007) has indicated the percentage of hen-housed egg production at 27 weeks for Lohmann Brown and Bovans Brown is to be 74.5% and 68.72%, respectively. Arega (2019) has revealed the AEW for Sasso, Kuroiler, Koekoek and S-RIR at 32 weeks is 53g, 52g, 52g and 51g respectively, while 49g, 59g and 60g is reported by Desalew (2012) for Koekoek, Isa brown and Bovans Brown in their respective order. According to Yakubu *et al.* (2007) the AEW at 27 weeks of age for Lohmann Brown and Bovans Brown is reported to be 53.70g and 52.43g in their respective order.

2.1.2.2. Growth performance of exotic chickens

According to Dessie (2017) in Ethiopia, male chickens of Kuroiler, Koekoek, Sasso and S-RIR achieved higher body weight and ADG than nationally reported figures for indigenous chicken. Yakubu *et al.* (2007) reported that 1.75 and 1.69kg body weight at 27 weeks of age for Lohmann Brown and Bovans Brown, respectively. Similarly, Taddelle and Fasil (2016) reported also that the average body weight for Koekoek at twenty weeks of age is reported to

be 1.3-1.7kg. According to Shumuye *et al.* (2018) the average body of male Koekoek at five, eight and twelve month's age is reported to be 1.33, 1.87 and 2.47kg; and 1.2, 1.64 and 1.59kg for the female chicken, respectively. On related study, Arega (2019) the average body weights of female chickens at 20 weeks of age is reported to be 1728, 1697, 1673 and 1653g for Kuroiler, Saso, Sasso RIR and Koekoek breed respectively while the weights for the male chicken at the same age to be 1909, 1875, 1847 and 1834g in their respective order. Dessie (2017) indicated Sasso is generally the heaviest of the imported strains although their average daily growth is the lowest of the imported strains. According to Yakubu *et al.* (2007) in Nigeria body weight at 27 weeks of age for Lohmann Brown and Bovans Brown is reported to be 1.75kg and 1.69kg, respectively.

2.2. Phenotypic Description of the Introduced Breeds used in this Study

2.2.1. Phenotypic description of Koekoek chicken breed

The Koekoek is a barred colored dual purpose breeds Known in rural farmers of South Africa and neighboring countries which can produce up to 196 brown eggs per year with egg weight of 55.7g under intensive management system (Grobbelaar *et al.*, 2010, quoting Fourie and Grobbelaar *et al.*, 2003). Study from Tigray, Ethiopia indicated that Koekoek chicken breed is good scavenger, non-selective for feed, adaptable to the midland agro-ecology and give good production (meat and egg) in smallholder production system (Shumuye *et al.*, 2018).

2.2.2. Phenotypic description of Kuroiler chicken breed

The Kuroiler is a multi-coloured dual purpose chicken developed in India by Keggfarms private limited company, it begins laying eggs at age of 180 days and can produce 150 eggs per year, and achieves a body weight of 3.5 Kgs under farmer management conditions (Vinod and Singh, 1990). It weighed more than the local chicks at day old by 4.7g, by 219.5g at the age of 4 weeks and by 772.9g at the age of 20 weeks in Uganda (Kayitesi *et al.*, 2015).

2.2.3. Phenotypic description of Sasso chicken breed

Sasso is an internationally popular breed originating from France and can be raised in different production systems from intensive production as well as down to earth simple sheds on deep litter with basic equipment, in backyard, in forests areas, in the hills and even in the dry lands and in hot deserts (Ganpule, 2015). According to Dessie (2017) Sasso were generally the heaviest breeds and started laying eggs earlier although their ADG was the lowest as compared to the other imported dual-purpose breeds (Koekoek, Kuroiler and S-RIR).

2.2.4. Phenotypic description of improved Horro chicken breed

Improved Horro chicken is an indigenous breed which have been developing through selective breeding programme since 2008 from western highlands of Ethiopia and the hatch weight of Horro chicken is 25g which is increased up to 621g at 16 weeks of age and Hens attained sexual maturity at an average of 190 days (Dana *et al.*, 2010). Even though the improved Horro chicken breed (7th generation) showed better performance over indigenous chickens their performance is still low as compared to commercial breeds (Wondmeh *et al.*, 2015).

2.3. Genotype by Environment Interaction

2.3.1. The idea of genotype by environment interaction

Genotype by environment interactions (GEI) means that different genotypes respond differently to environmental changes (Mulder, 2007). This interaction should be expected whenever more than one breed or more than one environment is considered (Mathur, 2003). GEI comes to be very important if individuals of a specific population is to grow under different situations and environmental sensitivity is not constant for all individuals (Falconer and Mack, 1996).

In the presence of significant GEI the comparative benefits of a breed may vary from one environment to the other (Mathur, 2003) but when there is no interaction, then the top breed in one environment will be the top in all (Falconer and Mack, 1996). The different genotypes may include breeds, lines, strains, progeny groups (Horn, 1990) and the environments usually include factors such as time, location, nutrition, management, housing, etc (Mathur, 2003).

Large variation between the environment of genetic improvement and the production causes the loss of productivity due to GEI (Montaldo, 2001). Extra genetic gain does not necessarily mean additional profit (Lin and Togashi, 2002), because the economic performance of good genetic value breeds may reduce, due to the negative interaction between the animal's genes and its environment when the production environment is not favourable (Montaldo, 2001).

The methods for estimating GEI depend on the nature of the genotypes and environments involved (Mathur, 2003). Genetic correlation, interaction correlation, and commonality of individuals selected between environments are the three methods for estimating GEI (Lin and Togashi, 2002). When the genotypes, environments and interactions are fixed effects

and the data are unbalanced, the magnitude of interaction effects can be estimated using least-squares procedure and the statistical significance of interaction effects can be tested through an analysis of variance followed by an F-test (Mathur, 2003). When there are several genotypes as random effects, genetic correlations are used as the methods for estimating the magnitude of GEI (Mathur, 2003, quoting Mathur and Horst *et al.*, 1994). The more significantly the genetic correlation (ratio of genetic variance to the sum of the genetic and interaction variances) deviated from unity, the greater the GEI (N'Dri *et al.*, 2007).

Statistically significant interactions may or may not be biologically relevant, e.g., if they do not affect the ranking order of specific breeds or lines from one environment to the other (Mathur, 2003). It is then possible and useful to estimate and compare the relative magnitudes of genotypic, environmental, and interaction effects using their respective variances (Mathur, 2003).

Greater GEI effects are related with characters having lower heritability (Yakubu *et al.*, 2007). The efficiency of genetic improvement programs involving animals in tropical areas and developing countries is potentially affected by GEI (Montaldo, 2001). The genotype by environment interaction effect on the performance of the strains can be utilized to identify specific germplasms suitable for different agro-ecological conditions (Bamidele *et al.*, 2020).

2.3.2. Effect of Genotype, Environment, and their interaction on egg production

According to Sabri *et al.* (1999) heritabilities for the egg traits (egg number and weight) ranged from 0.20 to 0.55, increasing with age of bird from 26 to 54 weeks of age.

Genotype has a significant effect on the average number of eggs laid under village production systems (Assefa *et al.*, 2018; Desalew 2012; Wondmeneh *et al.*, 2015). Arega (2019) also indicated that breed has a significant effect on egg production trait mean number of egg per week per hen among dual purpose breeds in Gonder Zuria and Kalu districts while Peter *et al.* (2018) in South Africa reported the insignificant effect of breeds on traits mean number of eggs among Venda, Koekoek, Ovambo and Naked Neck have 58, 60, 42 and 34 egg number per year respectively. According to Arega (2019) the average weekly egg production to 44 weeks of age for Kuroiler, Koekoek, Sasso and S-RIR is reported to be 5.11, 5.3, 4.84 and 6.07 while Solomon *et al.* (2019) reported 4.7, 5.4, 5.8, 5.5 and 5.9 eggs to 50 weeks of age for Horro, Koekoek, Kuroiler, Sasso, and S-RIR, respectively.

A study conducted by Arega (2019) indicated that breed has significant effect on the egg production performance trait AFE among the Kuroiler, Koekoek, Sasso and S-RIR in Gondar Zuria and Kalu districts. Similarly, Wondmeneh *et al.* (2015) reported difference on AFE among improved Horro, commercial layer, crossbred and unselected indigenous chickens in Ada and Horro districts. Zaman *et al.* (2004) reported also difference on AFE among four cross breeds in Bangladeshi. According to Arega (2019) and Dessie (2017) Sasso chicken started laying eggs earlier than the other imported dual purpose breeds. On the other hand, (Guni *et al.*, 2021) reported that breed has insignificant difference on AFE between Sasso (166.1±1.5 days) and Kuroiler (166.5±1.5 days) in Tanzania. According to, Grobbelaar *et al.* (2010) the AFE among the five indigenous breeds is reported to be insignificantly different in

south Africa. Similarly, insignificant difference on AFE between the Bovans Brown and Koekoek is reported by Gezahegn *et al.* (2016). According to Desalew (2012) the AFE for S-RIR is reported to be 147 days. Similarly, Biratu and Hailu (2018) reported that the AFE for Koekoek chicken is reported to be 220 days and 217 days for Horro breed (Aman *et al.*, 2017). Shumuye *et al.* (2018) reported that difference in management could be the main reasons for the lateness or earliness of egg laying. According to Peter *et al.* (2018) small body size could be responsible for early achievement to sexual maturity while Zaman *et al.* (2004) reported that the differences in AFE may be due to the genetic differences among the studied breeds. Several report stated that breed effect is more pronounced in AEW, among breeds Koekoek, Kuroiler, Sasso and S-RIR at 36 weeks, in Ethiopia (Arega, 2019); between Bovans Brown and Koekoek in South Wollo, Ethiopia (Gezahegn *et al.*, 2016); between Lohmann Brown than Bovans Brown in Nigeria (Yakubu *et al.*, 2007) in Nigeria; among the Dominant red, Novo color, Koekoek and Lohmann brown at DZARC station (Lishan, 2017); and among Brown commercial layers, Araucana and Green leg Partridge hens ($P \leq 0.05$) (Sokołowicz *et al.*, 2019) in Poland. On the other hand, Rakonjac *et al.* (2017) reported no significant difference is observed on egg weight at 32, 48 and 72 weeks of age between Isa Brown and New Hampshire in Serbia. According to Sokołowicz *et al.* (2019) layers tended to produce heavier eggs with advancing age ($P \leq 0.05$). whereas, Mbaga *et al.* (n.d.) reported there are variations between breeds on egg weight.

According to Guni *et al.* (2021) from Tanzania breed has significant effect on HDEP% and HHEP% in which Sasso produces the highest HDEP% (87.5 ± 1.8) and HHEP% (49.5 ± 1.1) than Kuroiler at 52 weeks age while Zaman *et al.* (2004) from Bangladish reported that Rhode Island Red x Fayoum produced the highest eggs per hen day (41.6%) and per hen housed

(32%) during a period up to 46 weeks of age than the rest cross-breeds. According to Bamidele *et al.* (2020) the HDEP at 30 weeks for the Sasso chicken breed is reported to be 36.5% in Tanzania. With this regard (Grobbelaar *et al.*, 2010) reported also a significant difference on percentage of hen-housed egg production per production cycle between the White Leghorn (83.2%) and all four of the indigenous breeds including the Koekoek (67.8%) in Nigeria. According to Okfar (2019) the HHEP at 36th week of age for local chicken, Funaab Alpha and Shika Brown is reported to be 57%, 50% and 35%, respectively in Nigeria. Wondmeneh *et al.* (2015) reported 46.83, 46.19, 43.46, and 43.46% HHEP for improved Horro breeds at 3, 6, 9 and 12 months age. Arega (2019) stated that the mean hen-day egg production% for the Kuroiler, Sasso, S-RIR and Koekoek is 72.54, 69.04, 86.4 and 74.06 respectively, and hen-housed egg production% for the Kuroiler, Sasso, S-RIR and Koekoek is 64.82, 62.3, 78.96 and 68.84 at 32 weeks, respectively in Gonder and Kalu district. Similarly, a study conducted by Yakubu *et al.* (2007) revealed that breed has significant difference on hen-housed egg production percentage traits at 27 weeks of age which is significantly better in Lohmann Brown than Bovans Brown (74.5% and 68.7%), respectively (Table 1).

Table 1: Effect of Genotype on the laying performance of hens

Parameters	Genotype	
	Bovans Brown	Lohman Brown
Average weekly body weight (kg)	1.69±0.01 ^b	1.75±0.01 ^a
Hen-housed egg production (%)	68.72±0.86 ^b	74.50±0.84 ^a
Egg weight (g)	52.43±0.26 ^b	53.70±0.24 ^a

Means within rows designated by different superscripts differ significantly ($p < 0.05$).

Source: Yakubu *et al.* (2007).

Arega (2019) reported no district variation is observed on weekly egg production traits at the age of 32th and 36th weeks between Gonder Zuria and Kalu district. According to Arega (2019) the AFE of the Koekoek, Kuroiler, Sasso and S-RIR is highly significant different between Gonder Zuria and Kalu districts, Kalu district is favored for all chicken breeds than Gondar Zuria. Assefa *et al.* (2018) indicated that lowland agroecology is responsible for earlier maturity of chickens than midland agro-ecology in the Sidama zone of southern Ethiopia. Abraham and Yayneshet (2010) also reported watershed significantly affected the AFE with delayed days generally observed in Begashek than in Debre Kidan among Fayoumi, Rhode Island Red and White Leghorn chicken breeds. On the other hand Zaman *et al.* (2004) reported location has no effect on AFE recorded 201.5, 205.6 and 207.2 days respectively at three locations in Bangladesh.

Shumuye *et al.* (2018) reported management including feeding, watering, housing, veterinary services and environmental conditions could be the main reasons for the lateness or earliness of egg laying respectively. Similarly, Zaman *et al.* (2004) reported that AFE egg influenced by many environmental factors, such as temperature, nutrition and day length, sexual maturity is decreased while the amount of supplementary feed is increasing. According to Peter *et al.* (2018) variation in AFE may be due to unstructured mating system adopted by farmers.

Zaman *et al.* (2004) reported location has no effect on egg production performance of egg weight recorded egg weight of 42.0g, 41.4g, and 41.7g at three locations in Bangladesh. The study of (Mbaga *et al.*, n.d) indicated that there are variations between managements on egg weight. Zaman *et al.*, 2004) indicated different HDEP% and HHEP% is recorded with different amounts of supplementary feed. According to Oleforuh and Udumma (2010)

estimated genetic association between AEW and total egg number is reported to change from negative to positive in Nigeria.

Wondmeneh *et al.* (2015) reported HHEP% is significantly different ($P \leq 0.001$) between Ada and Horro districts. Zaman *et al.* (2004) reported location has no effect on egg production performance of percentage of hen-day and hen-housed egg production; and recorded hen-day egg production of 26.9%, 34.0% and 26.4% and hen-housed egg production of 13.8%, 22.2% and 26.4% respectively at three locations in Bangladesh. On the other hand Arega (2019) indicated that egg production at 28th, 40th and 44th weeks of age is highly significant ($P \leq 0.01$) difference between Gondar Zuria and Kalu districts. According to Zaman *et al.* (2004) different HDEP and HHEP percentage is recorded with different amounts of supplementary feed, for example birds receiving 15, 30 and 45 (g/hen/day) supplementation feed recorded 31.6, 30.0 and 36.3 HDEP %; and 23.1, 21.0 and 30.1% HHEP %.

According to Arega (2019) a highly significant ($P < 0.001$) district effect is observed on AEW between Gondar Zuria and Kalu districts. Wondmeneh *et al.* (2015) also reported difference in HHEP% between Ada and Horro districts. Ahmed and Singh (2007) stated the performance of birds indicate their genetic constitution and adaptation to the specific environment while Yakubu *et al.* (2007) indicated laying hens differ in their adaptability to different husbandry systems. Bamidele *et al.* (2020) reported indigenous chicken breeds are more adaptable to the environment than the imported dual chicken breeds in Nigeria. Tadesse (2014) indicated the management level and egg production of the households were positively correlated ($r=0.53$; $n= 160$).

According to Bamidele *et al.* (2020) the effect of location on adaptability is reported to be significant only during the laying phase. Melesse *et al.* (2013) reported midland agro-ecology appears to favour AFE trait under scavenging conditions. Shumuye *et al.* (2018) reported management and environmental factors might be the main reasons for the lateness or earliness of egg laying, respectively.

Table 2: Effect of Location on sexual maturity and egg production of different breed

	Location1	Location2	Location3
Age of sexual maturity, days	201.5	205.6	207.2
Number of eggs, HD%	26.9	34.0	36.8
Rate of lay, HH%	13.8	22.2	26.4
Egg weight	42.0	41.1	41.7

^{abc} Means in the same row without superscript in common are different ($p < 0.05$). Location 1=Riverside, location 2=Semi-terraced, and 3=Terraced.

Source: Zaman *et al.* (2004).

According to Arega (2019) a significant breed effect is observed on AFE between districts in which Kalu district is favored for all chicken breeds (Koekoek, Kuroiler, Sasso and S-RIR) than Gondar Zuria district. Similarly, Wondmeneh *et al.* (2015) reported that commercial chickens reared in Horro district started egg laying earlier (143 ± 0.88 days) than Ada district (146.5 ± 0.83 days) compared to other chicken breeds. Peter *et al.* (2018) reported also high significant levels are observed between breeds and village interactions on AFE.

A study conducted at Ada and Horro district of Oromia region, has revealed a significant effect of breed by village interactions on hen-housed egg production at 6, 9 and 12 months of age (Wondmeneh *et al.*, 2015). Singh *et al.* (2009) reported significant breed by environment interactions on HDEP% at 30 weeks of age. Arega (2019) stated that egg weight is favoured

for all breeds of chicken in Gondar Zuria than Kalu district. Zaman *et al.* (2004) reported that breed by location interaction significantly affected egg weight in Bangladesh. On another hand, Mathur and Horst (1983) reported that genotype by environment interaction effects is lower for egg weight. Kinderen *et al.* (2020) reported also there is no significant difference on AEW among five breeds across five districts of Oromia Region.

2.3.3. Effect of Genotype, Environment, and their interaction on growth traits

According to Lwelamira (2012) the genetic correlation value (rg) for body weight traits at 8, 12, 16 and 20 weeks of age is reported to be 0.745, 0.757, 0.752 and 0.753, respectively, which indicates substantial (i.e., biologically important) GEI.

According to Kayitesi (2015) in Uganda body weight of chickens at all ages from hatching to 20 weeks is significantly affected by breed. Similarly, Lishan (2017) reported that growth of chickens is influenced by breed, mean values for live body weight are significantly different among dual purpose breeds at DZARC station. Arega (2019) from Gonder Zuria and Kalu district reported also body weight at 12,16 and 20 weeks of age is highly significant ($P \leq 0.001$) difference among four introduced exotic breeds, Kurioler breed exhibited higher body weight at 12,16 and 20 weeks of age followed by Sasso, S-RIR, Koekoek. Further, Guni *et al.* (2021) reported body weight is significantly different between Kuroiler and Sasso at 20 weeks of age on farm level in Tanzania.

According to Wondmeneh *et al.*, (2015) body weight at 12,16 and 20 weeks of age is different among improved Horro (7th generation), commercial layer, crossbred and unselected indigenous chickens breeds on-station level in Oromia region. In related study (Dessie, 2017) reported that Sasso chicken is generally the heaviest of the imported breeds, whereas Horro

chicken is always the lightest and slowest growing birds. Mulugeta *et al.* (2020) reported that the body weight at 16 weeks of age is highly significant difference between DZ-white and improved Horro breeds at three locations in Ethiopia. Studies by Assefa *et al.* (2018) from Ethiopia and Osei-Amponsah *et al.* (2012) from Ghana indicated that the body weight of the local chicken is lower than the exotic chicken. Similarly, Yakubu *et al.* (2007) reported that the body weight of Lohmann Brown at 27 weeks of age is significantly better than the Bovans Brown on station. Okfar (2019) reported also body weight is significantly different among Funaab Alpha, Local chicken and Shika Brown in Nigeria. Similarly, Zaman *et al.* (2004) reported body weight at 180 days is lowest in NN x Fayoumi than the other cross breeds in a scavenging system. According to Arega (2019) ADG is highly significant ($P \leq 0.01$) different among breeds and Kurioler breed exhibited higher average daily body gain. Another study by Bamidele *et al.* (2020) reported that the Sasso and Kuroiler breed were observed to be better suited for meat (BW) in Nigeria. Kayitesi (2015) reported that breeds of chickens have different genetic potential for growth.

Zaman *et al.* (2004) from Bangladeshi reported that location has significant differences in body weight as hens at location 3 have a lower body weight at 180 days, but no location effect is observed at 120 days. Similarly, Kayitesi (2015) indicated that effect of location on body weight of the chickens is significant at certain periods and not at others, chickens growing in Gulu district are significantly heavier than those reared in Kiryandongo district after nine weeks till 20th weeks, but not significant before the age of nine weeks in Uganda. Further, Arega (2019) reported that body weight at 12, 16 and 20 weeks of age is highly significant different between Gondar Zuria and Kalu districts. According to Mulugeta *et al.* (2020) chickens raised in Debre Berhan and Mekelle have the highest body weight at 16 weeks of age

as compared to those birds growing in MelkaWerer while the main factor location has no significant effect on ADG at 16 weeks of age. Zaman *et al.* (2004) stated the level of supplementary feed biologically influences the hens body weight.

Assefa *et al.* (2018) and Yakubu and Ari (2018) reported that the male chickens have significantly higher body weight than the female. According to Osei-Amponsah *et al.* (2012) sex has significant effects on wt90 and wt150 ($P \leq 0.01$) and reported to be males are heavier on day 90 and day 150 than females. Kayitesi (2015) indicated that the growth rate of male chickens between 12-16 weeks is significantly higher than female chickens, but not significantly different for the period 16-20 weeks. Miao *et al.* (2005) reported that at farmer level chicken production is determined by the genetics of the stock, the effectiveness of disease control in both sexes, the quality of supplementary feeds and availability of pastures.

According to Arega (2019) genotype by district interactions has a significant effect ($P \leq 0.001$) on body weight at 12, 16 and 20 weeks of age among Koekoek, Kuroiler, Sasso and S-RIR breeds between Gonder Zuria and Kalu district. Similarly, Mulugeta *et al.* (2020) reported that DZ-white exhibited the highest body weight at 16 weeks at Debre Berhan and Mekelle, while the lowest one is recorded for improved Horro at Debre Berhan and MelkaWerer. Abraham and Yayneshet (2010) indicated the body weight at 8 months is affected by the interaction between breed and watershed, the heaviest body weight measured in Rhode Island Red (2.2 kg) growing in Begasheka than in Debre Kidan watershed. According to Kayitesi (2015) the growth performance of Kuroiler chicken breed between 13 and 20 weeks of age is reported to be significantly different between Gulu and Kiryandongo districts in Uganda. Assefa *et al.* (2018) reported that body weight is higher among the Sasso chicken reared in the lowlands, which suggest that this breed is better adapted to the lowland agro-ecological zone. Further,

Lozano-Jaramillo *et al.* (2019) reported that the Sasso and Horro chicken have the highest and the lowest predicted body weights in Tigray region, whereas Koekoek and Kuroiler have the highest predicted body weights in Amhara and Oromia region.

Mulugeta *et al.* (2020) indicated the effect of breed by location interaction that DZ-white and improved Horro is insignificantly different on ADG in three locations Debre Berhan, MelkaWerer and Mekelle at 16 weeks of age. According to Lozano-Jaramillo *et al.* (2019) the performance of the Sasso chicken across location might be associated with temperature due to the fact that Sasso breed originates in warm, and dry areas of south France. Ahmed *et al.* (2019) reported free-range and semi-intensive systems largely influence body weight performance traits between 27 and 46 weeks of age.

Arega (2019) reported that male chickens of Koekoek, Kuroiler, Sasso and S-RIR have better growth performance than their female counterparts. According to Yakubu and Ari (2018) genotype by sex interaction has significant effect on body weight of Kuroiler, Sasso and local chicken breeds in Nigeria. Similarly, Bogale (2008) indicated that the body weight at 180 days of age for local males is reported to be 1.5kg while for females about 30% less. Assefa *et al.* (2018) reported among the male chicken genotypes Sasso chicken breeds are superior in body weight while local male chickens are inferior ($P \leq 0.05$). Osei-Amponsah *et al.* (2012) indicated that male chickens have significantly superior growth rates than females across all genotypes except from the 20th to the 28th week. Similarly, Lozano-Jaramillo *et al.* (2019) reported that at 166 days of age Sasso and Horro male chicken had the heaviest and lightest body weight as compared to the other imported dual purpose breeds. Solomon *et al.* (2019) reported the average weight of female birds of Horro breed is about 56.3%, 46.2%, 44.6% and 52.4% of the weight of Koekoek, Kuroiler, Sasso and S-RIR, respectively. Arega (2019)

reported body weight of 1847g for male S-RIR at the age of 140 days, 1909, 1875 and 1834g for male Kuroiler, Sasso and Koekoek at 20 weeks, respectively. According to Shumuye *et al.* (2018) the body weight of Koekoek and S-RIR are 1330g for male and 1200g for female at the age of 150 days. According to Biratu and Hailu (2018) from Mana district of Jima zone the body weight for male and female Koekoek is reported to be 1340g and 1030g respectively, and ADG (9.3g) during the first twenty weeks. Arega (2019) indicates that the mean male and female body weight at 12 weeks of age is highly significant difference between Gondar zuria and Kalu districts. He also indicated that the male and female body weight at 16 and 20 weeks of age is highly significant different in Gondar Zuria and Kalu districts.

According to Arega (2019) the performance of male and female chicken on body weight at 12, 16 and 20 weeks of age is reported to be significantly different among breeds in Gondar Zuria and Kalu districts, female Kurioler chicken has higher body weight followed by the female chicken of Sasso, S-RIR and Koekoek in Kalu district at 12, 16 and 20 weeks, respectively while male Kurioler exhibited higher body weight in both districts and all breeds favored by Kalu environment than Gondar Zuria. Lozano-Jaramillo *et al.* (2019) reported that among the imported dual-purpose breeds Sasso male and female chicken always had the highest predicted body weights in Tigray than Amhara, Oromia and SNNP regions, Ethiopia. Further, Abraham and Yayneshet (2010) reported that male and female chicken of Rhode Island Red raised in Begasheka watershed are reported to be heavier than the remaining chicken breeds growing in both watersheds at 8 months. In related study Arega (2019) reported that the Koekoek male and female chickens breeds has lighter body weight gain than Kuroiler, S-RIR and Sasso chicken breeds at 12, 16, 20 weeks age in Gonder Zuria district and the ADG for male S-RIR chicken is reported to be better than all male chicken in Kalu district.

3. MATERIALS AND METHODS

3.1. Description of the Study Areas

This study was conducted in two districts of eastern and south eastern zone of Tigray national regional state namely Kelte-Awlaelo and Seharti-Samre, respectively.

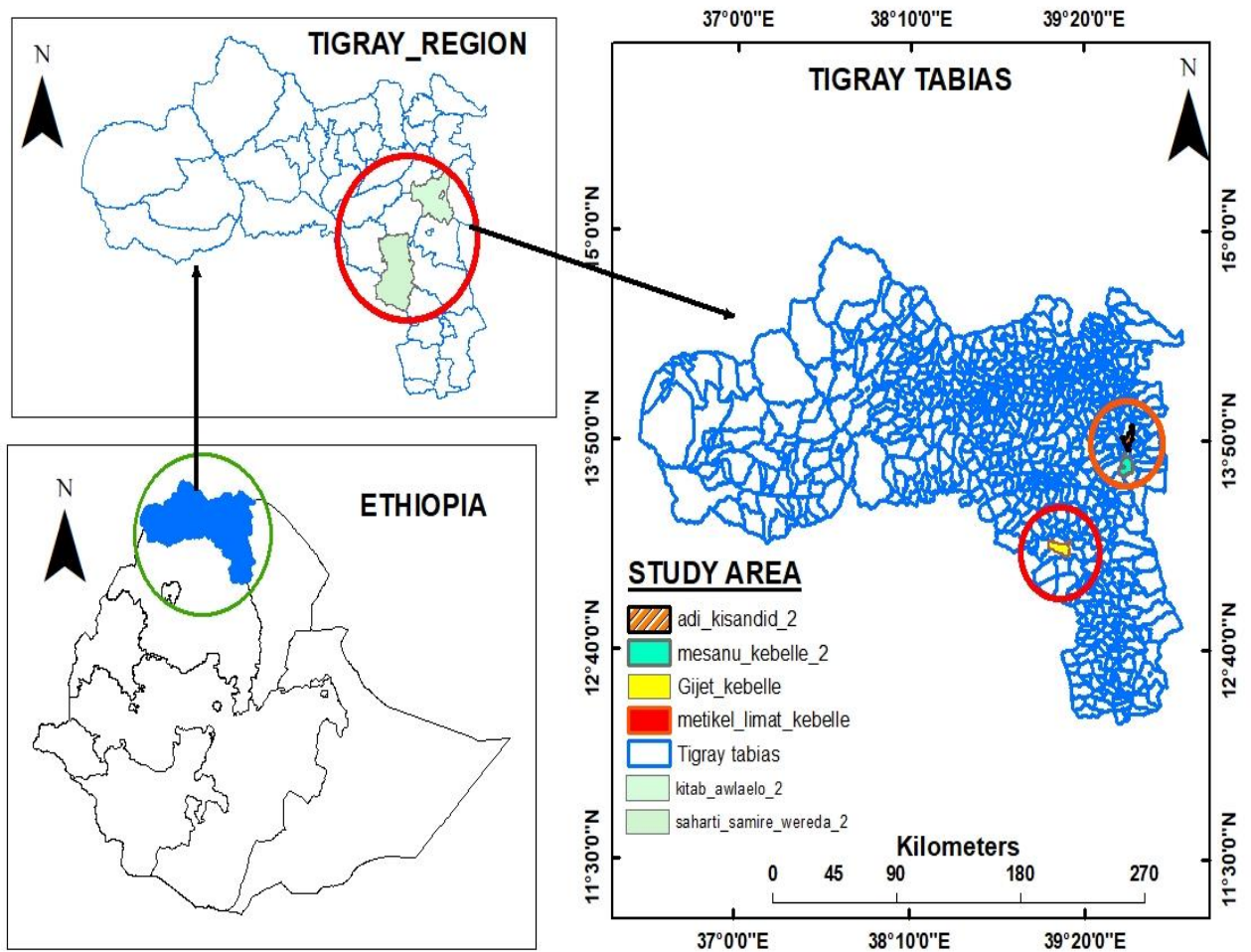


Figure 1: Study Areas Map

Seharti-Samre

Seharti-Samri is one of the four rural districts in the south eastern Zone of Tigray region that has 23 villages: 21 rural villages and 2 urban villages. The district capital Samre is located 57kms far away from the regional capital, Mekelle, with an elevation of 2017 m.a.s.l. The district's climatic zones are lowland, midland & highland with a proportion of 47%, 50% and 3%, respectively. The annual average daily temperature ranges from 21°C to 27°C. The annual amount of rainfall ranges from 350 –700 mm. Agriculture plays a major role in the rural household economy in the district (Ayenew *et al.*, 2011). The district has 124,499 human population (115,314 in rural and 9185 in urban) (FDREPCC, 2008). The district capital Samre is located at a latitude and longitude of 13° 42'N 39° 36'E.

Kelte-Awlaelo

Kelte-Awlaelo district has a total of 15 villages and it is situated at 45 Km north of Mekelle, as part of the Eastern Zone of the Tigray Regional State, northern Ethiopia. It is located between latitude: 13° 45' N- 14° 00' N and longitude: 39° 30' E -39° 45' E. The district's climatic zones are lowland, midland and highland with ratio of 3%, 82% and 15% of the districts, respectively. The elevation of the district varies from 1980 to 2500 m.a.s.l. The mean daily air temperature ranges from 15°C to 30°C and the average annual rainfall is about 558mm. The area is considered as drought prone, and the rainfall is very erratic (Gebreegziabher, 2005). According to FDREPCC (2008) the total human population of the district is about 129,896 (94,883 are living in rural and 35,013 in urban). Tesfa (2012) reported that the livelihoods of the majority of the rural population in the district depend on agriculture, which is characterised by small-scale subsistence mixed farming-systems. Barley, wheat, teff and finger millet are the major crops

while in some villages where irrigation is available vegetables are also grown (onion, tomato, green pepper and cabbages). Livestock production contributes significantly in rural household economy as a source of food, income and power for ploughing in the district.

3.2. Sampling methods

The study areas were purposively selected based on the distribution and abundance of exotic and indigenous chicken. Selection of villages and households involved in the study was done in collaboration with researchers, district experts and development agents purposively, based on the chicken population density and the experience of farmers in poultry management practices (keeping chicken for at least 2 years, commitment to provide shelter, to supplement feed). Following this, two villages were selected from each district that is Mesanu and Adiksanded from Kelte-Awlaelo and, Hayelom and Gijet from Seharti-Samre district and, from each village, 40 households and a total of 160 farmers were then selected randomly from the purposively selected farmers of both districts and participated in the on-farm research.

3.3. Experimental Chicken Breeds and their Distribution

3.3.1. Experimental chicken breeds

The five chicken breeds used in the study were Koekoek, Kuroiler, Sasso, S-RIR which are tropically adapted dual-purpose chickens breeds and the indigenous improved Horro chicken breed. Eggs were collected and introduced from different countries and incubated at Debre Zeit Agricultural Research Center. After being hatched birds were kept for six weeks of age until distribution, and then distributed for farmers when they achieved six weeks of age.

3.3.2. Distribution and registration of experimental chicken breeds

The five breeds were tested in four villages, in two districts of the Tigray Region (Kelte-Awlaelo and Seharti-Samre districts). A total of 160 farmers were selected purposively who fulfill the criteria set by ACGG project (their experience in chicken management practices and willingness and commitment to participate in the project). Each household received 25 chickens of one type of breed randomly and all breeds were tested in each Village, while only one breed was tested in each household. Birds which were grown under on-station until six weeks of age and received all standard vaccinations were distributed to the farmers under extensive management systems to be tested. Upon delivery of the introduced birds, all introduced birds were tagged and existing (household) birds were registered and sexed. All introduced birds and existing household flock birds which were +/-2 weeks of the age of the introduced birds were tagged (i.e., introduced birds were delivered at 6 weeks old so existing household flock that aged between 4 and 8 weeks were tagged).

3.4. Type of Data and Collection Methods

Since dual-purpose breeds are not fast-growing chickens like the meat producers (pure meat type) data on body weight were assessed at 90, 120, 150 and 180 days and average daily gain (ADG) between 90 and 180 days of age. On egg production performance average egg weight (AEW), hen-day egg production percentage (HDEP %), hen-housed egg production percentage (HHEP %) to 30 weeks and age at first egg laying (AFE) were taken. Hanging spring balance was used to measure body weight performance under rural village conditions. Taking into account the number of birds weighed, were converted the group weight to average individual body weight. Egg weight was measured using sensitive balance. Data on egg

production and growth performance traits were collected every 2 and 4 weeks in ACGG data collection sheet, respectively. The studied parameters were calculated using the following formula:

- Weight gain was calculated as the initial body weight subtracted from the final weight, then divided by the number of days to obtain the growth rate per bird per day in grams.
- HDEP%- is the number of eggs in relation to existing hens during the period, but it does not consider mortality. It was calculated by dividing the number of eggs laid by the number of hens alive at the end of the experiment multiplied with the number of days in lay.
- HHEP%- is the number of eggs in relation to the number of hens placed, it includes mortality. It was calculated by dividing the total number of eggs by the number of hens initially housed multiplied with the number of days in lay.
- AFE- is the day old chick's age to produce the first egg. It was calculated from the hatching date of the hen to the production of the first egg.

3.5. Study Design

The on-farm test consisted of evaluating growth and egg performance of four exotic breeds and one improved local chicken. All breeds were tested in each Village, and one breed was tested in each household. The on-farm trial on growth performance was a 5x2x2 factorial with 5 breeds, 2 districts and 2 sexes. The experiment on egg production performance was a 5x2 factorial with 5 breeds and 2 districts. The five breeds were improved Horro, Koekoek, Kuroiler, Sasso and S-RIR. The two districts were: Kelte-Awlaelo and Seharti-Samre districts and the sex effects of birds: male and female.

3.6. Data Management and Analysis

The on-farm data were entered and managed using Microsoft Excel 2010 computer program. Data on quantitative traits were analyzed using the general linear model procedure of R v.3.6.1 running on RStudio version 1.2.5001 (R Core Team, 2005). Factors fitted in the model included breed, district, sex, breed by district interactions, breed by sex interactions, district by sex and breed by district by sex interactions. By fitting the breeds, district, and sex as fixed effects and all two and three-way interactions for body weight. Breeds and districts were considered as fixed effects and their two-way interactions for egg production. Mean comparisons were undertaken when there was significant difference between and among independent variables and tested at 5 percent level for the growth and egg production traits. The following linear model was used during analysis of quantitative data: growth performance and egg production performance.

The models used for growth performance was:

$Y_{ijkl} = \mu + B_i + D_j + S_k + (B*D)_{ij} + (B*D*S)_{ijk} + e_{ijkl}$, Where

Y_{ijkl} = body weight at 90,120,150,180 days, ADG (in breed i , in district j , of chicken sex k)

μ = overall mean

B_i = effect due to i^{th} breed (i = Kuroiler, Koekoek, Sasso, S-RIR and Horro)

D_j = effect due to j^{th} district (j = Seharti-Samre and Kelte-Awlaelo)

S_k = effect due to k^{th} chicken sex (k =male and female)

$(B*D)_{ij}$ = effect due to interaction between i^{th} breeds and j^{th} district

$(B*D*S)_{ijk}$ = effect due to interaction between i^{th} breeds, j^{th} district and k^{th} sex

e_{ijkl} = random error, independently distributed with zero mean and common variance.

The models used for egg production performance was:

$Y_{ijk} = \mu + B_i + D_j + (B \times D)_{ij} + e_{ijk}$, Where

Y_{ijk} = egg production traits on AEW, AFE, HDEP% and HHEP% (in breed i , in district j)

μ = overall mean

B_i = effect due to i^{th} breed (i = Kuroiler, Koekoek, Sasso, S-RIR and Horro)

D_j = effect due to j^{th} district (j = Seharti-Samre and Kelte-Awlaelo)

$(B \times D)_{ij}$ = effect due to interaction between i^{th} breeds and j^{th} district

e_{ijk} = random error, independently distributed with zero mean and common variance.

4. RESULTS AND DISCUSSIONS

4.1. Body Weight at Different Age Groups

4.1.1. Main factors effect on growth performance trait

4.1.1.1. The effect of Breed

The present study showed that breed had highly significant ($P < 0.001$) effect on growth performance of the breeds (Table 3) and Sasso chicken breed was significantly heavier ($P < 0.001$) at 90, 120 and 150 days of ages than the rest breeds followed by Kuroiler, S-RIR at 90; 120 and 150 days of ages. Similarly, Kuroiler chicken showed an outstanding growth performance ($P < 0.001$) on wt180 and ADG than the other breeds followed by Sasso and S-RIR at 180 days and ADG, respectively. While, the Koekoek and Horro chickens had significantly lower ($P < 0.001$) weight across all ages as compared to the other three breeds and had similar growth performance among them. S-RIR and Kuroiler chicken breeds displayed similar performance ($P > 0.05$) in most of the body weight measurements. This implies the performance of body weight across all ages varies among chicken breeds. The observed significant variation on body weight across ages among the breeds which according to Miao *et al.* (2005) may be associated with the smallholder production systems in which the productivity of chickens is dependent on the genetics of the stock.

The significant effect of breed on body weight at 90, 120 and 150 days of ages, which is close agreement with the results reported by Arega (2019) stated that Kuroiler chicken breed was significantly heavier ($P < 0.01$) as compared to the Koekoek, Sasso and S-RIR chicken breeds at 84, 112 and 140 days of age in Gonder Zuria and Kalu districts, in Ethiopia. Similarly, Guni *et al.* (2021) reported that Sasso chicken breed had significantly higher ($P < 0.05$) body weight

than the Kuroiler chicken at 140 days of ages at farm level in Tanzania. The current result weight at 180 days was in close agreement with the findings of Yakubu et al. (2007) who reported that the Lohmann Brown had significantly heavier body weight than the Bovans Brown at 189 days of age. The present result on ADG was consistent with the findings of Arega (2019) who reported that the Kurioler breed had higher ($P \leq 0.001$) ADG than the Koekoek chicken breeds. Another study by Bamidele *et al.* (2020) reported that the Sasso and Kuroiler breed were observed to be better suited for meat (BW) in Nigeria. This has also been shown by Dessie (2017) who reported that the Sasso was generally the heaviest of the imported strains, whereas Horro chicken were always the lightest and slowest growing birds in Ethiopia.

Table 3: Effect of breed on body weight at different age groups (Mean \pm SD)

Breed	Wt90 (g)	Wt120 (g)	Wt150 (g)	Wt180 (g)	ADG (g/day)
Horro	686.6 ^c \pm 26.50	932.3 ^d \pm 118.77	1105.7 ^d \pm 437.23	1243.5 ^b \pm 442.06	9.1 ^b \pm 9.08
Koekoek	756.4 ^c \pm 107.89	973.1 ^d \pm 143.05	1224.2 ^d \pm 328.70	1450.4 ^b \pm 414.94	10.3 ^b \pm 8.57
Kuroiler	884.1 ^b \pm 166.63	1194 ^b \pm 158.39	1648.6 ^b \pm 356.10	1922.7 ^a \pm 220.02	15.5 ^a \pm 7.08
Sasso	954.7 ^a \pm 138.47	1273.1 ^a \pm 102.81	1853.7 ^a \pm 387.57	1905.3 ^a \pm 308.68	13.6 ^a \pm 6.79
S-RIR	873.2 ^b \pm 142.47	1112.4 ^c \pm 161.22	1508.3 ^c \pm 408.16	1825.3 ^a \pm 338.78	15.1 ^a \pm 7.97
P-value	<0.001	<0.001	<0.001	<0.001	<0.001

^{a,b,c} Means between breeds within age group with different superscripts letters differ significantly ($P < 0.05$), Wt90= body weight at 90 days; Wt120=body weight at 120 days; Wt150=body weight at 150 days; Wt180=body weight at 180 days; ADG= Average daily gain between 90 and 180 days

4.1.1.2. The effect of District

As indicated in Table 4, non-significant district effect was observed on body weight at different age groups except wt90 and wt180. The present result implies that the body weight performance of chickens varies only at certain ages between districts. This might be attributed to the fact that the two districts are located at a short distance and their similarity in most environmental factors like temperature, rainfalls and agro-ecology. However, numerically chickens reared in Seharti-Samre district were heavier than those raised in Kelte-Awlaelo district on body weight across all ages. The difference in growth performance of chickens between the two districts which according to Miao *et al.* (2005) may be associated with at farmer level the productivity of chicken is really on the accessibility of supplementary and green feeds and disease control. According to Zaman *et al.* (2004), the amount of supplementary feed biologically influences the hens body weight.

This observation is supported by Kayitesi (2015) who reported that the effect of district on body weight of chickens was significant at certain periods, chickens reared in Gulu district were significantly heavier than those reared in Kiryandongot at 91 days of ages in Uganda; A similar observation has been also reported by Zaman *et al.* (2004) that location effect was observed at 180 days of ages while no location effect was observed at 120 days in Bangladish. Further, this result agreed with the observations of Arega (2019) that the body weight at 84 days of age was highly significant different between Gondar Zuria and Kalu districts. However, different results had been reported by Kayitesi (2015) in which district had a significant effect on body weight at 119 days between Gulu and Kiryandongo district in Uganda. Such different results between the present study and that of Kayitesi (2015) might be due to variations in breed type, agro-ecology and other environmental factors.

Table 4: Effect of district on body weight at different age groups (Mean \pm SD)

District	Wt90 (g)	Wt120 (g)	Wt150 (g)	Wt180 (g)	ADG (g/day)
Kelte-Awlaelo	764.2 ^b \pm 129.64	1072.9 ^a \pm 175.95	1410.8 ^a \pm 384.53	1610.7 ^b \pm 381.41	12.8 ^a \pm 8.33
Seharti-Samre	877.9 ^a \pm 150.20	1096.69 ^a \pm 190.40	1479.2 ^a \pm 461.40	1730.7 ^a \pm 437.92	12.9 ^a \pm 8.29
P-value	<0.001	0.50	0.28	0.05	0.57

^{a,b} Means between districts within age group with different superscripts letters differ significantly ($P < 0.05$), Wt90= body weight at 90 days; Wt120=body weight at 120 days; Wt150=body weight at 150 days; Wt180=body weight at 180 days; ADG= Average daily gain between 90 and 180 days

4.1.1.3. The effect of Sex

The growth performance at different age groups were significantly affected ($P < 0.05$) by sex (Table 5). Male chickens were significantly heavier ($P < 0.05$) than females on body weight measured at all ages. This implies the body weight performance of chickens varies between sexes across all ages. The observed significant variation on body weight in both sexes could be explained by the fact that male and female chickens respond differently to diet on body weight (Shahin *et al.*, 2019) and male chicken recorded better feed conversion efficiency and gained more body weight than females (Benyi *et al.*, 2015).

The current result was in agreement with the reports of Osei-Amponsah *et al.* (2012) that sex had significant effects on body weight ($P < 0.01$) and males were heavier on day 90 and day 150, than females in Ghana. This has also been shown by Kayitesi (2015) who reported that males were significantly heavier than females from the 15 to the 140 days of age. Further, this was in line with that of Assefa *et al.* (2018) and Yakubu and Ari (2018) who observed that male chickens had significantly higher body weight compared to their female counterparts. The significant difference in ADG between male and female chickens in the present study

agreed with the findings of Osei-Amponsah *et al.* (2012) which indicated that male chickens had significantly superior growth rates than females among all genotypes.

Table 5: Effect of sex on body weight at different age groups (Mean \pm SD)

Sex	Wt90 (g)	Wt120 (g)	Wt150 (g)	Wt180 (g)	ADG (g/day)
Female	811.1 ^b \pm 141.78	1076.4 ^b \pm 181.70	1402.5 ^b \pm 409.70	1653.7 ^b \pm 406.55	12.1 ^b \pm 7.67
Male	868.4 ^a \pm 165.34	1106.6 ^a \pm 189.45	1542.4 ^a \pm 459.58	1733.2 ^a \pm 439.18	14.2 ^a \pm 9.24
P-value	0.023	0.029	<0.001	0.04	0.008

^{a,b} Means between sexes within age group with different superscripts letters differ significantly ($P < 0.05$), Wt90= body weight at 90 days; Wt120=body weight at 120 days; Wt150=body weight at 150 days; Wt180=body weight at 180 days; ADG= Average daily gain between 90 and 180 days

4.1.2. Two-way interaction effect on growth performance trait

4.1.2.1. Interaction effects of Breed by District

The interaction of breed by district significantly ($P < 0.001$) affects the body weight of chickens across all ages (Table 6). Very high significant difference ($P < 0.001$) was observed on body weight at different age groups within the studied chicken breeds raised in both districts. Sasso and S-RIR chickens reared in Seharti-Samre district were significantly ($P < 0.001$) higher than those reared in Kelte-Awlaelo in most of the body weight measurements while, Horro and Koekoek chicken breeds raised in Kelte-Awlaelo district showed higher ($P < 0.001$) performance than in Seharti-Samre on body weight under different age groups except at 90 days of age. The Sasso and Kuroiler chickens raised in Seharti-Samre district were significantly heavier ($P < 0.05$) than the other three chicken breeds at 90, 120 and 150 days of ages. The improved local Horro chicken had significantly ($P < 0.05$) less body weight at different age levels as compared to the exotic chicken breeds reared in Seharti-Samre district

except for Koekoek. Similarly, among the exotic chicken breeds reared in Seharti-Samre district, the Koekoek chicken were significantly ($P < 0.05$) inferior on body weight across all ages. The Sasso and Kuroiler chicken reared in Kelte-Awlaelo district showed significantly ($P < 0.05$) superior performance in most of the body weight measurements as compared to the other chicken breeds. While, the Koekoek and Horro chicken breeds had significantly ($P < 0.05$) lower performance on the studied body weight measurements than the other chicken breeds reared in Kelte-Awlaelo district. The S-RIR chicken reared in Seharti-Samre district had better ADG than the remaining chicken breeds reared in both districts.

Overall, the Sasso chicken performed better on body weight across all ages as compared with the other chicken breeds raised in Seharti-Samre district except ADG. Except for wt180 and ADG, the Sasso chicken still showed an outstanding growth performance on the studied ages as compared with the other breeds reared in Kelte-Awlaelo district. However, the Horro and Koekoek chickens were inferior in most of the body weight measurements than the remaining breeds in both districts and had similar growth performance among them. Similarly, the Kuroiler and S-RIR chicken breeds reared in Seharti-Samre district had similar performance at different age levels. The current result implies that the body weight performance of different chicken breeds varies from district to district across all ages (Figure 2) therefore, it is essential to consider the mean values of the growth performance trait across both districts while selecting among breeds to improve meat productivity. Based on this result the meat productivity of both districts can be improved by distributing Sasso chicken followed by Kuroiler to farmers. The superiority of Sasso chicken on body weight at different age groups irrespective of districts is most likely to be associated with the fact that the breed originates

in warm, and dry areas of south France (Lozano-Jaramillo *et al.*, 2019) and the drought prone study areas seems to be favourable to the breed as it originates in warm, and dry areas.

This result is in good agreement with Arega (2019) who found that the Koekoek, Kuroiler, Sasso and S-RIR chicken breeds reared in Kalu district had significantly higher ($P < 0.001$) body weight at 84, 112 and 140 days of ages than Gonder Zuria. A similar observation has been also reported by Kayitesi (2015) that the growth performance between 91 and 140 days of Kuroiler were significantly different between Gulu and Kiryandongo districts. Further, this observation was supported by Lozano-Jaramillo *et al.* (2019) who reported that the Sasso and Horro chicken had the highest and the lowest expected body weights in Tigray region.

These findings was in contrast to the body weights found by Lozano-Jaramillo *et al.* (2019) who reported that the Koekoek and Kuroiler had the highest predicted body weights in Amhara and Oromia region. The significant difference in ADG within the breeds across both districts in the present study disagreed with the findings of Mulugeta *et al.* (2020) who indicated that the ADG of DZ-white and improved Horro were similar in three locations. According to Miao *et al.* (2005) disease control, accessibility of green and supplementary feeds are the main factors that determines chicken production performance under smallholder production systems.

Table 6: Interaction effects of breed by district on body weight at different age groups (Mean \pm SD)

District	Breed	Wt90 (g)	Wt120 (g)	Wt150 (g)	Wt180 (g)	ADG (g/day)
Saharti-Samre	Sasso	1033.6 ^a \pm 103.81	1315.8 ^a \pm 0.00	2064.4 ^a \pm 234.24	2085.4 ^a \pm 156.89	15.2 ^{ab} \pm 6.40
	Kuroiler	959.7 ^{ab} \pm 139.86	1226.5 ^{ab} \pm 138.70	1664.7 ^b \pm 305.00	1970.4 ^a \pm 164.10	14.9 ^b \pm 7.04
	S-RIR	932.9 ^{bc} \pm 118.65	1163.9 ^b \pm 133.16	1690.4 ^b \pm 358.15	2023.0 ^a \pm 192.62	18.0 ^a \pm 7.56
	Koekoek	763.4 ^d \pm 75.05	929.8 ^{cd} \pm 106.61	1115.0 ^{cd} \pm 306.20	1360.7 ^{ef} \pm 407.00	7.7 ^c \pm 6.83
	Horro	696.7 ^d \pm 27.40	860.2 ^d \pm 0.00	913.4 ^d \pm 146.87	1149.8 ^f \pm 262.26	5.0 ^c \pm 3.02
Kelte-Awlalo	Sasso	869.3 ^c \pm 121.50	1226.9 ^{ab} \pm 136.3	1625.5 ^b \pm 398.23	1746.0 ^{bc} \pm 357.44	11.9 ^{bc} \pm 7.06
	Kuroiler	727.4 ^d \pm 91.45	1128.5 ^b \pm 180.71	1615.3 ^b \pm 455.58	1823.9 ^{ab} \pm 287.76	16.8 ^{ab} \pm 7.26
	S-RIR	772.5 ^d \pm 123.13	1025.5 ^c \pm 170.95	1201.2 ^{cd} \pm 289.55	1499.0 ^{de} \pm 260.45	8.7 ^{bc} \pm 2.98
	Koekoek	748.4 ^d \pm 136.66	1022.2 ^c \pm 163.49	1348.1 ^c \pm 312.47	1552.3 ^{cd} \pm 405.38	13.2 ^b \pm 9.49
	Horro	666.2 ^d \pm 0.00	1076.4 ^{bc} \pm 98.34	1490.2 ^{bc} \pm 614.79	1498.0 ^{de} \pm 728.46	17.2 ^{ab} \pm 14.8
Source of variation (P-value)						
District (D)		<0.001	0.50	0.28	0.05	0.57
Breed (B)		<0.001	<0.001	<0.001	<0.001	<0.001
D \times B		<0.001	<0.001	<0.001	<0.001	<0.001

^{a,b,c,d,e,f} Means between breeds within age group with different superscripts letters differ significantly (P <0.05) within district, Wt90= body weight at 90 days; Wt120=body weight at 120 days; Wt150=body weight at 150 days; Wt180=body weight at 180 days; ADG= Average daily gain between 90 and 180 days

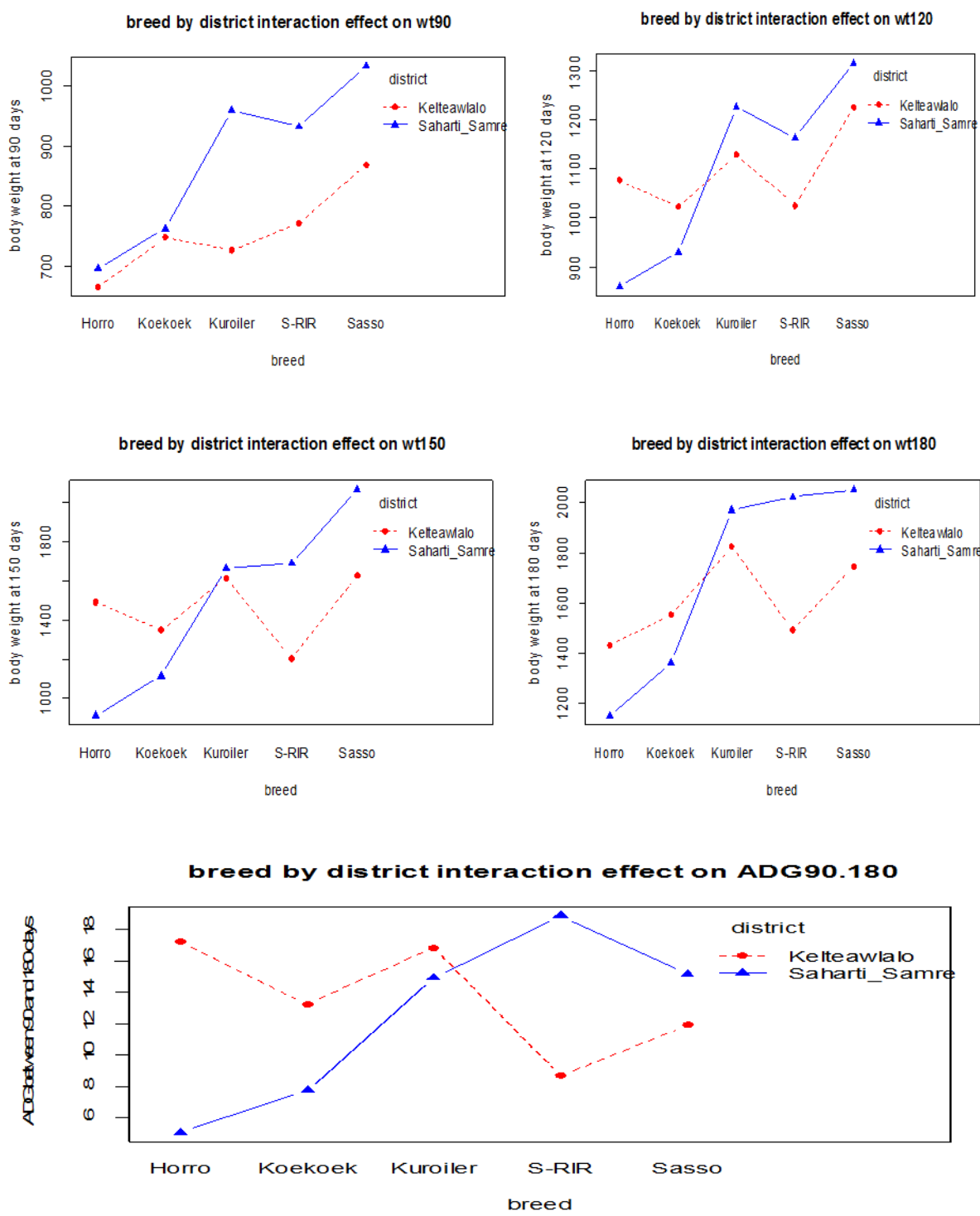


Figure 2: Crossover and non-crossover GEI on body at different age groups

4.1.2.2. Interaction effect of Breed by Sex

The interaction breed by sex was not significant ($P > 0.05$) for any of the body weight measurements under different age groups (Table 6). The insignificant breed by sex interaction on body weight measurements indicated that the factors under consideration (breed x sex) perform independently of each other on body weight at different age group.

The improved Horro male chickens were significantly ($P < 0.05$) inferior on the studied body weight measurements as compared to the exotic male chicken breeds except for Koekoek. Similarly, among the exotic male chicken breeds, male chicken of Koekoek had significantly ($P < 0.05$) less body weight at all ages. Among the female chickens, female Sasso were significantly ($P < 0.05$) higher in most of the body weight measurements followed by Kuroiler at 90, 120 and 150 days of age. The Koekoek and Horro female chickens had lower ($P < 0.05$) body weight across all ages than the female chickens of Sasso, Kuroiler and S-RIR.

Overall, the Sasso male chicken had higher mean values for the studied body weight measurements as compared to the other male chicken breeds (except wt90). Similarly, except for wt180 and ADG, the female Sasso weighed more across ages than the rest of the female chickens. However, both sexes of the Horro and Koekoek chickens were significantly ($P < 0.05$) inferior in most of the body weight measurements than the remaining chicken breeds and had similar growth performance among them. The superior performance of male and female Sasso chicken followed by Kuroiler in this study might be related to the function of Sasso and Kuroiler breed which were reported to be best suited for meat (BW) in Nigeria (Bamidele et al., 2020).

The current result was in agreement with the findings of Assefa *et al.* (2018) who reported that the effect of breed by sex interaction was insignificant for body weight. These findings was in close agreement with the reports of Lozano-Jaramillo *et al.* (2019) that at 116 days of age Sasso and Horro male chicken breeds recorded heavier and lower body weight as compared to the other imported dual purpose breeds. Further, this observation is supported by Assefa *et al.*, (2018) who reported that among the male chicken breeds, the male Sasso were superior in body weight and local male were inferior. He also indicated that female Sasso had a higher body than the remaining female chickens. The average body weight of Koekoek and S-RIR attained in this result were similar as reported; 1330g for male and 1200g for female koekoek at the age of 150 days (Shumuye *et al.*, 2018) and 1847g for male S-RIR at the age of 140 days (Arega, 2019). But, higher body weight 1909 and 1834g for male Kuroiler and Koekoek; and lower 1875g for male Sasso chicken breed reported at 140 days of age in Gonder Zuria and Kalu districts, Ethiopia (Arega, 2019). However, this observation was in contrary to the reports of Yakubu and Ari (2018) that breed by sex interaction had significant effect on body weight of Kuroiler, Sasso and local chicken breeds in Nigeria. This disagreement in results between this study and that of Yakubu and Ari (2018) and (Arega, 2019) is possibly due to the difference in locally available feed resources, management of the farmers and agro-ecology.

Table 7: Interaction effects of breed by sex on body weight at different age groups (Mean \pm SD)

Sex	Breed	Wt90 (g)	Wt120 (g)	Wt150 (g)	Wt180 (g)	ADG (g/day)
Male	Sasso	983.9 ^{ab} \pm 152.10	1287.8 ^a \pm 83.95	2080.6 ^{ab} \pm 408.71	2096 ^a \pm 317.09	16.8 ^{ab} \pm 7.22
	Kuroiler	1009.6 ^a \pm 125.71	1270.6 ^{ab} \pm 74.83	1688.7 ^{bc} \pm 293.33	1984.7 ^a \pm 142.23	14.3 ^b \pm 6.76
	S-RIR	937.9 ^{ab} \pm 127.69	1224.5 ^{abc} \pm 124.5	1866.2 ^{ab} \pm 439.36	1956.8 ^a \pm 370.07	21.0 ^a \pm 8.55
	Koekoek	766.8 ^c \pm 122.63	968.0 ^d \pm 131.89	1262.3 ^{de} \pm 267.95	1522.1 ^b \pm 438.87	11.6 ^{bc} \pm 9.63
	Horro	715.9 ^c \pm 22.91	860.2 ^d \pm 0.00	986.1 ^e \pm 176.50	1209.7 ^b \pm 384.92	5.5 ^c \pm 4.53
Female	Sasso	938.4 ^a \pm 132.45	1264.8 ^a \pm 113.80	1726.1 ^{bc} \pm 320.97	1853.8 ^a \pm 301.60	11.8 ^{bc} \pm 6.04
	Kuroiler	829.7 ^b \pm 153.43	1161.7 ^b \pm 174.08	1631.3 ^c \pm 383.43	1895.8 ^a \pm 243.46	16.1 ^b \pm 7.26
	S-RIR	848.2 ^b \pm 141.74	1069.1 ^c \pm 154.20	1369.8 ^d \pm 302.28	1774.4 ^a \pm 317.60	12.7 ^{abc} \pm 6.40
	Koekoek	749.3 ^c \pm 97.34	976.5 ^d \pm 151.48	1198.2 ^e \pm 364.86	1401.5 ^b \pm 395.14	9.5 ^c \pm 7.78
	Horro	671.9 ^c \pm 11.88	968.3 ^d \pm 133.78	1165.4 ^e \pm 529.67	1260.4 ^b \pm 502.37	10.9 ^{bc} \pm 10.67
Source of variation (P-value)						
Sex (S)		0.023	0.029	<0.001	0.04	0.008
Breed (B)		<0.001	<0.001	<0.001	<0.001	<0.001
B \times S		0.64	0.33	0.32	0.70	0.49

^{a,b,c,d,e} Means between breeds within age group with different superscripts letters differ significantly (P <0.05) within sex, Wt90= body weight at 90 days; Wt120=body weight at 120 days; Wt150=body weight at 150 days; Wt180=body weight at 180 days; ADG= Average daily gain between 90 and 180 days

4.1.2.3. Interaction effect of District by Sex

District by sex interaction was not significant ($P > 0.05$) for any of the body weight measurements as indicated in Table 8. There was non-significant difference ($P > 0.05$) for the studied body weight performance between districts within sexes. Although the data indicated district by sex interaction had no significant differences on body weight across ages, there was a tendency that both sexes were favoured by Seharti-Samre district than Kelte-Awlaelo (Figure 3). This insignificant difference might be attributed to the fact that the studied breeds have similar functions (dual-purpose breed) and the two districts are located at a short distance and their similarity in most environmental factors like rainfall, temperature and agro-ecology.

The non-significant effect of district by sex interaction on body weight under different age groups are in contrast with a recent study of Arega (2019) who reported that male and female chicken's body weight at 84, 112 and 140 days of age was highly significant different between Gondar Zuria and Kalu districts. The difference between the two studies might be associated with the fact at farmer level the production performance of chicken is really on the availability of green and supplementary feeds and disease control (Miao *et al.*, 2005) and Zaman *et al.* (2004) stated also the level of supplementary feed biologically influences the hens body weight.

Table 8: Interaction effects of district by sex on body weight at different ages (Mean \pm SD)

District	Sex	Wt90 (g)	Wt120 (g)	Wt150 (g)	Wt180 (g)	ADG(g/day)
Saharti-Samre	Male	895.0 ^a \pm 154.57	1112.9 ^a \pm 197.08	1547.3 ^a \pm 490.42	1737 ^a \pm 450.80	13.4 ^a \pm 8.74
	Female	863.5 ^b \pm 146.13	1083.3 ^b \pm 185.18	1422.8 ^b \pm 431.67	1725.5 ^b \pm 430.47	12.3 ^b \pm 7.93
Kelte-Awlalo	Male	780.2 ^a \pm 174.00	1085.9 ^a \pm 165.70	1526.3 ^a \pm 351.24	1720.8 ^a \pm 411.92	16.9 ^a \pm 10.55
	Female	760.2 ^b \pm 117.82	1069.8 ^b \pm 179.42	1382.9 ^b \pm 389.51	1584.0 ^b \pm 372.05	11.9 ^b \pm 7.47
Source of variation						
District (D)		<0.001	0.50	0.28	0.05	0.57
Sex (S)		0.023	0.029	<0.001	0.04	0.008
D \times S		0.86	0.50	0.63	0.34	0.13

^{a,b} Means between districts within age group with different superscripts letters differ significantly (P <0.05) within sex, Wt90= body weight at 90 days; Wt120=body weight at 120 days; Wt150=body weight at 150 days; Wt180=body weight at 180 days; ADG= Average daily gain between 90 and 180 days

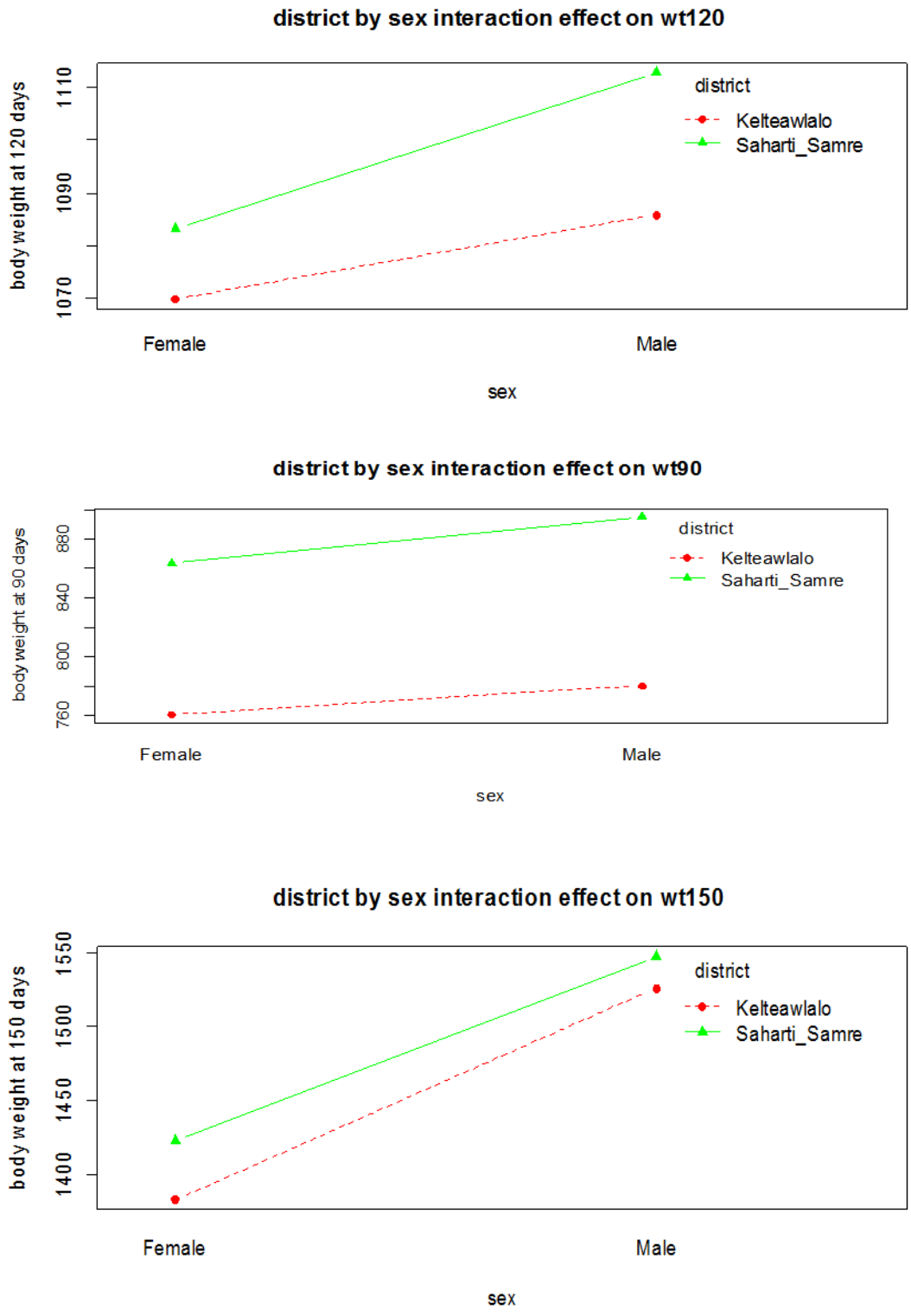


Figure 3. Sex by district interaction plot on body weight at different age groups

4.1.3. Three-way interaction effect on growth performance trait

As indicated in Table 9, the three-way interactions between breed, district and sex factors were found to be significant only for the growth trait of ADG. The growth performance of the same chicken breed at different age group is insignificantly different ($P > 0.05$) within sex across districts except for ADG which implies the effect of the three main factors were independent on each other's and are non-significant for the body weight measurements except ADG.

The improved local Horro male chickens had significantly ($P < 0.05$) less body weight across all ages as compared to the exotic male chicken breeds reared in Seharti-Samre district except for Koekoek. Similarly, among the exotic male chicken breeds reared in Seharti-Samre district, Koekoek chicken were significantly ($P < 0.05$) inferior on body weight across all ages. Except for Kuroiler, female chicken of Sasso were heavier ($P < 0.05$) at 90, 120 and 150 days of ages as compared to the other female breeds raised Seharti-Samre district. Except for Sasso, among the male chickens, male S-RIR had higher ($P < 0.05$) ADG as compared to the other chicken breeds reared in Seharti-Samre district. Except for Koekoek, both sexes of Horro chickens showed significantly ($P < 0.05$) lower ADG as compared to other chicken breeds reared in Seharti-Samre district. The S-RIR male chicken breeds were significantly ($P < 0.05$) superior on ADG in Seharti-Samre district than Kelte-Awlaelo while, the male Koekoek chickens had higher ($P < 0.05$) ADG in Kelte-Awlaelo district than Seharti-Samre. Overall, among the male chicken, Sasso performed better on the body weight across ages as compared with the other breeds in both districts. Similarly, female Sasso and Kuroiler are preferable breeds than the other female chickens to improve meat production in Seharti-Samre and Kelte-Awlaelo districts, respectively. Improved male and female Horro chickens reared in both districts performed less in most of the body weight measurements than the other exotic dual-

purpose breeds in this study which according to (Wondmeneh *et al.*, 2015) may be associated with the fact that their performance is still low as compared to commercial breeds.

The finding of the current study is consistent with what was reported by Lozano-Jaramillo *et al.* (2019) that among the imported dual-purpose breeds both sex chicken of Sasso always had higher predicted body weights in Tigray than Amhara, Oromia and SNNP regions, Ethiopia. However, the current study disagrees with Abraham and Yayneshtet (2010) reported that both sex chicken of Rhode Island Red raised in Begasheka watershed was significantly heavier than the remaining chicken breeds growing in both watershed at 8 monthes. Similarly, the present result obtained did not conform with that observed by Arega (2019) the male Kurioler chicken achieved higher body weight at 84, 112 and 140 days of age in both districts and female Kurioler showed higher body weight than the rest females in Kalu district. This disagreement in results between this study and that of Arega (2019) might be associated with the variation in the 3-way interaction effects between breed, district and sex.

Table 9: Interaction effects of breed by district by sex factors on body weight at different age groups (Mean \pm SD)

District	Sex	Breed	Wt90 (g)	Wt120 (g)	Wt150 (g)	Wt180 (g)	ADG (g/day)
Saharti-Samre	Male	Sasso	1049.25 ^a \pm 101.57	1315.8 ^{ab} \pm 0.00	2203.9 ^a \pm 98.58	2215.1 ^a \pm 0.00	17.9 ^{abc} \pm 6.19
		Kuroiler	1009.60 ^{ab} \pm 125.71	1270.6 ^{ab} \pm 74.82	1688.7 ^{bc} \pm 293.33	1984.7 ^{ab} \pm 142.23	14.3 ^{bcde} \pm 6.76
		S-RIR	956.98 ^{abc} \pm 114.63	1233.4 ^{abc} \pm 126.17	1925.5 ^{ab} \pm 207.98	2031.8 ^a \pm 276.42	22.8 ^a \pm 7.04
		Koekoek	767.2 ^{de} \pm 67.12	921.1 ^f \pm 124.81	1134.5 ^{de} \pm 221.25	1379.5 ^{cde} \pm 414.40	7.4 ^e \pm 5.95
		Horro	715.9 ^{de} \pm 22.91	860.2 ^f \pm 0.00	986.2 ^e \pm 176.51	1209.7 ^{de} \pm 384.92	5.5 ^e \pm 4.53
	Female	Sasso	1020.2 ^{abc} \pm 108.68	1315.8 ^{ab} \pm 0.00	1944.8 ^{ab} \pm 255.92	1998.72 ^{ab} \pm 204.78	12.8 ^{bcde} \pm 6.04
		Kuroiler	919.2 ^{bc} \pm 141.27	1190.7 ^{bcd} \pm 168.41	1645.2 ^c \pm 322.35	1958.8 ^{ab} \pm 183.75	15.5 ^{bcd} \pm 7.43
		S-RIR	916.3 ^c \pm 122.15	1116.1 ^{def} \pm 118.90	1528.7 ^{cd} \pm 207.98	2017.1 ^{abc} \pm 115.23	16.22 ^{bcd} \pm 6.86
		Koekoek	760.0 ^{de} \pm 83.11	937.7 ^f \pm 124.81	1097.3 ^{de} \pm 371.58	1343.5 ^{de} \pm 409.13	8.0 ^e \pm 7.67
		Horro	677.6 ^{de} \pm 15.96	860.2 ^f \pm 0.00	890.6 ^{de} \pm 83.00	1089.8 ^e \pm 114.05	4.6 ^e \pm 1.35
Kelte-Awlalo	Male	Sasso	853.2 ^a \pm 162.02	1231.8 ^{abcd} \pm 145.40	1833.9 ^{abc} \pm 712.0	1860.5 ^{abc} \pm 525.79	14.6 ^{bcde} \pm 10.10
		S-RIR	728.3 ^{cde} \pm NA	1122.2 ^{cdef} \pm NA	1214.4 ^{de} \pm NA	1261.9 ^{de} \pm 287.76	4.5 ^e \pm NA
		Koekoek	766.2 ^{de} \pm 186.02	1046.4 ^{ef} \pm 161.14	1475.3 ^{cd} \pm 196.44	1759.96 ^{bc} \pm 384.02	18.6 ^{ab} \pm 10.72
	Female	Sasso	874.6 ^c \pm 116.6	1225.3 ^{abcd} \pm 142.30	1556.0 ^{bc} \pm 263.80	1741.2 ^{bc} \pm 326.28	11.0 ^{cde} \pm 6.28
		Kuroiler	727.4 ^{cde} \pm 91.45	1128.5 ^{cde} \pm 124.81	1615.3 ^c \pm 455.58	1823.9 ^{ab} \pm 287.76	16.9 ^{bcd} \pm 7.25
		S-RIR	775.5 ^{cde} \pm 126.86	1019.1 ^f \pm 174.92	1200.3 ^{de} \pm 299.67	1515.6 ^{cd} \pm 250.68	9.0 ^{de} \pm 2.86
		Koekoek	739.9 ^{de} \pm 109.20	1010.6 ^f \pm 166.60	1287.0 ^d \pm 341.74	1452.6 ^{cde} \pm 383.40	10.7 ^{de} \pm 7.83
		Horro	660.2 ^e \pm 0.00	1076.4 ^{def} \pm 98.34	1490.3 ^{cd} \pm 614.79	1498.0 ^{cde} \pm 728.46	17.2 ^{abcd} \pm 14.81
Source of variation (P-value)							
District (D)			<0.001	0.50	0.28	0.05	0.57
Breed (B)			<0.001	<0.001	<0.001	<0.001	<0.001
Sex (S)			0.023	0.029	<0.001	0.04	0.008
D×B			<0.001	<0.001	<0.001	<0.001	<0.001
D×S			0.86	0.50	0.63	0.34	0.13
B×S			0.64	0.33	0.32	0.70	0.49
B*D*S			0.65	0.88	0.38	0.15	0.05

^{a,b,c,d,e,f} Means between breeds within sex in age group with different superscripts letters differ significantly (P <0.05) within districts, Wt90= body weight at 90 days; Wt120=body weight at 120 days; Wt150=body weight at 150 days; Wt180=body weight at 180 days; ADG= Average daily gain between 90 and 180 days; NA=Not available

4.2. Egg Production Performance

4.2.1. Main factors effect on egg production traits

4.2.1.1. The effect of Breed

The present study revealed that breed had a significant effect on the studied egg production traits (Table 10). The current result indicated that Sasso chicken had lower ($P < 0.05$) mean age at first egg as compared to the Horro and Koekoek chicken breeds, while Horro hens had significantly higher ($P < 0.05$) mean age at first egg than the Sasso and Kuroiler chickens. This implies the egg production performance trait age at first egg varies among chicken breeds. The difference in egg laying performance trait age at first egg among the breeds in this study might be due to the genetic variation among the breeds as suggested by Zaman *et al.* (2004).

The significant difference of AFE among breeds found in this study is supported by Arega (2019) who indicated that the AFE were significantly different among breeds (Koekoek, Kuroiler, Sasso and S-RIR) in Gondar Zuria and Kalu districts. The present result was also in line with that of Dessie, (2017) who reported that Sasso chicken started laying eggs earlier whereas, Horro chicken matured later than other strains. The values (188 and 190 days) for AFE of the S-RIR and Koekoek breeds obtained in this study was lower than that of 147 and 154 reported by Desalew (2012) and Wondmeneh *et al.*, (2015); but faster than reported by Biratu and Hailu (2018) for Koekoek and Aman *et al.* (2017) for Horro. The insignificant difference on AFE between Kuroiler and Sasso in this study was in agreement with the reports of Guni *et al.*, (2021) that insignificant difference was observed between Sasso and Kuroiler chickens on AFE in Tanzania. However, this result was in contrast with the findings of Gezahegn *et al.*, (2016) who reported insignificant difference on AFE between Bovans Brown

and Koekoek in Ethiopia. The difference between the present result and the result obtained by Gezahegn *et al.*, (2016) might be associated with the fact that difference in management could be the main reasons for the lateness or earliness of egg laying (Shumuye *et al.*, 2018).

The current finding indicate that Horro hens had higher ($P < 0.05$) HHEP% to 30 weeks of ages as compared to the other chicken breeds followed by Kuroiler whereas, Koekoek and S-RIR showed lower ($P < 0.05$) HHEP% and had similar performance between them. The Horro chicken superiority on egg production trait HHEP% could be explained by the fact that indigenous chicken breeds have lower mortality than the imported chicken breeds (Bamidele *et al.*, 2020). The significant difference on HHEP% among breeds found in this study was supported by Guni *et al.* (2021) reported that different performance on HHEP% between Sasso and Kuroiler chicken breeds in Tanzania. Similarly, the current result was in agreement with the reports of Okfar (2019) that local chicken produced the highest eggs per hen housed (57%) than Funaab Alpha (50%) and Shika Brown (35%) at 36th week of age, in Nigeria. However, this findings was higher than Wondmeneh *et al.* (2015) reported 46.83, 46.19, 43.46, and 43.46% HHEP for improved Horro breeds at 3, 6, 9 and 12 months age, but lower than to the result obtained by Arega (2019) 82.0, 71.7, 69.8 and 69.4% HHEP for the S-RIR, Koekoek, Kuroiler and Sasso chicken breeds at 32 weeks of age, respectively. The observed difference between the current study and that of Arega (2019) and Wondmeneh *et al.* (2015) could be associated with the fact that management level and egg production of the households were positively correlated ($r=0.53$) (Tadesse, 2014).

S-RIR chicken had higher ($P < 0.001$) HDEP% to 30 weeks of age followed by the others except Sasso chicken. Horro and Koekeok chickens produced heavier ($P < 0.05$) eggs as compared to the Kuroiler and Sasso chickens. The observed significant difference on egg production traits among the breeds which according to Miao *et al.* (2005) may be associated with at farmer level the productivity of chicken is really on the genetics of the stock.

The significant difference of HDEP% among breeds found in this study was in agreement with the reports of Arega (2019) that HDEP% was significantly different among breeds at 32 weeks of ages in which S-RIR performed better than the other breeds (Koekoek, Kuroiler, Sasso). The value (69%) for HDEP of the Sasso breed obtained in this study is higher to that of 36.5% given by Bamidele *et al.* (2020) at 30 weeks in Tanzania. The current result on AEW is in agreement with the reports of Arega (2019) that significant difference was observed among breeds (Koekoek, Kuroiler, Sasso and S-RIR) at 36 weeks of age. However, the current result on AEW was in contrast with the findings of Rakonjac *et al.*, (2017) reported that Isa Brown and New Hampshire breeds were insignificantly different for egg weight in Serbia. This disagreement in results between this study and that of Rakonjac *et al.*, (2017) is likely due to the difference in breeds on AEW (Mbaga *et al.*, n.d.) and the positive correlations between hens age and AEW (Sokołowicz *et al.*, 2019).

Table 10: Effect of breed on egg production performance traits (Mean \pm SD)

Breed	AEW (g)	AFE (days)	HDEP%	HHEP%
Kuroiler	45.7 ^{bc} \pm 1.74	177.1 ^{bc} \pm 19.77	71.5 ^{bc} \pm 9.00	66.1 ^b \pm 13.00
S-RIR	45.8 ^{abc} \pm 2.18	188.5 ^{abc} \pm 16.58	75.0 ^a \pm 6.88	52.0 ^d \pm 11.97
Sasso	45.3 ^c \pm 2.00	174.0 ^c \pm 27.38	69.0 ^c \pm 7.45	61.4 ^c \pm 14.91
Koekoek	46.5 ^{ab} \pm 2.09	189.9 ^{ab} \pm 12.71	71.8 ^b \pm 10.27	51.9 ^d \pm 26.55
Horro	46.9 ^a \pm 1.72	201.7 ^a \pm 13.47	71.5 ^{bc} \pm 6.24	69.9 ^a \pm 4.57
P-value	0.037	0.004	<0.001	<0.001

^{a,b} Means between breeds for the egg laying traits with different superscripts letters differ significantly (P <0.05), AEW= Average egg weight; AFE=age at first egg; HDEP%=hen-day egg production percentage; HHEP%= hen-housed egg production percentage

4.2.1.2. The effect of District

According to the current study district had significant effect (P <0.001) on the studied traits used to express egg production performance except AFE (Table 11). The current result revealed that the highest egg production performance (AEW, HDEP% and HHEP %) was recorded in Kelte-Awlaelo districts than Seharti-Samre. This implies the egg production performance of chickens varies from district to district except AFE. The difference on egg laying performance between both districts which according to Zaman *et al.* (2004) the highest rate of lay, hen-day was obtained with the highest level of supplementary feed and the protein sources available in the different locations are suggested to be the reason for this variation. According to Oleforuh and Udumma, (2010) estimated genetic association between AEW and total egg number is reported to change from negative to positive in Nigeria.

This observation was also made by Arega (2019) reported that egg weight was highly significant different between Gondar Zuria and Kalu districts. Similarly, Wondmeneh *et al.* (2015) reported that HHEP% was significantly different ($P < 0.001$) between Ada and Horro districts. However, different results had been reported by Zaman *et al.* (2004) in which insignificant differences were observed for AEW, HDEP% and HHEP% at three locations in Bangladesh. The observed variations between this study and that of Zaman *et al.* (2004) might be associated with the effect of location on adaptability was only significant during the laying phase (Bamidele *et al.*, 2020). The non-significant difference ($P > 0.05$) between districts for AFE might be because the two districts are located at a short distance and their similarity in most environmental factors. The present result on AFE was in conformity with that reported by Zaman *et al.* (2004) insignificant difference was observed for AFE in three locations in Bangladesh. However, on the contrary, Arega, (2019) reported significant differences for AFE between Gondar Zuria and Kalu districts among Koekoek, Kuroiler, Sasso and S-RIR breeds. The inconsistent results between the present results and that of Arega, (2019) might be associated with the management practices and environmental factors responsible for the lateness or earliness of egg laying (Shumuye *et al.*, 2018).

Table 11: Effect of district on egg production performance traits (Mean \pm SD)

District	AEW (g)	AFE (days)	HDEP%	HHEP%
Saharti-Samre	44.5 ^b \pm 1.53	183.7 ^a \pm 19.78	64.7 ^b \pm 4.30	51.5 ^b \pm 14.40
Kelte-Awlalo	47.5 ^a \pm 0.94	188.7 ^a \pm 21.40	78.90 ^a \pm 2.67	69.00 ^a \pm 14.65
P-value	<0.001	0.285	<0.001	<0.001

^{a,b} Means between districts for the egg laying traits with different superscripts letters differ significantly ($P < 0.05$), AEW= Average egg weight; AFE=age at first egg; HDEP%=hen-day egg production percentage; HHEP%= hen-housed egg production percentage

4.2.2. Two-way interaction effect on egg production traits

4.2.2.1. Interaction effect of Breed by District

The effect of breed by district interaction was significant ($P < 0.05$) for the egg traits studied except for AEW as presented in Table 12. The present result implies the egg production performance of the five chicken breeds is dependent on the district, in which they were introduced, thus all breeds on farm data on the studied egg traits should be collected and analysed across districts to select among the breeds best fitted to enhance egg productivity at smallholder production level.

The current finding revealed Kuroiler, Koekoek and S-RIR chicken reared in Seharti-Samre district attained early maturity (AFE) than in Kelte-Awlaelo district. Whereas, Sasso and Horro chicken breeds attained earlier maturity (AFE) in Kelte-Awlaelo district. The Sasso chickens had lower ($P < 0.05$) mean age at first egg as compared with the other chicken breeds reared in Kelte-Awlaelo district. Numerically, Kuroiler chicken had lower maturity age (AFE) as compared with the other chicken breeds reared in Seharti-Samre district. While, Horro chicken had the higher ($P < 0.05$) mean age at first egg than the remaining chicken breeds raised in Seharti-Samre district. Generally, earlier maturity (AFE) was recorded from Sasso chicken reared in Kelte-Awlaelo district. Whereas, the delayed maturity (AFE) was recorded from Horro chicken breed reared in Seharti-Samre district. Except Sasso and Horro all chicken breeds attained earlier maturity (AFE) in Seharti-Samre district than in Kelte-Awlaelo.

Improved Horro had higher mean age at first egg as compared to the other imported dual-purpose breeds in both districts in this study may be associated with the fact that their performance is still low as compared to crossbred and commercial breeds (Wondmeneh *et al.*, 2015). According to our results, Arega (2019) found a significant breed by district interaction

effects on AFE, Kalu district was favored for all chicken breeds (Koekoek, Kuroiler, Sasso and S-RIR) than Gondar Zuria. Wondmeneh *et al.* (2015) also got a significant breed by district interaction effects on AFE between the commercial, crossbred and improved Horro chicken breeds reared in Horro and Ada districts, in which all breeds favored by Horro district. This observation was also made by Peter *et al.* (2018) who reported high significant levels were observed between breeds and village interactions on AFE.

All chicken breeds reared in Kelte-Awlaelo district were significantly ($P = 0.01$) superior for the mean HDEP% to 30 weeks of age than in Saharti-Samre. However, in Saharti-Samre district the S-RIR chicken had higher ($P = 0.01$) HDEP% as compared with the other breeds. Koekoek chicken had higher ($P < 0.001$) HDEP% to 30 weeks of age as compared to the Horro and Sasso chickens reared in Kelte-Awlaelo district. Overall, Koekoek chicken reared in Kelte-Awlaelo district showed an outstanding performance on HDEP% to 30 weeks of age than the remaining breeds in both districts, while this trait had lower values for Koekoek chickens in Saharti-Samre district. The current result on HDEP% is in agreement with the reports of Singh *et al.* (2009) that significant breed by environment interactions was observed for HDEP% at 30 weeks of age.

Except for S-RIR chicken, the HHEP% to 30 weeks of age was significantly higher ($P < 0.001$) for all chicken breeds reared in Kelte-Awlaelo district than those of the Saharti-Samre. The Horro chicken reared in Saharti-Samre district had higher ($P < 0.05$) HHEP% than the other breeds except for S-RIR. While, S-RIR chicken had lower ($P < 0.05$) values for HHEP% to 30 weeks of age as compared to the other breeds raised in Kelte-Awlaelo district. Overall, Kuroiler breed reared in Kelte-Awlaelo district showed an outstanding performance on HHEP% to 30 weeks of age than the remaining chickens in both districts followed by

Koekoek and Horro in Kelte-Awlaelo district. In line with this a study conducted at Ada and Horro districts of Oromia region, has revealed a significant effect of breed by district interactions on HHEP% at 6, 9 and 12 months of age (Wondmeneh *et al.*, 2015).

The Horro chicken produced significantly ($P < 0.05$) heavier eggs as compared to the Sasso and S-RIR breeds reared in Saharti-Samre district. The Koekoek chicken had the highest egg weight as compared with other breeds reared in Kelte-Awlaelo district followed by Horro and Kuroiler but were not statistically significant. The non-significant difference of AEW within the breeds reared in both districts found in this study supported by Kinderen *et al.* (2020) who reported that there was no significant difference on AEW within breeds in five districts of three Oromia zones. It is also in agreement with the reports of Mathur and Horst (1983) that genotype by environment interaction effects is lower for AEW. However, contrary findings by Arega (2019) stated that AEW was favoured for all breeds reared in Gondar Zuria district than Kalu district. Zaman *et al.* (2004) also reported that AEW was significantly affected by the interaction effects of breed by location among three locations in Bangladesh. Inconsistent results between the present study and that of Arega (2019) and Zaman *et al.* (2004) could be explained by the fact that breed and husbandry practices can affect AEW (Mbage *et al.*, n.d.). Generally, except S-RIR, all chicken breeds reared in Kelte-Awlaelo district were superior in most of the egg production traits studied than of those chickens reared in Saharti-Samre (Figure 4). The difference in mean values between the districts could be explained by the fact that disease control, availability of green and supplementary feeds are the most important factors that determine chicken production at farmer level (Miao *et al.*, 2005). The Koekoek and Kuroiler; and S-RIR chicken breeds are the best options to improve egg production in Kelte-Awlaelo and Saharti-Samre district, respectively.

Table 12: Effect of breed by district interactions on egg production traits (Mean \pm SD)

District	Breed	AEW (g)	AFE (days)	HDEP%	HHEP%
Saharti-Samre	Sasso	43.6 ^d \pm 0.00	185.7 ^{bcd} \pm 25.37	62.1 ^f \pm 0.02	47.42 ^e \pm 2.4
	Kuroiler	44.6 ^{cd} \pm 1.45	165.4 ^{de} \pm 15.65	63.2 ^{ef} \pm 1.67	54.0 ^d \pm 3.42
	S-RIR	43.8 ^d \pm 0.32	175.2 ^{cde} \pm 10.71	70.2 ^d \pm 6.87	63.2 ^c \pm 0.79
	Koekoek	45.0 ^{cd} \pm 1.96	184.8 ^{bcd} \pm 11.00	62.1 ^f \pm 0.00	26.9 ^g \pm 3.16
	Horro	45.8 ^{bc} \pm 1.93	207.5 ^a \pm 0.00	65.9 ^e \pm 1.78	65.9 ^c \pm 1.74
Kelte-Awlalo	Sasso	47.0 ^{abcd} \pm 1.12	162.4 ^e \pm 26.53	76.2 ^c \pm 0.74	75.4 ^{ab} \pm 2.55
	Kuroiler	47.0 ^{abcd} \pm 1.30	188.8 ^{abc} \pm 17.09	79.8 ^{ab} \pm 3.07	78.2 ^a \pm 1.58
	S-RIR	47.8 ^{abcd} \pm 0.62	201.7 ^{ab} \pm 8.07	79.8 ^{ab} \pm 1.26	40.9 ^f \pm 3.16
	Koekoek	48.0 ^{abc} \pm 0.42	195.0 ^{abc} \pm 13.30	81.5 ^a \pm 1.61	77.0 ^{ab} \pm 3.16
	Horro	47.9 ^{ab} \pm 0.56	195.8 ^{abc} \pm 17.96	77.2 ^{bc} \pm 2.42	74.0 ^b \pm 1.77
Source of variation (P-value)					
District (D)		<0.001	0.285	<0.001	<0.001
Breed (B)		0.037	0.004	<0.001	<0.001
B*D		0.274	0.005	0.001	<0.001

^{a,b,c,d,e,f,g} Means between breeds for the egg laying traits with different superscripts letters differ significantly (P <0.05) within district, AEW= Average egg weight; AFE=age at first egg; HDEP%=hen-day egg production percentage; HHEP%= hen-housed egg production percentage.

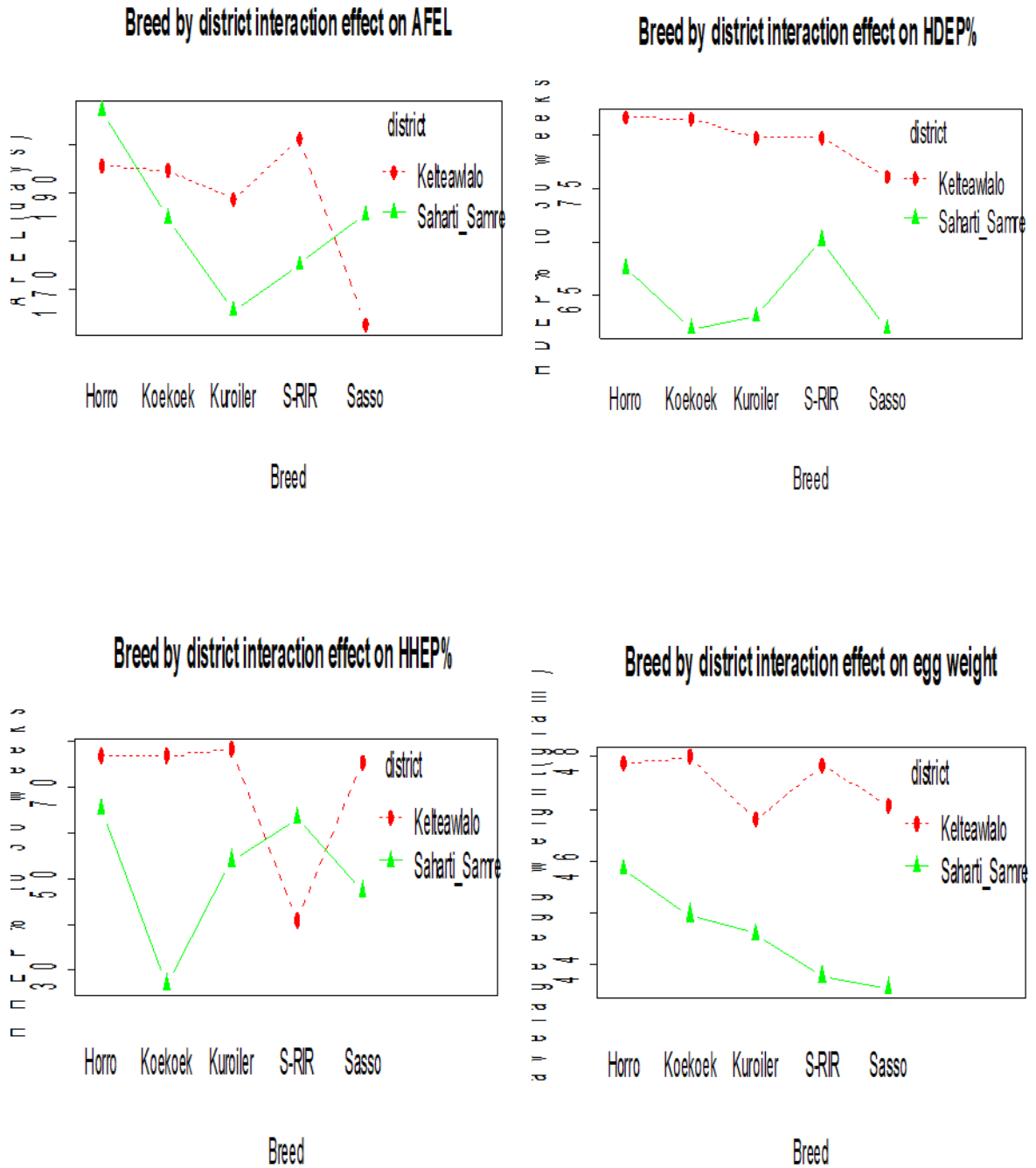


Figure 4: Crossover, non-crossover and non-significant GEI on egg production traits.

5. SUMMARY AND CONCLUSION

The aim of the study was to evaluate genotype by environment interactions (GEI) on growth and egg production traits of tropically adapted chicken breeds under smallholder production systems. The study was conducted in Kelte-Awlaelo and Seharti-Samre districts of eastern and south eastern zones of Tigray region, Ethiopia. The present study revealed that Sasso chickens showed superior performance than the remaining chicken breeds in most of the body weight measurements, while Horro and Koekoek chickens were inferior as compared to the other breeds on body weight across all ages and had similar growth performance among them. Except wt90 and wt180, chickens showed similar body weight performance between Seharti-Samre and Kelte-Awlaelo districts under different age groups. Male chickens performed better than the female on the body weight measurements across all ages. The male Sasso chicken had higher mean values for the body weight across ages than the other male chicken breeds except wt90. Similarly, female Sasso performed better than the rest of the female chickens on body weight at all ages except wt180 and ADG. Both sexes of Horro and Koekoek chickens were inferior ($P < 0.05$) in most of the body weight measurements than the rest breeds.

The Sasso and S-RIR chicken breeds reared in Seharti-Samre district showed higher performance than Kelte-Awlaelo in most of the parameters used to determine body weight trait, while Horro chicken had the highest value in Kelte-Awlaelo district for the body weight across all ages. This implies that it is important to consider the mean values of the growth traits across districts while selecting among breeds to improve meat productivity. Male chickens displayed similar performance on the body weight under different age groups than their female counterparts. Male chickens had similar body weight in both districts across the studied ages. Irrespective of district, male chickens performed better than the females on body

weight at different age levels. This indicates that the meat productivity of districts can be improved by introducing male chicken breeds. Male chickens of S-RIR reared in Seharti-Samre district performed better than Kelte-Awlaelo on ADG while this value was higher in Kelte-Awlaelo for male Koekoek. Overall, both sexes of Sasso chicken showed superior performance than the remaining chicken breeds on body weight across all ages in both districts, which implies its adaptability regardless of districts as compared to the other imported breeds. Therefore, meat productivity can be increased by introducing Sasso chicken followed by Kuroiler to the study districts.

The Sasso, S-RIR and Horro chickens showed better performance as compared to the other breeds on AFE, HDEP% and HHEP%, respectively. Koekoek and Kuroiler chickens reared in Kelte-Awlaelo district performed better than the remaining breeds in most of the studied egg traits. Whereas, S-RIR chickens showed higher performance in most of the egg traits as compared to the other breeds in Seharti-Samre district. Chickens reared in Kelte-Awlaelo district performed better than Seharti-Samre on the studied egg production traits except AFE. The Kuroiler, Koekoek and S-RIR chicken breeds attained early maturity (AFE) in Seharti-Samre district while these values were lower in Kelte-Awlaelo district for Sasso and Horro chickens. All chicken breeds showed better performance on hen-day egg production and hen-housed egg production percentage (except S-RIR) in Kelte-Awlaelo district than Seharti-Samre. While, the S-RIR chicken breeds exhibited superior performance in the egg production traits age at first age and hen-housed egg production percentage in Seharti-Samre district than Kelte-Awlaelo. This suggests that both districts' on-farm data on egg production performance traits have important inference while selecting and distributing different chicken breeds to

boost egg productivity at smallholder production systems (the production system where GEI commonly exist).

Based on this study, it can be concluded that the performance of body weight across all ages varies among chicken breeds and between sexes, while only varies at certain ages between districts. The body weight performance of different chicken breeds varies from district to district across all ages. Irrespective of district, body weight of male chicken is similar at various age levels. The growth performance of different chicken breeds does not vary within sex across districts under different age groups except ADG. The performances of egg production vary among chicken breeds and between districts. The egg production performance of different chicken breeds varies from district to district.

Recommendations

Based on the findings of this study, the following recommendations are made:

- The meat and egg production performance of different chicken breeds vary from district to district, therefore the dissemination of breeds should be considered the GIE.
- Sasso breed is recommended to be reared in both districts to improve the meat productivity while, Koekoek and Kuroiler; and S-RIR breeds needs to be promoted to Kelte-Awlaelo and Seharti-Samre districts respectively, to enhance egg productivity of farmers.
- Since, Horro chicken is being locally improved with no need of importation and adaptation problems but still performed less on body weight measurements across all ages as compared to the exotic breeds, so further genetic improvement is recommended.

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7. APPENDIX

Table 1: ANOVA table for body weight at 90 days

Source of variations	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Breed	4	1208193	302048	23.115	1.91e-15 ***
District	1	567304	567304	43.414	4.67e-10 ***
Sex	1	68062	68062	5.209	0.0236 *
Breed:district	4	346959	86740	6.638	5.24e-05 ***
Breed:sex	4	32721	8180	0.626	0.6445
District:sex	1	396	396	0.030	0.8620
Breed:district:sex	2	10978	5489	0.420	0.6576
Residuals	181	2365161	13067		

Table 2: ANOVA table for body weight at 120 days

Source of variations	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Breed	4	2632385	658096	35.501	< 2e-16 ***
District	1	8114	8114	0.438	0.5091
Sex	1	89494	89494	4.828	0.0293 *
Breed:district	4	557141	139285	7.514	1.27e-05 ***
Breed:sex	4	85161	21290	1.148	0.3353
District:sex	1	8326	8326	0.449	0.5036
Breed:district:sex	2	4432	2216	0.120	0.8874
Residuals	181	3355297	18538		

Table 3: ANOVA table for body weight at 150 days

Source of variation	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Breed	4	11012643	2753161	26.568	< 2e-16 ***
District	1	119700	119700	1.155	0.283916
Sex	1	1219244	1219244	11.766	0.000747 ***
Breed:district	4	5078702	1269675	12.252	7.75e-09 ***
Breed:sex	4	485618	121404	1.172	0.324907
District:sex	1	24058	24058	0.232	0.630511
Breed:district:sex	2	200891	100446	0.969	0.381312
Residuals	181	18756664	103628		

Table 4: ANOVA table for body weight at 180 days

Source of variations	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Breed	4	10589065	2647266	25.710	< 2e-16 ***
District	1	390676	390676	3.794	0.05*
Sex	1	435049	435049	4.225	0.0413 *
Breed:district	4	3966946	991736	9.632	4.39e-07 ***
Breed:sex	4	224792	56198	0.546	0.7023
District:sex	1	91844	91844	0.892	0.3462
Breed:district:sex	2	387555	193777	1.882	0.1553
Residuals	181	18636837	102966		

Table 5: ANOVA table for ADG between 90 and 180 days

Source of variation	Df	Sum	Sq Mean Sq	F value	Pr(>F)
Breed	4	1183	295.8	5.672	0.000253 ***
District	1	17	16.6	0.319	0.572780
Sex	1	371	370.6	7.107	0.008373 **
Breed:district	4	1971	492.8	9.450	5.85e-07 ***
Breed:sex	4	178	44.6	0.855	0.491906
District:sex	1	118	117.8	2.259	0.134596
Breed:district:sex	2	322	161.1	3.090	0.047902 *
Residuals	181	9439	52.1		

Table 6: ANOVA table for hen-day egg production percentage

Source of variations	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Breed	4	172.3	43.1	5.970	0.000728 ***
dist_code	1	2520.0	2520.0	349.224	< 2e-16 ***
Breed:dist_code	4	155.6	38.9	5.391	0.001439 **
Residuals	40	288.6	7.2		

Table 7: ANOVA table for hen-housed egg production percentage

Source of variations	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Breed	4	2665	666	105.4	<2e-16 ***
dist_code	1	3869	3869	612.1	<2e-16 ***
Breed:dist_code	4	7224	1806	285.7	<2e-16 ***
Residuals	40	253	6		

Table 8: ANOVA table for age at first egg

Source of variations	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Breed	4	4879	1219.7	4.543	0.00405 **
dist_code	1	315	315.0	1.173	0.28522
Breed:dist_code	4	4769	1192.3	4.441	0.00460 **
Residuals	40	10740	268.5		

Table 9: ANOVA table for average egg weight

Source of variations	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Breed	4	15.44	3.86	2.829	0.0371 *
dist_code	1	110.12	110.12	80.691	3.88e-11 ***
Breed:dist_code	4	7.29	1.82	1.335	0.2737
Residuals	40	54.59	1.36		

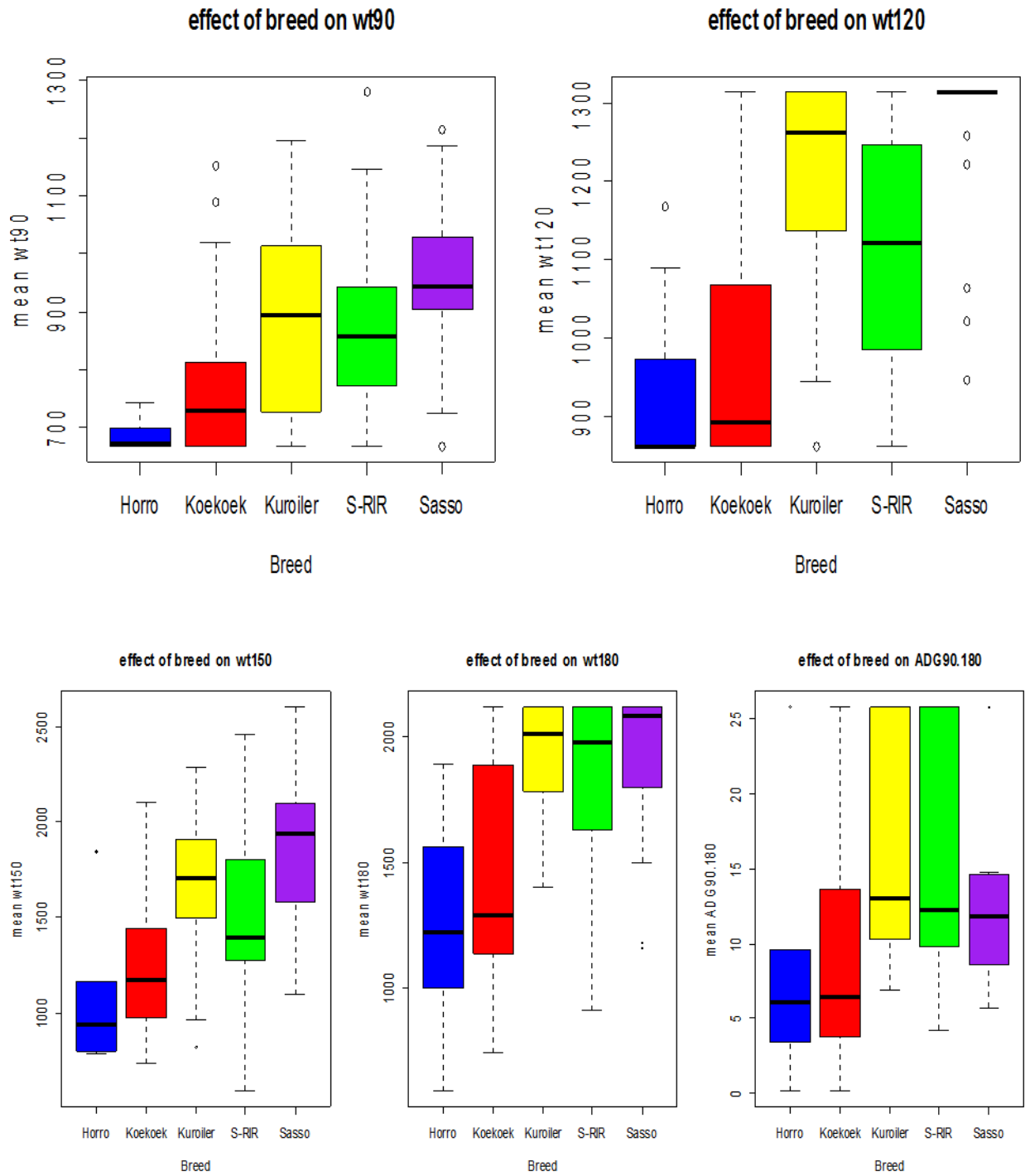
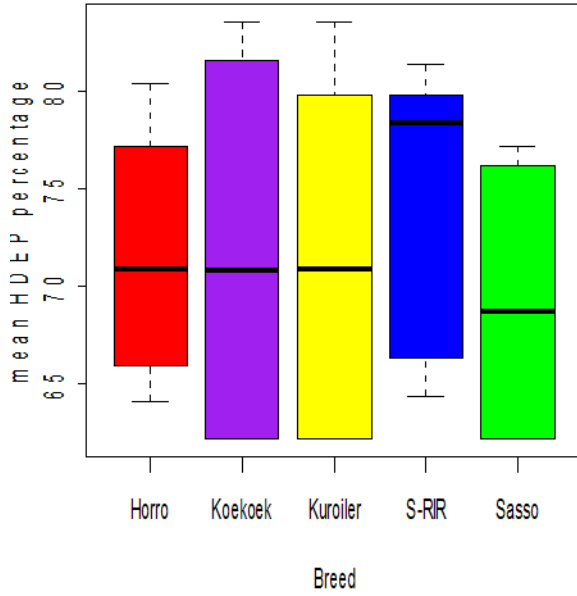
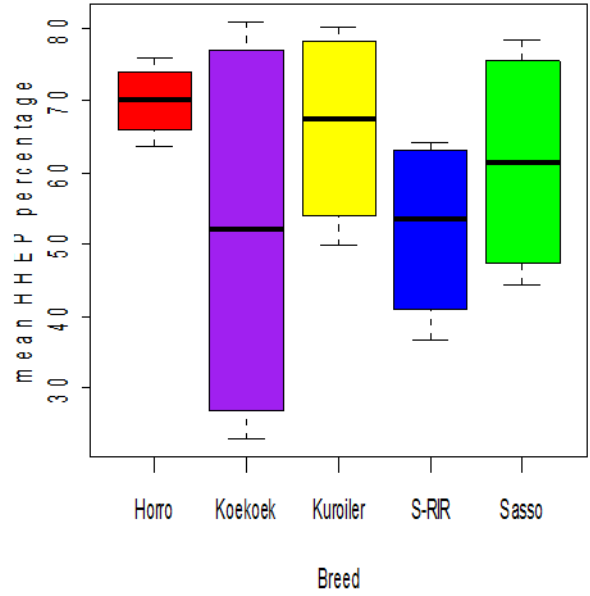


Figure 1: Main effect of Breed on body weight trait

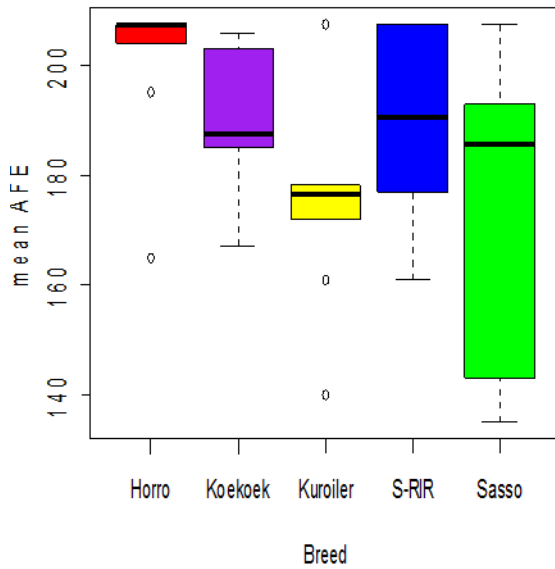
effect of Breed on HDEP percentage at 30 weeks of age



effect of Breed on HHEP percentage at 30 weeks of age



effect of Breed on age at first egg



effect of Breed on Average egg weight

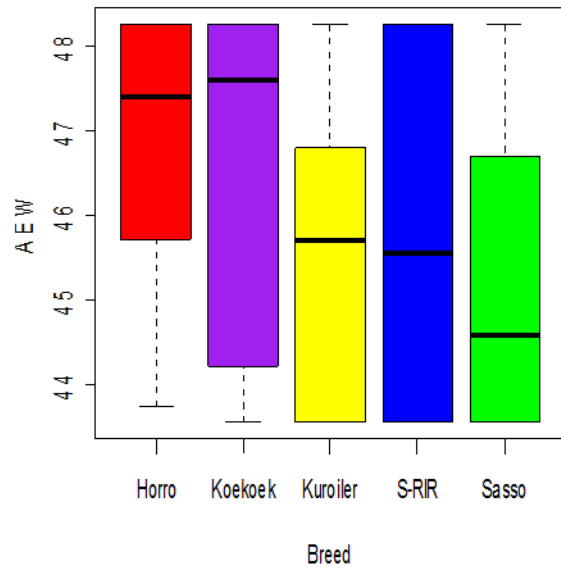


Figure 2: Main effect of Breed on egg production performance traits

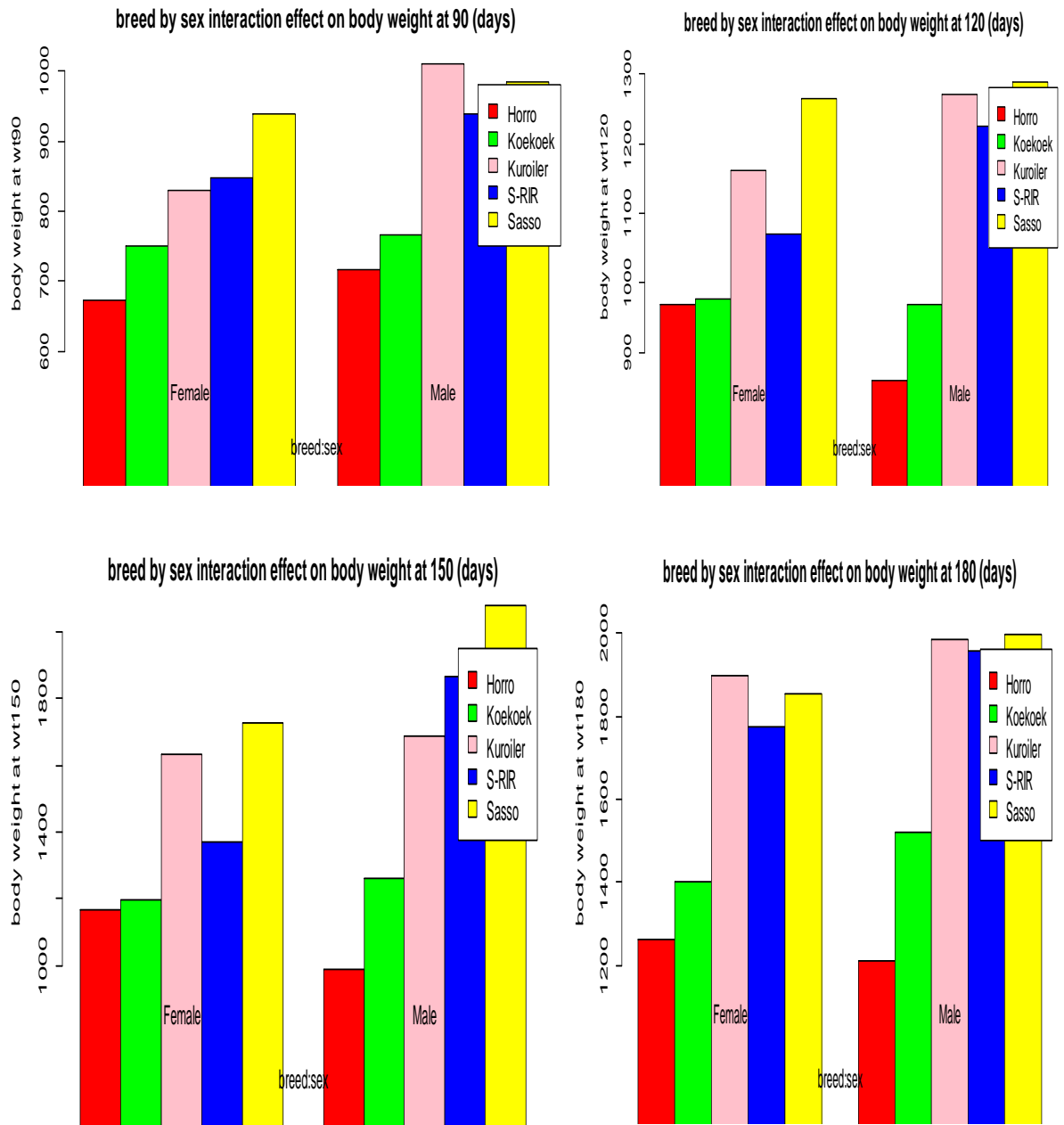
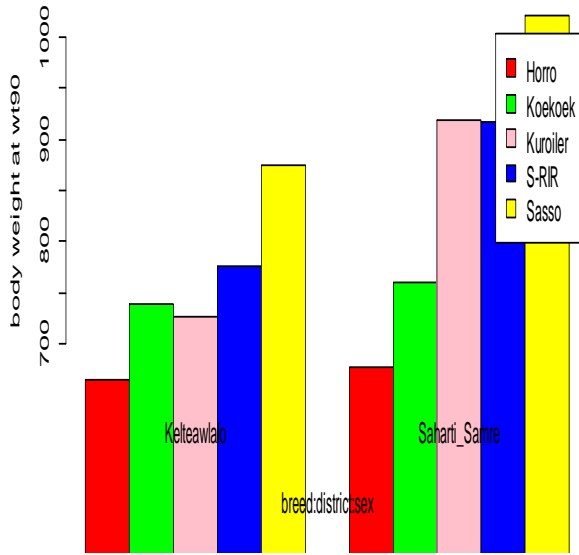
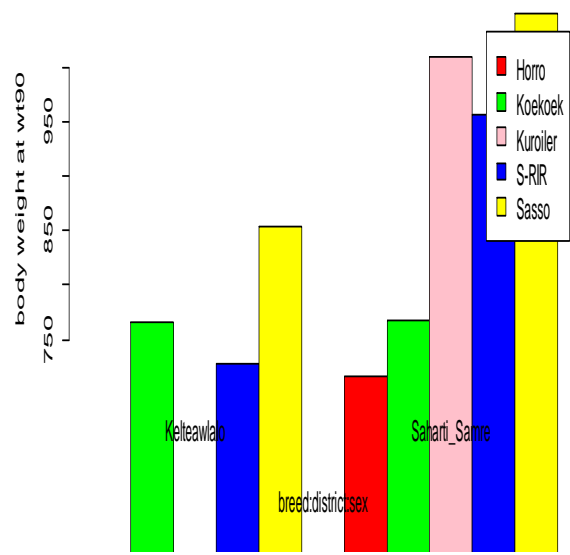


Figure 3: Breed by sex interaction effect on body weight trait

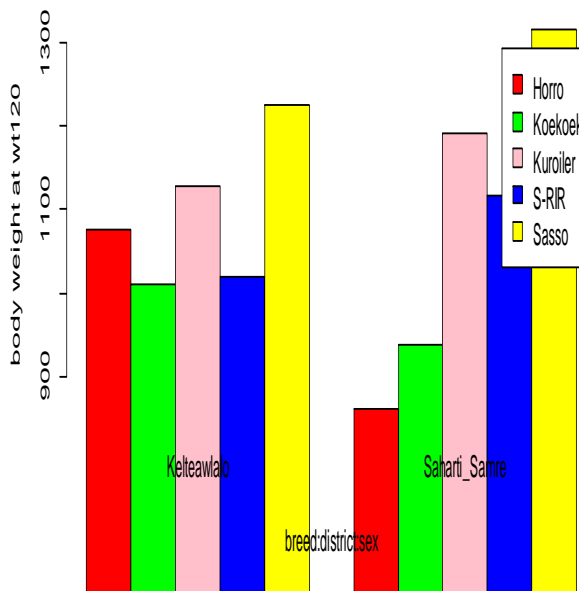
breed:district:sex interaction effect (female body weight at 90 days)



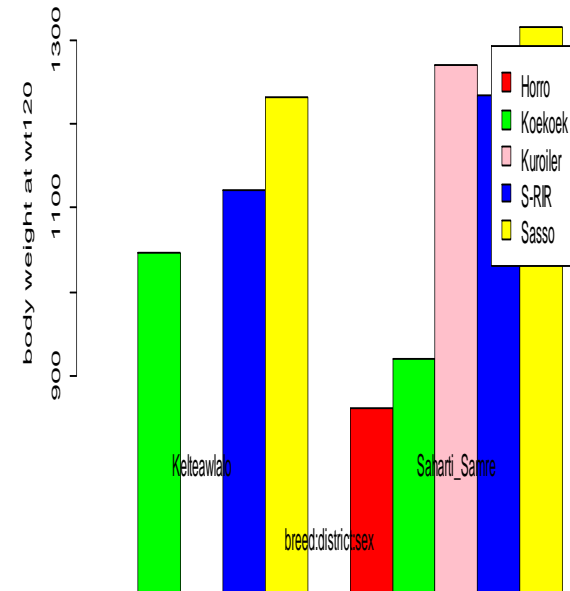
breed:district:sex interaction effect (male body weight at 90 days)



breed:district:sex interaction effect (female body weight at 120 days)



breed:district:sex interaction effect (male body weight at 120 days)



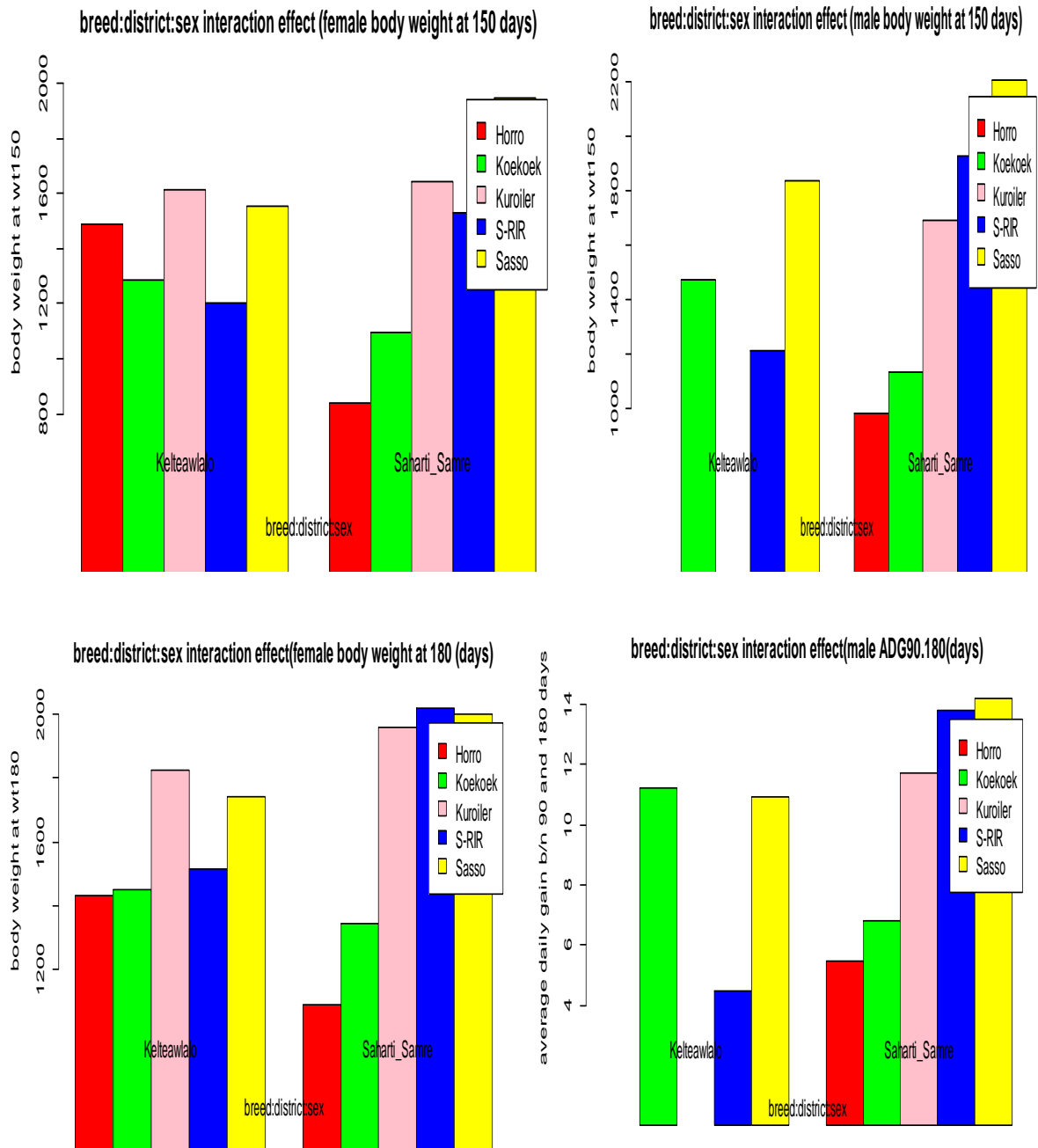


Figure 4: Breed × district × sex interaction on body weight trait

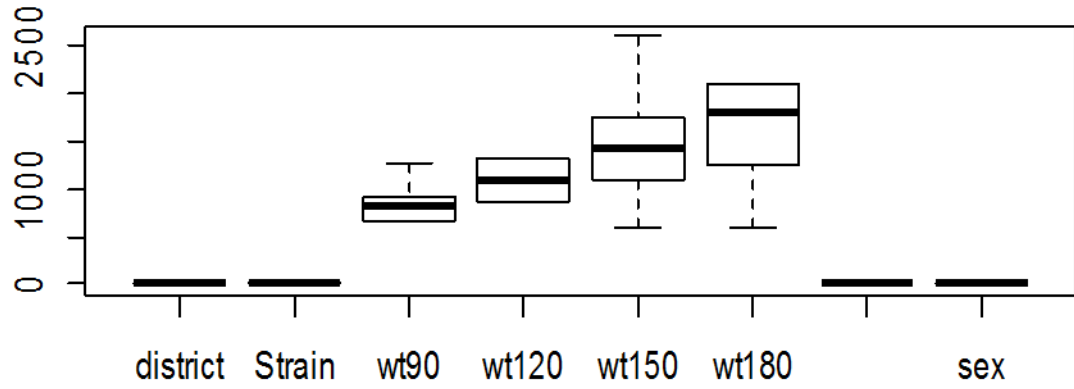


Figure 5: Boxplot of the studied variables on body weight trait

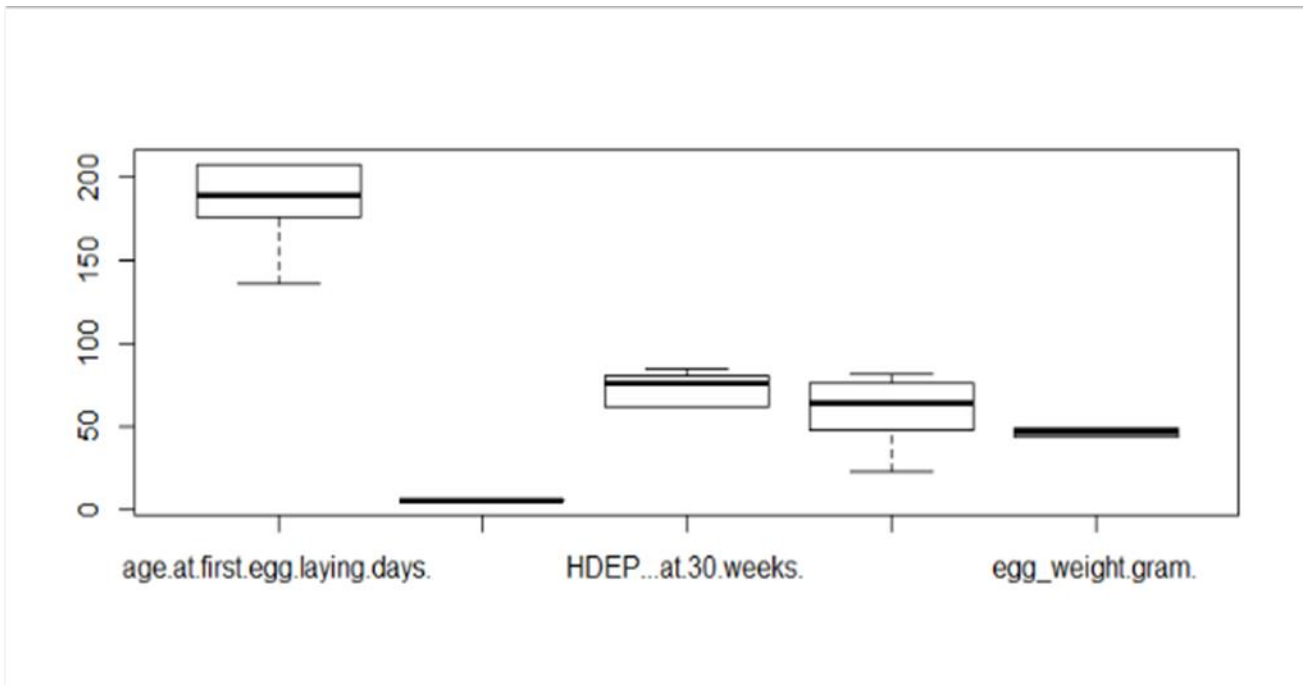


Figure 6: Boxplot of the studied variables on egg production traits