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# Effect of the Genotype by Environment Interaction on the Productive and Reproductive Performance of Livestock in Ethiopia: A Reviews

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**Abstract:**
The review was undertaken with the aim of assessing the effect of genotype-environment interaction (GEI) on the productive and reproductive performance of livestock across tropical countries, including Ethiopia. This review is based on published scientific research investigating the effects of genotype-environmental interaction on the productive and reproductive performance of selected livestock species in tropical countries. Genetic correlation and heritability estimates were assessed as indicators for the presence of GEI for traits among the environments. Spearman's ranking correlation was also assessed as a means for appropriate sire re-ranking for selection. According to the reviews, significant GEI was observed over productive milk traits such as lactation milk yield, initial milk yield, and average milk yield. Similarly, a significant GEI effect was also observed in the body weight gain performance of livestock in Ethiopia and other tropical countries. Reproductive traits such as age at first service, service period, and age at first lambing were also affected by GEI. The chicken egg traits such as shell thickness, egg weight, egg width, and egg length were also affected by the differences in environments and management conditions. The influence of GEI on the phenotypic expression of traits among environments was assessed based on assumptions indicating that GEI has significant importance if the genetic correlation of traits between environments is less than 0.80. General, genetic correlation, and heritability estimates in the tropics showed significant GEI for the productive and reproductive performance of animals, and hence the genetic evaluation and selection of sires require information from both locations to accurately select the most appropriate sire for each location.

*Keywords: GEI, genetic correlation, heritability, traits*

## INTRODUCTION

The interaction of genotype by environment (GEI) refers to the different responses of genotypes to different environmental conditions. It also explains the change in the relative performance of two or more genotypes measured in two or more environments (Wakchaure et al., 2016). Understanding the genotype through environmental interaction is crucial for developing appropriate breeding and management strategies that best suit a specific environmental management setting. By identifying the most suitable genotypes for different environments, livestock producers can optimize productivity and reproductive performance, ultimately contributing to the sustainable development of the livestock. Rashid et al. (2016) stated that the most important thing in the field of animal breeding is mostly associated with identifying and developing genotypes that provide continuous economic performance under varied production. Most importantly, understanding the opportunities and limitations of the production environment where animals are maintained provides an important basis for sustainable livestock intensification and the appropriate use of livestock genetic resources (Ashebir et al., 2014). This is mostly associated with the fact that the expression of inherited genetic merit varies across environmental conditions and is greatly influenced by non-genetic factors (Dal et al., 2003). Usman et al. (2013) stated that the full expression of the genetic worth of animals depends on the extent of genotype and environmental interaction. Hence, it needs the appropriate quantification of GEI for maximizing yield from livestock (Paula et al., 2009). Williams et al. (2012), in line with these results, mentioned that the appropriate knowledge of GEI helps livestock producers select the best animals that are proven to have the best performance. Usman et al. (2013) state that animals perform well in their natural home. Their work further reported that 30–40% milk yield reduction temperate dairy cattle breeds evaluated in the tropics. Appropriate quantification of GEI can improve artificial selection progress and increase the efficiency of genetic evaluation of sires that are managed under different environmental conditions (Guidolin et al., 2012).

Scholars have used different approaches to know the presence of an estimate GEI. The basic approach was associated with estimating the genetic correlation between phenotypes for given traits under different environmental conditions (Wakchaure et al., 2016). Many studies indicated that estimating genetic correlations between or among environments has been mostly used to indicate the influence of GEI on the expression of phenotypic performance of traits (Ashebir et al., 2014; Rashid et al., 2016; Wakchaure et al., 2016). A high GEI variance component will result in a low (Kang, 2002), which could also mean assessing the influence of GEI.

Earlier studies have reported the existence of significant GEI in different productive and reproductive traits. Rashid et al. (2016) reported the presence of large effects of GEI on the growth traits of Brahman crossbred cattle kept on station and in farm conditions. This interaction has become a critical component in livestock production due to producers selecting sires for improved performance, which is not being observed in the performance of the offspring (Wakchaure et al., 2016). Therefore, it is important to understand the production environment while making management decisions, such as selecting breeds in a crossbreeding system, since interactions may influence reproductive efficiency.

In the absence of GEI, the expected genetic correlation across environments is one. Greater than 0.80 genetic correlations between environments do not show evidence for strong GEI (Wakchaure et al., 2016). A large genetic correlation of traits between environments indicates a slight GEI effect, whereas a small genetic correlation between traits indicates a strong GEI influence on the phenotypic performance of animals. A long-term study by Robertson (1959) reported that serious reductions in the efficiency of animal breeding programs may occur when the genetic correlation between environments is lower than 0.8. Low genetic correlations were obtained between countries that differ considerably in climate, management, and production systems.

In tropical countries with diverse agro-ecological conditions and livestock management practices, the performance of genotypes may differ substantially across the range of available environmental conditions (Ashebir et al., 2014). Kolmodin and Bijma (2004) reported that the phenotypic expression of a trait in different environments would be determined by different sets of genes that are differently expressed under different environments and management conditions. The variation of genotype in different environments is attributed to factors such as climate, feed resource availability, prevalence of disease, and other associated variables. It can be evident that tropical countries, including Ethiopia, are endowed with varied agro-ecological zones where the performance of different livestock genotypes can vary significantly within the specific agro-ecological zones. This variation is attributed to factors such as climate, feed availability, disease prevalence, and other environmental variables. Therefore, based on the above background facts, current reviews assess the effects of genotype and environmental interaction on the productive and reproductive performance of selected livestock species (cattle, sheep, and poultry) in tropical countries, including Ethiopia.

## LITERATURE REVIEWS

### Genotype by Environmental Interaction

A genotype by environment interaction is manifested when genotypes (individuals, lines, varieties, breeds, etc.) show a differential phenotypic response across one or more environments. Stated differently, an interaction occurs when yield/product gains made in a particular environment are not transferred to another environment. The presence of a genotype by environment interaction with widely divergent genotypes and environments is well known and documented in both plants and animals. Studies of genotype x environment interactions are becoming more important as cattle genotypes are now being managed in a diverse range of environments (Bryant *et al*., 2005). Furthermore, Dominik *et al*. (2001) postulate that different genetic relationships exist between different traits across environments. This is supported by different genetic correlations for milk, fat and protein in the high and low yield environments in dairy cattle reported by Castillo-Juarez *et al*. (2002).

Genotype by environment interaction (GEI) could be defined as a change in the relative performance of two or more genotypes measured in two or more environments (Ashebir *et al*, 2014). The G×E means simply that the effect of the environment on different breeds or genotypes is not the same which implies there is no universally best genotype (Rashid et al., 2016). The authors reported that the performance of best genotype vary from one environment to other. The performance of best genotype depends on prevailing environment condition which needs genotype by environment interaction should be considered.

In the presence of GEI interaction, the expression of phenotypic traits in different environment is/are determined by different set of the genes (Kolmodin and Bijma, 2004). Under condition like this, the breeding goal should account for both traits and environment under which these traits would be expressed (Ashebir *et al*., 2014). GEI interaction may result in heterogeneity of genetic variances across environments which alter ranking series of genotype between environments (Callus, 2006). Genotype by environmental interaction that alters the ranking of series of genotypes between environments could considerably hamper selection.

### Effects of Genotype by Environment Different Livestock

#### *Estimation of Genotype by Environment Interaction for Cattle Milk Traits:*

Genotype by environmental interaction has been reported for the association of milk traits such as protein, fat yield, and somatic cell score (Raffrenato et al., 2003), milk yield with fitness traits (Beerda et al., 2007), and milk yield with age at first calving (Ruiz-Sánchez et al., 2007). A recent study conducted in Ethiopia also observed a significant influence of GEI over milk production traits in Bako and Holetta, Ethiopia (Ashebir et al., 2014). The influence of GEI on cattle milk traits in Ethiopia is presented in Table 1.

According to the result for GEI, Holstein Friesian (HF) crossed cows had a higher least mean square (LSM) for milk traits such as lactation milk yield, initial milk yield, peak milk yield, and average milk yield than Simmental and Jersey crossed cows at Holetta. Similarly, the LSM value of the HF-crossed cow at Holetta was higher as compared with the same LSM value for the HF, Jersey, and

Simmental-crossed cow at Bako for milk production traits involved. However, there was no significant difference observed for traits (all) between Jersey and Simmental crossed cows at Holetta ($p<0.05$). Indigenous cattle breeds such as Boran and Horro didn't have significant effect of GEI over milk production considered at $p<0.05$ in Holetta and Bako area.

According to Ashebir et al. (2014), the observed significant difference between indigenous and crossed cows for traits was due to the large genetic difference between additive genetic effects introduced and non-additional genetic effects generated by crossbreeding. The issue of GEI arises when the performance of different genotypes is not equally influenced by different environments, such as climatic and management differences at Holetta and Bako, as indicated by Ashebir et al. (2014).

**Table 1: Least square mean ± standard errors for GEI of selected milk production traits in Holetta and Bako**

| GEI | LMY (kg) | IMY (kg) | PMY (kg) | AMY (kg) |
|---|---|---|---|---|
| Bako –B | 965.57 ±38$^{d}$ | 2.17±0.49$^{e}$ | 3.60±0.51$^{g}$ | 2.34±0.33$^{e}$ |
| Bako –H | 1172.68±33.97$_{d}$ | 2.87±0.15$^{e}$ | 4.73±0.16$^{fg}$ | 2.68±0.10$^{e}$ |
| Bako –FXB | 1703.21±25.06$^{b}$ | 6.03±0.21$^{c}$ | 8.64±0.12c | 5.19±0.08$^{c}$ |
| Bako –JXB | 1575.06±26.06$^{c}$ | 5.54±0.12$^{cd}$ | 7.89±0.13$^{d}$ | 4.81±0.08$^{d}$ |
| Bako - SXB | 1725.06±38.50$^{b}$ | 6.00±0.18$^{c}$ | 8.75±0.18$^{c}$ | 5.29±0.12$^{bc}$ |
| Holetta – B | 1369.72±76.75$^{cd}$ | 4.72±0.35$^{d}$ | 6.99±0.37$^{de}$ | 3.49±0.24$^{e}$ |
| Holetta – H | 1205.88±96.65$^{d}$ | 4.17±0.44$^{de}$ | 6.11±0.46$^{ef}$ | 2.86±0.30$^{e}$ |
| Holetta – FXB | 2111.91±16.88$^{a}$ | 9.26±0.08$^{a}$ | 11.64±0.08$^{a}$ | 6.57±0.05$^{a}$ |
| Holetta – JXB | 1793.11±22.91$^{b}$ | 7.83±0.11$^{b}$ | 9.96±0.11$^{b}$ | 5.60±0.07$^{b}$ |
| Holetta – SXB | 1807.03±34.17$^{b}$ | 7.79±0.16$^{b}$ | 10.35±0.16$^{b}$ | 5.72±0.11$^{b}$ |

Superscript for least square mean with different letter ($^{a,b,c,d,e,f,g}$) are significantly different ($P<0.0001$). GEI – Genotype by Environment Interaction, LMY stands for lactation milk yield, IMY stands for initial milk yield, PMY stands for peak milk yield and AMY stands for average milk yield. B stands for Borana cattle breed, H stands for Horro cattle breed, FXB stands for Friesian crossbred, JXB stands for Jersey crossbreed and SXB stands for Simmental crossbreed.

Variance components such as sire additive genetic variance, permanent environmental variance, residual variance, and phenotypic variances were estimated for milk production traits under Holetta and Bako (Table 2). The larger sire additive genetic variance was for all traits except lactation yield at Bako than at Holetta (Ashebir et al., 2014). On the other hand, lower permanent environmental variances, residual variances, and phenotypic variances were observed for all traits at Bako than at Holetta.

Heritability estimates in relation to the environment were conducted by different researchers in different areas (Gebreyohannes et al., 2013; Sofla et al., 2011; Ojango and Pollott, 2002). A study conducted in Ethiopia by Gebregziabher et al. (2014) estimated lower heritable values for cattle breeds reared in Bako and Holetta research stations for milk production traits (Table 3). The relatively higher heritability value estimated at Bako than Holetta was largely due to higher permanent environmental variances (Table 2, lactation milk yield 66,554.2 kg2 at Bako vs. 125,166 kg2 at Holetta) at Holetta than Bako. The study conducted on the same cattle population by Gebreyohannes et al. (2013) using a single trait repeatability animal model and a combined dataset from the same population showed the heritable estimate for lactation milk yield was 0.36.

The report of the previous result showing a lower heritable value at Holetta than Bako suggests the higher production (for example, milk yield difference) was probably due to a greater extent of favorable environmental conditions than genetic differences among sires. The study conducted on Holstein cattle in Iran reported the heritable estimate was 0.28 and 0.30 over Holstein cattle reared in dry desert and semi-dry desert, respectively. The areas represent less favorable climates, but the values were similar or higher than the heritable estimate under more favorable climates (Sofla et al., 2011). Comparative studies focused on the milk yield performance of Holstein showed a higher milk yield in the UK than in Kenya (Ojango and Pollott, 2002). The heritability estimate for first lactation based on 305-day milk yield was higher in the UK (0.45) than in Kenya, according to the report by Ojango and Pollott (2002). The result suggested a combination of lower adaptability and lower feed intake under tropical conditions (Kenya), which would be otherwise different under the temperate conditions where Holstein originated.

**Table 2: Variance components for lactation pattern and milk production traits at Bako and Holetta**

| Location | Traits | | | | |
|---|---|---|---|---|---|
| | Variance | Lactation milk yield ($kg^2$) | Initial milk yield ($kg^2$) | Peak milk yield ($kg^2$) | Average milk yield ($kg^2$) |
| Bako | | | | | |
| | $\sigma s^2$ | 14,446.5 | 0.33 | 0.37 | 0.19 |
| | $\sigma pe^2$ | 66,544.20 | 1.15 | 2.07 | 0.78 |
| | $\sigma e^2$ | 118,158.00 | 3.36 | 2.98 | 1.28 |
| | $\sigma p^2$ | 199,148.70 | 4.83 | 5.41 | 2.25 |
| Holetta | | | | | |
| | $\sigma s^2$ | 18,681.10 | 0.24 | 0.33 | 0.17 |
| | $\sigma pe^2$ | 125,166.00 | 1.95 | 2.30 | 1.10 |
| | $\sigma e^2$ | 142,012.00 | 4.19 | 3.47 | 1.41 |
| | $\sigma p^2$ | 285,859.10 | 6.38 | 6.11 | 2.68 |

$\sigma s^2$ – sire additive genetic variance, $\sigma pe^2$ – permanent environmental variance, $\sigma e^2$ – residual variance and $\sigma p^2$ – phenotypic variance

**Table 3: The estimated heritability ($h^2$) of lactation patterns and milk production traits at Bako and Holetta, Ethiopia (adopted from Gebregziabher et al., 2014).**

| Traits | Heritability | |
|---|---|---|
| | Bako | Holetta |
| Lactation milk yield (kg) | 0.29 ± 0.12 | 0.26 ± 0.08 |
| Initial milk yield (kg) | 0.27 ± 0.11 | 0.15 ± 0.06 |
| Peak milk yield (kg) | 0.27 ± 0.01 | 0.22 ± 0.01 |
| Average milk yield per day (kg) | 0.34 ± 0.13 | 0.26 ± 0.08 |

The genetic correlation across environments in the absence of GEI is expected to be one (Ashebir et al., 2014). The genetic correlation value is significantly less than one, which indicates the presence of GEI. Under this condition, GEI needs to be considered in the genetic statistical model used for the genetic evaluation and selection of animals.

In the study conducted by Ashebir et al. (2014), the genetic correlation between Bako and Holetta for lactation milk yield, initial milk, and average milk yield was estimated to be 0.82, 0.53, and 0.62, suggesting GEI between these two locations. The result of the authors was in agreement with the genetic correlation value (0.78) of milk yield obtained from the Jersey cattle population of South Africa for the locations between Drier Overberg and the South Cape region versus Subtropical Limpopo and Northern KwaZulu-Natal (Van Niekerk et al., 2006). A similar genetic correlation estimate (0.80) was also reported by Nauta et al. (2006) between a conventional production system and an organic production system, which also indicates the presence of GEI for milk yield. A study conducted in Canada by Boettcher et al. (2003) estimated a genetic correlation (0.93 ± 0.04) for milk yield for herds managed between intensive rotational grazing and conventional grazing involving stored feed, suggesting minor GEI effects for milk yield. A previous study conducted in Ethiopia by Ashebir et al. (2014) indicated the difference in climate and feeding management over Bako and Holetta was responsible for lower genetic correlation for traits as compared with the higher genetic correlation estimate observed in Canada by Boettcher et al. (2005), where the difference seems minimal.

**Table 4: The estimate of genetic correlation of different traits between environments Bako and Holetta**

| Traits | Trait's type | GC | Location | Sources |
|---|---|---|---|---|
| LMY (kg) | Milk traits | 0.82 ± 0.32 | Bako vs. Holetta, Ethiopia | Ashebir *et al*. (2014) |
| IMY (kg) | Milk traits | 0.53 ± 0.39 | Bako vs. Holetta, Ethiopia | Ashebir *et al*. (2014) |
| AMY (kg) | Milk traits | 0.61 ± 0.33 | Bako vs. Holetta, Ethiopia | Ashebir *et al*. (2014) |
| AMY (kg) | Milk traits | 0.93± 0.04 | Intensive vs. conventional management, Canada | Boettcher *et al*. (2003) |
| LMY (kg) | Milk traits | | Humid vs. dry climate, Iran | (Wakchaure *et al*. (2016) |
| | - | 0.49 | USA vs. Kenya | (Ojango and Pollot (2002) |

*p<0.0001, LMY – stands for lactation milk yield, IMY stands for initial milk yield and AMY stands for average milk yield.

The spearman correlation can be used to indicate the presence of GEI across the location. It reflects the difference in environmental condition across locations which can be used for re-ranking of breeding sires considering their breeding values between the locations. The spearman correlation value between Holetta and Bako areas for lactation milk yield, initial milk yield, and average milk yield ranged between 0.86 and 0.87 (Table 4; Ashebir et al., 2014). Generally, GEI observed based on genetic correlation as well as Spearman's rank correlations between sire predicted breeding values across locations suggested that genetic evaluation and selection of sires would require information from both locations to accurately select the most appropriate sires for each location.

***Estimation of Genotype by Environment Interaction for Cattle Growth Traits:***

The study was conducted to evaluate the effects of genotype-environment interaction on the growth traits of Brahman crossbred cattle raised in intensive versus semi-intensive systems in Bangladesh (Rashid et al., 2016). The authors observed GEI influence for growth traits. The genetic correlation was estimated between three months and two to 24 months. According to the result, there was a decreasing trend for genetic correlation as the age of the animal increased, indicating a higher GEI influence for older animals as compared with younger animals. The trend of genetic correlation over the development stage is presented in Table 5. The genetic correlation obtained on the growth traits of Brahman crossed cattle was within the range of agricultural and biological importance. The decision was made based on long-term research by Robertson (1959) suggesting that GEI should be considered when genetic correlations were less than 0.8.

The result of Assenza et al. (2010) was in agreement with the result of Rashid et al. (2016), indicating the existence of significant GEI for yearling weight and growth during the post-weaning period in Creole cattle fattened under two contrasting environments, and the authors measured the reduced genetic correlation as the age of the animal increased. The estimated genetic correlation of Nellore cattle reared in feedlots and on pasture on final weight was reported to be 0.75 (Raidan et al., 2015). On the other hand, Beffa et al. (2009) observed a high genetic correlation estimate (0.96) for different growth traits across different management environments.

**Table 5: The genetic correlation for growth traits of Brahman crossed cattle in Bangladesh.**

| Age (months) | 3MW | 6MW | 9MW | 12MW | 18MW | 24MW* |
|---|---|---|---|---|---|---|
| Genetic correlation | 0.74 | 0.72 | 0.72 | 0.64 | 0.53 | 0.57 |

*MW- Month Weight

***Genotype by Environmental Interaction for Chicken Production Traits:***

A previous study (Abebe et al., 2009) conducted in Southern Ethiopia evaluated the productive performance of two chicken breeds—Rhode Island Red and Fayoumi—that were kept under two management systems—on station and on farm at different ages, and the results were compared with local chickens owned by farmers. The result of the study showed that significant breed-environment interaction was observed for all the traits (egg production, egg quality, body weight, feed conversion efficiency) measured in both systems. Accordingly, Fayoumi chicken provided more eggs than Rhode Island Red in both environments. Similarly, Fayoumi chicken had higher feed conversion efficiency than Rhode Island Red. On the other hand, Rhode Island had a higher value for egg quality traits and gained more weight than Fayoumi. Moreover, chickens kept on the farm (local chickens compared) had poorer performance than those at the station for almost all traits except yolk color.

Another recent study by Kejela et al. (2019) was conducted with the objective of analyzing egg quality parameters of chickens (local, Sasso, and Bovans brown) reared in Hawassa and Yirgalem towns, southern Ethiopia. The study reported a high egg weight variation between genotype and environment for three categories of chickens (Table 3). The egg quality-related parameters studied by Kejela et al. (2019) included egg weight, egg length, egg width, dry shell weight, and shell thickness.

**Egg Weight:**

A previous study by Gezahegn et al. (2016) reported that the size and weight of eggs are moderately heritable traits that are influenced by genotype and environmental interaction. Recent research results (Kejela et al., 2019) and research conducted in the Oromiya region (Tadesse, 2012, and Tadesse et al., 2015) reported that eggs obtained from Sasso and Bowans brown chickens had a higher weight than the local chickens studied.

The result Kejela et al. (2019) showed that there was no significant weight difference between Sasso and Bowan brown in Hawassa town, which was on the other hand shown in Yirgalem town, where Bown brown had a higher egg weight performance than the Sasso chicken breed ($P<0.05$). The result of the current study was in agreement with other findings from Ethiopia (Emebet, 2015; Aberra et al., 2012; and Molla, 2010). Another study by Zita et al. (2009) reported the presence of a correlation among the genotype of chickens, their weight, and their eggs. The other research work also reported that the age of the chicken and the weight of its egg are correlated in line with the quality and availability of feed the chicken is given; better quality feed availability caused the chicken to lay a relatively heavy egg (Padhi et al., 2013).

**Shell Thickness:**
Shell thickness constitutes external egg quality and can be defined as a measure of the shell strength of an egg associated with reduced eggshell breakage (Alewi et al., 2012). There have been a number of reports on egg shell thickness in different parts of the world. Research work from an on-station experiment over naked-neck chicken in Ethiopia reported the value of egg shell thickness being 0.370 mm (Melese et al., 2010). The higher comparative value (0.580 mm) on egg shell thickness was reported by Fayye et al. (2005) in their research work conducted on the scavenging Fulani ecotype of Nigeria. This variation in egg shell thickness in different regions could be associated with the quality, quantity, and nutrition composition of the available feeds for chickens (Abera et al., 2012).

A similar result on shell thickness was reported by Kejela et al. (2019) over three chicken types studied in Hawassa and Yirgalem towns in southern Ethiopia. The author (s) reported average egg shell thickness values (mm) of 0.22, 0.25, and 0.28 for local, Sasso, and Bowans Brown chickens, respectively. The result showed significant genotype-environment interaction in terms of egg shell thickness across two locations. The higher egg shell thickness value was observed for Sasso chicken in Hawassa town than in Yirgalem town. In contrast, the egg shell thickness of Bovans Brown chicken had a higher value in Yirgalem town than Hawassa. Abera et al. (2012) reported that the overall shell thickness of indigenous chickens under different agro ecologies in the Amhara Region was 0.309 mm. Other finding in the Jimma Zone of Ethiopia reported that the overall shell thickness of fresh and aged (stayed) eggs was 0.38 and 0.33 mm, respectively (Molla, 2010). This may be attributed that egg are laid at different time, may contribute for egg shell thickness difference.

According to Abera et al. (2012), egg shell thickness is a moderately heritable trait that is influenced by the genotype and calcium and phosphorous metabolism, which could vary across different ages of chickens and the nutrients (minerals) mentioned above.

**Table 6: The shell thickness of egg in different regions (Ethiopia)**

| **Chicken breed/ecotypes** | **Shell thickness (mm)** | **Place** | **Sources** |
|---|---|---|---|
| Local chicken Hawassa | 0.24 | Ethiopia | Kejela *et al*. (2019) |
| Local chicken Yirgalem | 0.19 | Ethiopia | Kejela *et al*. (2019) |
| Sasso in Hawassa town | 0.26 | Ethiopia | Kejela *et al*. (2019) |
| Sasso in Yirgalem town | 0.24 | Ethiopia | Kejela *et al.* (2019) |
| Bovan browns in Hawassa town | 0.24 | Ethiopia | Kejela *et al.* (2019) |
| Bovan brown in Yirgalem town | 0.32 | Ethiopia | Kejela *et al*. (2019) |
| Local chicken in Jimma (fresh egg) | 0.38 | Ethiopia | Meseret (2010) |
| Local chicken in Jimma (aged egg) | 0.33 | Ethiopia | Meseret (2010) |
| Local chicken in Amhara region | 0.31 | Ethiopia | Abera *et al*. (2012) |
| Naked-neck chicken | 0.37 | Ethiopia | Melese *et al*. (2010) |
| Fulani ecotype | 0.58 | Nigeria | Fayye *et al*. (2015) |

Chicken under Hawassa and Yirgalem was compared for Genotype by environment interaction.

**Length of Egg:**

The result showed that the egg length of chickens varied over two locations in southern Ethiopia (Kejela et al., 2019), showing an interaction effect of genotype by environment ($p<0.05$). A similar report was available showing the varied length of eggs across chicken genotypes, which is also influenced by non-genetic factors (Isidahomen et al., 2014). There have been different previous studies in different parts of Ethiopia. The egg length of the Sasso chicken breed in Hawassa and Yirgalem towns was reported at 55.77 and 55.63 mm, respectively (Kejela et al., 2019). According to the same authors, an average egg length of 55.79 mm and 55.39 mm was recorded for eggs collected from Bovans brown chickens kept in Hawassa and Yirgalem, respectively. On the other hand, a lower mean value was observed for Fayoumi crossed (50.0 mm) and Rhode Island Red crossed (51.4 mm) chickens kept under the Gurage Zone of Southern Ethiopia (Alewi et al., 2012). A similar result (51.3 mm) was reported based on research conducted in the Amhara region (Abera et al., 2012). A relatively higher average value (53.8 mm) of egg length was reported from research conducted in the western lowland area of the Tigray region (Markos et al., 2017). However, a lower mean value (48.3 mm) was reported for native chickens in Bangladesh (Islam and Dutta, 2010). Therefore, it is concluded that egg length is influenced by chicken genotype and environmental interaction.

**Egg Width:**

Markos et al. (2017) and Kejela et al. (2019) reported the presence of genotype-environmental interaction for differences among eggs from different chickens. According to Kejela et al. (2019), varied egg width was observed across genotype and location. The egg from local chicken was found to be narrower when compared with that from exotic chicken (Isidahomen et al., 2013). The findings of Abera et al. (2012) from the Amhara region and Markos et al. (2017) from the midland of the Tigray region were in agreement with the results of Isidahomen et al. (2013). The result of Kejela et al. (2019) showed a higher average egg width value for exotic chickens (Sasso and Bovan Brown), which also showed variation across the locations (Hawassa town and Yirgalem town). According to the results of Alewi et al. (2012) and Padhi et al. (2013), the width of the egg is associated with the stage of egg laying, in which the egg laid prior to mounting became larger than that laid at the start.

***Genotype Environmental Interaction for Sheep Traits:***

**Productive Traits:**

The growth traits of indigenous sheep reared in different parts of Ethiopia are presented in Table 7. According to the report by Taye et al. (2010), the productive performance of sheep is varied across different environmental conditions. The better birth weight performance was observed for Arsi-Bale indigenous sheep managed on farm than in station conditions (Legesse, 2008). However, sheep that were managed under on-station conditions showed a higher value (kg) for weaning weight as compared with those managed under farmer conditions, indicating a higher daily weight gain between the management conditions (Table 7).

**Table 7: Birth and weaning weight (kg) of indigenous Ethiopia sheep under different management condition.**

| Indigenous sheep breed | Management Condition | Birth weight (Kg) | Weaning weight (Kg) | ADWG (gm/day) | Reference |
|---|---|---|---|---|---|
| Adal | On farm | 2.5 | 13 | | |
| Adilo | On farm | 2.29 | 11.18 | 98.77 | Legesse, 2008 |
| Arsi-bale | On farm | 2.89 | 12.23 | 102.01 | Legesse, 2008 |

| | | | | | |
|---|---|---|---|---|---|
| Arsi-bale | On Station | 2.8 | 13.5 | Na | Brannang *et al*., 1987 |
| Bonga | On farm | 2.86 | 11.6 | Na | Belete, 2009 |
| Horo | On Station | 2.4 | 9.48 | 78 | Tibbo, 2006 |
| Menz | On farm | 2.9 | 14.38 | 105 | Hassen *et al*., 2014 |
| Menz | On station | 2.06 | 8.64 | 72.6 | Tibbo, 2006 |
| Washara | On farm | 2.7 | 11.9 | 59.1 | Taye *et al*., 2010 |

A similar condition was observed for the birth weight performance of indigenous Menz sheep between on-farm and on-station management conditions based on different time research works (Tibbo, 2006; Hassen et al., 2014). Observation based on these results showed improvement between 2006 and 2014 in terms of both birth weight (2.06 vs. 2.9) and weaning weight (8.64 vs. 14.38), for which the main reason could be a difference in time and management conditions**.**

**Reproductive Traits of Sheep:**

A comparative study of Begait sheep in government ranches, private ranches, and private farms was conducted in the northern western part of Ethiopia (Ashebir et al., 2016). The author reported a relatively higher twining (13.4%) rate in government ranches and the lowest in private farms (6.52%). The mean value for age at first service, service period, age at first lambing, and lambing interval was reported at 579.61±0.6, 206.25±0.2, 731.67±0.3, and 256.60±60 days, respectively (Ahebir et al., 2016). The authors further reported that service period and age at first service showed significant differences among different locations. However, lambing interval and age at first lambing were not affected by location at $P<0.05$.

**Table 8: The Reproductive performance (Mean±SE) of Begait sheep kept under three locations studied**

| Location | N | AFS (days) | SP (days) | AFL (days) | LI (days) |
|---|---|---|---|---|---|
| Gov. Ranch | 50 | 576±1.1$^{a}$ | 206.48±0.4$^{b}$ | 733±0.5$^{b}$ | 254.32±0.5$^{a}$ |
| Private Ranch | 50 | 582±0.9$^{b}$ | 207.10±0.3$^{b}$ | 730±0.2$^{a}$ | 259.80±0.6$^{a}$ |
| Private Ranch | 50 | 580±0.8$^{b}$ | 205.16±0.3$^{a}$ | 732±0.3$_{b}$ | 257.82±0.6$^{a}$ |
| Mean | 50 | 579.61±0.6 | 206.25±0.2 | 731.67±0.3 | 256.60±0.3 |

AFS – Age at first service, SP – Service period, AFL – Age at first lambing and LI – Lambing interval

Previous studies confirmed that age at first lambing showed variation among breeds and production systems. Study by Legesse (2008) and Girma (2008) showed a big variation in age at first lambing among production systems and breeds.

## SUMMARY AND RECOMMENDATION

The review was undertaken with the general aim of assessing the effects of genotype-environment interaction on the productivity and performance of livestock in Ethiopia and tropical countries. Genotype-environment interaction is defined as a change in the relative performance of two or more genotypes measured in two or more environments. The issues of GEI arise when the performance of the different genotypes is not equally influenced by the different environments. Genetic correlation and estimates of heritability between traits were commonly used to assess the effect of GEI influence on the phenotypic performance of animals. Exiting evidence indicated that a genetic correlation lower than 0.8 between traits requires consideration of GEI influence when planning for animal genetic evaluation and sire selection. This review observed different milk production-related traits such as lactation milk yield, initial milk yield, and average milk yield of cattle, as indicated by the genetic correction of these traits across locations.

Significant GEI influence was also observed for the growth traits of cattle in Ethiopia and other tropical countries. Similarly, the effect of GEI prevailed for chicken egg parameters such as egg width, shell thickness, length of egg, and width of egg among chicken breeds investigated in different environments. Sheep growth traits (birth and weaning) and productive traits (age at first services, age at first lambing, and service periods) were significantly influenced by the effects of GEI. General genetic correlation and heritability estimates in the tropics and Ethiopia showed significant GEI for the productive and reproductive performance of animals, and hence the genetic evaluation and selection of animals require information from intervention locations to accurately select the most appropriate animals for each location. Further in-depth research and continued evaluation of this interaction are essential for the development of targeted breeding programs and improved livestock management practices across various agro-ecological zones in the tropics.

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