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REGULAR ARTICLES

Genetic and non-genetic factors influencing the performance of the West African Dwarf (WAD) goat kept at the Kintampo Goat Breeding Station of Ghana

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Abstract

A study was conducted to analyze the effect of genetic and non-genetic factors influencing the growth performance of the West African Dwarf goat. Breed records of 836 kids born by 259 does, and 8 bucks from 2011 to 2017 at the station were used. Growth performance traits studied were birth weight, weaning weight, 6-month body weight, 9-month body weight, yearling weight, and pre-weaning and post-weaning growth rates. The fixed effects of sex of kid (male or female), season of kidding (major, minor, and dry), year of kidding (2011–2017), and type of birth (single, twins, or triplets) on growth performance were determined. Genetic parameters such as heritability and correlations among the traits were also estimated. The non-genetic data (fixed factors) obtained were analyzed using the general linear model procedures of GenStat (Discovery Edition 12). Heritability estimates obtained for the growth traits were 0.45 ± 0.15, 0.57 ± 0.29, 0.04 ± 0.05, 0.74 ± 0.59, 0.49 ± 0.35, 0.55 ± 0.39, and 0.54 ± 0.36, respectively, an indication of high genetic variation existing among the traits (with the exception of 6-month body weight). This could be harnessed and utilized for genetic improvement within the flock. The phenotypic correlation coefficients among the traits ranged from low to high (0.04–0.95), indicating that there is a linear relationship among body traits of the goats which may be caused by either genetic or environmental factors of correlation. The genetic correlations were also medium to high (0.30–0.96). The general implications are that selection for any of these growth traits in a breed improvement programme would have a considerable simultaneous positive impact on each other. The overall birth weight, weaning weight, 6-month body weight, 9-month body weight, yearling weight, and pre- and post-weaning growth rates obtained were 1.48 kg, 5.35 kg, 6.56 kg, 8.30 kg, 10.00 kg, 32.26 g/day, and 19.39 g/day, respectively. These growth performances were found to be significantly influenced by the non-genetic factors studied. There is therefore the need to factor these in future breed improvement programmes to ensure their success.

Keywords Heritability · Phenotypic correlation · Genetic correlation · Genetic variation · Genetic improvement

Introduction

It is reported that Africa held approximately 35% of the world's goat population as at 2012, with the species being the most abundant production livestock species on the continent (FAO 2014). Goats play critical roles in supporting families in most parts of rural Africa, including contribution to nutrition and food security, employment for income generation, soil fertility management, etc. (FARM-Africa 2007; Ofori 2008). Through the African Goat Improvement Network (AGIN) of the USAID's Feed the Future Initiative, over 46 breeds of goats have been identified in Africa, out of which 14 are indigenous breeds, and one of these native breeds is the West African Dwarf (WAD) goat (also known as Djallonké, an achondroplastic dwarf) which is found in most West African countries (Huson et al. 2014). In Ghana, the extensive acceptance of the WAD goat breed makes it an integral part of the mixed farming systems of most rural households, serving as a coping mechanism against crop failure among other benefits. According to the Ghana Livestock Development Policy and Strategy 2016 (MoFA 2016), goats, mainly the WAD goats, are the most commonly reared ruminant livestock in Ghana, and this is due to the breed's desirable

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traits such as hardiness/adaptability, relatively high prolificacy, precociousness, and trypanotolerance and the fact that goat meat is widely acceptable with good market share in the country (Adzitey 2013). Thus, it may be worthwhile to take advantage of these tropically favourable characteristics of the WAD goat to build food security resilience in the face of global climate change. Consequently, improving the productivity and the entire value chain of the WAD goat breed may create an alternative livelihood for poverty alleviation and enhancement of living standards among the rural poor and facilitate attainment of some other Sustainable Development Goals (SDGs) such as zero hunger, gender equality, decent work and economic growth, responsible consumption and production, ensured good health and well-being, and climate action.

Genetic improvement through well-designed selection programme can contribute to the desirable increase of the productivity of the WAD goat. The implementation of a scheme such as the Open Nucleus Group Breeding Scheme will generate genetically superior animals which can be distributed efficiently to the farmers. Such scheme could help to overcome current barriers caused by the community and village semi-intensive and extensive goat production characterized by communal grazing, multi-sire flock, small flock size, uncontrolled mating, and absence of animal identification and performance records, which hinder the breed improvement at the farm/household level.

The potential of genetic improvement of the trait of interest is largely dependent on the genetic variation of the trait within the population, its heritability value, and genetic relationship (correlation) with other traits of economic importance upon which some selection pressure may be applied (Falconer and Mackay 1996). Data on heritability and correlation is essential and a prerequisite for planning efficient breeding programmes and for estimation of breeding values, construction of selection indices, and prediction of response to selection (Falconer and Mackay 1996). However, when selection starts in a breeding scheme and the rate of inbreeding (family relationship or relatedness) is not checked, genetic variation within the population may be reduced and may impede genetic progress. Moreover, it is imperative to reassess genetic parameters including the level of inbreeding after a certain period of continuous selection since these may change over time.

Even though some studies by (Rashidi et al. 2008; Thiruvenkadan et al. 2009; Alade et al. 2010; Faruque et al. 2010; Birteeb et al. 2015; and Jembere 2016) on the effect of genetic and non-genetic factors affecting growth performance of WAD goats have been done, little work has been on the WAD goat populations in Ghana (Ayizanga et al. 2013). Research is therefore necessary to estimate genetic parameters to provide up to date data for breeding decisions. The objective of this study was therefore to estimate heritability and correlation for some production traits and the effects of non-genetic factors on the growth performance of the WAD goats in Ghana. The results of this study may provide useful information and guidelines for suitable improvement and conservation of the breed, particularly at the National Goat Breeding Station at Kintampo in the Bono East Region of Ghana.

Materials and methods

Description of study area

The study was carried out at the National Goat Breeding Station at Kintampo in the Bono East Region of Ghana, which was established in 1972 by the Animal Production Directorate (APD) of the Ministry of Food and Agriculture (MoFA) with the aim of sustaining a National WAD Goat Nucleus Breeding Centre. Kintampo is located on latitude 8°03′ N and longitude 1°43′ W (Ghana Districts 2014) as cited by Birteeb and Lomo (2015). Physically, the district is hilly in the south with elevation ranging from 700 to 1200 m above mean sea level and fairly flat and undulating in the north with elevations of 350 m to 500 m above sea level. The mean annual rainfall is between 1400 and 1800 mm, and the mean temperature ranges between 20 and 36 °C. The area is in the transitional agro ecological zone and has three distinct seasons defined as follows: major rainy season (April–July), minor rainy season (August–November), and dry season (December–March). The vegetation is semi-deciduous forest type which graduates into the woody savannah type characterized by ground layer of annual grasses, scattered shrubs and dawadawa, baobab, and sheanut trees in the northern sector.

Flock management

The flock of WAD goats is managed at the station under the semi-intensive system. The pens are mainly stalls with concrete floors filled with litter. The goats are stratified and housed according to their ages in groups of lactating dams and kids, adult breeding does, and pregnant does. Usually, kids are weighed within 24 h after birth with a spring balance and are identified using indelible ink and later given permanent identification with ear tags. Subsequently, the kids are weighed on weekly basis in the first month and thereafter on monthly basis to a year. All animals are weaned at 120 days of age. Pasture mating is practiced where males are introduced to does during a mating period of 45 days at a ratio of 1:30. The animals are allowed to graze on cultivated pastures made up of *Cajanus cajan*, *Panicum maximum*, *Cynodon* spp., *Centrosema pubescens*, *Stylosanthes hamata*, and *Ficus* spp. Routine feed supplementation (especially in the dry season with groundnut and cowpea haulms, rice bran, corn chaff, cotton seed, cassava peels, etc.) and medication regimes (deworming of adults and weaners with Albendazole or Avomec, administration of antibiotics, vaccination against

Peste des petits ruminants (PPR), spraying to control ticks and other ectoparasites) are followed.

Data collection

A 7-year progeny records consisting of 836 kids born by 259 does and 8 bucks from 2011 to 2017 at the National Goat Breeding Station in Kintampo was collected, cleaned/edited, and used for the analysis. The records used were birth weight (BWT), weaning weight (WWT), 6-month weight (6MWT), 9-month weight (9MWT), and yearling weight (YWT). Pre-weaning average daily gain or growth rate (ADG1) and post-weaning average daily gain or growth rate (ADG2) were calculated as follows:

$$\mathrm{ADG1}\left(\frac{\mathrm{g}}{\mathrm{day}}\right)=\frac{\mathrm{WWT}-\mathrm{BWT}}{120\ \mathrm{days}}x100g\ \text{and}\ \mathrm{ADG2}\left(\frac{\mathrm{g}}{\mathrm{day}}\right)=\frac{\mathrm{YWT}-\mathrm{WWT}}{245\ \mathrm{days}}x1000g.$$

Data analysis

To determine the effect of non-genetic factors on growth performance, a fixed effect model was fitted using the generalized linear model (GLM) procedure of GenStat (Discovery Edition 12) to investigate the fixed effects of season of kidding (3 classes), type of birth (3 classes), sex of kid (2 classes), and year of birth (7 classes) on the growth performance of the WAD goats. Where differences in means were observed, the means were separated using the least significant difference at 5% level of significance. The statistical model for the birth weight and other growth performance traits was as follows:

$$Y_{\mathrm{ijkl}}=\mu+S_{\mathrm{i}}+T_{\mathrm{j}}+Z_{\mathrm{k}}+Y_{\mathrm{l}}+e_{\mathrm{ijkl}}$$

where Y_{ijkl} is any of the growth traits, μ overall mean of the trait, S_i fixed effect of i^{th} season of kidding (1, 2, 3), T_j fixed effect of j^{th} type of birth (1, 2, 3), Z_k fixed effect of k^{th} sex of kid (1, 2), Y_l fixed effect of l^{th} year of birth (1, 2,…7), and e_{ijkl} random error associated with each observation.

To estimate heritability, variance components of the sire, dam, and progeny were first calculated according to the analysis of variance (ANOVA) procedure for unbalanced nested full-sib mating design (Becker 1992) as cited by Alade et al. (2010), Faruque et al. (2010), and Okafor (2012). The statistical model for nested mating design is:

$$Y_{\mathrm{ij}}=\mu+S_{\mathrm{i}}+D_{\mathrm{j}}+e_{\mathrm{ij}}$$

where Y_{ij} is the record of the i^{th} progeny of the j^{th} dam mated to the k^{th} sire, μ is the common mean, S_i is the effect of the i^{th} sire, D_{ij} is the effect of the j^{th} dam mated to the i^{th} sire, and e_{ijk} is the uncontrolled environmental and genetic deviations attributable to the individuals. The heritability (h^2_S) from sire component was then estimated according to Becker (1992) as follows:

$$h^2_S=\frac{4\sigma^2_S}{\sigma^2_S+\sigma^2_D+\sigma^2_W}$$

where $4\sigma^2_S$ is the additive genetic variance, σ^2_S sire component of variance, σ^2_D dam component of variance, and σ^2_W progeny component of variance.

To estimate the genetic correlation (r_G) between traits, covariance components of the sire, dam, and progeny were first calculated according to the analysis of covariance (ANCOVA) procedure for unbalanced nested full-sib mating design (Becker 1992) as cited by Alade et al. (2010) and Okafor (2012). Subsequently, the genetic correlation (r_G) between two traits (x, y) was then estimated from the additive covariance and variance components of the sire according to Becker (1992) as follows:

$$rG=\frac{4\mathrm{Cov}_{S(xy)}}{\sqrt{4\sigma^2_{S(x)}.4\sigma^2_{S(y)}}}$$

where $4\mathrm{Cov}_{S(xy)}$ is the sire component of additive covariance between trait x and y, $4\sigma^2_{S(x)}$ sire variance for trait x, and $4\sigma^2_{S(y)}$ sire variance for trait y. The phenotypic correlations were estimated using GenStat (Discovery Edition 12) (VSNI 2012).

Results and discussion

Heritability

Results of heritability estimates for the growth performance traits studied are presented in Table 1. The heritability values ranged from low (0.04) to high (0.45–0.74) and are comparable with earlier works.

The heritability estimate obtained for the birth weight (0.45) is higher than the findings of Das et al. (1996), Okafor (2012), Mugambi et al. (2007), Rout et al. (2018), Thiruvenkadan et al. (2009), Faruque et al. (2010), and Jembere (2016) who recorded low birth weights of 0.15, 0.15, 0.13, 0.11, 0.06, 0.05, and 0.16 for the Blended goats of Tanzania, WAD goat populations of Nigeria, Kenyan dual purpose goats, Jamunapari goats of India, Tellicherry goats of India, Black Bengal goats of Bangladesh, and indigenous goats of Ethiopia, respectively. The value of 0.45 is also higher than the outcomes of other works including Schoeman et al. (1995), Rashidi et al. (2008), Gholizadeh et al. (2010), and Ayizanga et al. (2013) who respectively reported moderate heritability estimates of 0.33, 0.26, 0.32, and 0.24 for the Boer goats of the Cape Province of South Africa, Markhoz

Table 1 Heritability estimates and standard errors (S.E.) for some production traits of the WAD goat

Traits	Sire component of heritability (h_S^2) ± S.E.
BWT	0.45 ± 0.15
WWT	0.57 ± 0.29
6MWT	0.04 ± 0.05
9MWT	0.74 ± 0.59
YWT	0.49 ± 0.35
ADG1	0.55 ± 0.39
ADG2	0.54 ± 0.36

BWT birth weight, *WWT* weaning weight, *6MWT* 6-month body weight, *9MWT* 9-month body weight, *YWT* yearling weight, *ADG1* pre-weaning growth rate, *ADG2* post-weaning growth rate

goats of Iran, Raeini goats of Iran, and WAD goats of Ghana. The results of the present study, however, confirms the report of Alade et al. (2010) and Bosso et al. (2007) who obtained higher heritability estimates of 0.47 and 0.50 for local goats of Nigeria and WAD goats at the International Trypanotolerance Centre in the Gambia, respectively.

The fairly high heritability estimate of 0.57 recorded for weaning weight in the current study differs from the results of some previous studies which recorded low-moderate heritability of 0.04–0.34 (Alade et al. 2010; Das et al. 1996; Rashidi et al. 2008; Ayizanga et al. 2013; Jembere 2016; Gholizadeh et al. 2010; Faruque et al. 2010; Thiruvenkadan et al. 2009) for the trait. The current findings agree with the outcomes of Rout et al. (2018) and Okafor (2012) who indicated that the heritability of weaning weight could be fairly high as 0.43 and very high as 0.88, respectively.

The estimate for the 6-month body weight was low (0.04) confirming the results of Das et al. (1996) who reported 0.15, contrary to the results from the investigations of Okafor (2012) and Faruque et al. (2010) who have shown high heritability estimates of 0.75 and 0.77, respectively. The present results contradict findings by Rout et al. (2018) and Thiruvenkadan et al. (2009) who have both stated moderate heritability estimate of 0.37 for 6-month body weight similar to Rashidi et al. (2008) who recorded 0.21. The result obtained for 9-month body weight was high (0.74) and disagrees with the findings of most research works (Rout et al. 2018; Alade et al. 2010; Thiruvenkadan et al. 2009; Faruque et al. 2010; Jembere 2016) who have described low to moderate heritability estimates of 0.11–0.33 for the trait. The fairly high estimate of 0.40 for yearling weight reported by Rashidi et al. (2008) is similar to the value of 0.49 obtained in the present study. This outcome is however higher than the results of investigators (Rout et al. 2018; Alade et al. 2010; Thiruvenkadan et al. 2009; Faruque et al. 2010; Jembere 2016; Ayizanga et al. 2013) who reported low to moderate heritability of 0.13–0.31 for yearling weight in various breeds of goats including the WAD goat. Other traits of economic importance in meat goat breeding are pre-weaning and post-weaning growth rates, which have been contended to be of low heritability with values of 0.03 to 0.18 (Das et al. 1996; Alade et al. 2010; Ayizanga et al. 2013), contrary to the results of the present study which have recorded high estimate of 0.55 and 0.54 for pre-weaning and post-weaning growth rates, respectively.

The differences in heritability estimates of traits studied in the present work in relation to other works could be due to differences in genetic variance in the respective goat breed populations, the differences in environments, differences in accuracy and number of the observations or recordings (sample size), and the method of estimation, and that any similarities in the current results when compared with others suggest that the aforementioned determining factors might have been similar. The differences in heritability estimates of the contemporary work and the various studies are not unexpected. According to Falconer and Mackay (1996), the value of heritability depends on the magnitude of all the components of variance, and therefore a change in any of the components of variance will affect it as quoted by Ayizanga et al. (2013). Van Vleck et al. (1987) also noted that heritability is specific to the population and trait under consideration and that if either the genetic or environmental variance for the same trait in two populations varies, its heritability will also vary. It has also been established that environmental variance is dependent on the conditions of management under which the animals are kept. More variable environmental conditions reduce the genetic additive variance and hence the heritability while more uniform environmental conditions increase the additive genetic variance and the heritability. The generally high heritability estimates obtained in the current study suggest high genetic variation which may be utilized as raw material to improve on the performance of the WAD goat at the National Goat Breeding Station at Kintampo.

Correlation

The estimates for correlation coefficients are presented in Table 2. All the correlations were positive and ranged from low to high, similar to what earlier studies have reported for growth traits in various breeds of goats.

In the present study, the phenotypic correlation coefficient between weaning (WWT) and pre-weaning growth rate (ADG1) was high (0.93) ($p < 0.001$) which agrees well with the values of Ayizanga et al. (2013), Bosso et al. (2007), and Alade et al. (2010) who found a high phenotypic correlation coefficient of 0.98, 0.99, and 0.91 for the WAD goats in Ghana, the Gambia, and the local goats of Nigeria, respectively. Again, Ayizanga et al. (2013) and Bosso et al. (2007) respectively obtained high phenotypic correlation of 0.77 and 0.74 between yearling weight and post-weaning growth rate which confirm the high value of 0.73 ($p < 0.001$) obtained in the current research. On the other hand, Bosso

Table 2 Estimates of phenotypic correlations (above diagonal) and genetic correlations (below diagonal) between traits studied

Traits	BWT	WWT	6MWT	9MWT	YWT	ADG1	ADG2
BWT		0.50**	0.38**	0.38**	0.18**	0.15**	0.04
WWT	0.60		0.92**	0.86**	0.81**	0.93**	0.18**
6MWT	0.67	0.92		0.93**	0.86**	0.90**	0.37**
9MWT	0.30	0.84	0.91		0.95**	0.83**	0.58**
YWT	0.72	0.75	0.72	0.93		0.76**	0.73**
ADG1	0.56	0.69	0.66	0.64	0.73		0.18**
ADG2	0.59	0.81	0.90	0.89	0.96	0.77	

**Phenotypic correlation is significant ($p < 0.001$)

et al. (2007) and Ayizanga et al. (2013) respectively recorded low phenotypic correlation coefficient of 0.11 and 0.10 between birth weight and pre-weaning growth rate similar to the low coefficient of 0.15 ($p < 0.001$) obtained in the present work. Furthermore, the low phenotypic correlation figure of 0.04 between birth weight and post-weaning growth rate recorded in this study supports the findings of Alade et al. (2010) who has indicated correlation of 0.02. Alade et al. (2010) however had exceptions of low negative phenotypic correlations between weaning weight and pre-weaning weight gain (− 0.06) which differs from the high value of 0.93 noted in this research. A study by Thiruvenkadan et al. (2009) has also shown that the phenotypic correlations among different body weights (birth, 3-month, 6-month, 9-month, and 12-month weights) in the Tellicherry goats were positive and low to high in magnitude (0.16–0.91), similar to the results of the study conducted by Rashidi et al. (2008) who reported 0.12–0.79 among birth, weaning, 6-month, 9-month, and yearling weights for the Markhoz goats; these findings conform with results (0.18–0.95) of the present work for the WAD goats. In principle, the phenotypic correlation findings of the current research are indication that there is a linear relationship among body traits which may be caused by either genetic or environmental factors of correlation.

A high genetic correlation coefficient of 0.77 between pre-weaning and post-weaning growth rates was obtained in the present study which is close to 0.83 and 0.85 reported by Ayizanga et al. (2013) and Bosso et al. (2007). The near-perfect genetic correlation coefficient of 0.99 reported between yearling weight and post-weaning growth rate (Ayizanga et al. 2013), is similar to the value of 0.96 obtained in the present work. Again, the genetic correlations among birth, weaning, and yearling weights and pre-weaning and post-weaning growth rates were medium to high (0.51–0.83) as presented by Ayizanga et al. (2013) support the outcomes (0.56–0.96) of this research. The results of the current study do not differ from the claims of Alade et al. (2010), Al-Shorepy et al. (2002), Thiruvenkadan et al. (2009), Neopane (2000), and McManus et al. (2008) who confirmed that genetic correlations between growth traits were positive and medium to high, similar to the outcomes of the study conducted by Rashidi et al. (2008) who reported 0.47–0.91 among birth, weaning, 6-month, 9-month, and yearling weights. The medium to high genetic correlations among body weights and growth traits obtained in the current work indicate that the same or similar sets of genes are responsible for these traits. It also suggests that the genes involved in these traits may be linked on the same chromosome and hence tended to be inherited together or may be pleiotropic and hence influence the traits by segregation. The general implications are that selection for any of these body weights and growth traits in a breed improvement program would have a considerable simultaneous positive impact on each other.

Effect of non-genetic factors on the growth performance

The effects of non-genetic factors on the growth performance of the WAD goats have been presented in Table 3. The type of birth influenced all performance traits except the post-weaning growth rate. Results obtained showed that type of birth significantly ($p < 0.05$) influenced birth, weaning, and 6-month body weight, with single-born kids weighing heaviest as compared with twins and triplets (Table 3). The weight of singles and triplets were however similar and higher ($p < 0.05$) than twins at 9 and 12 months, which might have resulted from the observed similarity in pre-weaning growth rate of the kids. This agrees with the findings of Das et al. (1996), Singh et al. (2002), Zhou et al. (2003), Ofori (2008), Rashidi et al. (2008), and Birteeb et al. (2015) who reported type of birth as a significant ($p < 0.001$) source of variation in kid birth weight, and that kids born single were heavier at birth than twins and triplets, contrary to the results of Ayizanga et al. (2013) who contended that type of birth did not significantly ($p > 0.05$) affect birth weight. The findings of the current work may be due to absence of intra-uterine nutritional and space competition in single-born kids unlike in multiple-born kids where there is competition (Deribe and Taye 2013) likewise the single-born kids did not experience competition for milk during the lactation period and hence were heavier than multiple-born kids at weaning, which in turn gave the former superior weight at 6 months of age than the later.

Sex did not significantly ($p > 0.001$) influence any of the traits studied, and thus, the traits did not exhibit sexual dimorphism. The findings of the current study are similar to the results of Birteeb et al. (2015) who indicated that sex of kid had no significant effect ($p > 0.05$) on birth weight, yearling weight, and post-weaning growth rate as both male and female kids were very comparable in these traits. The current result also agrees with Mioc et al. (2011) who reported no significant difference in birth weight as a result of the sex in Croatian multicolored goat kids, similar to Deribe and Taye (2013) who

Table 3 Influence of non-genetic factors on the growth performance of the WAD goats

Factor	BWT (kg)	WWT (kg)	6MWT (kg)	9MWT (kg)	YWT (kg)	ADG1 (g/day)	ADG2 (g/day)
Overall mean	1.48	5.35	6.56	8.30	10.00	32.26	19.39
Type of birth							
Singles	1.58[a]	5.52[a]	6.75[a]	8.50[a]	10.19[a]	32.81[b]	19.45
Twins	1.28[b]	5.01[b]	6.19[b]	7.89[b]	9.63[b]	31.06[b]	19.91
Triplets	1.15[b]	5.31[b]	6.36[b]	8.23[a]	9.88[b]	34.69[a]	19.22
s.e.d	± 0.10	± 0.29	± 0.36	± 0.41	± 0.43	± 2.25	± 1.12
Sex							
Males	1.49	5.35	6.56	8.28	10.00	32.16	19.38
Females	1.47	5.36	6.57	8.32	10.02	32.36	19.39
s.e.d	± 0.01	± 0.05	± 0.06	± 0.06	± 0.07	± 0.35	± 0.17
Season of birth							
Major rains	1.48[a]	5.35[a]	6.54[b]	8.29[b]	9.97[b]	32.26[a]	19.22[b]
Minor rains	1.44[b]	5.45[b]	6.78[a]	8.54[a]	10.22[a]	31.06[b]	19.89[a]
Dry	1.50[a]	5.31[a]	6.48[b]	8.20[b]	9.93[b]	31.75[b]	19.25[b]
s.e.d	± 0.02	± 0.06	± 0.07	± 0.08	± 0.08	± 0.44	± 0.22
Year of birth							
2011	1.23[c]	5.97[a]	7.65[ab]	9.28[a]	10.89[a]	39.48[a]	20.49[b]
2012	1.41[b]	5.41[b]	6.59[ab]	8.67[b]	10.58[b]	33.39[b]	21.53[a]
2013	1.53[a]	5.42[b]	6.67[ab]	8.37[c]	10.01[c]	32.48[bc]	19.13[c]
2014	1.54[a]	5.18[c]	6.32[c]	8.05[d]	9.80[de]	30.33[c]	19.22[c]
2015	1.60[a]	5.10[c]	6.17[c]	7.76[e]	9.37[e]	29.15[c]	17.79[d]
2016	1.46[b]	5.29[c]	6.50[b]	8.31[c]	10.08[c]	31.97[c]	19.95[c]
2017	1.57[a]	5.32[b]	6.40[b]	8.01[d]	9.60[e]	31.21[c]	17.85[d]
s.e.d	± 0.10	± 0.10	± 0.12	± 0.13	± 0.14	± 0.83	± 0.35

Means within the same column with different superscripts ([a, b, c, d, e,]) are significantly different ($p < 0.05$)

found that male and female kids of Abergele goats in Ethiopia were statistically similar from birth to 1 year old. On the contrary, Ayizanga et al. (2013) noticed that sex of kid influenced ($p < 0.01$) birth weight and weaning weight, similar to the observations of Turkson et al. (2004) who reported that the mean weaning weight of males was heavier than females of the same WAD goats and comparable with the findings of Das et al. (1996) who stated that at weaning, males weighed higher than females in the Blended goat. It is believed that male kids are more vigorous than female kids and thus have greater access to their dam's milk during lactation period resulting in rapid growth. Usually, in small ruminants, males tend to be heavier at birth and grow faster than their female counterparts even among multiple births, and Inyangala et al. (1992) attributed higher birth weight of males than females to hormonal differences between the sexes and the resultant effect on growth.

Season of birth was also found to have significantly influenced all the growth performance traits. Kids born in major rainy and dry season had similar and higher ($p < 0.001$) birth, weaning, 6 month, 9 month, and yearling weight than those born in the minor rainy season. This agrees with the findings from Deribe and Taye (2013) who also reported of a significant seasonal effect on birth and weaning weight. The similarly higher performance of the major rainy season and dry season–born kids from birth to 12 months might be due to the availability of more succulent/nutritious feeds and supplementary feeding, respectively. Inversely, Birteeb et al. (2015) maintains that the season of birth did not have significant effect ($p > 0.05$) on birth weight, weaning weight, and pre-weaning growth rate, but rainy season–born kids grew significantly faster post-weaning resulting in significantly higher yearling weight than their dry season–born counterparts. The results of the current research also revealed that kids born in the minor rainy and dry season had lower ($p < 0.001$) pre-weaning growth rate than kids born in the major rainy season, similar to the results of the study conducted by Baffour-Awuah et al. (2007) who reported higher ($p < 0.05$) pre-weaning growth rate for lambs born in the major rainy season. However, post-weaning growth rates of the major rainy and dry season–born kids were similar and lower ($p < 0.001$) than minor season–born kids (Table 3). Luginbul (2002) and Steve (2001) proposed that growth during pre-weaning period is largely determined by maternal milk production and competition for it among litter mates and hence the differences in their post-weaning growth rate. The higher post-weaning growth rate for minor rainy season–born kids observed in the current research might have also resulted from availability of adequate succulent and nutritious feeds in the minor rainy season as changes in climatic conditions are likely to change the growth patterns of some feeds. Each season has its own advantages and disadvantages. The rainy season supports the growth of sufficient feed but is troubled with disease and pest problems, while the dry season comes with scarcity of feed and/or water problems. Higher percentage of kidding usually takes place in times of higher rainfall and availability of forage (Payne 1990). Again, Ofori (2008) reported that when kidding coincides with period of good forage availability, there would be no problem of underfeeding and starvation. Thus, most seasonal breeding programs would mate animals in times such that parturition will coincide with period when there is abundance of feed (Ofori 2008). This helps the doe to have sufficient feed nourishment to produce milk for the kids. When animals are fed by grazing, seasonal variation in forage availability becomes a major production factor that affects performance. Since the WAD goats are kept on station under proper husbandry practices, their productivity will therefore depend on how management handles seasonal variations in feed, water, and health care.

The overall birth weight of 1.48 kg is higher than values of 1.40 kg, 1.31 kg, 1.30 kg, and 1.20 kg reported by Birteeb et al. (2015), Ayizanga et al. (2013), Ofori (2008), and Turkson et al. (2004), respectively, for WAD goats from the same station. Again, the overall weaning weight obtained in the present work is better than 5.3 kg, 4.6 kg, and 4.6 kg obtained by Birteeb et al. (2015), Ayizanga et al. (2013), and Ofori (2008), respectively. Similarly, the pre-weaning growth rate of 32.3 g/day recorded in the present study is better than values of 32.1 g/day, 27.6 g/day, and 26.8 g/day recorded Birteeb et al. (2015), Ayizanga et al. (2013), and Ofori (2008), respectively. The trend of the results indicates that over the past decade, the National Goat Breeding Station has made some gains in the average birth weight, weaning weight, and pre-weaning growth rate possibly due to improvement in the mothering ability of the dams, nutrition, favorable climatic conditions, positive maternal effects, and enhancement in general management conditions at the station. This agrees with observations made by Odubote and Akinokun (1992) that a considerable improvement in productivity has been achieved in the WAD goat in Nigeria by changes in management practices. However, the post-weaning growth rate and yearling weight over the years have been declining, implicating that improvement strategy at the station may not be targeting mature (yearling) weight.

Conclusion

Heritability estimates obtained were moderate to high, an indication that genetic improvement could be made in the WAD goat population at the National Goat Breeding Station at Kintampo in Ghana. Again, the positive phenotypic correlation coefficients among the various traits showed any improvement strategy adopted must consider multi-trait analysis. There is however the need to consider introducing new stock to ensure continuous genetic diversity within the population.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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