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Non-Genetic Factors Affecting Grasscutter Production Traits. 1. Growth Traits

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Abstract: This study was conducted at the grasscutter section of the University of Education, Winneba, Ghana, to estimate effects of non-genetic factors on growth traits. Data consisted of records of 502 kids born from 136 does and 40 sires from 2006 to 2010. Feed intake increased (P<0.01) with increasing parity and years, whilst feed efficiency declined (P<0.01) with years. Animals consumed less (P<0.01) feed in the dry season compared to the rainy season. Increased litter size resulted in decreased body weight (P<0.01) and growth rate (P<0.05) from birth to six months, after which the effect diminished (P>0.05). Males were significantly heavier (P<0.05) and grew faster (P<0.01) than females from weaning to adulthood. Body weight and growth rate increased significantly with increasing years (P<0.05). Animals that were conceived in the rainy season had heavier (P<0.01) weights at sexual maturity and grew faster (P<0.01) than those conceived during the dry season and those that were born in the dry season grew faster (P<0.05) at the age of 4-8 months than those born in the rainy season. It was concluded that the non-genetic factors influenced the traits studied; so appropriate adjustments must be made when estimating genetic values for a breeding programme in grasscutter.

Key words: *Thryonomys swinderianus* · Body weight · Growth rate · Feed intake · Feed conversion ratio · environmental factors

INTRODUCTION

Non-genetic factors are measurable environmental effects that affect animal performance. They include weight of dam, parity of dam, age of dam, sex of kid, litter size, age of kid, season of mating and of birth, year of birth etc. In selecting animals to be parents of the next generation, comparison should be made between contemporary groups of animals. To improve rate of genetic gain, measured performance of animals with respect to a particular trait should be adjusted for various known environmental or non-genetic factors which disguise or mask genetic expression for that trait [1-3].

The influence of non-genetic factors on growth performance of domestic livestock is very well documented in traditional livestock species reared in tropical environments [e.g. 3-7]. There is, however, scanty information in the literature about the effect of non-genetic factors on grasscutter growth traits. The objective of this work was to estimate effects of non-genetic factors on grasscutter growth traits.

MATERIALS AND METHODS

The study was carried out at the grasscutter section of the Department of Animal Science Education, University of Education, Winneba, Ghana, from 2006 to

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2010. Mampong-Ashanti is located in the transitional zone between the Guinea savanna zone of the north and tropical rain forest of the south of Ghana. It lies between latitude 07° 04' north and longitude 01° 24' west with an altitude of 457m above sea level. Maximum and minimum annual temperatures recorded during the study period were 30.6°C and 21.2°C, respectively [8]. Rainfall in the district is bimodal, occurring from April to July (major rainy season) and again August to November (minor rainy season) and is about 122 cm per annum. The dry season occurs from December to March. The vegetation is transitional savanna woodland. The common fodder species that are routinely fed to grasscutters, *Pennisetum purpureum* (elephant grass) and *Panicum maximum* (guinea grass) are readily available in this zone.

Data from a random mating population were used for the study. Data consisted of records on 502 kids born to 136 does and 40 sires over a period of 5 years (2006-2010). Dams from this group gave birth up to the third parity. Animals were fed a basal diet of elephant grass (*Pennisetum purpureum*) and a supplementary ration of concentrate that contained 14% crude protein. Concentrate supplement was composed of maize (44%), wheat bran (41%), soybean (9%), oyster shell (5%), common salt (0.5) and vitamin-mineral-premix (0.5). Chemical analysis of samples of elephant grass and concentrate were carried out, according to the procedure outlined by [9]. Results of the feed analysis are presented in Table 1. Animals were reared and housed in concrete and wooden cages placed in a large animal house. Mating took place throughout the year. Animals were identified by metal ear tags (Hauptner, Germany). Traits considered were dry matter feed intake (FI), feed conversion ratio (FCR), weights at birth (BWT), weaning (WWT), 4 months (BWT4), 6 months (BWT6), 8 months (BWT8) and growth rates from birth to 2 months (PWADG), 2-4 months (ADG4), 4-6 months (ADG6) and 6-8 months (ADG8). Feed intake for both concentrate and grass were measured for a random sample of 199 animals at age 4-6 months.

Data were subjected to least squares analysis using Generalized Linear Models (GLM) Type III procedure of SAS [10] on the following fixed models:

$$y_{ijklmnp} = \mu + T_i + S_j + P_k + V_l + Z_m + Y_n + Ts_{ij} + TP_{ik} + TV_{il} + Tz_{im} + TY_{in} + SP_{jk} + SV_{jl} + SZ_{jm} + SY_{jn} + PV_{kl} + PZ_{km} + PY_{kn} + VZ_{lm} + VY_{ln} + ZY_{mn} + e_{ijklmnp}$$

Where $y_{ijklmnp}$ is the observation or trait being considered; μ = the overall mean; T_i = the effect of the i^{th} type of birth (TOB), i = 1…7; S_j = the effect of the j^{th} sex of kid, j = 1..2; P_k = the effect of the k^{th} parity of dam, k = 1… 3; V_l= the effect of the l^{th} season of mating (SOM), l = 1..3; Z_m = the effect of the m^{th} season of birth (SOB), m = 1..3; Y_n= the effect of the n^{th} year of birth (YOB), n = 1…5; TS, TP, TV, TZ, TY, SP, SV, SZ, SY, PV, PZ, PY, VZ, VY and ZY are the corresponding 2-way interactions and $e_{ijklmnp}$ is the random error term. Three-way and higher level interactions were not considered important. Differences between means of significant effects were separated by probability of difference (PDIFF) procedure of SAS [10].

The relative importance of a fixed factor in influencing a trait was determined by using the coefficient of determination (R^2) through regression analysis [10]. The backward elimination procedure, which involves starting with all candidate variables and testing them one by one for statistical significance, deleting any that are not significant was used [11].

RESULTS AND DISCUSSION

Effect of Non-genetic Factors on Feed Intake and Feed Conversion Ratio

Average Values of Feed Intake and Feed Conversion Ratio: Least squares means of FI and FCR are shown in Table 2. Feed intake and FCR were measured from 4-6 months. Average dry matter daily feed intake of 108.2 g/day obtained for growing grasscutters between the weight of 954.9-1374.4 g is within the range of values (53.8-132.3 g/day) reported for the same age and weight range [12-15]. Mean FCR of 14.4 is also within the range

Table 1: Proximate analysis of elephant grass and concentrate supplement

	Elephant Grass			
Nutrient Composition	Major Rains	Minor Rains	Dry Season	Concentrate
Crude Protein (%)	9.3	7.9	5.1	13.9
Crude Fibre (%)	31.0	32.8	58.6	5.4
Ether Extract (%)	1.2	1.0	1.5	3.0
Ash (%)	9.8	6.3	5.2	8.1
Dry Matter (%)	34.3	89.8	92.5	87.2
Nitrogen Free Extractives (%)	49.3	52.1	29.6	69.7
ME (kcal/kg)	-	-	-	1845.6

Table 2: Least square means and standard errors for the effect of fixed factors on feed intake and feed efficiency

Fixed Factor	No.	Feed Intake (gDM/day)	Feed Efficiency (Ratio)
Type of birth[2]		*0.3956*	*0.0300*
1	1	114.9±6.43	19.4±3.94[a]
2	6	107.1±4.73	15.4±2.90[ab]
3	37	109.7±1.64	16.0±1.00[a]
4	77	110.9±1.33	13.4±0.81[b]
5	62	107.4±1.60	16.4±0.98[a]
6	10	118.3±6.49	10.5±3.98[b]
7	6	109.7±2.70	13.8±1.66[b]
Sex of Kid[2]		*0.5298*	*0.8812*
Female	92	110.7±1.72	14.9±1.06
Male	107	111.6±1.75	15.0±1.08
Parity[2]		*0.0176*	*0.8018*
1	79	111.0±1.77[ab]	14.7±1.08
2	72	108.2±2.04[a]	14.8±1.25
3	48	114.2±2.01[b]	15.4±1.23
Year of birth[2]		*0.0021*	*0.0004*
2006	20	105.0±3.27[a]	17.3±2.01[a]
2007	46	108.3±1.75[a]	12.2±1.08[b]
2008	40	109.5±2.53[a]	11.3±1.55[b]
2009	73	111.3±1.99[a]	17.5±1.22[a]
2010	20	121.7±3.54[b]	16.6±2.18[a]
Season of measurement[2]		*0.0136*	*0.0072*
Major rains	108	114.8±2.04[a]	16.7±1.25[a]
Minor rains	52	110.1±2.09[b]	15.7±1.28[a]
Dry season	39	108.5±1.93[b]	12.6±1.19[b]
Overall	199	108.2±0.68	14.4±0.42

[1]*Number of animals*

[2]*Probability value of test of main effects*

[abc]*Means in the same column and within the same effect, with different superscripts are significantly different*

(4.9-29.0) reported by the same authors. The current FCR is better than 29.0 obtained by [13] feeding grass alone but poorer than 5.1 and 7.5 obtained by [15] feeding concentrate alone and 15%:85% grass-concentrate mixture, respectively. The FCR is 3.8 times poorer when compared to those of rabbits [16].

Feed conversion ratio is the effectiveness with which feed is converted to saleable meat product. Feed costs are becoming a major input in grasscutter production systems because of the use of concentrate and labour cost of cutting grass. Genetic improvement in FCR or its reciprocal, feed conversion efficiency may therefore have an important influence on profitability [17]. There is substantial genetic variation in FCR [18]. Since grasscutters can be caged individually and fed, selection can easily be done to improve the trait because feed intake can be measured on individual grasscutters. Furthermore, since FCR is negatively and favourably correlated with body weight and growth rate [19], genetic improvement of body weight or growth rate will lead to a negative correlated response in FCR.

Effect of Litter Size: Litter size (type of birth) had little effect ($P > 0.05$) on FI but FCR improved ($P < 0.05$) with increasing litter size (Table 2). Type of birth explained 10% of the variation in FCR. Effect of litter size on FI and FCR has not been studied in the grasscutter. However, several studies on other litter bearing species have been conducted in pigs and rabbits. [20] found no significant effect of litter size on FI and FCR in pigs. [21] found significant effect of litter size on FI and FCR in rabbits. In that experiment, on per capita basis, rabbits from large litters consumed less ($P < 0.05$) feed than those from small litters and animals raised in large litters had the best ($P < 0.05$) feed conversion ratio compared to those raised in small litters. Carcasses of animals in large litters contained significantly more water and nitrogen, relatively more protein and less fat than those in small litters. [21] further explained that energy requirement for maintenance of animals in large litters was probably lower due their smaller body weight. Relatively more energy must have been available for body growth in animals of large litters resulting in better feed conversion. The results obtained in this work on FCR could be explained by the same reasons given above by [21].

Effect of Sex of Kid: Sex had little effect (P > 0.05) on both FI and FCR (Table 2). Thus, sex was not relatively important in explaining variation in either FI or FCR. Sex usually influences FI and FCR because males and females produce different sex hormones, which affect these traits differently. The quantity of progesterone, testosterone and oestrogen released by the body has effects on feed intake, growth rate and feed efficiency [22]. In goats, [23] found no difference (P > 0.05) between the two sexes consuming crop residues, but found an effect (P < 0.05) of sex on FCR, with FCR being better in bucks than in does. In poultry, FCR of female broilers was found to be poorer than male birds of comparable ages. The reason for this was that female birds tend to deposit proportionally more fat in the carcass [24]. Body fat takes more feed energy to produce than does muscle.

Effect of Parity of Dam: Parity largely affected (P < 0.05) FI but had little effect (P > 0.05) on FCR (Table 2). Animals from different parities consumed similar (P > 0.05) amount of food, with the exception of those in parity 3, which consumed 6.0 gDM more (P < 0.05) feed per day than those in parity 2. Increasing parity by 1 level increased FI by 2.0 g/day. Parity explained 2.6% of the variation in FI. Feed intake increased with increasing parity because kids from older does were heavier and grew faster than those from younger does. [25] reported that parity significantly affected litter FI or FCR in rabbits. However, [25] indicated that parity did not influence FI although it significantly affected FCR in rabbits.

Year Effects: Both FI and FCR increased (P < 0.01) slightly with increasing years (Table 2). A one unit increase in year increased FI by 2.5 g/day and FCR by 1.2. Year of birth accounted for 7.5 and 4.9% of the variation in FI and FCR, respectively. Feed intake and FCR increased with years, indicating less efficiency. Increasing FI probably resulted from increasing weight and growth rate of animals over the years (Tables 3-5) because heavy and fast growing animals consume more feed than lighter and slow growing ones. Small-sized animals are more efficient in converting feed into muscle than large-sized ones [24, 21].

Table 3: Least square means and standard errors for the effect of fixed factors on birth, weaning and 4-month weights

	BWT		WWT		BWT4	
Fixed effect	No.[1]	g	No.[1]	g	No.[1]	g
Type of birth[2]		*< 0.0001*		*< 0.0001*		*< 0.0001*
1	8	155.2±7.47[a]	7	824.2±49.39[a]	7	1433.4±87.88[a]
2	14	146.4±5.72[a]	10	670.3±41.56[b]	10	1213.4±74.20[b]
3	96	134.2±2.43[b]	84	581.5±16.63[c]	80	1011.1±31.25[c]
4	179	129.1±1.94[b]	165	578.9±12.94[c]	155	983.3±24.57[c]
5	157	112.5±1.93[c]	131	455.2±13.63[d]	117	874.4±26.86[d]
6	24	106.4±4.69[cd]	24	470.5±29.21[d]	24	872.9±53.52[d]
7	24	96.6±4.81[d]	20	395.9±32.97[d]	20	785.0±59.71[d]
Sex of Kid[2]		*0.1415*		*0.0513*		*0.0143*
Female	245	124.3±2.21	219	555.7±15.09[a]	205	996.0±28.08[a]
Male	257	127.2±2.12	222	580.4±14.85[b]	208	1053.6±27.26[b]
Parity[2]		*P = 0.4754*		*P = 0.2226*		*P = 0.7886*
1	224	124.7±2.11	195	553.3±14.14	183	1014.2±25.99
2	203	127.3±2.21	188	574.8±14.50	176	1030.2±27.30
3	75	125.4±3.16	58	576.2±22.79	54	1029.9±41.05
Year of birth[2]		*< 0.0001*		*< 0.0001*		*< 0.0001*
2006	79	115.5±3.24[a]	70	509.3±21.33[a]	67	892.7±38.77[a]
2007	117	123.3±2.80[b]	115	520.5±18.25[a]	115	882.2±33.02[a]
2008	91	136.2±2.80[c]	82	567.0±18.68[b]	81	1020.5±33.45[b]
2009	148	130.0±2.30[d]	133	626.5±15.34[c]	124	1107.4±28.12[c]
2010	67	123.8±3.25[b]	41	617.1±25.23[c]	26	1221.1±53.56[d]
Mating season[2]		*< 0.0001*		*< 0.0001*		*0.1877*
Major rains	188	117.7±2.88[a]	169	513.1±19.87[a]	155	984.3±37.48
Minor rains	165	128.3±2.77[b]	141	588.2±18.46[b]	131	1034.4±35.40
Dry season	149	131.2±2.47[b]	131	603.0±17.19[b]	127	1055.6±31.14
Season of birth[2]		*< 0.0001*		*0.0017*		*0.0057*
Major rains	133	117.5±3.06[a]	116	522.4±21.02[a]	108	1017.5±39.86[ab]
Minor rains	98	131.5±2.99[b]	82	581.9±20.23[b]	73	954.8±38.36[a]
Dry season	271	128.3±2.15[b]	243	600.0±14.62[b]	232	1102.0±27.08[b]
Overall	502	123.6±0.26	441	535.6±7.39	413	954.9±13.35

[1]*Number of animals*
[2]*Probability value of test of main effects*
[abc]*Means in the same column and within the same effect, with different superscripts are significantly different*
Birth weight (BWT); weaning weight (WWT); 4 month weight (BWT4).

Table 4: Least square means and standard errors for the effect of fixed factors on 6- and 8-month weights and pre-weaning growth rate

	BWT6		BWT8		PWADG	
Fixed effect	No.[1]	g	No.[1]	g	No.[1]	g/day
Type of birth[2]		*< 0.0001*		*0.0001*		*< 0.0001*
1	6	1667.7±131.67[a]	6	2490.8±151.28[a]	7	11.1±0.77[a]
2	9	1661.2±110.40[a]	6	1942.5±156.17[b]	10	8.6±0.65[b]
3	75	1418.2±45.31[b]	70	1792.3±55.25[b]	84	7.4±0.26[b]
4	144	1431.8±35.98[b]	117	1838.5±43.85[b]	165	7.5±0.20[b]
5	117	1315.2±38.66[c]	102	1728.9±50.53[b]	131	5.7±0.21[c]
6	21	1331.3±79.35[c]	21	1718.5±92.32[b]	24	6.1±0.46[c]
7	20	1142.2±83.85[d]	17	1710.9±111.15[b]	20	4.9±0.52[c]
Sex of Kid[2]		*0.1877*		*0.0010*		*0.0849*
Female	190	1401.8±41.52	157	1819.6±52.77[a]	219	7.2±0.24
Male	202	1446.1±39.43	182	1958.2±51.66[b]	222	7.5±0.23
Parity[2]		*0.0482*		*0.6439*		*0.2483*
1	176	1373.2±38.99[a]	162	1883.7±49.07	195	7.1±0.22
2	162	1459.2±40.04[b]	138	1920.5±49.23	188	7.4±0.23
3	54	1439.4±58.88[b]	39	1862.6±79.34	58	7.4±0.36
Year of birth[2]		*< 0.0001*		*< 0.0001*		*< 0.0001*
2006	67	1383.0±55.41[a]	67	1799.9±68.42[ab]	70	6.5±0.33[a]
2007	112	1225.8±48.01[a]	111	1727.8±61.18[b]	115	6.6±0.29[a]
2008	66	1478.9±50.58[b]	59	1908.7±64.99[a]	82	7.1±0.29[a]
2009	121	1515.0±41.10[b]	81	1846.4±53.71[ab]	133	8.2±0.24[b]
2010	26	1517.0±74.90[b]	21	2161.8±95.70[c]	41	8.2±0.39[b]
Mating season[2]		*0.0003*		*< 0.0001*		*< 0.0001*
Major rains	134	1417.6±57.20[a]	118	2121.5±79.30[a]	169	6.5±0.31[a]
Minor rains	131	1546.0±51.15[b]	95	1942.4±62.88[b]	141	7.6±0.29[b]
Dry season	127	1308.3±44.18[a]	126	1602.8±54.18[c]	131	7.8±0.27[b]
Season of birth[2]		*0.3684*		*0.0121*		*0.0068*
Major rains	108	1434.6±57.41	107	1986.4±74.72[a]	116	6.7±0.33[a]
Minor rains	60	1371.6±58.83	55	1964.4±76.90[a]	82	7.4±0.32[a]
Dry season	224	1465.7±39.81	177	1715.9±53.82[b]	243	7.8±0.23[b]
Overall	392	1374.4±18.12	339	1690.1±23.20	441	6.9±0.11

[1]*Number of animals*

[2]*Probability value of test of main effects*

[abc]*Means in the same column and within the same effect, with different superscripts are significantly different*

Six month weight (BWT6); 8 month weight (BWT8); pre-weaning growth rate (PWADG).

Table 5: Least square means and standard errors for the effect of fixed factors on growth rates from weaning to 4 months, 4-6 and 6-8 months.

	ADG4		ADG6		ADG8	
Fixed effect	No.[1]	g/day	No.[1]	g/day	No.[1]	g/day
Type of birth[2]		*0.0028*		*0.7780*		*0.0314*
1	7	10.3±0.95[a]	6	7.7±1.69	6	11.4±1.49[a]
2	10	8.9±0.80[ab]	9	7.0±1.42	6	7.0±1.54[b]
3	80	7.3±0.34[bc]	75	7.6±0.58	70	7.4±0.54[b]
4	155	6.8±0.26[c]	144	8.0±0.46	117	6.7±0.43[b]
5	117	7.1±0.29[c]	117	7.9±0.50	102	6.8±0.50[b]
6	24	7.2±0.58[bc]	21	8.7±1.02	21	5.8±0.91[b]
7	20	6.4±0.65[c]	20	6.6±1.07	17	8.0±1.09[ab]
Sex of Kid[2]		*0.1255*		*0.0010*		*< 0.0001*
Female	205	7.5±0.30	190	6.9±0.53[a]	157	6.4±0.52[a]
Male	208	7.9±0.30	202	8.4±0.51[b]	182	8.8±0.51[b]
Parity[2]		*P = 0.9917*		*P = 0.0256*		*0.5903*
1	183	7.7±0.28	176	7.1±0.49[a]	162	7.3±0.48
2	176	7.7±0.30	162	8.4±0.51[b]	138	7.7±0.48
3	54	7.7±0.44	54	7.5±0.76[ab]	39	7.8±0.78

Table 5: Continued

	ADG4		ADG6		ADG8	
Fixed effect	No.[1]	g/day	No.[1]	g/day	No.[1]	g/day
Year of birth[2]		*< 0.0001*		*0.0006*		*0.0467*
2006	67	6.4±0.42[a]	67	8.2±0.71[ac]	67	6.7±0.67[a]
2007	115	6.1±0.36[a]	112	6.1±0.62[b]	111	7.3±0.60[a]
2008	81	7.6±0.36[b]	66	7.1±0.65[abc]	58	7.1±0.64[a]
2009	124	7.9±0.30[b]	121	7.4±0.53[a]	81	7.2±0.53[a]
2010	26	10.6±0.58[c]	26	9.5±0.96[c]	21	9.7±0.94[b]
Mating season[2]		*0.8854*		*< 0.0001*		*< 0.0001*
Major rains	155	7.8±0.41	134	7.8±0.73[a]	118	9.7±0.78[a]
Minor rains	131	7.8±0.38	131	9.7±0.66[b]	95	7.3±0.62[b]
Dry season	127	7.6±0.34	127	5.4±0.57[c]	126	5.8±0.53[c]
Season of birth[2]		*< 0.0001*		*0.6707*		*0.0264*
Major rains	108	8.6±0.43[a]	108	7.9±0.74	107	8.2±0.74[a]
Minor rains	73	6.3±0.42[b]	60	7.8±0.76	55	8.4±0.76[a]
Dry season	232	8.4±0.29[a]	224	7.2±0.51	177	6.2±0.53[b]
Overall	413	7.0±0.14	392	6.8±0.22	339	6.2±0.21

[1]*Number of animals*

[2]*Probability of test of main effects*

[ab]*Means in the same column and within the same effect, with different superscripts are significantly different*

Growth rate from 2-4 months (ADG4); growth rate from 4-6 months (ADG6); growth rate from 6-8 months (ADG8).

Season of Measurement Effects: Animals consumed more ($P < 0.05$) feed in the major rainy season than in the dry season (Table 2). Animals consumed similar ($P > 0.05$) amount of feed in the minor rainy season and in the dry season. Season of measurement explained 1.8% of the variation in FI. Feed conversion ratio of animals in the dry season was better ($P < 0.01$) than those in the two rainy seasons (Table 2). Animals in the two rainy seasons had similar ($P > 0.05$) efficiencies (Table 2). Season of mating explained 10% of the variation in feed conversion ratio. Thus the effect of season of measurement was important in influencing FI and FCR.

Low FI of the animals in the dry season may be a survival strategy. In the wild, there are usually abundant feed resources in the rainy season but feed becomes scarce in the dry season. Rodents have the capacity to adjust their digestive attributes to changes in food availability and/or quality in order to maximize overall energy return [27, 28]. Furthermore, FI in the dry season was low because the quality of grass in the dry season was poor due to low crude protein, high fibre and low soluble carbohydrate content (as indicated by the nitrogen free extractives content) (Table 1). The feed in the dry season was thus highly lignified (containing high fibre) with less proportion of leaves [29, 30]. Levels of fibre and protein in the grass will limit feed intake. Studies on the influence of fibre in the diet on the growth rates and digestibility of nutrients in grasscutters have proved that animals fed high fibre diets had reduced feed intake, digestibility of dry matter, protein and fat and exhibited significantly lower growth rates than animals fed low fibre diets [31].

Effect of Non-genetic Factors on Body Weight and Growth Rate

Average Values of Body Weight and Growth Rate: Least squares means of body weights are shown in Table 3 and 4. Mean values of growth rates are shown in Table 4 and 5. The mean BWT and WWT obtained in this study fall within the range of weights reported in the literature. The average birth weight of 123.6 g obtained in this study is slightly higher than 120.5 g reported by [32] but lower than 151.2 g obtained by [33]. The mean WWT (535.6 g) is also higher than 450.9 and 513.0 g reported by [32] and [34], respectively but lower than 660.0 g reported by [35]. The mean BWT4, BWT6 and BWT8 are below, but close to the reported values. [36, 37] reported BWT4 of 1053.0-1118.0 g and 1069.0-1679.0 g, respectively, which are all higher than 954.9 g observed in this work. The mean BWT6 of 1374.4 g is below 1500.0 g and 1550.0 g reported by [37] and [13], respectively. The mean BWT8 of 1690.1 is also below the range of 1843.0-2370.0 g, reported by [36] and [37].

Differences in weights may be due to different environments (nutrition, country, farm management etc.) characterizing this study and the others. The other studies originate from Ghana, Benin and Nigeria. Microclimatic differences between and within different countries, affect the nutritive value of grass [38]. Farm management practices can also affect variation in animal performance. For example, whilst [13] in Ghana used guinea grass in their study, [39] in Benin used concentrate, whilst other studies used both concentrate and grass in different proportions.

The mean PWADG (6.9 g/day) is within the range (5.0-7.2 g/day) previously reported [34, 36, 40-42]. However, mean ADG4 (7.0 g/day), ADG6 (6.8 g/day) and ADG8 (6.2 g/day) are below, but close to the ranges (7.7-8.2 g/day; 7.0-12.0 g/day; 7.0-12.0 g/day, respectively) previously reported [34, 36, 40-42]. Differences in values obtained in this study and those previously reported could be due to similar reasons assigned above for live weights.

Effect of Litter Size: Birth weight decreased ($P < 0.01$) with increasing litter size, with animals born singly having the highest BWT and those in the largest litters having the lowest BWT (Table 3). Similar trends were observed for WWT, BWT4 (Table 3) and BWT6 (Table 4). However, at 8 months this effect diminished (Table 4). At this age, animals of all litter size levels had similar ($P > 0.05$) weights, except single born animals which were still heavier ($P < 0.01$) than the rest. For every 1 unit increase in litter size, there were 8.8, 50.2, 67.0, 54.5 and 82.6 g loss in BWT, WWT, BWT4, BWT6 and BWT8, respectively. Litter size at birth accounted for 16.7, 13.4, 8.1, 3.1 and 5.2% of the variation in BWT, WWT, BWT4, BWT6 and BWT8, respectively.

Litter size affected PWADG ($P < 0.01$), ADG4 ($P < 0.01$) and ADG8 ($P < 0.05$) (Table 4 & 5) but it had little effect ($P > 0.05$) on ADG6 (Table 5). Effects of litter size on growth rate were thus similar to those in body weights. Regression of PWADG, ADG4 and ADG8 on litter size at birth resulted in decrease in growth rate of 0.7, 0.3 and 0.5 g/day respectively. Litter size at birth explained 10.7, 2.2 and 1.2% of the variation in PWADG, ADG4 and ADG8, respectively.

Similar observations were made in grasscutters by [32, 34]. Their observations confirm the work of [43] who reported that body weights of rodents at weaning are believed to be inversely related to the number of animals in the litter during the birth-to-weaning period. It has also been observed in rats that animals born in large litters grow more slowly, weigh less and contain less fat at weaning and throughout adulthood than those born in small litters [44, 45]. Differences in size and body composition have been attributed to the limited amount of milk available to kids in large litters [43]. The disadvantage is seen in adulthood, but the effect is reduced in late adulthood by compensatory growth [46]. A similar effect was found in this study. Increasing litter size was related to decreasing growth and live weights from birth to six months, after which period the effect diminished.

Effect of Sex: Although male kids were slightly heavier than females at birth (Table 3), the difference in weight (2.9 g) had little effect ($P > 0.05$) on the trait. There was also little effect ($P > 0.05$) of sex on BWT6 (Table 4). However, male kids were heavier than females at weaning ($P < 0.05$), 4 months ($P < 0.05$) and 8 ($P < 0.01$) months (Table 3 and 4). At weaning, male kids were 4% heavier than females and the advantage was carried to 4 and 8 months at which time males were 6 and 8% heavier than females, respectively. Sex explained 0.3, 0.5, 1.2, 0.2 and 3.1% of the variation in BWT, WWT, BWT4, BWT6 and BWT8, respectively. It was concluded that sexual differences on body weight were more important at the post-weaning stage than pre-weaning.

Male kids grew faster than females by 4% from birth to weaning and by 5% from weaning to 4 months but the difference in growth had little effect ($P > 0.05$) on the trait in both cases. Thus, PWADG and ADG4 were similar in both males and females (Table 4 and 5). Growth rates from 4-6 and 6-8 months were higher ($P < 0.01$) in males than females (Table 5). Males grew faster ($P < 0.01$) than females by 22 and 38% from 4-6 and 6-8 months, respectively. Sex accounted for 0.4, 1.0, 2.0 and 6.3% of the variation in PWADG, ADG4, ADG6 and ADG8, respectively. It was again concluded that sexual differences on growth rate were more important at the post-weaning stage than pre-weaning.

Sex had little or no influence on growth and body weight from birth to weaning, but was significant from weaning to adulthood in this study. Results of the study are in agreement with that of [47] who observed no significant differences between males and females at birth and at weaning. However, [34] observed that sex of kid significantly influenced birth and weaning weights, with male kids weighing heavier than females. Results of the study also agree with the findings of [48]. At the post-weaning stage of growth, they observed that the growth rate and body weight of male grasscutters were significantly higher than those of females. It was therefore concluded that sexual differences in growth and body weight are not important at the pre-weaning stage, but become prominent from about 4 months to adulthood, at which time males are significantly heavier than females.

Effect of Parity: Parity had little effect (P > 0.05) on BWT, WWT, BWT4 and 8WT (Table 3 & 4) but had large effect on (P < 0.05) on BWT6 (Table 4). Animals born to dams of the first parity were lighter (P < 0.05) at 6 months than those in the second and third parity. Animals in the second and third parity had similar (P > 0.05) BWT6. For 1 unit increase in parity level, there was 51.2 g increase in BWT6. Parity accounted for 1.0% of the variation in BWT6.

Parity also had little effect (P > 0.05) on PWADG, ADG4 and ADG8 (Table 4 & 5) but had large effect (P < 0.05) on ADG6. There appeared to be no pattern or trend of the effect of parity on ADG6 (Table 4). Parity accounted for 0.4% of the variation in ADG6.

Parity of dam had little to no influence on body weights and growth rates. Similar results were observed by [34] in Nigeria who reported that parity had no effect on birth and weaning weight or pre-weaning daily gain. Although parity has been reported to influence maternal behaviour and thereby affect body weights and growth rates in rodents [49, 50], results of this study did not detect any such effect. This may be due to the few parity levels (1, 2 and 3) involved or the few observations for parity 3, compared with parities 1 and 2.

Year Effects: Year of birth influenced (P < 0.01) all body weight traits. In all these traits, animals born at the beginning of the study period (2006) were mostly lighter than those born in later years (Table 3 & 4). Body weight increased with increasing years. BWT, WWT, BWT4, BWT6 and BWT8 increased by 2.2, 39.6, 91.3, 91.7 and 91.7 g weight, respectively with a unit increase in the number of years. Year of birth accounted for 1.4, 10.2, 16.4, 9.9 and 7.0% of the variation in BWT, WWT, BWT4, BWT6 and BWT8, respectively.

Effects of year of birth on growth rate were similar to its effects on body weights. A unit increase in year resulted in a corresponding increase in average PWADG, ADG4, ADG6 and ADG8 by 0.6, 0.8, 0.5 and 0.5 g/day, respectively. Year of birth accounted for 10.3, 12.6, 1.8 and 2.9% of the variation in PWADG, ADG4, ADG6 and ADG8, respectively.

There are no previous reports on effects of year of birth on growth and body weight of the grasscutter. There is also little information on year effects on traits of rodents. However, year effects have been extensively studied in traditional livestock species. In this study, growth and live weights increased significantly with increasing years. Differences in growth due to year of birth can be brought about by deliberate as well as uncontrollable changes in various factors of management and environment [4, 5, 51]. Management changes could have affected the growth and development of the animals. For instance, in 2006, animals were fed solely on grass without supplementary feed. In 2007, supplementary feed (concentrate) containing 10% crude protein (*soybean source*) was introduced. In 2008 onwards, crude protein concentration of the feed supplement was increased to 14%. Other factors which differed from year to year such as diseases, nutritional quality of grass and experience of the stockmen could also have contributed to the significant year of birth effect.

Seasonal Effects: Season of mating had a very large effect (P < 0.01) on BWT, WWT, BWT6 and BWT8 but little effect (P > 0.05) on BWT4 (Table 3 & 4). Kids conceived in the dry season were 12 (P < 0.05) and 18% (P < 0.01) heavier in BWT and WWT, respectively than those conceived in the major rainy season. However, this advantage disappeared after 4 months of age. At this age, there was no influence (P > 0.05) of season of mating on body weight (Table 3). Kids that were conceived in the major rainy season had similar (P > 0.05) BWT6 as those in the dry season, but had higher (P < 0.01) BWT8 than those conceived in the dry season (Table 4). Season of mating explained 0.3, 0.3, 0.0, 1.5 and 6.4% of the variation in BWT, WWT, BWT4, BWT6 and BWT8, respectively.

Season of mating had little effect (P > 0.05) on ADG4 but a very large effect (P < 0.01) on PWADG, ADG6 and ADG8 (Table 4 & 5). Thus, effects of season of mating on growth traits were similar to its effect on body weights. Season of mating explained 0.3, 0.4, 2.4 and 5.6% of the variation in PWADG, ADG4, ADG6 and ADG8, respectively.

Kids born in different seasons had similar (P > 0.05) BWT6 (Table 4). However, differences (P < 0.01) existed among kids born in the three seasons for BWT, WWT, BWT4 and BWT8 (Table 3 & 4). Kids born in the dry season had higher (P < 0.01) BWT and WWT than those born during the major rains (Table 3). Those born during the minor rains had similar (P > 0.05) BWT and WWT as those born in the dry season (Table 3). At 4 and 6 months of age, kids born in the dry and the major rainy season had similar (P > 0.05) weights and in the 8 month the kids of the major rains were heavier (P < 0.05) than those in the dry season (Table 4). Season of birth explained 0.6, 0.1, 0.0, 0.7 and 0.3% of the variation in BWT, WWT, BWT4, BWT6 and BWT8, respectively.

1Table 6: Interaction effects of fixed factors on growth traits

Type of Interaction	FI	FCR	BWT	WWT	BWT4	BWT6	BWT8	PWADG	ADG4	ADG6	ADG8
TOB*Sex	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
TOB*Parity	ns	ns	**	*	**	**	ns	ns	**	ns	ns
TOB*YOB	ns	ns	**	*	ns	ns	ns	*	*	ns	ns
TOB*SOM	ns	ns	ns	**	ns	*	ns	**	ns	ns	ns
TOB*SOB	ns	ns	ns	**	*	**	*	**	ns	ns	ns
Sex*Parity	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Sex*YOB	*	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Sex*SOM	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Sex*SOB	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Parity*YOB	*	ns	ns	ns	ns	ns	*	ns	ns	ns	ns
Parity*SOM	ns	ns	ns	ns	**	ns	**	ns	**	ns	ns
Parity*SOB	ns	ns	ns	**	**	ns	ns	**	*	ns	ns
YOB*SOM	ns	ns	**	ns	**	**	ns	ns	**	*	ns
YOB*SOB	ns	ns	**	**	ns	**	ns	**	ns	*	ns
SOM*SOB	ns	ns	ns	ns	*	*	ns	ns	ns	ns	ns

** = P < 0.05; ** = P < 0.01; not significant (ns)*

Feed intake (FI); Feed conversion ratio (FCR); birth weight (BWT); weaning weight (WWT); 4 month weight (BWT4); six month weight (BWT6); 8 month weight (BWT8); pre-weaning growth rate (PWADG); growth rate from 2-4 months (ADG4); growth rate from 4-6 months (ADG6); growth rate from 6-8 months (ADG8).

Season of birth had a large effect on PWADG (P < 0.01), ADG4 (P < 0.01) and ADG8 (P < 0.05) (Table 4 & 5) but little effect (P > 0.05) on ADG6 (Table 5). Kids born in the dry season had higher (P < 0.01) PWADG than those born in the major rainy season, but this advantage was no longer present at the ADG4 stage. At 8 months, the kids in the major rains weighed heavier (P < 0.05) than those in the dry season (Table 5). Season of birth explained 0.1, 0.2, 2.2 and 2.2% of the variation in PWADG, ADG4, ADG6 and ADG8, respectively.

Grasscutters attain sexual maturity at 4-9 months [36, 52]. Season of mating was more important in explaining post-weaning growth performance after 6 months of age, which is within the period of sexual maturity, than growth performance from birth to 6 months. Animals conceived in the rainy seasons had heavier sexual mature weights and grew faster than those conceived in the dry season. Animals born in the dry season grew faster at the age of 4-8 months than those born in the rainy season.

Lack of seasonal differences on growth and body traits before sexual maturity has been reported in studies in rodents. This has been attributed to climate and the continuous availability of resources, especially quantity and quality of grass. These effects are more marked when animals are not given supplementary feed. In this study, animals of all classes were given supplementary feed in all seasons of all years, except in the first year (2006).

Lack of seasonal effects on growth rate and body weight of kids indicates no benefit from restricting kidding to any season of the year. [32, 47] have already demonstrated that there is an all year round breeding for captive grasscutter. Also, [53] observed that seasonal breeding does not confer any major advantage on live weight development of Maasai SEA goat herds and concluded that there would be little to be gained in terms of growth performance from attempting to control breeding. All year round production is necessary to insure continuous supply of grasscutter meat. There did not seem to be nutritional stress on pregnant does in this study, because supplementary feed was provided and so it was expected that season of mating and season of birth would have had no effect on body weight and growth rate from birth to maturity. However, we do not know if the supplementary feed given was adequate for pregnancy and/or lactation because the feed was prepared based on the standards for growth. It may therefore be concluded that the supplementary feed provided might not have been adequate for pregnancy and/or lactation since seasonal differences were observed in growth and live weights of the animals.

Interaction Effects of Fixed Factors on Traits: Interaction effects of type of birth with parity, year and seasons were important on some growth traits (Table 6). Interaction effects of sex with all other fixed factors on growth traits were not significant. Parity x seasons and year of birth x season effects were also important in some traits. Interaction effects of almost all fixed factors on FI, FCR and ADG8 were not important.

Significant first order interactions observed in this study in some growth traits indicates that the ranking of levels of the same factor do not hold when combined sets of levels of two factors are considered. There has never been a study of fixed factor interactions in the grasscutter. However, studies in rodents and other farm animal species have confirmed existence of some of these interactions. Type of birth x parity interactions were found to be significant for body weight and growth rate in mice [54] and in sheep [55]. Chineke [56] also reported significant interactions of parity x season on live weight and litter weight in rabbits. The parity x year interaction effect on birth weight was significant in cattle [57]. Importance of interactions of fixed factors has been recognized in farm animal genetic improvement and evaluation programmes. For example, in absence of interactions genetic parameter estimates can be overestimated or underestimated [58-60]. These authors observed that estimates of direct-maternal genetic correlations for weaning weight were inflated when the effects of sire × year interaction were not included in the model. Inclusion of a sire x year interaction term has been reported to reduce both direct heritability and direct-maternal correlation estimates [60, 61]. It is therefore concluded in this work that interaction effects of fixed factors on growth traits are important in the grasscutter and must be considered in grasscutter genetic improvement and evaluation programmes.

CONCLUSION

The mean values of traits obtained in this study are comparable to values from similar studies conducted in sub-Saharan Africa on the grasscutter. In most cases, this study showed that non-genetic effects did influence selected traits. It is important that the extent to which these environmental factors influence traits under study be evaluated for appropriate adjustments to be made when estimating genetic values for a breeding programme in grasscutter. Interaction effects were important in the grasscutter and must also be considered in breeding programmes.

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