

Variations in reproductive and egg traits correlation estimates of two strains of *Archachatina marginata* snails (var. *ovum* and var. *saturalis*) and crosses



*Ibom, L. A., Okon, B., Dauda, A. and Patani, I

Department of Animal Science, University of Calabar, Calabar, Nigeria

*Corresponding author: ibomlawrence@gmail.com, Tel: +2348033508663

Abstract

A study was conducted to assess variations in the reproductive traits and egg traits correlation estimates of the two strains of *Archachatina marginata* snails (var. *ovum* and var. *saturalis*) and their crosses. Ninety sexually mature *A. marginata* snails, forty-five each of the two strains (var. *saturalis* and var. *ovum*) were selected from a base population for the study. The live weight of the snails ranged from 256.43 – 566.25 g for both strains. Selection of the snails was based on active appearance and lack of injury on the foot and on shells. The snails were randomly allotted into three mating models (treatments) of 30 each of var. *saturalis*, var. *ovum* and mixed strains (at 15 var. *ovum* : 15 var. *saturalis*). The models were designated as homozygous var. *ovum* main cross (AMO X AMO), homozygous var. *saturalis* main cross (AMS X AMS) and heterozygous (var. *ovum* x var. *saturalis*) cross (AMO X AMS). Each of the three models was replicated 15 times with two snails to a tub/cell for purposes of reproduction. Results from the study showed that the three mating models expressed significant ($P < 0.05$) differences in the reproductive traits evaluated. Whereas some of the traits were not significantly ($P > 0.05$) different between the AMO X AMO and AMO X AMS mating models, significant ($P < 0.05$) differences existed between all the traits when the AMS X AMS mating model was compared with the AMO X AMO and AMO X AMS mating models. The clutch size ranged from 7.00 ± 0.35 (AMS X AMS) through 9.40 ± 0.35 (AMO X AMS) to 9.90 ± 0.35 (AMO X AMO), while the values for mean egg weight at lay ranged from 1.59 ± 0.03 g (AMS X AMS) through 1.78 ± 0.03 g (AMO X AMO) to 1.79 ± 0.03 g (AMO X AMS). Percent hatchability value was highest in the AMO X AMO mating model (93.30 %), followed by the AMS X AMS mating model (91.10 %), while the AMO X AMS mating model recorded the lowest value (88.50 %). Percent survivability value was highest in the AMO X AMS mating model (84.00 %), followed by the AMO X AMO mating model (82.00 %), while the AMS X AMS mating model recorded the lowest value (80.00 %). The egg traits correlation estimates (r_p) revealed that except for one pair of trait each in the mating models, all the other pairs of traits expressed positive and significant correlation coefficients/values. The AMO X AMS mating model recorded the highest correlation (r_p) value (0.826) for the pair of ELH vs EWH, while the AMS X AMS mating model recorded the lowest correlation (r_p) value (-0.058) for the pair of ELH vs CSE. The percent egg shell colour distribution showed that the shell of eggs laid by the homozygous crosses (AMO X AMO and AMS X AMS) expressed two colours. The egg shell of eggs laid by AMO X AMO mating model expressed mikado yellow and maize yellow colours, while those laid by AMS X AMS mating model expressed mikado yellow and amber colours. The shell of eggs laid by the heterozygous cross however expressed three colours; mikado yellow, maize yellow and amber. Based on the reproductive traits results, it could be recommended that the AMO X AMS mating model be adopted by farmers for optimum production and returns on investment.

Keywords: Correlation, reproduction, snails, strains, traits, variations

Introduction

Due to the prevailing economic recession in Nigeria, the farming of giant African land

snails, achatiniculture has become a new frontier to generate income and improve the livelihood of people as well as curb

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unemployment. This is perhaps because snail farm can be started with little capital and the management practices are easy (Omole *et al.*, 2011). Besides, Ademosun and Imevbore (1988) reported that snail meat (Congo meat) compares favourably with other protein sources in terms of protein, amino acids and vitamin contents. Nigeria is richly endowed with land snail breeds (*Archachatina marginata*, *Achatina achatina*, *Achatina fulica* and *Limicolaria* species) and their production on large scale could be a succor and relief to the dwindling economic earnings of individuals and the nation. However, these snail breeds vary in size, colour, adaptability and performance (Amusan and Omidiji, 1998; Okon *et al.*, 2012a). Besides, the reproductive ability of snails as well as other farm animals is to a large extent influenced by genetic (strain/genotype, age of the breeder, physiology, mating ratio, semen quality and dose, possession of major genes) and non-genetic/environmental (nutrition, exposure to light, water, medication) factors.

According to Amubode (1994); Okon *et al.* (2012a), *Archachatina marginata* and *Achatina achatina* are the two most abundantly distributed and popular breeds of land snail in Nigeria. On the other hand, Omole (1997) reported that *A. marginata* is the most common edible land snail found and reared in Nigeria. These snails play important role in the economy of rural families where they serve as the cheapest sources of animal protein, especially during the rainy season (period of abundance) (Ibom *et al.*, 2011). The *A. marginata* snail breed has two varieties/strains (*A. marginata var. ovum* and *A. marginata var. saturalis*) which are similar in various characteristics (foot colour, meat quality, habitat, shell shape and pattern, etc). The difference between these varieties/strains is in the colour of the columella (outer lip) and

parietal wall of their shells. The colour of the columella and parietal wall of the shell of *A. marginata var. ovum* is bluish-white or white, while the columella and parietal wall of the shell of *A. marginata var. saturalis* is somewhat reddish or apricot red. This difference could be genetic in origin and have effects on the snail's traits, including reproductive traits.

Earlier reports on the reproductive performance of *Archachatina marginata* snails combined these two varieties/strains (*var. ovum* and *var. saturalis*) as one breed and this has not really given out the true difference(s) in the performance of these varieties/strains. This study examined variations in the reproductive traits and egg traits correlation estimates of the two strains of *A. marginata* snails (*var. ovum* and *var. saturalis*) and their crosses.

Materials and methods

Experimental site

This research was conducted at the Botanical Garden, University of Calabar, Calabar, Nigeria. Calabar is geographically situated between latitude 4°58' and 15°39'N and longitude 8°17' and 10°43'E of the equator, with annual temperature and rainfall ranges of 25°C to 28°C and 1260 mm to 1280 mm respectively. The relative humidity rarely drops below 60% and fluctuates between 90 and 100% most months of the year (NMA, 2016). The area where this study was conducted possessed a mini-climate similar to the natural habitat of snails. The area has some permanent tree crops (mango, gmelina, almond and pawpaw), cultivated crops (cassava and yam) and undergrowth of wild shrubs. These plants provided shade that protected the hutches and snails from harsh environmental factors such as heavy rainfall, direct sunlight and high ambient temperature.

Experimental animals

Ninety sexually mature *Archachatina marginata* snails, 45 each of the two strains/varieties (*var. saturalis* and *var. ovum*) were selected from a base population purchased from a reputable snail farm in Calabar, Nigeria. The live weight of the snails ranged from 256.43 – 566.25 g for both strains/varieties. Selection of the snails was based on active appearance and lack of injury on the foot and on shells. The snails: *var. saturalis* (n=45) and *var. ovum* (n=45) were randomly allotted into three mating models (treatments) of 30 *var. saturalis*, 30 *var. ovum* and 30 mixed varieties (15 *var. ovum* : 15 *var. saturalis*).

The models were designated as homozygous *var. ovum* main cross (AMO X AMO), homozygous *var. saturalis* main cross (AMS X AMS) and heterozygous (*var. ovum* x *var. saturalis*) cross (AMO X AMS). The snails were balanced weight for weight to ensure uniformity in average weight for all three models (treatments). Each of the three models was replicated fifteen (15) times with two snails to a tub/cell for purposes of reproduction. Confining two snails in a tub ensured that eggs collected from there are the product of mating between these two. The mating arrangement is shown in Table 1.

Table 1: Mating arrangement of experimental animals

Mating model	Number of snails	Number of cells/tubs
Homozygous <i>var. ovum</i> main cross (AMO X AMO)	2	15
Homozygous <i>var. saturalis</i> main cross (AMS X AMS)	2	15
Heterozygous (<i>var. ovum</i> x <i>var. saturalis</i>) cross (AMO X AMS)	2	15

AMO = *A. marginata var. ovum*, AMS = *A. marginata var. saturalis*

Management of experimental snails

The experimental snails were housed in a hutch compartment raised 30 cm from the ground and contained series of tubs measuring 40 cm (length) x 40 cm (width) x 30 cm (depth). The bottom of the tubs were perforated (to allow drainage of excess moisture) and lined with sterilized loamy soil. The snails were reared on a mixed feeding regime of pawpaw leaves and concentrate. The concentrate was formulated to contain 25% CP, 12% Ca and 2650 Kcal/kgME using the following ingredients; maize offal 33%, soybean meal 36%, wheat offal 12%, PKC 6%, crayfish dust 8%, bone meal 4.50% and mineral/vitamin premix 0.50%. Feed and water were given *ad libitum* throughout the experimental period (35 weeks).

Management of eggs

Eggs collected from the three mating models of the snails were sorted against

cracks and other physical deformities before measurements (egg weight, egg length and egg width) were taken. Thereafter, good eggs were incubated in improvised incubators (plastic containers perforated at the bottom and lined with sterilized loamy soil). The soil was sterilized to eliminate pathogenic organisms that would have otherwise attacked and killed the eggs. Incubated eggs were monitored until hatch.

Data collection

Data were collected on reproductive traits: clutch size (counted as the number of eggs laid by each mating model), egg weight at lay, egg length at lay, egg width at lay, hatchling weight at hatch, hatchling shell length at hatch, hatchling shell width at hatch, percent hatchability and percent survivability] of the snails. The eggs quality in terms of colour was determined by matching the colour of eggs shell against a

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standard colour chart (Raggett, 2002). Weights were measured using S. Miller® electronic scale with sensitivity of 0.01 g, while the dimensional shell traits were measured using Vernier caliper.

Statistical analysis

Reproductive traits data were subjected to analysis of variance (ANOVA) using Genstat (2014), while significant means among traits were separated using Duncan's Multiple Range Test (Duncan, 1955). Correlation estimates of egg traits were done according to methods outlined by

Falconer (1989) and Ibe (1998). Percent hatchability and percent survivability were estimated according to the procedures of Ibom (2009).

Results and discussion

The results of reproductive traits of the three mating models [homozygous var. ovum main cross (AMO X AMO), homozygous var. saturalis main cross (AMS X AMS) and heterozygous (var. ovum x var. saturalis) cross (AMO X AMS)] are shown in Table 2.

Table 2: Reproductive performance of *Archachatina marginata* snails mating models

Parameter	AMO X AMO	AMS X AMS	AMO X AMS	SEM
Mean clutch size	9.90 ^a	7.00 ^c	9.40 ^b	0.35
Mean egg weight at lay (g)	1.78 ^a	1.59 ^b	1.79 ^a	0.03
Mean egg length at lay (mm)	1.58 ^b	1.59 ^b	1.67 ^a	0.02
Mean egg width at lay (mm)	1.26 ^b	1.23 ^c	1.30 ^a	0.01
Mean hatchling weight at hatch (g)	1.40 ^a	1.26 ^c	1.30 ^b	0.03
Mean hatchling shell length at hatch (mm)	1.57 ^a	1.53 ^b	1.56 ^a	0.01
Mean hatchling shell width at hatch (mm)	1.24 ^a	1.21 ^b	1.23 ^a	0.01
% Hatchability	93.30 ^a	91.10 ^b	88.50 ^c	1.39
% Survivability	82.00 ^b	80.00 ^c	84.00 ^a	1.16

AMO = *A. marginata* var. ovum, AMS = *A. marginata* var. saturalis, SEM = Standard Error of Mean

^{abc}Means with different superscript along the same row are significantly different (P<0.05)

Significant (P<0.05) differences existed between the traits of the three mating models, with the heterozygous cross (AMO X AMS) expressing superiority (P<0.05) in three traits (egg length at lay, egg width at lay and percent survivability) over the homozygous crosses (AMO X AMO and AMS X AMS). One of the homozygous cross (AMO X AMO) was however superior (P<0.05) in three traits (clutch size, hatchling weight at hatch and percent hatchability) to the heterozygous cross (BO X BS) and the other homozygous cross (AMS X AMS) (Table 2).

The clutch size results (Table 2) were higher than the range of 1 to 4 and 2 to 6 reported by Ubu (2004) for *A. marginata* var. ovum and *A. marginata* var. saturalis homozygous crosses respectively. These results were

also higher than the range of 5.08 to 6.58 reported by Ibom et al. (2015) for *A. marginata* var. ovum snails. However, the results were within the range of 2 to 15 and 1 to 16 reported by Akintomide (2004) and Okon and Ibom (2012) respectively for *A. marginata* snails. The clutch size was also within the range of 2 to 13 and 1 to 9 reported by Ibom (2009) for black skinned and white skinned *A. marginata* snails, respectively.

The mean egg weight at lay showed that the AMO X AMO and AMO X AMS mating models were statistically the same (P>0.05), but superior (P<0.05) to the AMS X AMS mating model (Table 2). The results (range of 1.59 g to 1.79 g) were within the range of 1.15 g to 1.83 g reported by Okon et al. (2012b) for *F₁ Achatina achatina*

snails, but lower than the range of 2.6 g to 5.0 g reported by Amubode (1994) for *A. marginata* snails. These egg weights were lower than the values of 1.90 g and 1.80 g reported by Okon et al. (2009) and Ibom et al. (2008) as weight at lay for black skinned ectotype of *A. marginata* snails, respectively. The mean egg weight values were higher than the mean value at lay (1.05 g) reported in Ibom et al. (2008) for albino *A. marginata* snails. The mean egg length at lay showed that the heterozygous cross (AMO X AMS) was superior ($P < 0.05$) to the homozygous crosses (AMO X AMO and AMS X AMS) which were statistically the same ($P > 0.05$) (Table 2). The mean egg length values were close to the mean value (1.61 mm) reported by Ibom et al. (2008) for black skinned *A. marginata* snails, but higher than the mean value (1.43 mm) reported for albino ectotype of the same snail breed. The mean egg length values were lower than the mean values of 14.32 mm and 15.35 mm reported by Okon et al. (2010) for parities 1 and 2 respectively of albino *A. marginata* snails. The mean egg length was also lower than the values of 19.70 mm reported by Amubode (1994) for black skinned ectotype of *A. marginata* snails and 1.68 mm reported by Okon et al. (2012b) for F_1 *A. achatina* snails. Similarly, the egg length were lower than the range values at lay (1.22 to 1.50 cm) reported by Ibom et al. (2015) for *A. marginata* var. ovum snails. The results of mean egg width at lay (Table 2) expressed significant ($P < 0.05$) differences across the mating models, with the AMO X AMS recording the highest value (1.30 mm), followed by the AMO X AMO (1.26 mm), while the AMS X AMS had the lowest value (1.23 mm). The mean egg width were close to the mean value of 1.29 mm reported by Ibom et al. (2008) for black skinned *A. marginata* snails, but

higher than the mean value of 1.05 mm reported by the same authors for albino ectotype of the same snail breed. The mean egg width values were lower than the mean values of 10.78 mm and 10.94 mm reported by Okon et al. (2010) for parities 1 and 2 respectively of albino *A. marginata* snails. The mean egg width values were also lower than the range values at lay (0.97 to 1.23 cm) reported by Ibom et al. (2015) for *A. marginata* var. ovum snails.

The results of mean hatchling weight at hatch of this study (Table 2) showed that significant differences ($P < 0.05$) existed across the mating models. The AMO X AMO model recorded the highest value (1.40 g), followed by the AMO X AMS model (1.30 g), while the AMS X AMS model recorded the lowest value (1.26 g). The mean hatchling weight results were within the range of 0.69 to 1.42 g reported by Odido (2007), but lower than the range of 2.1 to 2.5 g reported by Akinnusi (2004) for black-skinned snails. The results were however higher than the range value of 0.53 to 0.93 g reported by Ibom *et al.* (2015) for *A. marginata* var. ovum snails. The results of mean hatchling shell length and width at hatch (Table 2) followed the same trend. The results showed that the AMO X AMS and AMO X AMO mating models were statistically the same ($P > 0.05$), while they differed significantly ($P < 0.05$) from the AMS X AMS mating model. The mean hatchling shell length at hatch were within the range values of 1.40 mm to 1.49 mm and 1.25 mm to 1.41 mm reported by Okon et al. (2012a) and Ibom et al. (2012) for black skinned *A. marginata* snails respectively. On the other hand, the mean hatchling shell width were higher than the range values of 1.00 mm to 1.18 mm reported by Okon et al. (2012b) for F_1 *A. achatina* snails and 0.99 mm to 1.16 mm reported by Ibom et al. (2012) for black skinned *A. marginata*

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snails.

The percent hatchability results (Table 2) showed that significant ($P < 0.05$) differences existed across the mating models. The AMO X AMO model recorded the highest value (93.30 %), followed by the AMS X AMS model (91.10 %), while the AMO X AMS model recorded the lowest value (88.50 %). The percent hatchability results were within the range of 77 to 100 % and 0 to 100 % reported by Wosu (2003) and Odido (2007) respectively for black-skinned snails. The percent hatchability was higher than the range of 50.50 to 58.58 % reported by Ibom et al. (2015) for *A. marginata* var. ovum snails. The percent survivability results (Table 2) showed significant ($P < 0.05$) differences across the mating models. The AMO X AMS model recorded the highest value (84.00 %), followed by the AMO X AMO model (82.00 %), while the AMS X AMS model recorded the lowest value (80.00 %). These values were lower than the value of 100 % and range of 83.00 to 92.08 % reported by Fapohunda et al. (2007) and Ibom et al. (2015), respectively. The results of egg traits correlation estimates (r_p) of the homozygous crosses/models (AMS X AMS and AMO X

AMO) in this study are presented in Table 3. The results revealed that except for one pair of trait each in these mating models (AMS X AMS and AMO X AMO), all other pairs of traits evaluated expressed positive and significant correlation coefficients/values. The results further showed that the AMO X AMO mating model recorded higher correlation (r_p) values than the AMS X AMS mating model for any given pair of traits (Table 3). This could imply that these traits were influenced by the same gene(s) in the same direction. Besides, selection and improvement of one of the positively correlated traits could lead to improvement in the other trait. The correlation (r_p) coefficients corresponding to egg length (ELH) vs egg width (EWH) and egg length (ELH) vs clutch size (CSE) were the highest and the lowest respectively in both the AMO X AMO and AMS X AMS mating models. The results of egg traits correlation estimates (r_p) of the heterozygous cross/model (AMO X AMS) are presented in Table 4. The results showed the same trend as those of the homozygous models (AMO X AMO and AMS X AMS); positive and significant correlation coefficients, except for one pair of the traits.

Table 3: Correlation (r_p) estimates of egg traits of the homozygous mating models (AMS X AMS and AMO X AMO) of *A. marginata* snails

AMS X AMS				
Trait	EWT	ELH	EWH	CSE
EWT	1.000	0.526**	0.600**	0.291*
ELH	0.536**	1.000	0.784**	-0.058
EWH	0.604**	0.820**	1.000	0.202*
CSE	0.298*	-0.060	0.208*	1.000
Trait	EWT	ELH	EWH	CSE
AMO X AMO				

EWT = Egg Weight, ELH = Egg Length, EWH = Egg Width, CSE = Clutch Size
 ** = Significant ($P < 0.01$), * = Significant ($P < 0.05$)

Table 4: Correlation (r_p) estimates of egg traits of the heterozygous mating model (AMO X AMS) of *A. marginata* snails

Trait	AMO X AMS			
	EWT	ELH	EWH	CSE
EWT	1.000			
ELH	0.546**	1.000		
EWH	0.608**	0.826**	1.000	
CSE	0.305*	-0.062	0.214*	1.000

EWT = Egg Weight, ELH = Egg Length, EWH = Egg Width, CSE = Clutch Size

** = Significant (P<0.01), * = Significant (P<0.05)

The positive correlation (r_p) values recorded in this study were similar to the range of positive values [0.49 for egg weight (EWT) vs egg length (ELH) to 0.89 for egg length (ELH) vs egg width (EWH)] reported by Ibom (2009). The positive correlation among most of the paired traits could imply that these traits were influenced by the same gene(s) in the same direction; hence selection and improvement in one trait could lead to improvement in the other. On the contrary, the negative correlation values among some other pairs of traits could mean that these traits were influenced by different gene(s) in opposite direction and selection for improvement of one trait could lead to the reduction in performance of the other. These results agreed with the position of Ehiobu and Kyado (2000) that correlations between traits could be high or low, positive or negative. The authors also reported that positive correlations expressed among pairs of traits could suggest there is a direct relationship between them.

The percent egg shell colour distributions of the three mating models are presented in Figure 1. The results showed that the egg shell laid by the homozygous crosses (AMO X AMO and AMS X AMS) expressed two colours. The colours were mikado yellow and maize yellow for AMO X AMO model, while the colours expressed

by the AMS X AMS model were mikado yellow and amber. The shell of eggs laid by the heterozygous cross (AMO X AMS) however expressed three colours, namely: mikado yellow, maize yellow and amber. This could imply that eggs laid by the heterozygous model were hybrids and contained the genes responsible for the egg shell colours of the homozygous crosses. The colours of egg shells were at variance with the yellow egg shell colour reported by Otu (2016) and the light yellow and milk white egg shell colours reported by Ibom et al. (2017) for the black skinned and white skinned ecotypes of *A. marginata* var. *saturalis* snails.

The differences in mean reproductive traits values and the colour of egg shells recorded in this study with earlier reports could be attributed to the variety/strain, age and sizes of snails used, genetic composition of the snails, differences in egg sizes among the mating models and other prevailing environmental conditions like temperature, relative humidity, type of feeding and soil conditions. The differences between egg traits correlation (r_p) estimates of this study and those in available literature could be attributed among other things to differences in the pairs of traits, sizes of the eggs used, the genetic constitution of snails used and the prevailing environmental conditions.

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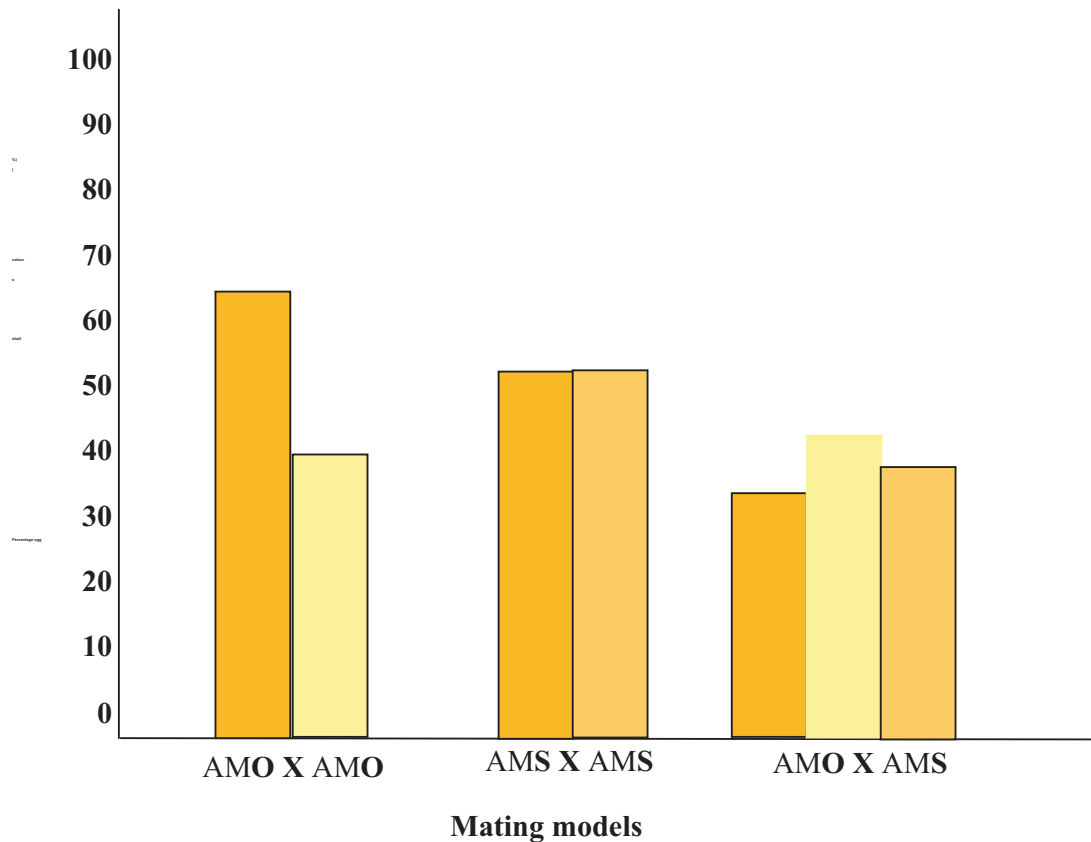


Fig. 1: Percentage egg shells colour distribution of *A. marginata* snails mating models.

KEY:

- = Mikado yellow
- = Maize yellow
- = Amber

Conclusion

The relationship among the three mating models (AMO X AMO, AMS X AMS and AMO X AMS) evaluated revealed that the AMO X AMO and AMO X AMS models performed alike in some of the traits, while AMO X AMS (heterozygous cross) performed better than the two homozygous crosses (AMO X AMO and AMS X AMS) in some other traits, probably because of heterotic effect. The egg traits correlation

estimates (r_p) results also revealed that the AMO X AMS model recorded higher correlation coefficients for the pairs of traits evaluated. It could therefore be recommended that the AMO X AMS model be adopted by farmers for optimum production and returns on investment.

References

Ademosun, A. A. and Imevbore, E. A. 1988. An evaluation of the

- nutritive value of the African giant land snail, *Archachatina marginata* in relation to some popular protein sources. *Journal of Animal Production Research*. 8(2):76–87.
- Akinnusi, O. 2004.** *Introduction to Snails and Snail Farming*. 2nd ed. Abeokuta, Nigeria. Triolas Exquisite Ventures. Pp. 90.
- Akintomide, T. O. 2004.** *Tropical snail farming*. 1st. Ed., Abeokuta, Nigeria. Oak Ventures. P. 56.
- Amubode, F. O. 1994.** Growth and Reproductive Performance of Two Species of African Giant Snail (*Achatina achatina* and *Archachatina marginata*). *Journal of Tropical Forestry Research*, 9&10:68–74.
- Amusan, J. A. and Omidiji, M. O. 1998.** *Edible land snails. A Technical guide to snail farming in the Tropics*. Variety Printers Limited. 10–15.
- Duncan, D. B. 1955.** Multiple ranges and multiple F-test. *Biometrics* 11:1 – 262.
- Ehiobu, N. G. and Kyado, J. A. 2000.** Heritability, Repeatability and Genetic correlation of Swine. *Proceedings of the 25th Annual Conference of Nigerian Society for Animal Production (NSAP)*. March 19 – 22, 2000. Umudike, Nigeria. Pp. 260–261.
- Falconer, D. S. 1989.** *Introduction to Quantitative Genetics*. 3rd ed. Burat Mill, England. Longman Group Limited. Pp. 162–169.
- Fapohunda, J. B., Omole, A. J., Obi, O. O. and Adebowale, E. A. 2007.** Nutritional value of chicken offal as a replacement for local fish meal in growing snail. *Proceedings of 32nd Annual Conference of Nigerian Society for Animal Production (NSAP)*. March 18 – 21, 2007, University of Calabar, Calabar, Nigeria. Pp. 363–364.
- GenStat 2014.** GenStat Release 10.3DE (PC/Window Vista) VSN International Ltd. (Rothamsted Experimental Station). GenStat Discovery Edition 4.
- Ibe, S. N. 1998.** *An Introduction to Genetics and Animal Breeding*. Ikeja, Nigeria. Longman Nigeria. Plc. Pp. 150.
- Ibom, L. A., Okon, B. and Essien, A. 2008.** Morphometric analysis of eggs laid by two ectotypes of Snails *Archachatina marginata* (Swainson) raised in captivity. *Global Journal of Agricultural Sciences*. 7(2):119–121.
- Ibom, L. A. 2009.** Variations in reproductive and growth performance traits of White-skinned x Black-skinned African giant snail hatchlings [*Archachatina marginata* (Swainson)] in Obubra, Nigeria. *Ph. D. Thesis*, Department of Animal Science, University of Calabar, Calabar, Nigeria. Pp. 166.
- Ibom L. A., Okon, B. and Adinya, I. B. 2011.** Evaluation of growth and body traits of snaillets obtained from the crossbreeding of black skinned x white skinned snails [*Archachatina marginata* (S)] in the Niger Delta area of Nigeria. *African Journal of Agricultural Research*. 6(21):4968–4972.
- Ibom, L. A., Okon, B., Adinya, I. B. and Okon, F. I. 2012.** Reproductive Performance and correlation among Egg Traits of Two Ectotypes of Adult Snails

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- (*Archachatina marginata* var. *saturalis*) in the Humid Tropics. *World Journal of Zoology*. 7(2):113–117.
- Ibom, L. A., Okon, B., Okon, F. I. and Owoyemi, J. D. 2015.** Reproductive Performance of *Archachatina marginata* var. *ovum* Snails in Calabar, Nigeria. *Journal of Molluscan Research*. 1:64–73.
- Ibom, L. A., Okon, B., Akpe, A. E. and Okon, F. I. 2017.** Genetic and Phenotypic Variations in Egg Shell Colour of Two Ecotypes of Giant African Land Snail (*Archachatina marginata* var. *saturalis*). *African Journal of Biotechnology*. 16(31):1646–1649.
- NMA 2016.** Nigerian Metrological Agency, Margaret Ekpo International Airport, Calabar, Nigeria.
- Odido, E. E. 2007.** Evaluation of reproductive performance and some egg quality parameters of black x white (Albino snail) skinned snails (*Archachatina marginata saturalis*) in Cross River State. *B. Agric. Project*, Animal Science Department, University of Calabar, Calabar. Pp. 62.
- Okon, B., Ibom, L. A., Williams, M. E. and Akpakpan, I. E. 2009.** Comparative evaluation of reproductive performance and some egg quality parameters of black and white skinned snails. *Global Journal of Agricultural Sciences*. 8(1):77–80.
- Okon, B., Ibom, L. A., Williams, M. E. and Akwa, N. T. 2010.** Parity effects on Breeding and Morphometric Traits of Eggs and Hatchlings of Purebred Albino Snails [*Archachatina marginata* (Swainson)]. *Journal of Agriculture, Biotechnology and Ecology*. 3(1):44–54.
- Okon, B. and Ibom, L.A. 2012.** *Snail breeding and snailery management*. Fresh dew productions, Calabar, Nigeria. Pp. 90.
- Okon, B., Ibom, L. A., Williams, M. E. and Ekong, N. B. 2012a.** Effects of Breeds on Reproductive Efficiency of Two Most Popular Snails [*Archachatina marginata* (S) and *Achatina achatina* (L)] in Nigeria. *Journal of Agricultural Science*, 4(8):236–245.
- Okon, B., Ibom, L. A., Nsa, E. E. and Ubuja, J. A. 2012b.** Reproductive and Growth Traits of Parents and F₁ Hatchlings of *Achatina achatina* (L) Snails under Mixed Feeding Regime with Graded Levels of Swamp Taro Cocoyam (*Cytosperma chamissonis*) and Pawpaw leaves (*Carica papaya*). *Journal of Agricultural Science*. 4(9):289–298.
- Omole, A. J. 1997.** The utilization of different energy supplements on performance characteristics of grower edible giant land snail (*Archachatina marginata*). *M. Sc. Thesis*. Department of Animal Science, University of Ibadan, Ibadan, Nigeria. Pp. 13–34.
- Omole, A. J., Osunkeye, O. J., Odejide, J. O., Sodamola, M. O. and Popoola, Y. A. 2011.** *The African Giant Land Snails*. Green Choice Agric. Publications. Pp.56.
- Otu, B. O. 2016.** Genetic and Phenotypic Parameters of Growth and Reproduction among F₁ and F₂ Crossbreds of Two Ecotypes of *Archachatina marginata* (S)

- Snails. *Ph. D. Thesis*. Department of Animal Science, University of Calabar, Calabar, Nigeria. Pp. 241.
- Raggett, D. 2002.** Dave Raggett's Introduction to CSS. World Wide Consortium. Retrieved June, 2017.
- Ubuu, J. A. 2004.** Reproductive Potentials of two snails – *Archachatina marginata ovum* and *Archachatina marginata saturalis* in the Swamp Forest Zone of Nigeria. M. Sc. Thesis, Department of Animal Science, University of Calabar, Calabar, Nigeria. Pp. 85.
- Wosu, L. O. 2003.** Commercial Snailery Production, A Guide. AP Express Publishers Limited, Nsukka, Nigeria. Pp. 5–35.

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