INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 13, No. 4, p. 46-54, 2018

RESEARCH PAPER OPEN ACCESS

Genetic analysis of some zootechnical performances in the breed hyplus of the rabbit, *Oryctolagus cuniculus*, raised in Côte d'Ivoire

Samy Tioyé[1*], Yves-Nathan T. Tian-Bi[1,2], Paulin D. Sokouri[1], Simon-Pierre A. N'Guetta[1]

[1]*Laboratoire de Génétique, UFR-Biosciences, Université Félix Houphouët-Boigny, 22 BP 582 Abidjan 22, Côte d'Ivoire*

[2]*Centre Suisse de Recherches Scientifiques (CSRS) en Côte d'Ivoire, 01 BP 1303 Abidjan 01, Côte d'Ivoire*

Key words: Rabbit Hyplus, Zootechnical performances, Genetic analysis, Côte d'Ivoire.

http://dx.doi.org/10.12692/ijb/13.4.46-54 Article published on October 14, 2018

Abstract

This study aimed to assess the potentials of the rabbit breed Hyplus imported from France for the improvement of rabbit production in Côte d'Ivoire. Thirty rabbits with 24 females and 6 males were monitored in a local private farm over one year, following a quantitative genetics design. Reproductive performances and production traits were measured in adult females and in young rabbits, respectively. Regarding reproductive performances, all females were receptive to males. Gestation lasted 30.58 days. Number of litters per female was 4.63. Litter sizes at birth and at weaning were 5.95 and 5.45, respectively. Stillbirth and birth-to-weaning mortality rates were 8.27% and 4.89%, respectively. Concerning production traits, young rabbits' weight from birth to 90 days varied from 53.98 to 2006.05 g. Average daily gain from birth to 60 days after weaning ranged between 12.42 and 21.15 g/day. Negative phenotypic correlations were observed between gestation duration and litter size at weaning ($r = -0.16$) and, between reproductive and production performances ($-0.23 \leq r \leq -0.13$). Heritability values for production performances ranged between 0.00 and 0.10. Repeatability values for these traits varied from 0.20 to 0.91. On the whole, most of the measured performances showed lower values compared with those observed in the native region of the Hyplus breed. Heritability values were low, indicating a strong environmental effect in the expression of production performances. However, their repeatability values were significantly high, revealing potentials for the use of these traits of the Hyplus breed to improve rabbit production in Côte d'Ivoire.

* **Corresponding Author:** Samy Tioyé ✉ tioyesamy@yahoo.fr

Introduction

In Côte d'Ivoire, more than 60% of the animal protein needs are covered by imports of meat and fishery products (UEMOA, 2002; CNRA, 2009). The point being that until recently the country's animal production only accounted for 2% of its GDP (Coulibaly, 2013). Developing livestock farming through diversified products at national level is therefore very important and necessary. In this respect, the breeding of prolific animal species such as rabbit (*Oryctolagus cuniculus*), could help fill meat deficit in the country. Moreover, rabbit meat has excellent nutritional properties (Dalle Zotte, 2002; Hernández and Dalle Zotte, 2010). This meat contains protein, essential amino acids (Lysine, threonine, valine), vitamins (E, B2, B3, B5, B12), mineral salts (iron, phosphorus, selenium) and unsaturated fatty acids (linoleic acid, α -linoleic), which contents are higher than or at least equivalent to those of other meats (Dalle Zotte, 2014).

Rabbit breeding in Côte d'Ivoire remained traditional since a long time ago, using local breeds, which generally exhibit low zoo technical performances (Bodji, 1992). Modern rabbit production is a recent practice in the country (Kimsé *et al.*, 2017). Mastering this form of breeding is important for the development of intensive rabbit production. Modern rabbit breeding is based on the use of improved breeds, most of which are imported from Europe. These strains usually exhibit very good performances in their native areas. An effective use of these breeds could help increase the local rabbit production. However, these types of rabbit may show low productivity in the tropics, due to the effect of high environmental variance on the heritability of the improved traits.

In Côte d'Ivoire, one of the most commonly improved breeds used in modern rabbit production is Hyplus, which is imported from France. It is a white-coated rabbit with 10.5-11 bunnies born alive/calving/doe and 10 weaned bunnies/calving/doe, in terms of reproductive performances, in the native region. Moreover, 0.5 kg for the average weight at weaning and 2.57 kg for weight at 70 days of age are reported in terms of production performance (Lebas, 2007; 2009; CPLB, 2018). Such characteristics could be used not only to increase rabbit production in Côte d'Ivoire, but also to improve some traits in local breeds. However, what about the zoo technical performances of the breed Hyplus in local farms?

Here we carry out a genetic analysis of some reproductive and production traits in the rabbit breed Hyplus raised in Côte d'Ivoire, as to get a grasp of the potentials of this imported breed for the improvement of local rabbit production.

Material and methods

Study site, housing and breeding equipments

This study was conducted at a private farm called Société Agro-Piscicole de la Mé (SAP DE LA ME), located 15 km from the city of Adzopé (South-East Côte d'Ivoire, 6° 6' 25.7" N 3° 51' 19.3" W, altitude: 107 m). The climate in the area is humid tropical with an average temperature of 26.7 °C, 1424 mm of rain per year and an average humidity of 63.58%.

The SAP DE LA ME farm has modern characteristics, comprising six houses, three of which are dedicated to calving and three others to the rabbit growth. Houses are built with clay bricks, with tile roof and louvers in the walls, as to obtain a good regulation of internal temperature and ensure sufficient room ventilation and lighting.

The dimensions of each house are L x l x h: 21 m x 7 m x 1.5 m. Metal rabbit hutches (L x l x h: 75 cm x 46 cm x 30 cm) are positioned inside the houses, with feeders and a system for watering animals. There is also a forage rack and precision scales.

Animals

The study focused on 30 sexually mature rabbits of the Hyplus breed, including 24 females and 6 males. The females are primiparous and 5 months old on average, for a weight of 3 kg and the males are 6 months old on average, for a weight of 3.5 kg at the first reproduction.

Experimental protocol

The protocol was based on a quantitative genetics approach.

A three-digit identifier code was assigned to each of the 30 animals prior to the experiment implementation. These animals were divided into six batches each consisting of four females and one male. The males were reared separately from the females, outside the mating periods. For conducting mating, the female was presented to the male inside its cage, just for the time of protrusion, which lasts a few minutes after which the female was removed and placed in an individual cage. Twelve to fourteen days after the protrusion, pregnancy diagnosis was performed by palpation of the female abdomen. After this diagnosis, non-gestating females were put again into contact with the males the following day. Pregnancy monitoring was conducted in good sanitary conditions until calving. Around 15 days after protrusion, pregnant females were isolated in individual cages for calving. For this purpose, a nest (20 cm x 30 cm x 30 cm) containing dry straw was positioned in each cage. After calving, the bunnies were placed in the nest. These latter were kept in contact with their mothers until weaning, which took place when bunnies were 30-35 days old and had an average weight of 400 g. In order to optimize the rabbit reproduction, protrusions were conducted according to a semi intensive rhythm. To this end, after a reproductive cycle (protrusion - gestation - parturition), protrusion was conducted from 12 to 15 days after parturition. In total, five reproductive cycles were performed over one year.

Feeding and hygiene

Gestating and lactating females were fed a manufactured food called "Lapin Repro" produced by the company "Fabrication d'Aliments Composés Ivoiriens (FACI)". This food contains 14.2% cellulose and 16.4% protein. These females were fed a ration of 180-200 g pellets per individual per day. Non-lactating females received 150 g pellets per individual per day. Bunnies and sires were fed another food called "Lapin Croissance" for the growth of individuals. This food, which is manufactured within the farm SAP DE LA ME, contains 14.7% cellulose and 15.4% protein. Moreover, during their first 15 days of life, the bunnies were exclusively fed from mother's milk. From the 3rd week, in addition to milk, the bunnies received some food pellets (30 g/individual/day) and water (200 ml/ individual/ day). Sires received a pellet ration of 250 g/individual/day and bunnies, 60 g/individual/day, after weaning. Feed was supplemented with some leaves, stems and roots of *Moringa oleifera*. Water (300 ml/ individual/day) was also provided to all adults and young rabbits after weaning.

Newborns rabbits were handled with clean, odor-free hands, to prevent mothers from abandoning their calves or feeding on them by cannibalism. The equipment used during this study was cleaned and disinfected daily. Access to the breeding houses was restricted to the personnel only.

Data collection and statistical analysis

Seven reproductive parameters were measured, which can be divided into three categories. The first category consists of the female receptivity rate which characterizes the ability of females to accept males for mating. The second category includes five parameters related to rabbit prolificacy; these are mean gestation duration (GD), mean number of litters per female (NL), litter size at birth (LSB) corresponding to the ratio of the total number of live-born bunnies to the total number of litters and litter size at weaning (LSW) which is the ratio of the total number of weaned rabbits to the total number of litters. The third category consists of parameters related to the mortality/survival of young rabbits; these are the stillbirth rate (SB), which is the ratio of the total number of stillborn to the total number of born rabbits and the birth-to-weaning mortality rate (BW) obtained from the following formula:

$$\mathrm{BWM} = \frac{(\text{Total number of live born bunnies} - \text{Total number of weaned rabbits}) \times 100}{\text{Total number of live born bunnies}}$$

Concerning production performances, seven parameters were also measured in bunnies. Four parameters were related to the weights of the animals: mean weight at birth (W_0), mean weight at weaning (W_{30}), mean weight at age of 60 days (W_{60}) and mean weight at age of 90 days (W_{90}). Moreover, three parameters related to the average daily gain (ADG) (Adandé *et al.*, 2017) were measured: average daily gain before weaning (ADG_{0-30}), average daily gain 30 days after weaning (ADG_{30-60}) and average daily gain 60 days after weaning (ADG_{30-90}). For each reproductive and production performance, the 95% confidence interval of mean was estimated. In addition, an analysis of variance based on the general linear model (GLM) was used to test the effects of sire and dam on these parameters. The main factors (sire and dam) were tested on continuous variables (GD, weights and ADG) using a Normal error. The same effects were tested on count variable (NL, LSB, LSW, SB and BWM) using a Poisson error. Factors were tested using the following model: $y_{ij} = \mu + s_i + d_j + e_{ij}$; where y_{ij} is the value of an individual, μ is the mean of population, s_i is the sire effect, d_j is the dam effect and e_{ij} is the random residual error. Phenotypic correlations between performances were assessed using Spearman rank-order correlation coefficients. Heritability and repeatability of production performances were estimated. Heritability estimates were computed based on half-sib approach. Variance components for the estimation of heritability (*i.e.* additive variance or father-related inter-family variance and total phenotypic variance) were calculated using the restricted maximum likelihood (REML) procedure. Repeatability estimates were calculated using the method of Lessells and Boag (1987). All analyzes were performed using the STATA 9.0 software (Stata Corp., College Station, Texas). The procedure for controlling the false discovery rate (FDR) in multiple tests (Benjamini and Hochberg, 1995) was used for *p*-values adjustment.

Results

Variation in reproductive performances

All the 24 (100%) females were receptive to males during mating. Gestation duration (GD) was on average of 30.58 days. A total of 111 litters were recorded, with an average of 4.63 litters per female (NL). Means litter size at birth (LSB) and at weaning (LSW) were 5.95 and 5.45, respectively (Table 1).

A total of 674 young rabbits were obtained over all litters with 33 stillbirths, leading to an average stillbirth rate (SB) of 4.89%. Of the 641 live-born rabbits, 53 individuals died before the age at weaning, giving an average birth-to-weaning mortality rate (BWM) of 8.27%. No significant sire or dam effect was detected on these reproductive performances (Table 1).

Table 1. Mean values of some zootechnical performances and their variation related to sire and dam effects in the rabbit breed Hyplus.

Zootechnical performances		Mean ± SE (95 %)	Source of variation	
			Sire	Dam
Reproductive performances	GD	30.58 ± 0.26	*0.904*	*0.794*
	NL	4.63 ± 0.28	*0.557*	*0.457*
	LSB	5.95 ± 0.35	*0.948*	*0.796*
	LSW	5.45 ± 0.40	*0.819*	*0.970*
	SB	4.89% ± 1.5%	*0.075*	*0.087*
	BWM	8.27% ± 2.02%	*0.913*	*0.792*
Performances de production	W_0 (g)	53.98 ± 0.69	*<0.001*	*<0.001*
	W_{30} (g)	389.05 ± 4.04	*0.005*	*<0.001*
	W_{60} (g)	1371.57 ± 16.76	*0.019*	*<0.001*
	W_{90} (g)	2006.05 ± 25.88	*0.004*	*<0.001*
	ADG_{0-30} (g/day)	12.42 ± 0.13	*0.014*	*<0.001*
	ADG_{30-60} (g/da)	32.75 ± 0.38	*0.040**	*<0.001*
	ADG_{30-60} (g/da)	21.15 ± 0.38	*0.002*	*<0.001*

GD = gestation duration in days, NL = number of litters, LSB = litter size at birth, LSW = litter size at weaning, W_0 = mean weight at birth, W_{30} = mean weight at weaning, P_{60} = mean weight at age of 60 days, W_{90} = mean weight at age of 90 days, ADG_{0-30} = average daily gain before weaning, ADG_{30-60} = average daily gain 30 days after weaning, ADG_{30-90} = average daily gain 60 days after weaning. Performance values correspond to overall means calculated over the 24 females monitored. SE (95 %) = standard error of confidence interval at 95 %. P-values related to sire and dam effects are indicated in italics. *Adjustment of p-values based on FDR (Benjamini and Hochberg, 1995) revealed that sire effect on ADG_{30-60} was not significant.

Variation in production performances

Over the 641 live-born rabbits, mean values of weight at birth (W_0), at weaning (W_{30}), at age of 60 days (W_{60}) and at age of 90 days (W_{90}) were 53.98 g, 389.05 g, 1371.57 g and 2006.05 g, respectively. The values of average daily gains before weaning (ADG_{0-30}), 30 days after weaning (ADG_{30-60}) and 60 days after weaning (ADG_{30-90}) were 12.42 g/day, 32.75 g/day and 21.15 g/day, respectively (Table 1). Analysis of variance revealed a significant sire effect on six of the seven production performances, the *p*-value related to the ADG_{30-60} having been rejected as a result of the adjustment by FDR procedure. Conversely, a significant maternal effect was detected on all of the seven production performances (Table 1).

Phenotypic correlations

Concerning reproductive performances, positive correlations were detected between the number of litters, litter size at birth (LSB), and litter size at weaning (LSW) (Table 2). In addition, a negative correlation (r = -0.16) was observed between gestation duration and litter size at weaning (Table 2).

Table 2. Phenotypic correlations between zootechnical performances.

	GD	NL	LSB	LSW	W_0	W_{30}	W_{60}	W_{90}	ADG_{0-30}	ADG_{30-60}
NL	-0.03 (1.00)									
LSB	-0.10 (0.33)	0.46 (<0.001)								
LSW	-0.16 (0.003)	0.38 (0.001)	0.86 (<0.001)							
W_0	0.05 (1.00)	0.03 (1.00)	-0.18 (<0.001)	-0.23 (<0.001)	0.43 (<0.001)					
W_{30}	0.00 (1.00)	0.01 (1.00)	-0.06 (1.00)	-0.12 (0.15)	0.43 (<0.001)					
W_{60}	-0.01 (1.00	0.030 (1.00)	-0.09 (0.82)	-0.13 (0.034)	0.38 (<0.001)	0.75 (<0.001)				
W_{90}	-0.05 (1.00)	0.05 (1.00)	-0.08 (1.00)	-0.20 (<.001)	0.33 (<.001)	0.71 (<0.001)	0.81 (<0.001)			
ADG_{0-30}	-0.01 (1.00)	0.03 (1.00)	-0.02 (1.00)	-0.07 (1.00)	0.21 (<0.001)	0.96 (<0.001)	0.72 (<0.001)	0.68 (<001)		
ADG_{30-60}	-0.04 (1.00	0.03 (1.00)	-0.09 (0.08)	-0.12 (0.086)	0.33 (<0.001)	0.61 (<0.001)	0.97 (<0.001)	0.76 (<0.001)	0.57 (<0.001)	
oADG_{30-90}	-0.05 (1.00)	0.04 (1.00)	-0.04 (1.00)	-0.18 (<0.001)	0.15 (0.004)	0.40 (<0.001_	0.36 (<0.001)	0.80 (<0.001)	0.40 (<0.001)	0.31 (<0.001)

GD = gestation duration, NL = number of litters, LSB = litter size at birth, LSW = litter size at weaning, W_0 = mean weight at birth, W_{30} = mean weight at weaning, P_{60} = mean weight at age of 60 days, W_{90} = mean weight at age of 90 days, ADG_{0-30} = average daily gain before weaning, ADG_{30-60} = average daily gain 30 days after weaning, ADG_{30-90} = average daily gain 60 days after weaning. P-values associated to correlation coefficients are indicated in parentheses. Correlation coefficients in bold are significantly different from zero at 0.05 level.

With regard to the production performances, all the associations were positive with high correlation values (0.68 ≤ r ≤ 0.97) observed between means weight (W_0, W_{30} and W_{90}) and average daily gains (ADG_{0-30}, ADG_{30-60} and ADG_{30-90}) (Table 2).

Conversely, all the significant associations detected between reproductive and production performances were negative and included correlations between LSW and W_{60}, W_{90} and ADG_{30-90} (-0.23 ≤ r ≤ -0.13). Similarly, LSB and W_0 were negatively correlated (r = -0.18) (Table 2).

Inheritability and repeatability of production performances

Heritability estimates were low and ranged between $3.28.10^{-5}$ and 0.10. These estimates differed all from zero ($P < 0.001$) except for that of ADG_{30-60} (Table 3).

On the other hand, repeatability values were high and varied from 0.20 to 0.91. All these values differed from zero ($P < 0.001$) (Table 3).

Discussion

In this study, all the females were receptive to males. This behavior of females constitutes a good characteristic for a better assessment of subsequent zootechnical performances (e.g. number of litters and traits related to prolificacy) and could be explained by a long-term proximity between animals (males and females) in the study farm as reported by Berepudo *et al.* (1993).

In addition, none of the measured reproductive performance was influenced by sire and dam effects. This could reflect similar genetic contributions, on average, between breeding pairs of rabbits. This result could also rely on the homogenous rearing conditions maintained between rabbits in the study farm; the studied individuals can be considered almost isogenic as they are produced from the same Hyplus breed (Lebas, 2007; 2009). Moreover, according to Matheron and Rouvier (1978), these reproductive performances are generally related to non-genetic factors, especially maternal effects, which could indicate low variation of behavior among females. Some reproductive performance values obtained in this study such as those of NL (4.63), LSB (5.95) and LSW (5.45) were lower than those reported on the Hyplus breed in France (NL = 6.6, LSB = 10.13, LSW = 9.49) by Lebas (2007; 2009). This difference could be explained by the influence of environmental variance and by the difference in breeding techniques. Moreover, in France production of the Hyplus breed is based on intensive artificial insemination.

However, in this study, performance values related to mortality of bunnies (SB = 4.89%, BWM = 8.27%) were interestingly lower than those obtained (6.1% and 15.8%, respectively) by Lebas (2007; 2009) in the rabbit Hyplus. This might help offset the low values obtained for the other reproductive parameters, over a long exploitation period.

Table 3. Heritability and repeatability of production performances in the rabbit Hyplus.

Production performances	Heritability (h^2) ± SE (95 %)	Repeatability (*r*)
W_0	0.06 ± 0.058	0.91
W_{30}	0.08 ± 0.07	0.48
W_{60}	0.10 ± 0.08	0.20
W_{90}	0.10 ± 0.09	0.30
$ADG_{0\text{-}30}$	0.04 ± 0.038	0.30
$ADG_{30\text{-}60}$	$3.28.10^{-5}$ ± $3.28.10^{-5}$	0.26
$ADG_{30\text{-}90}$	0.07 ± 0.067	0.32

W_0 = mean weight at birth, W_{30} = mean weight at weaning, P_{60} = mean weight at age of 60 days, W_{90} = mean weight at age of 90 days, $ADG_{0\text{-}30}$ = average daily gain before weaning, $ADG_{30\text{-}60}$ = average daily gain 30 days after weaning, $ADG_{30\text{-}90}$ = average daily gain 60 days after weaning. SE (95 %) = standard error of confidence interval at 95 %. Heritability estimates differed all from zero except for that of $ADG_{30\text{-}60}$. All repeatability values are significantly different from zero at 0.05 level.

Regarding production performances in young rabbits, all varied according to sire and dam effects, except for $ADG_{30\text{-}60}$. This result could be explained by a combination of genetic factors (father and mother) and environmental ones (including maternal effects and other uncontrolled factors). However, due to the chronological aspect of their assessment, variation of these production performances requires a sequential analysis. Indeed, as there was a limited intervention of technicians during the first 30 days of bunnies' lives, the genetic contributions of father and mother to the expression of early traits such as weight at birth and $ADG_{0\text{-}30}$ could be considered more important than for the other traits. However, maternal effects could also explain the variation observed in these two parameters. Sire and dam effects on other production performances measured after rabbit weaning could have been contaminated by uncontrolled environmental factors and, method of rabbit feeding and care. Values of some production traits such as weight at weaning (W_{30} = 389.05 g) and $ADG_{0\text{-}30}$ (12.42 g/day) were also lower than those reported by previous studies in the Hyplus breed (W_{30} = 500 g and $ADG_{0\text{-}30}$ = 21.4-32.5 g/day) (Lebas, 2007; 2009; CPLB, 2018).

The positive correlations detected, for example, between NL, LSB and LSW could indicate at least some stability of the relationship, over time, between the number of calving and the number of offspring produced by a Hyplus female. Moreover, the overlap of the confidence intervals of mean of LSB (CI: 5.60 -

6.30) and of LSW (CI: 5.05 - 5.95) indicates an absence of difference between both traits. Interestingly a negative correlation was observed between GD and LSW. This could reveal a trade-off (Wells, 2003) between these traits; in other words, the longer the gestation duration, the less the number of offspring. Another interesting trade-off between traits is illustrated by the negative correlation between LSB and W_0. This result is consistent with those of previous studies in plants (Sadras, 2007) and animals, both invertebrates (Ebert, 1993) and vertebrates (Mappes and Koskela, 2004). These studies agree that genetic factors influence such trade-offs (Stearns, 1989).

Heritability values of production performance were low ($h^2 \leq 0.1$), on the whole. However, they were significantly different from zero, except for that of $ADG_{30\text{-}60}$. This could indicate a strong influence of environmental factors in phenotypic variation observed for these traits (Falconer and Mackay, 1996; Conner and Hartl, 2004). Of note, heritability values of early traits, such as weight at birth (W_0) and $ADG_{0\text{-}30}$, are relatively lower than those of the others traits. This result seems to confirm the hypothesis of low heritability of early traits due to strong directional selection reducing genetic diversity at the involved loci in many species (Roff, 2002). In addition, the heritability values for production performances obtained in this study were much lower than those obtained by Soro *et al.* (2014) in the rabbit Cunistar-MDL, which is a synthetic breed obtained from the cross between a local breed and another imported from Germany. For example, for W_0 and W_{30}, heritability values in the Cunistar-MDL equaled ten times those obtained in the Hyplus breed in this study. This may show how it could be interesting to conduct crosses between hardy breeds and imported ones to improve rabbit production at local scale.In contrast, repeatability values for production performances were significantly high, ranging between 0.20 (for W_{20}) and 0.91 (for W_0). This result suggests that the heritability of these traits might increase (Falconer and Mackay, 1996) and that these traits may evolve (or be improved) by selection if the breeding conditions of the Hyplus rabbit in Côte d'Ivoire are improved. Similar studies in several parts of the country should however be conducted to confirm these results.

Conclusion

This study showed that most values of measured zoo technical performances (number of litters, litter size at birth and at weaning, average daily weight and gains of young rabbits) were lower compared with those observed in the Hyplus breed raised in its native area (France). However, bunnies showed lower mortality rates in this study. Heritability values of production performances were low in the Hyplus breed raised in Côte d'Ivoire. However, a high repeatability of these traits was observed.

Acknowledgements

The authors are grateful to the general manager of SAP DE LA ME and to all the technicians of the farm.

References

Adande R, Adjahouinou DC, Liady MND, Fiogbe ED. 2017. Alimentation des lapins (Oryctolagus cuniculus L.) à base de Azolla filiculoïdes, Elaeis guineensis, Ipomoea aquatica et Panicum maximum: Effet sur la croissance des lapins et potentiel nutritif des crottes pour l'aquaculture. International Journal of Biological and Chemical Sciences **11(6),** 2914-2923. https://dx.doi.org/10.4314/ijbcs.v11i6.28

Benjamini Y, Hochberg Y. 1995. Controlling the false discovery rate: a practical and powerful approach to multiple testing. Journal of the royal statistical society. Series B (Methodological), 289-300. https://dx.doi.org/10.2307/2346101

Berepudo, NA, Nodu MB, Monsi A, Amadi EN. 1993. Reproductive response of prepubertal female rabbit to photoperiod and/or male presence. World Rabbit Science **1(2),** 83-87. https://doi.org/10.4995/wrs.1993.199

Bodji NC. 1992. Elevage actuel en Côte d'ivoire, situation actuelle et perspective d'avenir. Premier congrès régional de cuniculture, 15-20 mars 1992 Cotonou (Bénin); 1-4.

CNRA. 2009. Le CNRA en 2008. 43 p. https://www.cnra.ci/downloads/le_CNRA_en2008. pdf.

Conner JK, Hartl DL. 2004. A Primer of Ecological Genetics. USA: Sinauer Associates, Inc.

Coulibaly D. 2013. Politique de développement de l'élevage en Côte d'Ivoire. In 9ème Conférence des Ministres Africains en Charge des Ressources Animales, Ministère des Ressources Animales et Halieutiques (ed). Abidjan, Côte d'Ivoire. 13 p.

CPLB. 2018. La coopérative des éleveurs de lapins. Access éd 06/06/2018. www.cplb.fr.

Dalle Zotte A. 2014. Rabbit farming for meat purposes. Animal Frontiers **4(4),** 62-67. https://doi.org/10.2527/af.2014-0035

Dalle Zotte A. 2002. Perception of rabbit meat quality and major factors influencing the rabbit carcass and meat quality. Livestock Prodion Science **75(1),** 11-32. https://doi.org/10.1016/S0301-6226(01)00308-6

Ebert D. 1993. The trade-off between offspring size and number in Daphnia magna: the influence of genetic, environmental and maternal effects. Arch. Hydrobiol, suppl **90,** 453-473.

Falconer DS, Mackay TFC. 1996. Introduction to Quantitative Genetics. New York: Longman

Hernández P, Dalle Zotte A. 2010. Influence of diet on rabbit meat quality. Nutrition of the rabbit, CABI, 163-178. https://doi.org/10.1079/9781845936693.0163

Kimsé M, Coulibaly KAS, Gnanda BI, Zongo M, Yapi YM, Fantodji TA, Otchoumou AA. 2017. Caractérisation des systèmes d'élevage cunicole dans le district D'Abidjan (Côte D'ivoire). Agronomie Africaine **29,** 185-196.

Lebas F. 2009. Quel génotype pour la production du lapin "Bio". Cuniculture Magazine **36,** 5-8.

Lebas F. 2007. Productivité des élevages cunicoles professionnels en 2006. Résultats de RENALAP et RENACEB. Cuniculture Magazine **34,** 31- 39.

Lessells CM, Boag PT. 1987. Unrepeatable repeat abilities: A common mistake. The Auk **104,** 116-121. https://doi.org/10.2307/4087240

Matheron G, Rouvier R. 1978. Etude de la variation génétique dans le croisement simple de 6 races de lapins pour les caractères de prolifcité, taille et poids de portée au sevrage. In: Proc. 2ème Journées de la Recherche Cunicole, April 4-5, 1978. Toulouse, France, 22.

UEMOA. 2002. Appui à la mise en œuvre de la politique agricole de l'union en matière de sécurité alimentaire. Programme régional de sécurité alimentaire : Côte d'Ivoire. 19 p. https://www.ipcinfo.org/Ffileadmin/user_upload/tcsf/pdf/cotedivoire.

Mappes T, Koskela E. 2004. Genetic basis of the trade-off between offspring number and quality in the bank vole. Evolution **58(3),** 645-650. https://doi.org/10.1111/j.0014-3820.2004.tb01686.x

Roff DA. 2002. Life History Evolution. Sunderland, MA: Sinauer Associates.

Sadras VO. 2007. Evolutionary aspects of the trade-off between seed size and number in crops. Field Crops Research **100(2-3),** 125-138. https://doi.org/10.1016/j.fcr.2006.07.004

Soro K, Sokouri DP, Bosso NA, Coulibaly M, N'Guetta ASP. 2014. Genetic parameters of some production traits of the synthetic breed Cunistar-MDL (Minimum Disease Level). International Journal of Agronomy and Agricultural Research **4,** 110-118.

Stearns SC. 1989. Trade-offs in life-history evolution. Functional ecology **3(3),** 259-268. https://doi.org/10.2307/2389364

Wells JC. 2003. The thrifty phenotype hypothesis: thrifty offspring or thrifty mother? Journal of Theoretical Biology **221(1),** 143-161. https://doi.org/10.1006/jtbi.2003.3183