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Evaluation Of The Productivity Of Local Rabbit Populations (Oryctolagus Cuniculus) From The Middle Cheliff Basin Compared To A White Breed: Assessment Of Reproductive Performance And Hormonal Regulation (Progesterone And Estradiol)

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Abstract
An experimental study was carried out in the Wilaya of Chlef, Algeria, to compare the reproductive performance and hormonal profiles of 80 female rabbits divided into three local population groups (20 does per group) and one purebred white group (20 does). All animals were raised under identical management and environmental conditions to eliminate external variation. The evaluated parameters included body weight at mating and at kindling, gestation length, as well as receptivity, fertility, kindling, weaning, neonatal mortality, and prolificacy rates. Simultaneously, serum concentrations of progesterone (P4) and estradiol (E2) were measured at four key stages of the reproductive cycle.
Statistical analyses revealed no significant differences between the local groups and the white breed in terms of weight at mating ($p = 0.076–0.28$), weight at kindling ($p = 0.38–0.74$), weight gain ($p = 0.25–0.76$), or gestation length ($p = 0.52–0.76$), indicating comparable reproductive performance. However, a significant weight increase between mating and kindling was observed across all groups ($p = 0.0011–0.0051$), consistent with normal gestational physiology.
Regarding progesterone, the sampling effect was highly significant ($p < 0.001$), showing a peak at the third sampling, although mean levels among groups did not differ significantly ($p = 0.37$). A specific difference was observed at the second sampling between group C and the white breed ($p = 0.049$). For estradiol, concentrations fluctuated significantly over time ($p < 0.001$) without an overall difference among groups ($p = 0.19$), except at the fourth sampling, where group C differed significantly from the white breed ($p = 0.008$).
Fertility rates ranged from 60% (group A) to 70% (groups C and D), kindling rates from 66.67% to 77.78%, and neonatal mortality from 13.68% (group D) to 23.81% (group A). Weaning and prolificacy rates were similar among all groups (89–90% and approximately seven kits per litter). No significant differences were found among groups for these parameters (Kruskal-Wallis test, $p = 0.30$).
Correlation analyses showed a strong negative relationship between weight at mating and weight gain ($r = –0.76$; $p = 5.42\times10^{-11}$), and a positive correlation between weights at mating and kindling ($r = 0.46$; $p = 0.000537$). The progesterone level at the second sampling was positively correlated with gestation length ($r = 0.30$; $p = 0.0173$). Prolificacy was significantly associated with progesterone concentration at the first sampling ($p = 0.02$), whereas estradiol levels showed no significant relationship with fertility or receptivity ($p > 0.05$).
In conclusion, despite overall comparable performance between groups, the reference white breed exhibited slightly superior productivity in some traits. These findings provide a solid foundation for the enhancement and valorization of local genetic resources through targeted improvement programs, including selective breeding, crossbreeding, and optimization of reproductive management protocols.
Keywords: *Local rabbit, reproductive performance, prolificacy, progesterone, estradiol, breeding management.*

INTRODUCTION

In Algeria, the rabbit farming sector offers a promising solution to help alleviate the national protein deficit a major nutritional concern in the country (Gacem et al., 2008; Berchiche et al., 2012). The rabbit (*Oryctolagus cuniculus*) represents a valuable asset in this regard due to its short reproductive cycle and high prolificacy, which enable efficient production of high-quality meat (Combes et al., 2005). Consequently,

rabbit production holds significant economic potential, particularly for young entrepreneurs seeking accessible and sustainable investment opportunities.

Historically, several constraints have hindered the development of the rabbit industry in Algeria. These include the use of imported genetic material often poorly adapted to local environmental conditions, as well as a general lack of technical knowledge and mastery of rabbit farming practices (ITELV, 2010). In response to these challenges, local rabbit populations resulting from crossbreeding between imported and indigenous strains have shown better adaptability to Algerian climatic and management conditions (Fellous et al., 2012). These local genotypes deserve particular attention, not only for their genetic potential but also for their important role in maintaining zoogenetic biodiversity.

The Middle Cheliff Basin region of Algeria is characterized by traditional rabbit production systems, where these local populations are commonly raised. Although these rabbits are well acclimatized and potentially more resistant to local stressors, their production capacity and reproductive physiology remain under-studied compared to those of improved commercial breeds. It is therefore essential to assess their productivity in order to determine their suitability for more intensive production systems and to guide future breeding or conservation programs.

Reproduction in the doe is a complex physiological process finely regulated by ovarian hormones such as progesterone (P4) and estradiol (E2). Monitoring these hormonal levels at key stages of the reproductive cycle (before mating, during gestation, and up to kindling) provides valuable insight into ovarian function, maintenance of gestation, and preparation for lactation. A better understanding of these hormonal patterns in local rabbit populations may reveal unique physiological features that explain their reproductive performance, or suggest potential strategies for improving productivity.

Therefore, the present study aims to evaluate and compare the reproductive performance and hormonal responses of does from three distinct local populations of the Middle Cheliff Basin, raised under standardized experimental conditions, with those of a globally recognized white breed. Parameters such as body weight at mating and kindling, gestation length, receptivity, fertility, kindling rate, weaning success, neonatal mortality, and prolificacy were assessed. In parallel, serum concentrations of P4 and E2 were monitored at regular intervals to characterize and compare reproductive hormonal profiles between genotypes.

The findings of this research are expected to contribute significantly to the valorization of local rabbit genetic resources from the Middle Cheliff Basin. By providing objective data on their productive potential and physiological particularities, this study aims to support the development of targeted genetic improvement programs and optimized breeding management practices tailored to local populations.

MATERIALS AND METHODS

Experimental Design and Location

This experimental study was conducted in the Wilaya of Chlef, Algeria, between **March 12 and June 12, 2022**. The objective was to evaluate and compare the reproductive performance and hormonal regulation of local rabbit populations with those of a purebred white population.

A total of **80 adult female rabbits** were used in this study, consisting of **60 local does** and **20 white hybrid does** (all albino).

The local does were collected from three geographical areas within Chlef Province **Krimia**, **Aïn Merane**, and **Sidi Akkacha** — with 20 animals representing each locality. This broad sampling provided a representative diversity of the local rabbit population of the Middle Cheliff Basin, encompassing both genetic and environmental variability.

The white hybrid does were obtained from specialized commercial farms in the same province.

All rabbits were of comparable age, averaging **six months** at the beginning of the experiment.

Husbandry Conditions

After collection, all 80 does were transferred to a single experimental rabbit breeding unit at the **Animal Production Center of the University of Chlef**. The animals were maintained under **uniform environmental and management conditions** to isolate genetic effects from potential environmental variation.

- **Ambient temperature:** maintained at **18°C** on average.
- **Relative humidity:** controlled at **65%**.
- **Lighting regime:** combination of natural daylight (via four windows) and controlled artificial lighting, providing **8 hours of darkness per day**.

- **Feeding:** all animals received the same commercial pelleted diet containing **16% crude protein**. Clean drinking water was provided *ad libitum*.
- **Housing:** each doe was housed individually in a galvanized wire cage measuring **89 × 69 × 28 cm**, allowing accurate individual monitoring.
- **Hygiene and health monitoring:** daily health checks were performed, including hygienic waste management and regular veterinary examinations throughout the study to ensure animal welfare.

Measurement of Reproductive Performance

Reproductive performance was monitored over **two reproductive cycles** for each doe. Data were recorded during the second cycle and included the following parameters:

- Body weight at mating and at kindling
- Gestation length
- Receptivity rate
- Fertility rate
- Kindling rate
- Weaning rate
- Prolificacy (number of kits per litter)
- Neonatal mortality rate

Hormonal Regulation Monitoring

Blood Sampling

Blood samples were collected from the **saphenous vein** of the hind leg of each doe using sterile 2.5 mL syringes. A volume of **2.5 mL of blood** was obtained per sample.

Sampling was performed at **four physiological stages** of the reproductive cycle, spaced **10 days apart**, with the **first sampling** taking place **five days before mating**.

Each sample was centrifuged at **1,200 rpm for 30 minutes** to separate serum, which was then stored at **–20°C** until hormonal analysis.

Hormone Assays

Serum concentrations of **progesterone (P4)** and **estradiol (E2)** were determined using the **Chemiluminescent Immunoassay (CLIA)** method. Analyses were performed using a **MINDRAY automated analyzer** with MINDRAY CLIA reagents specific for estradiol (E2) and progesterone (P4).

Statistical Analysis

Descriptive statistics (mean ± standard deviation) were calculated for all measured parameters within each group to evaluate variability and central tendencies.

Comparisons between the local populations and the white breed were made using **parametric tests** (*Student's t-test*) and **analysis of variance (ANOVA)** to determine statistically significant differences.

All statistical analyses were performed using **RStudio (version 2025.05.01-513)** with a **95% confidence level** and a **significance threshold of $\alpha = 0.05$**.

Additionally, **Principal Component Analysis (PCA)** was applied to explore potential correlations between hormonal levels and reproductive performance parameters.

RESULTS

Weight and Gestation Duration

Bivariate comparison of local groups with the reference group:

Student's *t*-tests and Wilcoxon (Mann–Whitney *U*) tests were performed depending on the distribution of the variables. Regarding the variable "gestation duration," the data did not follow a normal distribution, leading to the use of the Mann–Whitney *U* test. For the other variables, Fisher's exact test was conducted to verify equality of variances before applying Student's *t*-test. The results confirmed this assumption ($p > 0.05$ for all tested group pairs).

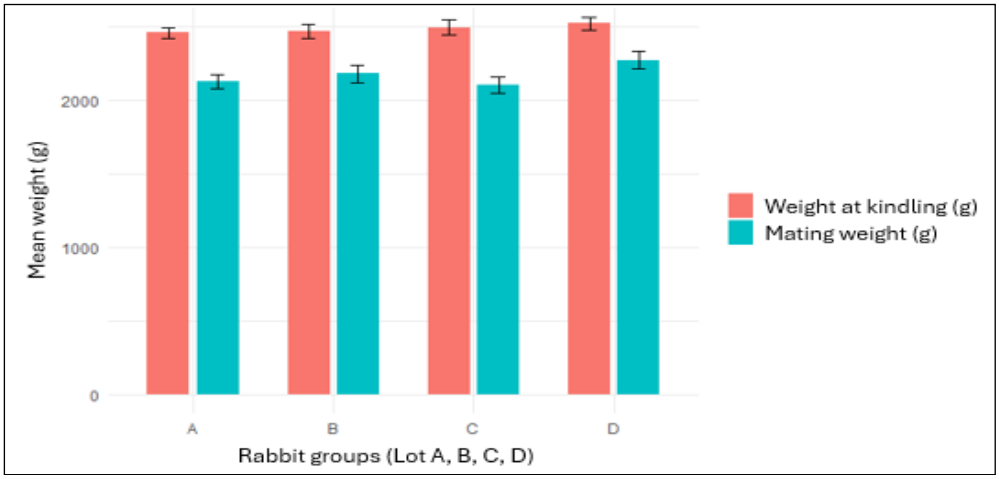
Table 1. *Comparison of the three local groups with the reference group*

Parameter	Group A vs D (*p*)	Group B vs D (*p*)	Group C vs D (*p*)
Weight at mating (g)	0.076	0.28	0.052
Weight at kindling (g)	0.38	0.49	0.74
Weight gain (g)	0.76	0.65	0.25
Gestation duration (days)	0.76	0.52	0.63

The results of these tests did not reveal any significant differences between the local rabbit groups and the reference group (white breed), suggesting that these local rabbits exhibit comparable performance in terms of mating weight, kindling weight, weight gain, and gestation duration. These findings indicate that despite their local origin, these rabbits possess growth and reproductive traits similar to those of selected breeds, which is of genetic and zootechnical interest as it demonstrates the potential of local populations to be enhanced for commercial production.

Difference between weight at kindling and weight at mating within each group

Figure 1. *Comparison between mating and kindling weights within each group*



The comparison was made between the weights of the same rabbits (from the same group) at two different time points; thus, a paired-sample *t*-test was performed.

The results revealed a highly significant difference between mating weight and kindling weight across all groups (A, B, C, and D), with p = 0.0043, 0.0011, 0.0014, and 0.0051, respectively. Figure (1) confirms these results by showing a consistently higher mean weight at kindling compared to mating. This difference can be attributed to gestational weight gain, reflecting the progressive accumulation of body reserves and fetal–placental development. This observation is consistent with reproductive physiology, where weight increase is expected to support gestational demands and prepare for lactation.

To perform the ANOVA test, a Shapiro–Wilk test was applied to assess the normality of variables within each group, allowing the selection of suitable variables:

- **Weight at mating (g)**: Group A: p = 0.09; Group B: p = 0.28; Group C: p = 0.25; Group D: p = 0.29.
- **Weight at kindling (g)**: Group A: p = 0.66; Group B: p = 0.94; Group C: p = 0.35; Group D: p = 0.21.
- **Weight gain (g)**: Group A: p = 0.41; Group B: p = 0.85; Group C: p = 0.053; Group D: p = 0.70.

The variable "gestation duration" did not follow a normal distribution within any group ($p < 0.05$ for all). A Levene's test for homogeneity of variances indicated equal variances ($p > 0.05$) for the variables weight at mating, weight at kindling, and weight gain, making them suitable for ANOVA. For "gestation duration," the Kruskal–Wallis test was applied instead.

The ANOVA results showed no significant differences among groups:

- Weight at mating: p = 0.17
- Weight at kindling: p = 0.86
- Weight gain: p = 0.61

Similarly, the Kruskal–Wallis test revealed no significant difference for gestation duration (p = 0.47). Therefore, post-hoc tests were not conducted since no significant effects were observed. These results confirm those obtained by the Student's *t*-test, reinforcing the hypothesis that local rabbit groups possess body weight characteristics comparable to those of the white breed.

Hormonal Profile

A repeated-measures ANOVA was applied since four samples were collected for each hormone. The results are as follows:

Table 2. *Mean progesterone concentrations across four sampling points for each group*

Sampling	Group A	Group B	Group C	Group D (Ref)

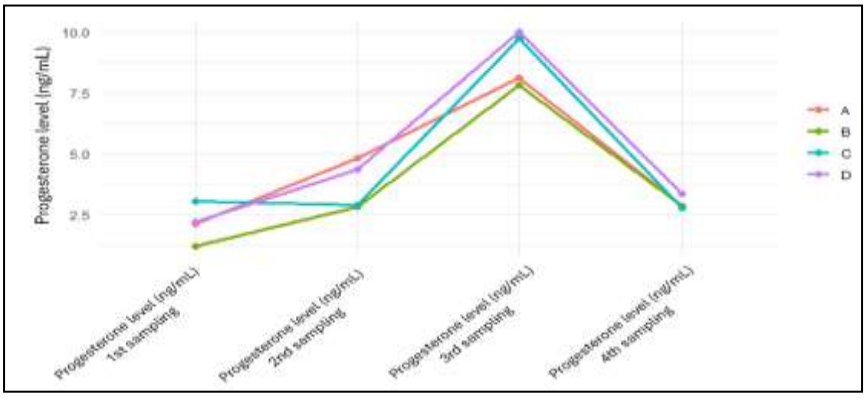
1st sampling	2.40	1.77	3.24	2.15
2nd sampling	4.39	3.45	3.44	4.82
3rd sampling	7.24	8.09	10.08	8.90
4th sampling	2.83	2.83	2.77	3.34

Table 3. *Comparison of groups, samplings, and their interaction for progesterone*

	***p*-value**
Group	0.37
Sampling	< 0.001
Group × Sampling	0.71

The repeated-measures ANOVA revealed that the overall mean progesterone (P4) levels did not differ significantly among groups ($p = 0.37$), indicating comparable average progesterone levels. However, the sampling effect was significant ($p < 0.001$), demonstrating variation in progesterone levels across the four sampling times. The group × sampling interaction was not significant ($p = 0.71$), suggesting similar temporal progesterone patterns among all groups. Since Mauchly's test of sphericity was significant ($p < 0.001$), the Greenhouse–Geisser correction was applied.

Figure 2. *Progesterone trends across four sampling times by group*



The hormonal profile shows a gradual increase in progesterone (except for Group C), reaching a peak at the third sampling before declining at the fourth. The reference group (D) displayed a slightly higher peak. This figure confirms the absence of significant intergroup differences despite temporal variations.

Table 4. *Comparison of progesterone concentrations between local groups and the reference group (Group D: white breed)*

Parameter	**Group A vs D (*p*)**	**Group B vs D (*p*)**	**Group C vs D (*p*)**
Progesterone – 1st sampling	0.93	0.12	0.074
Progesterone – 2nd sampling	0.68	0.091	0.049*
Progesterone – 3rd sampling	0.83	0.71	0.44
Progesterone – 4th sampling	0.25	0.21	0.17

Comparison of progesterone concentrations at the four sampling times between the local groups (A, B, C) and the reference group revealed no significant differences for the 1st, 3rd, and 4th samplings ($p > 0.05$). Only the comparison between Group C and Group D at the 2nd sampling showed a significant difference ($p = 0.049$), suggesting a distinct progesterone concentration at this specific stage for Group C. Overall, these findings indicate that progesterone secretion patterns are largely similar between local groups and the reference group, except for a transient divergence during the 2nd sampling in Group C.

Table 5. *Mean estrogen concentrations across four sampling points for each group*

Sampling	**Group A**	**Group B**	**Group C**	**Group D (Ref)**
1st sampling	46.58	46.22	49.32	38.71
2nd sampling	52.49	53.85	47.74	45.71
3rd sampling	91.84	95.32	84.78	88.22

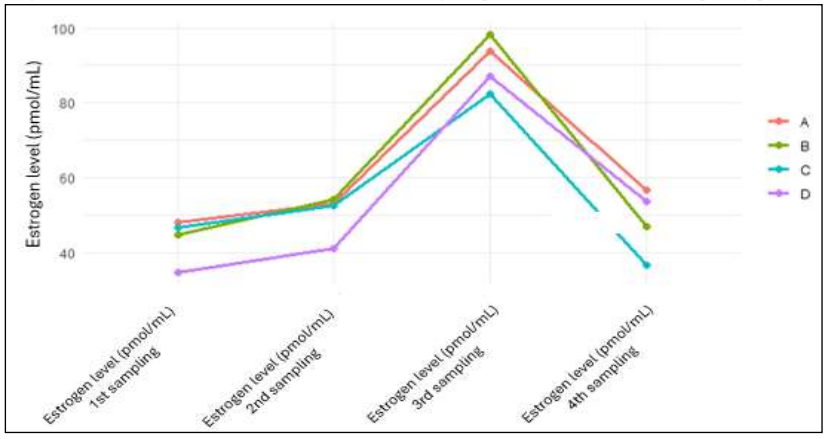
4th sampling	56.80	46.83	36.49	53.46

Table 6. *Comparison of groups, samplings, and their interaction for estrogen*

Effect	*p*-value
Group	0.19
Sampling	< 0.001
Group × Sampling	0.34

For estrogen, the overall means did not differ significantly among groups (p = 0.186), indicating homogeneity in average estrogen levels. The sampling effect was significant (p < 0.001), showing that estrogen levels varied over time. However, the interaction between group and sampling was not significant (p = 0.342), suggesting that all groups followed similar hormonal profiles throughout the four sampling points. As Mauchly's test of sphericity was significant (p = 0.006), a Greenhouse–Geisser correction (GG) was applied.

Figure 3. *Evolution of estradiol levels by group across the four sampling periods.*



Estradiol concentrations showed a slight increase between the first and second sampling, followed by a more pronounced rise reaching a peak at the third sampling. This hormonal profile indicates an overall temporal variation but **no statistically significant differences between groups**.

Table 7. *Comparison of estradiol concentrations between local populations (A, B, and C) and the reference group (D: white breed).*

Parameter	Lot A vs D (p)	Lot B vs D (p)	Lot C vs D (p)
Estradiol – 1st sampling	0.18	0.26	0.088
Estradiol – 2nd sampling	0.35	0.25	0.77
Estradiol – 3rd sampling	0.61	0.49	0.76
Estradiol – 4th sampling	0.63	0.32	**0.008****

Comparison of estradiol concentrations between the local groups (A, B, and C) and the control group (D) across the four sampling times revealed **no significant differences** during the first three samplings ($p > 0.05$). However, at the **fourth sampling**, a **highly significant difference** was observed between **lot C and lot D (p = 0.008)**, whereas no differences were detected for the other groups. These findings suggest that estradiol secretion profiles were overall comparable between the groups, except for **lot C**, which displayed a significantly lower level at the fourth sampling compared to the reference breed.

Correlation Analysis

This analysis uses **Spearman's correlation** and **Multivariate Analysis (PCA and Clustering)** to characterize significant physiological and productive links ($p<0.05$).

Table 8. *Key Significant Correlations (Spearman's Method)*:

Correlation	Coefficient (r)	p-value	Supported Physiological Role
Kindling Weight / Weight Gain	–0.76	5.42×10−11	Compensatory growth or reserve management.
P4 (1st Sample) / Prolificacy	–0.26	0.020	High early Progesterone (P4) may indicate a suboptimal state (pseudopregnancy).
E2 (4th Sample) / Kindling Rate	–0.40	0.0031	High late Estradiol (E2) compromises late gestation success.
Fertility / Neonatal Mortality	–0.95	<0.0001	Neonatal survival is critical for reproductive success.

Detailed Correlation Findings

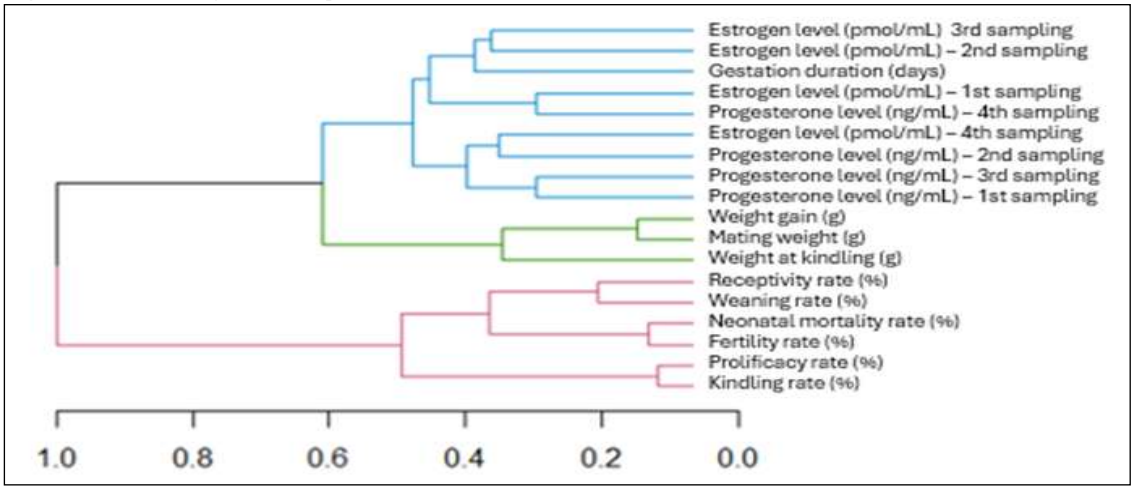
- **Weight-Growth Relationship**: A strong negative correlation was found between **kindling weight** and **weight gain** (r=–0.76; p=5.42×10−11). Rabbits with a higher initial weight tended to exhibit a lower relative weight gain during the study. Conversely, kindling weight was positively correlated with weight at parturition (r=0.46; p=0.000537).
- **Hormone and Prolificacy Relationship**: Progesterone (P4) levels measured at the **first sampling** (P1, pre-kindling) were significantly negatively correlated with the **prolificacy rate** (r=–0.26; p=0.020). Additionally, the progesterone level at the second sampling was positively correlated with the gestation length (r=0.30; p=0.0173).
- **Hormone and Parturition Relationship**: Estradiol (E2) at the **fourth sampling** (P4, late gestation) was negatively correlated with the **kindling rate** (r=–0.40; p=0.0031).
- **Reproductive Success**: An extremely strong negative correlation was established between the **fertility rate** and the **neonatal mortality rate** (r=–0.95; p<0.0001). Furthermore, the neonatal mortality rate is positively associated with **prolificacy** (r=0.45; p<0.0001), suggesting that larger litters carry an increased risk of perinatal mortality.

Multivariate Analysis (PCA and Clustering)

Principal Component Analysis (PCA) revealed that the measured variables cluster into three relatively independent physiological dimensions:

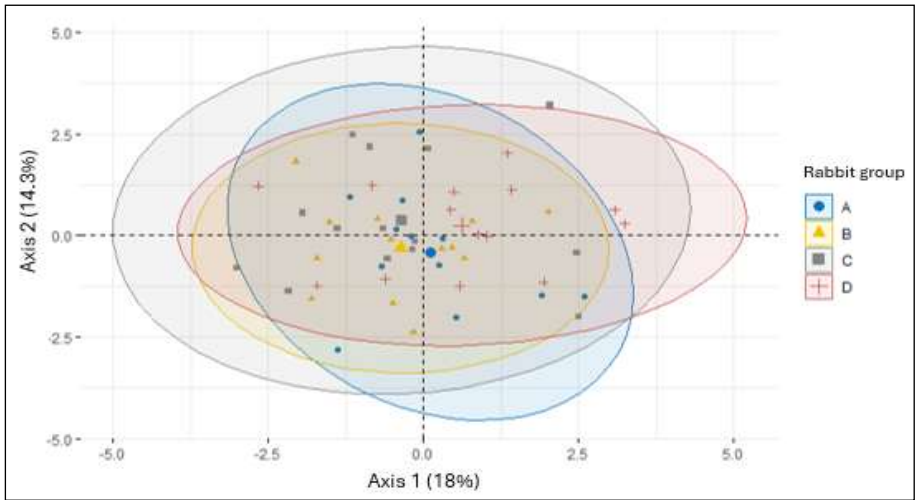
1. **Hormonal Cluster**: Including P4 and E2 at the four time points, and gestation length.
2. **Ponderal (Weight) Cluster**: Including kindling weight, weight at parturition, and weight gain.
3. **Reproductive Cluster**: Including fertility rate, prolificacy, neonatal mortality, receptivity, and weaning.

Figure 4: *Clustering hierarchique des variables*



Hierarchical clustering and PCA results (Figure 5) show that **Lot D** (reference) and **Lot C** (local) partially overlap, which reflects a degree of similarity in their morphological and hormonal profiles. **Lot A** is the most dispersed, indicating high intra-lot variability, while **Lot B** is concentrated but distinct. This structural grouping confirms that reproductive performance is a **multifactorial phenomenon** and that genetic improvement efforts must consider the entirety of these dimensions.

Figure 5: *Individual Representation - PCA Plot*



(The figure visually displays the distribution of the four rabbit lots (A, B, C, D) in a factorial plane, with Dim1 (18%) and Dim2 (14.3%) as the principal components. It illustrates the overlapping and distinct nature of the clusters as described above.)

The PCA further indicates that the local rabbits share certain characteristics with the white breed while exhibiting intra-lot variability, demonstrating both similarity and distinction across the studied populations.

Productive Performance

Based on raw data, different rates of fertility, kindling, weaning, receptivity, neonatal mortality, and prolificacy were calculated for each group.

Table 8. *Productivity Parameters of Rabbit Groups*

Parameter	Group A	Group B	Group C	Group D
Fertility rate (%)	60	65	70	70
Kindling rate (%)	66.67	68.42	77.78	70
Weaning rate (%)	89.06	90.79	89.19	86.59
Receptivity rate (%)	90	95	90	100
Neonatal mortality rate (%)	23.81	19.15	16.85	13.68
Prolificacy rate (%)	7.00	7.23	6.36	6.79

The fertility rate ranged from 60% in Group A to 70% in Groups C and D, indicating slightly higher reproductive capacity in the latter. The kindling rate followed a similar pattern, with Group C exhibiting the highest value (77.78%), whereas Group A showed the lowest (66.67%). Weaning rates were relatively homogeneous across groups (86.59–90.79%), suggesting good postnatal survival. Regarding receptivity, Group D reached 100%, while other groups ranged between 90% and 95%, indicating moderate variation in female receptivity. Neonatal mortality was highest in Group A (23.81%) and lowest in Group D (13.68%), which could reflect gestational condition differences between groups. Finally, prolificacy rates showed minimal variation (6.36–7.23), suggesting that the average litter size remained relatively stable across groups.

Overall, these data indicate that Groups C and D exhibited slightly superior reproductive performance, with lower neonatal mortality and higher fertility and kindling rates, whereas Group A displayed lower values in several productivity indicators. A **Kruskal–Wallis test** performed to assess the significance of these differences revealed no statistically significant variation ($p = 0.30$), suggesting that observed differences may result from random variation or the relatively small sample sizes per group. These findings imply that, based on the measured indicators, the local groups and the reference white breed demonstrate globally comparable reproductive performance, with nuanced distinctions in key parameters such as neonatal mortality and kindling rate.

GENERAL DISCUSSION

1. Body weight and reproductive performance: Validation of the potential of local populations

The results of the present study reveal the absence of significant differences between local rabbit populations from the Middle Cheliff Basin (groups A, B, and C) and the white reference population (group D) regarding body weight parameters and gestation duration. This observation contrasts with earlier findings that described the performance of Algerian local populations as "modest" (Zerrouki et al., 2014; Cherfaoui et al., 2015). Our results challenge the established paradigm suggesting that local populations possess intrinsic limitations. Indeed, under controlled breeding conditions (temperature 18°C, relative humidity 65%, standardized diet), local does achieved performances comparable to those of the reference white breed.

This alignment of performance suggests that historically observed differences were mainly linked to environmental conditions rather than to genetic factors. Several studies have confirmed that Algerian local populations exhibit growth and adult weight performances comparable to those of selected breeds (Zerrouki et al., 2001; Sid et al., 2018). The work of Belabbas et al. (2019) also reported similar growth performances between local and synthetic lines, emphasizing the productive potential of these animals.

The significant increase in weight between mating and kindling observed across all groups ($p < 0.01$) confirms the physiological normality of gestation and reflects the adaptive capacity of females to the increasing energetic demands of reproduction, consistent with Lebas (1975), who described the evolution of feed intake during pregnancy.

2. Hormonal profiles: Insights under controlled conditions

2.1. Hormone levels

The serum estradiol concentrations measured in our study (84.78–95.32 pg/ml at gestational peak) were markedly higher than those reported by Mazouzi (2016) in local does reared under uncontrolled conditions (18.7 ± 5.9 pg/ml). This major difference (a four- to fivefold increase) highlights the considerable influence of rearing conditions on ovarian function and hormone secretion. Similarly, our progesterone levels at gestational peak (7.24–10.08 ng/ml) fall within the optimal range for pregnancy maintenance, contrasting with the more variable levels reported in previous studies conducted under uncontrolled environments (Iles & Benazzoug, 2015). This stabilization of hormonal profiles likely explains the improvement in reproductive performance observed.

Our investigation of hormonal dynamics fills a knowledge gap regarding Algerian local rabbits. Studies focusing on biochemical parameters, such as that by Ezzeroug et al. (2023), have demonstrated variations in glucose and protein levels according to physiological stages (gestation, lactation) in local does an essential aspect for understanding adaptive metabolic responses. These authors notably reported strong mobilization of body lipids during pregnancy.

2.2. Hormonal kinetics and physiological significance

The absence of significant lot × sampling interactions ($p = 0.71$ for P4; $p = 0.34$ for E2) confirms the homogeneity of hormonal regulatory mechanisms among local populations and the reference breed. The significant variation in hormone levels across sampling times was expected and reflects the normal reproductive cycle dynamics of the rabbit, as described in cunicultural reproductive physiology by Boumahdi et al. (2019).

The estradiol peak observed at the third sampling corresponds to the follicular growth and ovulatory preparation phases, while the progressive rise in progesterone reflects corpus luteum establishment and gestational maintenance. This observation contradicts the hypothesis of major physiological disparities between phenotypes and suggests that the fundamental reproductive mechanisms are well established and functional in local populations (Boumahdi et al., 2019).

Minor differences particularly the higher E2 level at the fourth sampling for group C compared to group D may result from individual variability or specific physiological adjustments within this population, possibly revealing genetic or metabolic specificities of the Middle Cheliff Basin population.

2.3. Neutralization of seasonal variations

Unlike Mazouzi (2016), who reported pronounced seasonal variations (estradiol peaking in winter and progesterone in summer), our controlled environmental conditions neutralized such fluctuations. This standardization confirms the environmental origin of hormonal seasonality and demonstrates the feasibility of optimizing reproductive performance through climate-controlled housing.

3. Reproductive performance: Repositioning local populations

3.1. Achieved performance level

The reproductive performances recorded in our study fall within the upper range of values previously reported for Algerian local populations. With fertility rates of 60–70%, litter sizes of 6.36–7.23 kits per kindling, and weaning rates of 86.59–90.79%, our local populations exceed the values typically observed under traditional breeding systems. Comparison with literature data reveals substantial improvement:

- Fertility: 60–70% vs. 46–62% (Nabi & Zerrouki, 2012)
- Litter size: 6.36–7.23 vs. 5.6–7.1 Zerrouki, N et al . (2009)
- Receptivity: 90–100% vs. 38–80% Zerrouki, N., Berchiche, M., Lebas, F., Bolet, G. (2002)

The prolificacy values observed in our study are consistent with those reported by Moulla and Yakhlef (2007) and are often slightly lower than those of selected lines. For example, synthetic strains developed in Algeria (ITELV, 2006) can reach 9.5 total births, compared with 7.1 for local populations (Boudour et al., 2020; Gacem, M et al., 2009).

Selected breeds (group D) tend to show better neonatal survival (13.68% mortality vs. 23.81% for group A), consistent with the literature attributing higher mortality rates in local populations to lower fertility and weaker maternal care (Fellous, N et al 2012).

The fertility rates we observed (60% for group A and 70% for groups C and D) also fall within the lower range for selected lines. For instance, Gacem et al. (2009) reported fertility rates of 69.2% for a white population and up to 64.5% for a synthetic line.

3.2. Homogeneity among geographical populations

The absence of significant differences between the three local groups (Krimia, Aïn Merane, and Sidi Akkacha) suggests a relative genetic homogeneity among populations from the Middle Cheliff Basin, despite geographical separation. This observation contrasts with the phenotypic heterogeneity reported by other studies (Mazouzi, 2016; Bolet G et al., 2007 Bouhali, A, 2024) and may reflect significant gene flow among these populations or a relatively recent common origin.

4. Physiological relationships and regulatory mechanisms

4.1. Hormone–performance correlations

Our study reveals, for the first time in Algerian local rabbit populations, a significant correlation between progesterone levels at the first sampling and prolificacy ($r = 0.30$; $p = 0.02$). Although modest ($R^2 = 0.13$), this relationship suggests a role of early progesterone secretion in the establishment and maintenance of pregnancy, consistent with the mechanisms described by Spencer and Bazer (2002).

No significant correlation was found between estradiol levels and either receptivity or fertility, differing from Mazouzi (2016), who reported an association between estradiol and mating acceptance. This discrepancy likely arises from differing sampling periods (gestational vs. pre-mating) and confirms the time-specific nature of estrogenic action.

Our findings on endocrine profiles and sexual receptivity converge with those of Boumahdi (2019). Although no direct correlation between plasma hormone concentrations and receptivity could be established, our observations confirm the fundamental role of these hormones in the reproductive cycle, as previously emphasized by Remas ,K (2001). The complexity of endocrine–behavioral interactions highlights the importance of individual physiological variability.

Consequently, our results pave the way for future research. It is essential to deepen our understanding of the impact of environmental factors, such as seasonal changes and husbandry practices, on hormonal profiles in these animals. As suggested by Saidj et al. (2018), this line of research could significantly contribute to optimizing reproductive strategies for this population.

4.2. Multivariate analysis and physiological dimensions

Principal component analysis revealed a structuring of variables into three distinct dimensions: hormonal, weight-related, and reproductive. This relative independence between physiological systems suggests that performance improvement may require a multifactorial approach integrating optimized rearing conditions, selection based on body weight criteria, and monitoring of ovarian function. Hierarchical clustering confirmed this systemic organization and opens perspectives for integrated selection strategies accounting for interactions between these dimensions.

5. Zootechnical implications and prospects for improvement

Our results challenge the notion that Algerian local rabbit populations possess major intrinsic genetic limitations. Under optimized breeding conditions, these populations demonstrate productive potential comparable to that of selected breeds, indicating that historically reported low performance mainly

resulted from environmental constraints (Gacem et al., 2009; Boudour et al., 2020). This re-evaluation of the genetic potential of local populations opens new perspectives for their valorization in the development of the Algerian rabbit sector, without systematic reliance on imported genetic material.

Several levers for improving performance can be identified from our results:

- Neutralizing seasonal variations and optimizing hormonal profiles under controlled conditions underscore the critical importance of environmental management.
- Optimizing rearing conditions (nutrition, housing, prophylaxis) is essential to reduce mortality rates and maximize productivity. As noted by Maziz-Bettahar et al. (2024), improving biosecurity practices is crucial for the economic sustainability of rabbit production in Algeria.
- Techniques such as light stimulation and hormonal control prior to artificial insemination have proven effective in maximizing reproductive success (Theau-Clément, M. 2008. ; Theau-Clément et al.,2004).
- The homogeneity observed among geographical groups, combined with individual variability (does from females group C) revealed by PCA, suggests potential for within-population selection, as described by Zerrouki et al. (2001).
- Selecting the most productive individuals within local populations based on traits such as prolificacy and kit survival is an effective and sustainable strategy (Belabbas et al., 2011).
- The established correlations between hormonal profiles and performance pave the way for marker-assisted selection based on physiological indicators.

CONCLUSION

This study revealed that the local rabbit populations of the Cheliff Basin in Algeria possess a considerable yet largely underestimated genetic potential for the development of national rabbit farming. When raised under controlled and optimized breeding conditions, these populations exhibit reproductive performances and hormonal profiles (notably progesterone P4 and estradiol E2) that are generally comparable to those of the standard white breed.

However, despite this similarity in several zootechnical traits, the reference breed maintains a slight advantage in fertility rate, sexual receptivity, and, most importantly, neonatal survival a key determinant of overall productivity. Conversely, the local group **B** distinguished itself by showing a slightly higher prolificacy rate, making it a promising candidate for selective breeding programs.

To fully harness this potential and elevate local populations to a level of performance comparable or superior to the reference breed, **targeted genetic improvement strategies** are recommended. It is crucial to select females from the **C population** with high reproductive performance (fertility rate ≥ 80% and neonatal mortality ≤ 16%). The use of **artificial insemination** or **controlled matings** with males from the white breed could also contribute to improving the local genetic heritage while maintaining adaptability to the local environment.

The implementation of **modern reproductive management techniques** is equally essential. The use of **rapid and inexpensive hormonal assays** in the field (such as P4 tests) can be an effective tool to ensure insemination of only receptive females, thereby improving reproductive efficiency and reducing non-productive cycles.

The established correlations between hormonal and reproductive parameters provide a **solid scientific foundation** for future genetic improvements and the development of **more efficient and economically viable breeding protocols**. These findings pave the way for a **new approach to rabbit farming in Algeria**, emphasizing the **valorization of local genetic resources** rather than systematic reliance on imported breeds.

Finally, **complementary studies** will be required to adapt these results to traditional breeding conditions, considering local economic and technical constraints. Nevertheless, this analysis already provides a **reproducible and transferable methodology** for monitoring and optimizing rabbit production systems, while offering promising perspectives for the **selection of productive and locally adapted lines**.

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