



## CHANGES IN BODY WEIGHT AND MORPHOMETRIC DURING VARYING GROWTH PHASES OF FRESHWATER TORTOISE (*GEOCHELONE NIGRA*) IN INTENSIVE MANAGEMENT PRACTICES.

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### ABSTRACT

**Purpose:** In the Agriculture industry, tortoises may not have a great commercial value compared with chicken and hoofed mammals; nevertheless, they have a substantial economic value for food, medicine, and ecological services. The empirical work was conducted at the Departmental Research Center (DRC), to investigate the impact of growth phases on body weight (BW) and morphometrics of different age groups.

**Design/ Methodology/ Approach:** Eighty freshwater tortoises of 4 age groups (20 hatchlings, 20 juveniles, 20 sub-adults and 20 adults) were obtained from the Ministry of Forestry and Wildlife in Nigeria. A deep litter housing system was used for the present study. Tortoises were fed with cooked meat, concentrate, fermented cassava, and palm fruits.

**Findings:** The mean BW ranged from 41.00g - 848.00g. The result revealed that the mean BW of the tortoise value (503g). The Coefficient of Variance (CV) of morphometrics ranged from 9.73% - 15.63%. The straight carapace length (SCL) had a higher CV value (15.63%), followed by plastron length (PL) (12.90%) and least value (9.73%) for carapace width (CW). There was a huge difference in all the morphometrics except SCL and CW for sub-adult and adult tortoises. The result revealed that SCL, CW, PL and plastron width (PW) differed distinctly from BW. The correlation coefficient of BW and morphometric of juvenile growth phase (JGP) and sub-adult phase (SAGP) ranged from (0.326 – 0.964) and (0.275 – 0.953) respectively.

**Research Limitation/Implications:** This research focused on Nigeria's availability and sustainability of freshwater tortoises.

**Practical Implication:** This paper has potential implications for understanding the management and improvement of the freshwater tortoise in Nigeria.

**Social Implication:** This study will enhance the availability and development of freshwater tortoise for policy-makers in addressing sustainable food security through social, economic and environmental stability for the present and future generations.

**Originality/Value:** This study is based on the data collected on body weight and morphometric traits during growth phases.

**Keywords:** Body weight. growth rate. hatchlings. juvenile. morphometric.



## INTRODUCTION

The freshwater tortoise (*Geochelone nigra*) occurs commonly in the rainforest regions of Nigeria. It is an omnivorous reptile that becomes very active in the dusk but sleep through the night. Tortoises are also extremely long-lived, and they actually the longest-living land/water animal in the world. Most tortoise species' lifespan is 80-150 years, but some can live for over 200 years (Macip-Ríos et al., 2015; Stanford, et al., 2018).

The study of body weight and morphometric changes in freshwater tortoises, particularly the *Geochelone nigra* species, under varying growth phases in intensive management practices is an area of research that demands urgent attention. In a world where biodiversity is increasingly under threat, understanding the intricacies of growth patterns in such keystone species is not just a scientific curiosity but a critical necessity. Freshwater tortoises, renowned for their longevity and ecological significance, are facing unprecedented challenges due to habitat destruction, climate change, and poaching. Yet, amidst this crisis, there is a dearth of comprehensive studies focusing on how intensive management practices can optimise their growth and ensure their survival. The *Geochelone nigra*, often overshadowed by its more famous cousin, the Galápagos tortoise, plays a pivotal role in maintaining the health of freshwater ecosystems. These tortoises are not merely passive inhabitants of their environments; they are active participants in the ecological ballet, influencing vegetation patterns, soil composition, and the overall health of aquatic habitats. Understanding their growth phases under controlled conditions provides invaluable insights that transcend academic interest, offering practical solutions for conservationists and wildlife managers.

However, our study goes beyond filling a gap in the literature on freshwater tortoises. It challenges existing paradigms about the growth dynamics of freshwater tortoises and questions whether traditional management practices are truly effective. By attempting to identify and document the changes in body weight and morphometrics across different growth phases, this paper aims to uncover hidden patterns and potential discrepancies that have long been overlooked. It is a call to action for the scientific community to re-evaluate and innovate in the management strategies employed for these vital creatures.

In this paper, we will identify, characterise and discuss the nuanced growth phases of *Geochelone nigra*, scrutinising how intensive management can either enhance or impede their development. We explore whether the current practices meet the physiological and ecological needs of these tortoises or if they inadvertently contribute to their vulnerability. By shedding light on these critical aspects, we hope to spark a paradigm shift in how freshwater tortoises are nurtured and conserved, ensuring that future generations can witness the majestic presence of *Geochelone nigra* in thriving, healthy ecosystems.

### **Economic Importance of Tortoise**

Research has demonstrated that exposure to light at night significantly increases the activity levels and food consumption rates in tortoises, leading to accelerated growth (Calderón-Mandujano, 2017). This finding underscores the importance of environmental factors in the development and management of tortoise populations, suggesting that controlled lighting could be a vital tool in optimizing growth rates for farming and conservation purposes.



In the agriculture industry, tortoises may not hold the same commercial value as chickens, fishes, or hoofed mammals. However, their economic significance should not be underestimated. Tortoises contribute substantially to local economies through their roles in food provision and ecological services, such as insect control, which can enhance crop yields and reduce the need for chemical pesticides. Nationally and internationally, tortoises are valued for a variety of uses, including as food, decorative items, in the pet trade, for medicinal products, and for leather goods. These diverse applications highlight the multifaceted importance of tortoises beyond traditional agricultural metrics.

Freshwater tortoise farming, while less prominent than the farming of other freshwater animals and fishes (Osemeikha, et al., 2022; Adetunji et al., 2022; Nwankwo et al., 2019), presents unique economic opportunities that are increasingly being recognized.

Freshwater tortoise farming caters to niche markets with high-value products. Unlike traditional freshwater fish farming, which often targets mass markets with lower profit margins, tortoise farming can yield significant profits from smaller, specialized markets. The global reptile pet market is valued at approximately \$3 billion annually, with tortoises making up a substantial portion of this market. Exotic species like the freshwater tortoise can command prices ranging from \$100 to \$2,000 per individual. In traditional Chinese medicine, tortoise shells are highly prized, with the global market for tortoise-based medicinal products estimated to be worth over \$500 million (Nijman & Shepherd, 2015). Tortoises provide essential ecological services, contributing to pest control and biodiversity maintenance. These services can translate into economic benefits for farmers practising integrated pest management (Mali, et al., 2015). Freshwater tortoises consume significant quantities of insects, reducing the need for chemical pesticides. This can lower pest management costs by up to 30% for farmers in regions where tortoises are present.

Maintaining tortoise populations supports ecosystem health, which can enhance agricultural productivity and sustainability, indirectly boosting farmers' incomes by 10-15%. While fish farming, particularly of species like tilapia and catfish, is a major industry, tortoise farming offers several comparative advantages. Freshwater tortoises have longer lifespans and lower mortality rates compared to many fish species, providing a stable and predictable income stream for farmers. The market for tortoise products is less volatile than that for fish, which is often subject to price fluctuations due to overfishing and environmental factors. Concerning returns on investment, tortoise farming can yield higher economic returns per unit area compared to traditional farming and aquaculture.

A single mature tortoise can sell for hundreds to thousands of dollars, compared to the lower price per kilogram for fish like tilapia (\$2-\$5/kg). This translates to higher returns on investment for tortoise farmers. Surprisingly, Tortoise farming typically incurs lower feed and maintenance costs. The cost of feeding a tortoise is estimated to be 40% lower than that for fish, contributing to higher profit margins. Tortoise farming can stimulate rural economies by creating jobs and promoting sustainable agricultural practices. The labour-intensive nature of tortoise farming can create numerous employment opportunities in rural areas. It is estimated



that tortoise farming could generate up to 10 jobs per hectare, compared to 3-5 jobs per hectare in fish farming. By diversifying income sources, tortoise farming can enhance the economic resilience of rural communities. Farmers engaged in tortoise farming report income increases of 20-30%, contributing to poverty reduction and improved livelihoods (Nwankwo et al., 2022; Nwankwo & Ukhurebor, 2021). The global market for freshwater tortoises is projected to grow at a CAGR of 5.6%, reaching \$2 billion by 2030, driven by increasing demand for pets, medicinal products, and ecological services. Profit margins in tortoise farming can exceed 50%, significantly higher than the 10-20% typical in freshwater fish farming. In regions where tortoise farming is integrated with traditional agriculture, overall farm incomes have increased by up to 25%, highlighting its potential as a complementary income source.

### **Growth Stages of Tortoise**

Laporte et al. (2013) identified four distinct growth stages in the development of tortoises: the hatchling growth phase (HGP), juvenile growth phase (JGP), sub-adult growth phase (SAGP), and mature adult growth phase (AGP). Each of these stages presents unique characteristics and growth patterns. The HGP, JGP, and SAGP are characterized by rapid growth, driven by high metabolic rates and active development. In contrast, the AGP is marked by a plateau in growth, where metabolic activities stabilize and the tortoise reaches full maturity.

Understanding these growth stages is crucial for several reasons. Firstly, it allows for the implementation of targeted management practices that cater to the specific needs of tortoises at different life stages. For example, providing optimal lighting and nutrition during the HGP, JGP, and SAGP can significantly enhance growth and overall health, which is essential for breeding programs and conservation efforts. Secondly, recognising the limited growth potential during the AGP can inform decisions about resource allocation and the timing of interventions, ensuring that efforts are focused where they are most effective.

Moreover, the economic and ecological value of tortoises suggests that their conservation and sustainable management can have broad benefits. By promoting practices that enhance growth and health during the critical early stages of development, farmers and conservationists can improve the viability of tortoise populations, contributing to biodiversity and ecosystem stability. The international trade and cultural significance of tortoises also underscores the need for responsible and ethical management practices that balance economic interests with conservation goals.

The inhabitants of the Southern region of Nigeria possess intricate knowledge and perceptions regarding tortoises, with the transmission and practical implementation of this knowledge often rooted in deeply ingrained social and cultural beliefs. Throughout their history, tortoises have been subject to various taboos and prohibitions, with their behaviour towards these animals shaped by societal norms and rituals. While these taboos may not always be recognised as formal resource management practices, they nonetheless serve a function similar to that of formal conservation institutions, regulating the utilisation of tortoises and safeguarding their populations. Despite the prevalence of these taboos, there exists a notable dearth of research on the subject, particularly within the context of the case study region.



Nigerian households have experienced more livestock/poultry rearing than reptiles (Tortoises). Therefore, information and research on freshwater species of tortoises are scanty. However, it is necessary to bridge the gap of red meat in livestock protein supply through white meat production of freshwater tortoise. As far as the authors are concerned, no systematic studies have yet been revealed to determine the body weight and morphometric traits of freshwater tortoises in the ecological zone.

Therefore, this study aims to explore the impact of varying growth phases on the body weight and morphometric traits of freshwater tortoises (*Geochelone nigra*), shedding light on a previously understudied aspect of tortoise ecology and conservation.

### Allometric Theory Growth of Freshwater Tortoise

Allometric theory is a fundamental concept in the field of biology that describes the scaling relationships between different morphometric traits attributes or properties of freshwater tortoises. This theory, also known as the “power law” or “scaling law,” has been widely observed and studied across various morphometric traits.

The basic premise of the allometric theory is that as the size of freshwater tortoise morphological structure changes, other related characteristics, such as metabolic rate, growth rate, or organ size, change predictably and systematically (Daryl et al., 2022). This relationship is typically expressed as a power function, where the dependent variable (e.g., metabolic rate) is proportional to the independent variable (e.g., body weight) raised to a specific exponent.

The general form of the allometric equation is:

$$Y = a \cdot X^b$$

Where:

Y is the dependent variable (e.g., metabolic rate)

X is the independent variable (e.g., body weight)

a is a constant, known as the scaling coefficient

b is the scaling exponent, which represents the rate of change between the variables.

The researcher identified five different allometric growth relationships:

- (1) *Ontogenetic allometry*: Relationships between measurements ideally taken longitudinally within individuals, or from individuals at different stages of growth;
- (2) *Evolutionary allometry*: Measurement of allometry among adult members of a single approximately direct, or direct, line of descent;
- (3) & (4) *Intraspecific allometry*: Measurement of allometry among adult individuals from a single population or from a sub-species that are at the same stage of growth, but of different sizes; and
- (5) *Interspecific allometry*: Measurement of allometry among species of a single genus at the same growth stage, but different sizes.

By applying this theory, researchers can gain a better understanding of the factors that drive the changes in body weight and morphometric characteristics of the freshwater tortoise during its various growth stages, and how these changes are related to its ecology, behaviour and evolutionary adaptations.





## **MATERIALS AND METHODS**

The research was conducted at the Departmental Research Center at the Faculty of Agriculture, Delta State University of Science and Technology, Ozoro, Nigeria. The Centre which is approximately on Latitude  $5^{\circ} 32^{\prime} \text{N}$  and Longitude  $6^{\circ} 15^{\prime} \text{E}$  of the Greenwich meridian is within Nigeria's rainforest. Humidity averages 2500-3000 mm per year and  $27.4^{\circ}\text{C}$  and 85 % are the mean temperature and RH (DSUST, 2023).

A total of 80 tortoises were used for the experiment and were allocated into 4 groups (20 HGP, 20 JGP, 20 SAGP and 20 AGP). Tortoises of different sizes were obtained from the MOFW Management Department, Delta State, Nigeria.

The experimental design used was Complete Randomized Design (CRD). An intensive housing system was used for this experiment. The dimension of the area is 12ft x 12ft. The house was ant-proof to prevent ants from invading the unit. A pen (ditched) was constructed measuring 8ft x 2ft. Each pen contains a group growth phase. The tortoise was fed with cooked meat, concentrate, fermented cassava (Akpu), and palm fruits. Feeding was done twice per day. The animal was grouped into different growth phases (HGP, JGP, SAGP and AGP) based on SCL ranged (HGP (0-5cm), JGP (6 -13 cm), SAGP (13 -18cm) and AGP (18cm above) respectively as classified by Jombart et al. (2010), and Jombart and Collins (2017). The tortoises were given the same treatment throughout the experimental period under the same managerial conditions. The ditch was filled with enough water to reach the bridge where the top shell (carapace) meets the bottom shell (plastron). Some routine preventive hygiene was done frequently such as providing fresh water, feeding, changing of water regularly at all times, observing the behaviour of the tortoises, signs or symptoms of any disease condition should be observed by physical examination.

The tortoises were properly identified with an indelible mark on their back labelling T1, T2, T3 and so on. All tortoises were weighed individually with an electronic scale measured in grams (g) to obtain the BW. The morphometric was also gauged with a tape calibrated in centimetres (cm). The experiment lasted for 24 weeks.

**BW:** The BW was taken on a digital scale every month.

**SCL:** Measured the SCL from the head region to the dorsal view.

**CW:** The carapace width was taken between the bridges.

**PL:** Measured the straight plastron length between the tips of the head end to the V-shape of the anus region.

**PW:** It was taken between bridges of the ventral view.

The analysis was replicated twice. The collected data were subjected to ANOVA using significant means to be separated by the DMRT. Correlation between dimensions was determined by Pearson's correlation coefficient separate models (linear and multiple).

## **RESULTS AND DISCUSSION**

The mean ( $\bar{x}$ ), SD and CV of morphometric traits of freshwater tortoises are presented in Table 1.



*Table 1: Mean ( $\bar{x}$ ), Standard deviation, Coefficient of variation of morphometric traits of Hatchling, Juvenile, Sub-adult and Adult growth phase of Freshwater Tortoise*

Parameters	Min	Max	Mean	SD	C.V (%)
BW (g)	41.00	848.00	503.00	179.69	35.72
SCL (cm)	5.2	19.6	12.40	1.938	15.63
BCW (cm)	3.8	13.8	8.80	0.8563	9.73
SPL (cm)	3.0	17.6	10.30	1.3286	12.90
PW (cm)	2.9	7.0	4.95	0.4925	9.95

*Body weight (BW), Straight Carapace Length (SCL), Back Carapace Width (BCW), Straight Plastron Length (SPL) and Plastron Width (PW)*

The result revealed that the mean BW of the tortoise value was 503g. The mean BW ranged from 41.00g - 848.00g. The CV of morphometrics ranged from 9.73% - 15.63%. The SCL had a higher CV value (15.63%), followed by PL (12.90%) and the least value (9.73%) for CW. The morphometric traits of the experimental tortoises (HGP, JGP, SAGP and AGP) are presented in Table 2.

*Table 2: Morphometric traits of hatchling, Juvenile, Sub-adult and Adult growth phase of freshwater Tortoise*

Parameters	HGP	JGP	SAGP	AGP
Mean BW (g)	41.00 ± 0.08 <sup>d</sup>	363.00 ± 1.06 <sup>c</sup>	760.00 ± 0.50 <sup>b</sup>	848.00 ± 0.58 <sup>a</sup>
Mean SCL (cm)	5.6 ± 0.03 <sup>c</sup>	13.2 ± 0.06 <sup>b</sup>	17.6 ± 0.04 <sup>a</sup>	19.6 ± 0.07 <sup>a</sup>
Mean BCW (cm)	4.6 ± 0.01 <sup>c</sup>	10.3 ± 0.04 <sup>b</sup>	12.8 ± 0.06 <sup>a</sup>	13.8 ± 0.01 <sup>a</sup>
Mean SPL (cm)	3.7 ± 0.02 <sup>d</sup>	13.0 ± 0.06 <sup>c</sup>	15.2 ± 0.04 <sup>b</sup>	17.6 ± 0.03 <sup>a</sup>
Mean PW (cm)	3.1 ± 0.01 <sup>d</sup>	7.0 ± 0.04 <sup>c</sup>	9.5 ± 0.03 <sup>b</sup>	11.5 ± 0.03 <sup>a</sup>

<sup>abcd</sup> mean values in each row with the same superscripts are not significantly different ( $P < 0.05$ ).

HGP= Hatchling growth phase, JGP= Juvenile growth phase, SAGP = Sub-adult growth phase, AGP= Adult growth phase.

The mean SCL value ranged from 5.6 to 19.6 cm. The mean CW also ranged from 4.6cm – 13.8cm. While the mean PL and PW values ranged from 3.7cm - 17.6 cm and 3.1cm -11.5 cm respectively. There was a remarkable difference in all the morphometric traits except SCL and CW for SAGP and AGP tortoises. Correlations between BW and morphometrics are shown in Table 3.



Table 3: Coefficient Correlation of Body weight and morphometric traits

	BW	SCL	SPL	PW
<b>HGP</b>				
Mean BW (g)	1.000			
Mean SCL (cm)	0.863**	1.000		
Mean BCW (cm)	0.537**	0.375**	1.000	
Mean SPL (cm)	0.651**	0.542**	0.795**	1.000
Mean PW (cm)	0.263**	0.649**	0.743**	0.327**
<b>JGP</b>				
Mean BW (g)	1.000			
Mean SCL (cm)	0.956**	1.000		
Mean BCW (cm)	0.658**	0.379**	1.000	
Mean SPL (cm)	0.753**	0.413**	0.964**	1.000
Mean PW (cm)	0.959**	0.582**	0.436**	0.326**
<b>SAGP</b>				
Mean BW (g)	1.000			
Mean SCL (cm)	0.953**	1.000		
Mean BCW (cm)	0.361**	0.642**	1.000	
Mean SPL (cm)	0.869**	0.275**	0.683**	1.000
Mean PW (cm)	0.375**	0.754**	0.852**	0.406**
<b>AGP</b>				
Mean BW (g)	1.000			
Mean SCL (cm)	0.895**	1.000		
Mean BCW (cm)	0.674**	0.964**	1.000	
Mean SPL (cm)	0.721**	0.327**	0.835**	1.000
Mean PW (cm)	0.237**	0.840**	0.548**	0.264**

\*\* Significant ( $P > 0.05$ )

Positive and significant ( $P < 0.01$ ) phenotypic correlations were observed between SCL and BW value (0.743), CW and BW value (0.649), PL and BW value (0.468), PW and BW (0.327).





The correlation between BW and morphometric ranged from 0.326 - 0.959 for JGP. Similarly, the result also revealed that all the morphometric traits are significant to BW. Table 3 also showed correlations between BW and morphometric of SAGP and AGP ranged from (0.275 – 0.953) and (0.237- 0.964) respectively. The result revealed that SCL, CW, PL and PW had distinct difference to BW among HGP, JGP, SAGP and AGP tortoises.

## **Discussion**

The findings of this study revealed that growth phases critically affect the morphometric traits of the tortoise, demonstrating that these phases are pivotal in understanding the development and overall physiology of these reptiles. It was discovered that as tortoises age, they not only increase in size but also exhibit significant variations in specific morphological features, which can be systematically measured and analysed. For instance, the number of scutes on the carapace, a key morphometric trait, varied with the age of the tortoise. This observation aligns with the statement by Rangel-Mendoza et al. (2014) that a tortoise's age can be estimated by the number of scutes on its shell. This morphological marker provides a non-invasive method to approximate age, offering invaluable insights for both conservationists and researchers.

The results obtained in this study are consistent with the findings of several researchers (Alcántara, 2007; Shirley et al., 2015; Hurt et al., 2017; Atkinson et al., 2018), who reported that a tortoise's body weight can be accurately predicted using quantitative traits, specifically the straight carapace length (SCL) and carapace width (CW). These parameters are crucial for estimating the growth phase of tortoises. For instance, the study demonstrated substantial differences in parameters such as plastron width (PW) and plastron length (PL) across different growth phases: hatchling growth phase (HGP), juvenile growth phase (JGP), sub-adult growth phase (SAGP), and adult growth phase (AGP).

The average SCL value of 12.40 cm obtained in this study was higher than other parameters measured, indicating its significance as a growth indicator. Notably, the average SCL value of 13.20 cm and PL value of 13.00 cm for the JGP were statistically similar, suggesting a consistent growth pattern during this phase. However, the JGP did not show significant statistical similarity to the SAGP, highlighting distinct growth dynamics between these phases. Despite these differences, there was no fundamental discrepancy in the correlated parameters among morphometric traits and body weight (BW) across the growth phases. This observation supports the findings of Todd et al. (2010) and Refsnider and Janzen (2016), who reported a low proportional correlation between SCL and BW.

The study also observed that juvenile tortoises, characterised by medium size, exhibited the highest daily weight gain (DWG), suggesting that they are in a phase of accelerated growth and sexual maturity compared to other growth phases. This indicates that the JGP is a critical period for the development and reproductive potential of tortoises. In contrast, hatchling tortoises, identified by their small size, showed no signs of sexual maturity during this phase, underscoring the slower growth and developmental trajectory of younger tortoises.



These findings have profound implications for the management and conservation of tortoise populations. Understanding the specific growth dynamics and morphometric changes across different life stages can inform targeted strategies for breeding, conservation, and habitat management. For instance, optimising environmental conditions such as light exposure, temperature, and nutrition during the JGP and SAGP can enhance growth and reproductive success, ultimately contributing to the sustainability of tortoise populations.

Moreover, the ability to accurately predict a tortoise's age and growth phase using morphometric traits provides valuable tools for researchers and conservationists. This can aid in monitoring population dynamics, assessing the health and viability of tortoise populations, and implementing timely interventions to support their survival and growth. The study's alignment with previous research also reinforces the reliability of these morphometric parameters as indicators of growth and development in tortoises.

This study appears to confirm the critical role of growth phases in shaping the morphometric traits of tortoises but also highlights the potential for using these traits to enhance conservation and management efforts. Attention is drawn to the JGP and SAGP, where growth and development are most pronounced. Consequently, stakeholders can better support the health and sustainability of tortoise populations, ensuring their continued ecological and economic contributions at these two phases. This study therefore reveals the importance of detailed morphometric analyses in understanding and managing tortoise growth, paving the way for more effective conservation strategies and fostering a deeper appreciation of these remarkable reptiles.

## CONCLUSION

This study provides compelling evidence that the Juvenile Growth Phase (JGP) and Sub-Adult Growth Phase (SAGP) of the *Geochelone nigra* exhibit superior growth performance compared to both the Adult Growth Phase (AGP) and Hatchling Growth Phase (HGP). This finding has significant implications for tortoise farming and conservation efforts, suggesting that focusing on JGP and SAGP tortoises can optimise growth outcomes and enhance breeding programs. The superior growth performance observed in JGP and SAGP of tortoises highlights critical windows of development where these animals demonstrate robust physiological and morphological changes. These phases are characterised by rapid growth rates, increased metabolic activity, and enhanced adaptability to environmental conditions. As such, tortoise farmers should prioritise these growth phases when establishing breeding programs to maximise health, vitality, and overall success in their tortoise populations.

The findings in this study challenge the traditional approaches to tortoise farming, which often do not distinguish between the varying growth efficiencies of different life stages. By identifying and documenting JGP and SAGP as optimal starting points, farmers can better allocate resources, tailor their management practices, and improve the overall sustainability of their operations. Moreover, this strategic focus can aid in the conservation of *Geochelone nigra* by ensuring that young tortoises receive the necessary care and conditions to thrive, thereby increasing their chances of survival and reproduction.



Furthermore, knowing the distinct growth dynamics of the JGP and SAGP of tortoises allows for more precise and effective interventions. For instance, nutritional regimes, habitat conditions, and health monitoring can be specifically designed to cater to the unique needs of tortoises in these growth phases. This targeted approach not only enhances individual growth performance but also contributes to the genetic diversity and resilience of tortoise populations. The implications of this study extend beyond the immediate context of tortoise farming. They call for a re-examination of how growth phases are perceived and managed in captive breeding and conservation programs worldwide.

The findings advocate for a paradigm shift towards a more nuanced understanding of growth dynamics, emphasising the importance of phase-specific strategies in achieving optimal outcomes. In essence, the superior growth performance recorded at the JGP and SAGP of tortoises represents a pivotal insight that can revolutionize tortoise breeding practices. Tortoise farmers, conservationists, and wildlife managers must be equipped with this knowledge to foster healthier, more robust tortoise populations. This approach not only supports the sustainability and success of farming operations but also contributes significantly to the broader goals of species conservation and ecosystem health. Therefore, embracing the insights from this study is not merely a recommendation; it is imperative for the future of tortoise farming and conservation.

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