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# GENETIC ASSESSMENT OF THE REPRODUCTIVE ASPECTS OF MAGHREBI CAMELS IN THE WESTERN DESERT OF EGYPT

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## ABSTRACT

Despite camels' significance and their standing with harsh environmental conditions, information about their genetics and the impact of their surroundings was limited. This hindered the creation of a practical plan to optimize camel profits in Egypt. This study was to monitor the genetics and non-genetics affecting some reproductive performance of camels, including age at first calving (AFC), days open (DO), calving interval (CI), and the number of services/conceptions (NSC) in the western desert of Egypt. A total of 311 records of 33 Maghrebi she-camels at the Centre of Studies and Development of Camel Production, Marsa Matrouh governorate, Egypt, from 2012 to 2021 were included. The mean results of AFC, DO, CI, and NSC were 63.6 months, 193.4 days, 555.9 days, and 2.52 services, respectively. All of CI, NSC, and DO were significantly influenced by the calving year, while NSC was affected only by the calving season. The phenotypic trend for DO was in the desired negative direction (-0.316 days/year). Desired negative genetic trends (GT) were about -.051, - 0.25 days, and -0.013 services per year for DO, CI, and NSC, respectively. Heritability estimates were 0.15, 0.07, 0.08, and 0.10 for AFC, DO, CI, and NSC, respectively. The repeatability ranged from 0.22 to 0.29. She-Camels with negative breeding values represented about 50.7%, having favorable reproductive traits. Finally, the early selection for desirable reproductive traits combined with consistent care practices provides a promising strategy for enhancing camel breeding success in Egypt, leading to shorter reproductive periods and improved fertility.

***Keywords:*** Breeding values; Genetic; Heritability, Maghrebi camel, Reproductive.

## INTRODUCTION

The global camel population around the world was 39,295,752 head, and the majority were found in African countries (87.2%), such as Somalia, Chad, Sudan, and Egypt (FAO, 2021). Furthermore, camels contribute approximately 602645 tons of meat and 3,114,525 tons of milk to the global economy (LeJeune et al., 2021),

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and also improve the economic position and development of rural countries through their ability to adapt to severe climatic circumstances (Mayouf *et al.,* 2014; Faye, 2018).

In Egypt, the vast majority of Maghreb camels are located mainly in Matrouh Governorate and New Valley Governorate, due to the harsh climate prevailing in these regions (Ashour and Abdel-Rahman, 2022).

Reproductive performance is frequently cited as the most essential factor in improving animal production (Almasri *et al.,* 2023). Age at first calving (AFC) is a key trait, influencing female growth rate and contributing to genetic progress by reducing the generation interval (Pirlo *et al.,* 2000). Reduced AFC can lead to multiple births, increased milk production, and lower replacement costs. Poor nutrition causes delayed AFC, resulting in late sexual maturity (Duplessis *et al.,* 2015).

Days open (DO) can play an important role in the development of viable intervention methods for enhancing reproduction. Lower DO increases milk yield relative to labor and feed costs (Duplessis *et al.*, 2015), increases calving (Cabrera, 2014), and future days of profitability and decreases costs and culling rates (González-Recio *et al.*, 2004).

The calving interval (CI) significantly impacts reproductive success and enhances income from farm animals (Belina *et al.*, 2021). Camels with a typical CI experience higher reproductive success and more calving (Musa *et al.*, 2006). The average CI for camels is 23.8 months, ranging from 457 days to more than 900 days (Abdussamad *et al.*, 2011).

The number of services per conception (NSC) is significantly influenced by the breeding strategy used, as it is higher in natural breeding than in artificial insemination. Values of NSC for Iraqi she-camels among parities ranged from 1.64 to 1.84 services (Al-Fatlawi and Al-Hamedawi, 2017), while Kachchi she-camels had higher values of 5.36 and 3.83 services (Deen, 2013).

The demand for camel products has coursed because they have satisfied numerous living requirements and medical applications (Abri and Faye, 2019), necessitating the expansion of camel breeding. However, many reproductive and productive features of camels, particularly Maghrebi camels, are rare, particularly in regions with deficiencies in their descriptions (Belina *et al.,* 2021).

There is a lack of genetic evaluation studies for camels in Egypt. So, it is necessary to conduct more research on its performance and the influence of environmental factors on its genetic potential. This will help us understand the full potential of camels under Egyptian conditions and develop effective strategies to enhance their performance (Shehab El-Din *et al.,* 2022).

This study aims to conduct a genetic evaluation of some reproductive characteristics of Maghrebi camels in Egypt and the impact of some non-genetic factors on them, to develop strategies for enhancing their performance in desert environments.

## MATERIALS AND METHODS

***Location and Data Collection***

A total of 311 complete productive records for 33 Maghrebi she-camels, fathered by five sires and mothered by 11 dams, were compiled during a period from 2012 to 2021 at the Matrouh Center for Camel Studies and Production Development, belonging to the Animal Production Research Institute (APRI), located in Marsa Matrouh Governorate in the Northwest of Egypt (latitude 31.30°, longitude 27.20°, and elevation above sea level 7.00 m).

***Herd management.***

Maghrebi she-camels were housed in a yard with a concrete floor and a communal feeding area. Animals were provided with a daily diet comprising 3.5 kg of concentrate feed mixture, 2.5 kg of clover hay (*Trifolium Alexandrinum*), and 2.5 kg of rice straw, along with some fresh salt of Mediterranean saltbush and Atriplex halimus L/per animal. The concentrate feed mixture consists of 25% wheat bran, 25% yellow corn, 9% un-corticated cottonseed meal, 20% barley, 15% rice barn, 3% molasses, 2% premix, and 1% common salt.

The animals were fed twice daily rations that met their requirements based on their milk production, live body weight, and reproductive status, as recommended by APRI, at 8:00 a.m. and 5:00 p.m. Clean and fresh water was provided throughout the day.

All she-camels are mated naturally during the sexually active season between October and March, and the calving season lasts from November to April. She-camels were mated for the first parity at an appropriate weight or age (48 months of age or 350–400 kg of live body weight). In normal situations, females were mated for the advanced parities 60 days following parturition. Rectal palpation was conducted 60 days after the last mating to confirm pregnancy. Camels were permitted to roam in a secure barn. Monthly, all camels were vaccinated against external parasites and given the appropriate immunizations.

***Reproductive traits***

The reproductive trait was: age at first calving (AFC, month), days open (DO, day), Calving interval (CI, day), and number of services per conception (NSC, services).

***Statistical analysis***

The general linear model (GLM) procedure of SAS (2003) was used to determine which fixed effects should be included in the genetic parameter estimation models. All selected effects were considered significant ($P < 0.05$) involving biological significance and the availability of data.

Linear models for each trait are described below.

The model for AFC: $Y_{ij} = \mu + B_i + e_i$

The model for DO, CI, and NSC: $Y_{ijkl} = \mu + B_i + Ej + Sk + e_{ijk}$

Where:

$Y$: reproductive trait under study. $\mu$= the overall mean, $B_i$= the random effect of $i^{th}$ sire, $E_j$= the fixed effect of $J^{th}$ year of calving (J=2012 to 2021), $S_k$= the fixed effect of $k^{th}$ season of calving (k = winter and spring), $e$= the random error assumed normally and independently distributed (NID) with mean 0 and variance $\sigma^2_e$.

***Genetic parameters***

Heritability ($h^2a$), repeatability ($Re$), and predicted breeding values ($PBVs$) of studied traits were estimated with derivative-free restricted maximum likelihood (DFREML) procedures using the MTDFREMAL program of Boldman *et al.* (1995).

Two models were used: the univariate analysis of AFC, the first model: $Y = X_b + Z_a + e$, where $Y$ is the vector of observations, $X$ and $Z$ are the incidence matrices of the fixed effects and additive genetic random effects, respectively; $b$ is the vector of fixed effects, $a$ is the vector of additive genetic effects, and $e$ is the vector of residual effects. For DO, CI, and NSC, which are subject to repeated records, the second model includes the permanent environmental effect as common effects of repeated records on the same animal repeatability model: $Y = X_b + Z_a + W_{pe} + e$, where $W$ represents the incidence matrices of permanent environmental effects and $pe$ is the vector of permanent environmental effects.

The heritability ($h^2a$) for AFC was estimated as: $h^2a = \frac{\sigma^2 a}{\sigma^2 a + \sigma^2 e}$ , for DO, CI, and NSC were estimated as: $h^2a = \frac{\sigma^2 a}{\sigma^2 a + \sigma^2 pe + \sigma^2 e}$ , and the repeatability ($Re$) for DO, CI, and NSC was calculated as: $Re = \frac{\sigma^2 a + \sigma^2 pe}{\sigma^2 a + \sigma^2 pe + \sigma^2 e}$; where $\sigma^2 a$= additive genetic variance, $\sigma^2 pe$= permanent environmental variance, $\sigma^2 e$= residual variance

***Genetic (GT) and phenotypic (PT) trend***

The GT for DO, CI, and NSC were estimated by calculating the average means of *PBVs* and regressing them on the corresponding calving year. Meanwhile, PT was calculated by regressing the least squares mean of each trait on the calving year. Both PT and GT were calculated using the regression formula: $y = a + bx$, where $y$ = the reproductive traits, $a$ = stands for the intercept, $x$ = the calving year, and $b$ = the regression coefficient for $y$ on $x$ (SAS, 2003).

## RESULTS

### *Herd reproductive performance*

Reproductive performance statistics of Maghrebi she-camels are detailed in Table 1. Means of AFC, DO, CI, and NSC were 63.56 months, 193.43 days, 555.91 days, and 2.52 services, respectively. The largest coefficient of variation (40.87%) was observed for NSC. In contrast, AFC had the least coefficient of variation (5.2%).

### *Non-genetic factors affecting reproductive performance.*

The least-squares means of reproductive performance of Maghrebi she-camels, including (Table 2): the DO, CI, and NSC were significantly affected by the year of calving, with no preference for one year over another. The longest estimates, 233.0 days, 601.1 days, and 3.28 services were observed in 2017 for DO, CI and NSC, respectively.

Only NSC was significantly ($P\leq 0.01$) affected by the calving season (Table 2). She-camels calved during the spring season had a lower NSC value (2.03 service) than those calved during the winter season (2.51 service).

### *Genetic analysis*

Heritabilities ($h^2a$), permanent environmental effects ($pe^2$), repeatability (Re), and residual variance ($e^2$) for the reproductive traits of Maghrabian camels with their standard errors (SE) are presented in Table 3. The heritability estimates of DO and CI were very low (0.07 and 0.08, respectively). Furthermore, $h^2a$ tended to a moderate value of 0.10 for NSC and 0.15 for AFC, respectively.

The permanent environmental effect ($pe^2$) for DO, CI, and NSC had a higher variance than the additive genetic effect, ranging from 0.15 to 0.19. Moreover, the residual variance ($e^2$), which considers other non-genetic factors, represents the largest portion of the total variance, ranging from 0.71 to 0.85 (Table 3).

Predicted breeding values ($PBV_S$) for reproductive traits, standard errors (SE), the accuracy of prediction *(rA)*, and the percent of negative predicted breeding values *(%-*$PBV_S$) of she-camels were estimated, as the ranges of $PBV_S$ were 1.82 months for AFC, 21.51 days for DO, 66.39 days for CI, and 0.45 services for NSC (Table 4).

### *Phenotypic (PT) and genetic (GT) trend*

Trends of PT and GT for DO, CI, and NSC are presented in Table 5 and represented graphically in Figs. a, b, and c, respectively.

It appears that PT for DO was in the desired negative direction, with an annual decrease of -0.316 days/year. However, the value for NSC (0.0073 service/year) appeared small. On the other hand, PT for CI seemed positive, in the undesired direction, with an annual increase of 3.96 days per year.

Desired negative GT were observed in most periods of study, with negative annual GT of about -.051, -0.25 days, and -0.013 services per year for DO, CI, and NSC, respectively. However, the regression equations did not show any significant results, and the coefficients of determination ($R^2$) were less than 0.30 and ranged from 0.105 to 0.218.

**Table 1:** Descriptive statistics for studied reproductive traits of Maghrebi she-camels under the western Egyptian desert.

| Traits* | Mean | S. D. | C.V % |
|---|---|---|---|
| **AFC (month)** | 63.56 | 3.33 | 5.2 |
| **DO (day)** | 193.43 | 42.45 | 21.94 |
| **CI (day)** | 555.91 | 139.41 | 25.08 |
| **NSC (services)** | 2.52 | 1.03 | 40.87 |

AFC= age at first calving, DO= days open, CI= calving interval; NSC= number of services per conception, S.D. = standard deviations and C.V %= coefficients of variation.

**Table 2:** LSM±SE of reproductive traits of Maghrebi camels as affected by year and season of calving under the western desert of Egypt.

| Item | No. | DO (day) | CI (day) | NSC (services) |
|---|---|---|---|---|
| Overall mean | | 193.4±42.45 | 555.9±139.4 | 2.52±1.03 |
| Year of calving | 311 | ** | *** | *** |
| 2012 | 31 | 217.9±12.58$^{c}$ | 562.3±34.88$^{c}$ | 2.82±0.26$^{c}$ |
| 2013 | 29 | 207.9±11.44$^{c}$ | 536.5±36.60$^{b}$ | 2.78±0.28$^{bc}$ |
| 2014 | 30 | 193.0±11.14$^{ab}$ | 522.3±33.13$^{a}$ | 2.07±0.29$^{a}$ |
| 2015 | 32 | 183.4±13.47$^{a}$ | 511.4±38.19$^{a}$ | 1.97±0.26$^{a}$ |
| 2016 | 29 | 193.4±12.85$^{ab}$ | 531.8±38.34$^{a}$ | 2.21±0.27$^{ab}$ |
| 2017 | 33 | 233.0±12.53$^{d}$ | 601.1±35.18$^{d}$ | 3.28±0.29$^{d}$ |
| 2018 | 33 | 193.2±11.92$^{ab}$ | 525.6±39.15$^{b}$ | 2.19±0.25$^{ab}$ |
| 2019 | 29 | 218.0±10.87$^{c}$ | 579.2±41.04$^{d}$ | 2.92±0.25$^{c}$ |
| 2020 | 32 | 197.8±12.01$^{b}$ | 573.6±33.95$^{d}$ | 2.47±0.27$^{b}$ |
| 2021 | 33 | 198.4±11.55$^{b}$ | 562.1±36.33$^{bc}$ | 2.53±0.31$^{bc}$ |
| Season of calving | 311 | NS | NS | ** |
| Winter | 169 | 199.6±8.89 | 598.4±29.99 | 2.51±0.22$^{b}$ |
| Spring | 142 | 195.3±9.84 | 598.0±32.90 | 2.03±0.18$^{a}$ |

LSM= least squares mean and SE=standard error
Means followed by different superscripts are significantly different, **(P<0.01), ***(P<0.001), NS: Non-significant,

**Table 3**: Variance components and genetic parameters for reproductive traits

| Reproductive Traits | Variance components | | | | genetic parameters | | | |
|---|---|---|---|---|---|---|---|---|
| | $\sigma^2_a$ | $\sigma^2_{pe}$ | $\sigma^2_e$ | $\sigma^2_p$ | $h^2_a$±SE | $pe^2$±SE | *Re* | $e^2$±SE |
| AFC | 85.5 | _ | 484.5 | 570 | 0.15±0.07 | - | - | 0.85±0.07 |
| DO | 68.9 | 147.6 | 744.2 | 820 | 0.07±0.02 | 0.15±0.01 | 0.22 | 0.78±0. 02 |
| CI | 60.7 | 113.9 | 607.3 | 670 | 0.08±0.01 | 0.15±0.01 | 0.23 | 0.77±0.01 |
| NSC | 54.1 | 102.93 | 383.6 | 447.53 | 0.10±0.08 | 0.19±0.10 | 0.29 | 0.71±0.20 |

$\sigma^2_a$= additive genetic variance, $\sigma^2_{pe}$= permanent environmental variance, $\sigma^2_e$= residual variance, $\sigma^2_p$ total phenotypic variance**,** $h^2_a$= direct heritability, $pe^2$= fraction of phenotypic variance due to maternal permanent environmental effects *Re* =repeatability and $\sigma^2_e$fraction of phenotypic variance due to residual effects.

**Table 4:** Predicted breeding values ($PBV_S$) for reproductive traits, it standard errors (SE), the accuracy of prediction ($r_A$) and the percent of negative predicted breeding values (%-$PBV_S$) of She-camels.

| Reproductive traits | Minimum | | | Maximum | | | Range[1] | %-$PBV_S$ |
|---|---|---|---|---|---|---|---|---|
| | **$PBV_S$** | **SE** | $r_A$ | **$PBV_S$** | **SE** | $r_A$ | | |
| AFC | -1.12 | 1.7 | 0.37 | 0.7 | 0.93 | 0.56 | 1.82 | 57.6 |
| DO | -14.3 | 4.21 | 0.24 | 7.21 | 2.17 | 0.66 | 21.51 | 42.4 |
| CI | -37.35 | 2.03 | 0.40 | 29.03 | 1.40 | 0.69 | 66.39 | 48.5 |
| NSC | -0.27 | 0.51 | 0.25 | 0.18 | 0.35 | 0.68 | 0.45 | 54.5 |

[1] Range = Maximum – (Minimum)

**Table 5:** Linear regression equation of both phonotypic and genetic trend for reproductive traits on the year of calving for the Maghrebian camel.

| Traits | PT | | GT | |
|---|---|---|---|---|
| | Equation | $R^2$ | Equation | $R^2$ |
| DO day/year | 205.34-0.316$X$ | 0.004 | 0.476-0.0.051$X$ | 0.22 |
| CI day/year | 528.78+3.966$X$ | 0.17 | 1.013-0.250$X$ | 0.17 |
| NSC services/year | 2.48+0.0073$X$ | 0.003 | 0.078-0.013$X$ | 0.11 |

PT= phonotypic trend, GT= genetic trend and $R^{2=}$ coefficient of determinant

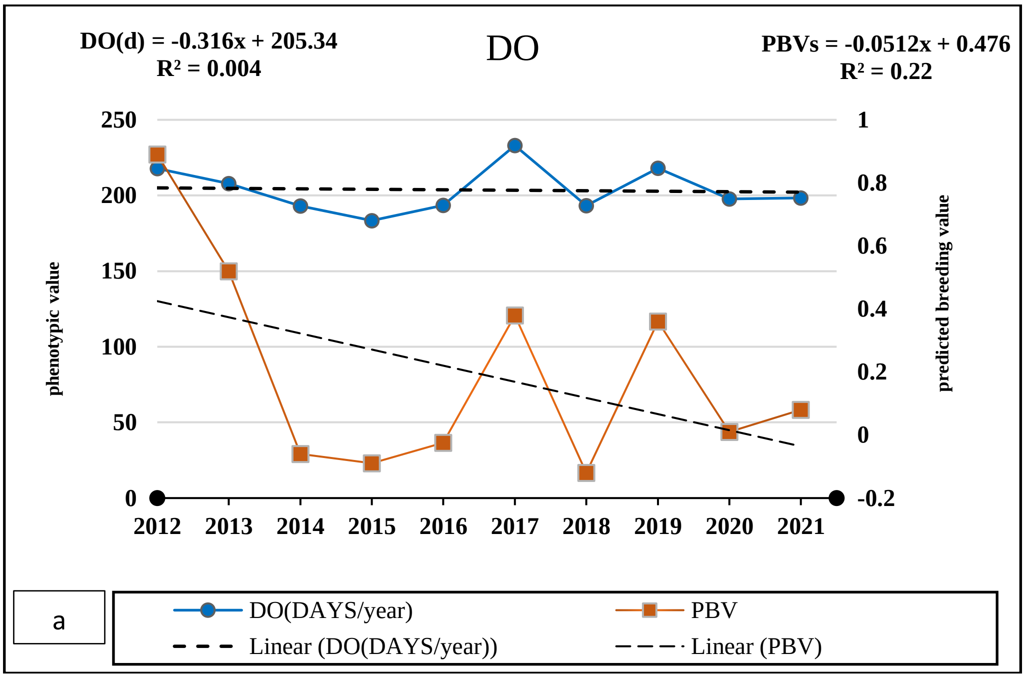


**Figure a:** Phenotypic and genetic trend for DO

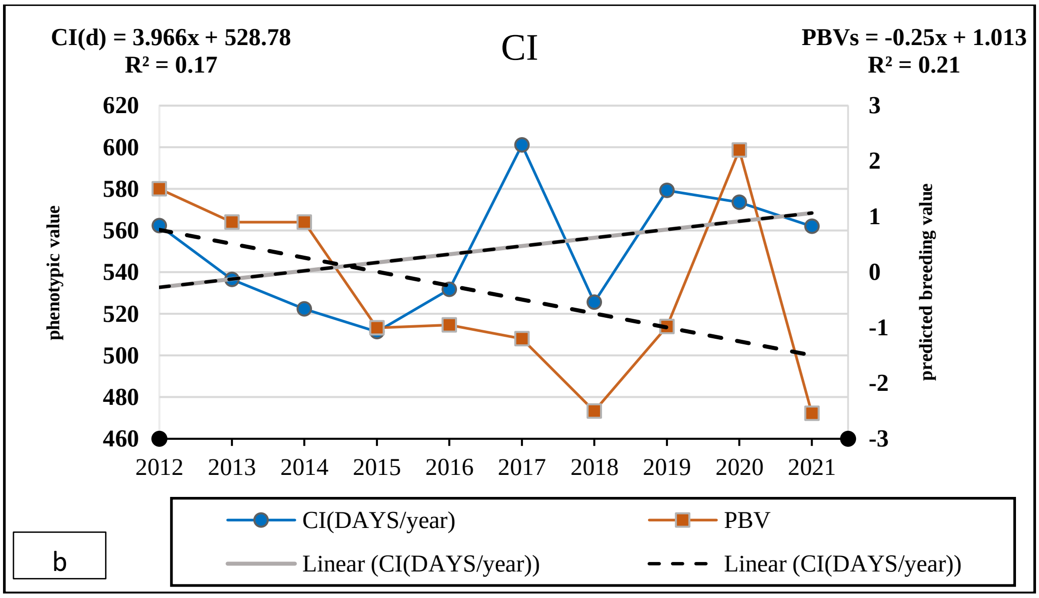


**Figure b:** Phenotypic and genetic trend for CI

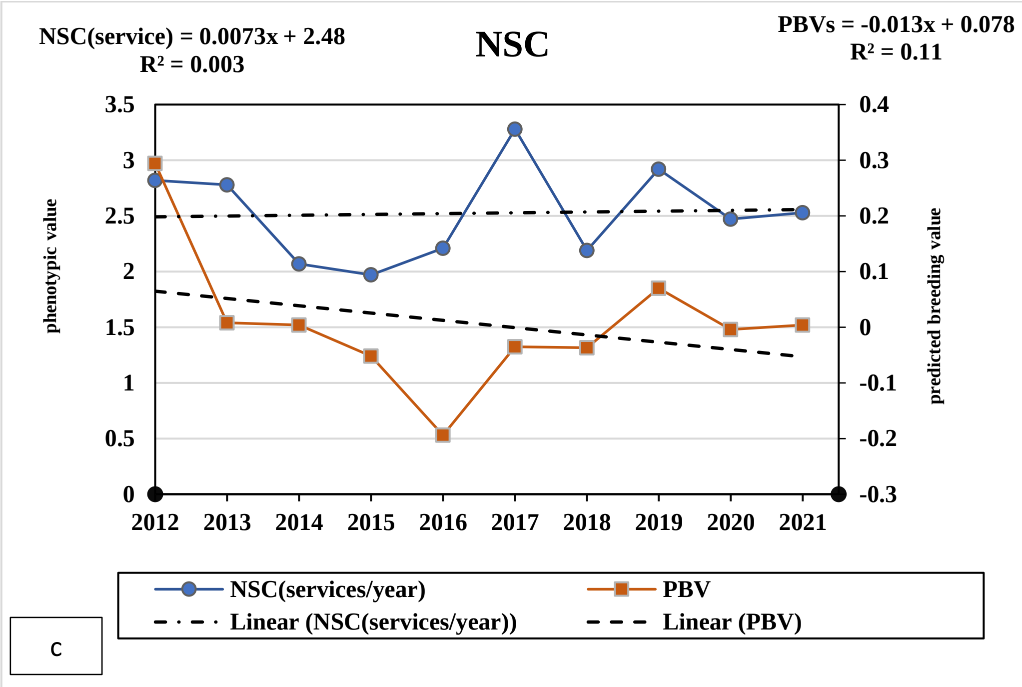


**Figure c:** Phenotypic and genetic trend for NSC

## DISCUSSION

There is a lack of published work on the genetic and non-genetic factors affecting camel performance under Egyptian conditions, and modern methods have not been used to assess these factors due to a lack of registered herds with recorded data (Shehab El-Din *et al.,* 2022). As a composite trait, improving reproductive traits genetically is challenging, as the genetic component is relatively low, and non-genetic factors also play a significant role (Gómez-Carpio *et al.,* 2023). Investigating genetic and non-genetic factors influencing camel reproductive ability is crucial for utilizing its productive capabilities and addressing the food gap in Egypt, especially for desert dwellers (Ashour and Abdel-Rahman, 2022). This will aid in establishing priorities and developing an effective genetic improvement strategy.

The farm's policy of not breeding female camels until they are 4 years old prevents difficulties during calving and ensures survival, especially in harsh climates. In the current study, the average AFC is higher than in Algeria (51.1 months, Gherissi *et al.,* 2020), but is consistent with previous reports on Maghrebi camels in Egypt (62.7 months, Farrag *et al.,* 2019). Early AFC and good fertility in dairy heifers are crucial for reduced replacement costs. In dairy cattle, genetic improvement in AFC can decrease its average value over generations, with lowering AFC to 24- and 21 months, reducing replacement costs by 4.3% and 18%, respectively (Gavan *et al.,* 2014 and Brz´akov´a *et al.,* 2019).

Dromedary camels have variable postpartum intervals for re-mating, which limits the use of DO as indicators of fertility and ovarian activity. Also, milking practices extend for more than a year after parturition, influencing DO length and variation and impacting females' re-breeding readiness (Almutairi *et al.,* 2010a). Moreover, uterine involution and tissue restoration post-calving are indefinite, making pregnancy confirmation dependent on regaining pre-pregnancy uterine size and structure (Zaky *et al.,* 2020). The mean value of DO in this study was lower than that reported in Ethiopia (580.7 days, Keskes *et al.,* 2013), but higher than that observed in Egypt (168.3 days, Farrag *et al.,* 2019).

Previous studies have shown that camels have a prolonged CI due to their long gestation period, limited breeding seasons, and unfavorable conception rate (Brzáková *et al.,* 2019). However, better feeding and management practices can help reduce the CI (Aslam *et al.,* 2002). The obtained CI value for dromedary camels is within Sudan's range (556.2 days, Abdel-Aziz *et al.,* 2016), but lower than Bangladesh's (672.8 days, Fazal *et al.,* 2017).

Camels have higher NSC due to seasonal polyestrous cycles, short breeding seasons, and diverse estrous cycles (Mostafa *et al.,* 2016; Zaky *et al.,* 2020). The estimated average of NSC in the current study is higher than those recorded for camels in Iraq (1.84 services, Al-Fatlawi and Al-Hamdawi, 2017). However, it is nearest to 2.27 services, which was reported for the same breed under Egyptian conditions (Zaky *et al.,* 2020).

Previous studies highlight potential variations across different camel populations, management systems, feeding schedules, sanitary standards, and breed types (Musa *et al.,* 2006; Mostafa *et al.,* 2016; Zaky *et al.,* 2020).

The coefficient of variation (CV%) for studied traits indicates the need for improved management procedures and feeding system conditions. The CV% was nearly equal for DO and CI, with moderate variation observed in AFC. However, NSC had the largest CV% due to factors like long lactation periods, long CI, multiple NSC, and the absence of assisted reproductive technologies like embryo transfer and artificial insemination (Skidmore, 2005). These factors contributed to the need for harmonized management procedures and feeding system conditions.

The year and season of calving were considered significant environmental factors that influence the reproductive performance of agricultural livestock herds, particularly multiparous females and heifers, during their first calving (Bolacali *et al*., 2017).

The study found that 2017 year was the worst year ever, with variations in the others between highs and lows. (Table 2). This may be reflected in the differences in environmental conditions, such as temperature and relative humidity, feeding, and management practices from year to year. Similar results were also reported by Aslam *et al.* (2002) and Farrag *et al*. (2019).

The season of calving significantly ($P<0.01$) affects NSC in camels. Spring-calving camels have lower NSC than those calved in winter. Although not statistically significant, measures for spring favor CI and DO, likely due to better environmental conditions and feedstuff. Almutairi *et al.* (2010b) reported longer CI (686 days) for camels calved Oct-Feb than Mar-Sept due to the mating season. Farrag *et al.* (2019) suggested that the season of calving may be due to variations in environmental conditions and feedstock.

When developing future breeding plans to improve reproductive traits, it is critical to accurately evaluate the genetic parameters, as well as trends in change in reproductive performance (Amin *et al.,* 2021). Recently, selection schemes around the world have incorporated fertility traits such as CI, DO, NSC, AFC, and related traits alongside productive traits (Guo *et al.,* 2014).

In this study, low estimates of $h^2a$ in DO and CI traits were reported, but it tended to be moderate estimates for AFC and NSC. Herd management (e.g., nutritional status, postpartum reproductive care, semen quality) and environmental conditions significantly affect these traits, resulting in low $h^2a$. The high residual variance ratio ($e^2$), which ranged from 0.71 to 0.85 (table 5), supports this observation.

Promising $h^2a$ values for AFC and NSC indicate potential for genetic improvement. Selecting animals with preferred breeding values, proper management practices, and adequate nutrition can help reduce environmental variation and improve $h^2a$ estimates of reproductive traits, consequently improving both reproductive traits and milk production.

Few studies have explored the genetic parameters of reproductive traits in camels, with high estimates of $h^2a$ for these traits compared to other species. These studies may have relied on records from the first lactation or the oldest analytical methods. The addition of new females can also result in variation in both phenotypic and genetic variance. In this regard, Ismail (2019) found high $h^2a$ values for the same reproductive traits in the Maghrebi camel, which were 0.28±0.06, 0.37±0.11, 0.64±0.14, and 0.06±0.05 for AFC, DO, CI, and NSC, respectively. Hermas (2002) reported $h^2a$ estimates for dromedary camels under Libyan conditions using the intraclass correlation between paternal half-sib groups. The estimates were 0.39, 0.40, 0.33, and 0.02 for AFC, DO, CI, and NSC, respectively.

Heritability estimates for fertility-related traits are often based on field data, but breeder decisions can affect the data, leading to underestimation of additive genetic variance in dams culled due to low production or reproductive issues (Malhado *et al.*, 2013).

The permanent environmental effect ($pe^2$) had a higher variance than the additive genetic effect in DO, CI, and NSC, resulting in an increase in *Re* compared to $h^2a$. The estimated *Re* ranged from 0.22 (DO) to 0.29 (AFC). In this respect, *Re*, a statistic indicating how much variation within individuals contributes to total variation in a population, can be used as an upper limit on heritability (Boake, 1989), making it a potential measure for selecting calves from a herd.

The study's estimates differ from previous ones due to factors like genetic diversity differences, statistical model variations, and diverse reactions of the same breed to different environmental conditions, which cannot be captured by fitted models (Shao *et al.*, 2021).

Researchers can estimate genetic variance among animals by analyzing animal breeding values for specific traits in the herd. A large range of values indicates significant genetic variance, allowing improved traits through selection based on superior breeding values (Abo-Elenin, 2018). In this respect, the *PBVs* estimated under study for She-camels were lower, which is consistent with this type of trait. Furthermore, the minimum and maximum *PBVs* obtained in this study had moderate accuracy ($r_A$) ranging from 0.24 to 0.68 for AFC, DO, CI, and NSC (Table 5).

Over half of the herd (54.5-57.6%) had negative *PBVs*, suggesting the potential for early selection strategies based on preferred *PBVs* under Egyptian conditions. This could involve reducing extended reproductive intervals and achieving fewer services per conception.

In general, there were unanticipated increases in PT for CI and NSC. The PT for DO appears to be heading in the desired negative direction, with an annual decrease of -0.316 days. From 2012 to 2015 and 2016, the PT for DO, CI, and NSC decreased consistently (Figures a, b, and c). Then there was an irregular trend, with some years positive and others negative, with clear CI harsh positive and negative slopes in 2017 and 2018, respectively.

In this respect, PT had two components: genetic and environmental trends. Consistent with the desired GT in the current study (Table 6), suggests that the decline in phenotypic performance was a result of non-genetic factors.

Studies attributed that environmental changes affect the reproductive traits of Arabian camels due to irregular factors such as age, disease, feed, climate, season, management, and hormonal conditions (Marai *et al.,* 2009; Almutairi *et al.,* 2010a and Ali *et al.,* 2017).

To define the progress of genetic changes, evaluate the selection program's aids, and implement necessary modifications through breeding programs, an estimate of the genetic trend achieved is needed (Euclides Filho *et al.,* 1997). In this regard, DO, CI, and NSC showed a low negative (favorable) GT. This aligns with the breeding program's objective, which aims for shorter reproductive periods and fewer NSC. However, the regression equations did not show any significant results, and the coefficients of determination ($R^2$) were less than 0.30 and ranged from 0.105 to 0.218, indicating no defined genetic trends for these traits.

The slow GT in reproductive traits can be attributed to two main factors. First, most dromedary breeders in the Arab region prioritize performance traits such as body weight or milk production over reproductive traits in their selection program. Second, reproductive traits have low $h^2a$, which may slow genetic progress. However, the current GT is promising, especially when considering the negative genetic correlation between productive traits (basic breeding criteria) and reproductive traits.

Graphs a, b, and c showed the consistent efforts to genetically regulate reproductive intervals and NSC in camels, with a decline in DO and NSC until 2016, and a maximum decrease in CI in 2018.

No GT studies have been conducted for reproductive traits in camels. Cattle studies in Egypt have shown fluctuations in GT for reproductive traits due to factors such as lack of selection and breeding techniques, small herd sizes, inbreeding, poor management practices, and random mating. However, desirable trends have been observed due to effective government support through project implementation and a well-structured national genetic program (Osman *et al.,* 2013, Sahin *et al.,* 2014, Abdel-Hamid *et al.,* 2017, and El-Awady *et al.,* 2017).

## CONCLUSIONS

Based on the current study's results, it is possible to enhance the reproductive capacity of camels by exploiting genetic variations among the individuals of the current herd and desirable genetic trends. This can be accomplished by implementing well-planned management practices, selective breeding programs based on desired breeding values, and further genetic evaluation studies using genomic procedures. These initiatives can be especially effective for dromedary camels, which live in harsh desert conditions. Therefore, it is recommended to conduct more comprehensive genetic studies to optimize the reproductive potential of camels.

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**Credit Author Contribution Statement**
A. M. Amer and A. A. Othman: collecting and editing data; M. I. Shehab El-Din and M. A. Kamal El-den: statistical genetic analysis, all authors shared in writing, reviewing and approved the final manuscript.

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# التقييم الوراثي للصفات التناسلية للإبل المغربية في صحراء مصر الغربية

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تهدف الدراسة الحالية الى دراسة بعض العوامل غير الوراثية والعوامل الوراثية وذلك لبعض الصفات التناسلية للإبل المغربى ، بما في ذلك العمر عند الولادة الأولى (AFC)، وعدد الأيام المفتوحة (DO)، والفترة بين ولادتين (CI)، وعدد مرات التلقيح حتى الاخصاب (NSC). تم تضمين 311 سجلاً لـ 33 ناقة مغاربية تابعة لمركز دراسات وتنمية إنتاج الإبل بمحافظة مرسى مطروح، التابع لمعهد بحوث الإنتاج الحيواني، وزارة الزراعة واستصلاح الأراضي، مصر، من عام 2012 إلى عام 2021 في هذه الدراسة. تظهر النتائج أن متوسطات العمر عند الولادة الأولى، وعدد الأيام المفتوحة ، والفترة بين ولادتين ، وعدد مرات التلقيح حتى الاخصاب كانت 63,6 شهرًا و193,4 يومًا و555,9 يومًا و2,52 تلقيحة على التوالي. كان لسنة الميلاد تأثير معنوى على كل الصفات محل الدراسة، بينما تأثر عدد مرات التلقيح حتى الاخصاب فقط بموسم الولادة. أظهر الاتجاه المظهري لـعدد الأيام المفتوحة إتجاهاً سالبا ، مع انخفاض سنوي قدره -0,316 يومًا / سنة. لوحظت الاتجاهات الوراثية السالبة المرغوبة في معظم فترات الدراسة يبلغ حوالي -0,051 و -0,25 يومًا و -0,013 تلقيحة سنويًا لـعدد الأيام المفتوحة ، والفترة بين ولادتين ، وعدد مرات التلقيح حتى الاخصاب على التوالي. كانت تقديرات المكافئ الوراثى 0,15 و 0,07 و 0,08 و 0,10 لـلعمر عند الولادة الأولى، وعدد الأيام المفتوحة ، والفترة بين ولادتين ، وعدد مرات التلقيح حتى الاخصاب على التوالي. تراوح المعامل التكرارى من 0,22 إلى 0,29. ومثلت الإناث ذات القيم التربوية السالبة حوالي نصف الحيوانات قيد الدراسة. مما سبق، يمكن الاستنتاج أن الانتخاب المبكر للإناث ذات الصفات التناسلية المرغوبة، مع الممارسات الرعوية المناسبة يوفر استراتيجية واعدة لتعزيز نجاح تربية الإبل في مصروأداء تناسلى أفضل لقطعان الابل.