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EFFECTS OF VARYING STOCKING DENSITY ON REPRODUCTIVE EFFICIENCY OF JAPANESE QUAILS (*Coturnix coturnix japonica*) IN A TROPICAL ENVIRONMENT

[1]Ahmed M.A., [2]Aro S.O. And [3]Adeosun T.A.

[1]Department of Agricultural Education, Federal College of Education (Technical) P.M.B. 1044, Asaba, Delta State Nigeria
[2]Department of Animal Production and Health, Federal University of Technology, P.M.B. 704, Akure, Nigeria
[3]Department of Agricultural Education, Federal College of Education (Technical), Bichi,
Corresponding Author: woleahmed2014@gmail.com.

Abstract
The aim of this study was to assess the effects of varying stocking density on reproductive efficiency of Japanese quails in a tropical environment. A total of two hundred and ninety-six Japanese quails were divided into four stocking densities of 252.20cm^2/bird (11birds); 173.43 cm^2/bird (16 birds), 132.10 cm^2/bird (21birds), and 106.73 cm^2/bird (26 birds) representing the treatments. The treatments were replicated four times in a completely randomized design and the study lasted for 8 weeks. Data generated were analysed using linear procedure for one way analysis of variance. The results revealed significant differences ($p \leq 0.05$) in the number of maturing follicles, pre-vitellogenic follicles and diameter of the Graafian follicles which were highest in T1 (2.75±0.25; 26.00±3.37 and 2.23±0.23cm) birds respectively. Percentage fertility (93.33±2.15%) and hatchability (90.00±1.01%) of Japanese quail eggs were better at low stocking density T1. Higher testicular weight (3.29±0.18g), testicular volume (2.48±0.50ml) and testicular density (1.44±0.20g/ml) in T1 all predisposed birds to higher sperm production (10.14±3.74) in T1 male Japanese quails. However, the birds in T3 (132.10cm^2/bird) compared favourably well with those in T2 and T1 and could therefore be considered for quail production during high environmental temperature without compromising quail welfare and reproductive capacity.
Keywords: Heat stress; Gonadal parameters; Folliculogenesis; Testicular homogenates, Hatchability.

Introduction

Sustainability of the poultry industry depends on the reproductive potentials of the breeding stocks (male and female). The rapid rate of production of viable chicks is a major way in poultry industry that guaranties its sustainability in the production of high quality animal protein food for man. The poultry breeder, thus, aims at optimum fertility and hatchability of poultry eggs to produce viable chicks for commercial production. The fertility and hatchability of eggs encompass the union of the spermatozoa and the ova, the initiation of development and the hatching of a viable chick at the end of incubation (Etches, 1996). The development of the reproductive organs and breeding efficiency are directly influenced by the stocking density. Stocking density in quail is the number of quail/m^2 either in the cage or on the floor Mahrose *et al.* (2019). The number of birds per cage in a given group may influence production and reproduction factors, particularly in breeders, due to the presence of different males in the same cage and the competition between males for females, sexual activity, social interactions and constant competition for space and feed. Increased stocking density of quails leads to increased cage heat coupled with increased environmental temperature above the standard environmental temperature of 18-22^{o}C (Murakami and Ariki 1998) for avian causes heat stress in quail reared during upsurge in environmental temperature. Heat stress effects had been considered to affect all phases of semen production in cock (Banks *et al.,* 2005). It depresses reproductive capacity, due to the decrease in seminiferous epithelium cell differentiation

which was revealed by decrease in semen quantity and quality (Obidi *et al.,* 2008) and inhibits intracellular ion exchange in the testis (McDaniel, 1995, 1996). Environmental stress depressed testicular homogenates and semen characteristics. Semen concentration, consistency and volume were affected at environmental temperature above the thermo neutral zone of 18-22ºC for birds (McDaniel, 1995). Increased environmental temperature and associated heat stress impaired libido and reduces mating activities of male bird probably through dehydration and change in secretion and activities of sex hormones. Heat stress also increases occurrence of sperm abnormalities such as bent head, broken mid-piece, micro-chepalic and cytoplasmic droplet which reduces fertility in birds (Penfold *et al.,* 2000).

Ovulation in bird is induced by the stimulation of the ovarian progesterone derived majorly from the granulosa layer of the largest preovulatory follicle and pituitary luteinizing hormone. Follicular selection, preovulatory follicular growth and ovulations in birds occur relatively on daily basis to generate a species-specific number of eggs within a clutch. The number of pre-ovulatory follicles developed and eventually ovulated is dependent on a number of environmental factors such as food availability, ambient temperature, and social factors (Gilbert *et al.,* 1978). Increasing urbanization, exploding human population, quest for human housing and industrialization among other factors has put pressure on land use. These factors are likely to force quail farmers to increase the number of quails reared per unit area thereby leading to overcrowding. This study thus aimed at assessing effects of varying stocking density on reproductive efficiency of Japanese quails in a tropical environment.

Materials and Methods

Experimental Site

The study was conducted at the Teaching and Research Farm (Livestock section) of the Federal University of Technology, Akure, and Ondo State, Nigeria. Akure is located at an altitude of 350.52m above mean sea level and on latitude 7º15'N and 5º12'E. The average annual temperature is 26.2ºC while the relative humidity is 78% (Climate data, 2018). Akure vegetation is of rainforest characterized by hot and humid climate and a bimodal rainfall distribution chart. The weather is characterized by two periods of seasonal upsurge in heat which is experienced during the transition from wet period to dry period in October to December and transition from dry period to wet period in February to April. This study was conducted during the upsurge in environmental temperature of transition from rainy period to dry season.

Experimental design

The Model for the study will be:

$Yik = \mu + Si + Eik$

Yik = record of the birds on i^{th} stocking density (252.20cm^2/bird, 173.43cm^2/bird, 132.10cm^2/bird and 106.73cm^2/bird)

μ = Overall mean

Si = Effects of the stocking density

Eik = Random error.

Management of the Experimental Birds

Two hundred and ninety-six sexed adult Japanese quails were reared under the same managerial and hygienic conditions. A completely randomized design was used for the experiment with four treatments and four replicates per treatment. The dimension of the cage space for the experiment

was 70cm x 50cm x 50cm (Length x Width x Height). This gives a cage space of 3500cm^2. The feeder dimension was 43cm x 8cm and gives an area of 344cm^2 while the area of the drinker was 380.29 cm^2. These give approximate space area occupied by drinker and feeder to be 725cm^2. The available space for quails per cage was 2775cm^2. A total of seventy four birds were used for each treatment at four stocking densities of T1-11, T2-16, T3-21 and T4-26 quails per cage equivalent to 252.20cm^2/bird, 173.43cm^2/bird, 132.10cm^2/bird and 106.73cm^2/bird respectively. The quails in T1 (252.20 cm^2/bird) served as control and all the birds in the study were fed formulated basal feed *ad-libitum* for 8 weeks.

Determination of Fertility and Hatchability of Japanese Quail Eggs

Both sexes of Japanese quail were housed together during the period of the experiment in 1: 4 (male: female) ratio. This was to enhance natural mating. Five eggs per replicate were selected for six consecutive days out of which a total of four hundred relatively good eggs were selected for incubation at 100 eggs per treatment. The eggs were fumigated with 25g of potassium permanganate and 35ml of formalin (40%) and the electric incubator were washed and also fumigated as above. The incubation temperature was approximately se at 37.5^{o}C and 60% relative humidity (RH) for the first 14 days and 37.2^{o}C and 70% RH from the 15th day to hatching.

The eggs were appropriately turned automatically during the fourteen days in the setter incubator to prevent the embryo from sticking to the shell. Eggs were candled on 7th and 12th days of incubation to identify and remove infertile and addled eggs. The remaining eggs were transferred from setter to hatcher at the14th day. At the end of the 17^h day, the hatcher was opened; hatched chicks were sorted out to different categories and weighed. Data on number of fertile eggs, number of fertile eggs hatched, fertile eggs not hatched and eggs not fertile were collected.

Percentage fertility and hatchability were determined using the following formulae given by (Aro and Samuel, 2018):

$$\% \text{ Fertility} = \frac{\text{Number of fertile eggs}}{\text{Number of eggs set}} \times 100$$

$$\% \text{ Hatchability} = \frac{\text{No. of chick hatched}}{\text{No. of fertile eggs set}} \times 100$$

$$\% \text{ hatchability of total egg set} = \frac{\text{Total number of hatched egg}}{\text{Total number of egg set}} \times 100$$

Quantitative Semen Analysis of Japanese Quail

Two mature male birds per replicate were slaughtered by slitting the jugular vein. After evisceration the left and right testes were removed, labelled for identification, weighed and the volume determined by Archimedes principle of water displacement (Aro, 2010). This was done by pouring normal saline water into the measuring cylinder to overflow the brim and the testis was then gently dropped into the cylinder. The water displaced by the testis was measured in millilitre (ml) and the densities of the testes were calculated as the ratio of the mass and volume of the testes. The left testes were homogenized with 10ml of normal saline using homogenizer at 1.30 speeds per minute for 1minute and the homogenate was strained into a plain bottle using cheese cloth. Sperm cells in the homogenates were counted with Neubauer haematocytometer to determine the testicular sperm count. This was achieved by counting the elongated spermatids and fully matured sperm cells in the binocular microscope (Olympus®) at initial 10x magnification field and a clear view at 40x magnification objective lens.

From the testicular sperm count, gonadal sperm reserve was calculated by multiplying the testicular sperm count by the paired testis weight. Daily sperm production was determined by dividing the gonadal sperm reserve by the time divisor for Japanese quail (2.69) given by Lin *et al.,* (1990). Time divisor is the number of days of production that these reserves represent (Almquist and Amann, 1961).

Testicular sperm count = 5 x 10 x 4.55 x Number of sperm cells counted (for left testis).

$$\text{Daily sperm production} = \frac{\text{Gonadal sperm reserve}}{\text{Time divisor}}$$

Spermatogenic efficiency was calculated from the testicular sperm count according to Aro (2012) as.

$$\text{Spermatogenic Efficiency} = \frac{\text{Daily sperm production}}{\text{Weight of paired testes}}$$

Statistical analysis

Generated data were analysed using linear procedure for one-way analysis of variance of SPSS version 22 (2013). Means with significant difference were separated using Duncan's New Multiple Range Test at 0.05 % level of significance.

Results and Discussion

Gonadal parameters of female Japanese quails reared under different stocking densities

Table 1 presents gonadal parameters of female Japanese quails reared under different stocking densities.

Table 1: Gonadal Parameters of Female Japanese Quails Reared Under Different Stocking Densities.

Parameters	T1	T2	T3	T4
Weight of ovary (g)	5.00±0.41	5.00±0.41	4.75±0.63	4.50±0.50
Weight of oviduct (g)	4.50±0.29^{a}	4.75±0.25^{a}	4.25±0.48^{b}	3.75±0.25^{b}
Weight of entire reprod. tract (g)	9.50±0.65^{a}	9.75±0.63^{a}	9.00±1.08^{b}	8.25±0.75^{b}
Length of infundibulum (mm)	3.80±0.44^{b}	4.30±0.63^{b}	4.15±0.53^{b}	5.05±0.58^{a}
Length of magnum (mm)	13.63±0.50	13.30±0.21	13.70±0.92	13.75±1.16
Length of isthmus (mm)	1.31±0.58^{a}	1.33±0.08^{a}	1.13±0.09^{b}	1.18±0.11^{b}
Length of uterus (mm)	4.68±0.13	4.45±0.26	4.10±0.22	4.35±0.22
No of Graafian follicles	1.75±0.25^{b}	2.00±0.41^{b}	2.75±0.48^{a}	3.00±0.41^{a}
No of pre-ovulatory follicles	2.00±0.00^{b}	1.75±0.25^{b}	2.75±0.48^{a}	2.25±0.63^{b}
No of maturing follicles	2.75±0.25^{a}	2.75±0.25^{a}	2.50±0.29^{a}	2.25±0.48^{b}
No of pre-vitellogenic follicles	26.00±3.37^{a}	24.75±3.50^{a}	17.75±1.25^{b}	23.50±2.90^{a}
Diameter of Graafian follicles (cm)	2.23±0.23^{a}	1.95±0.06^{a}	1.63±0.15^{b}	1.85±0.87^{b}

a, b, = Means on the same rows but with different superscripts are statistically (P<0.05) significant. T1 = 252.20cm^{2}/bird (11 birds), T2 = 173.43cm^{2}/bird (16 birds), T3 = 132.10cm^{2}/bird (21 birds) and T4 = 106.73cm^{2}/bird (26 birds).

Significant differences were not observed in the weight of the ovary, length of the magnum and length of the uterus. The weight of the oviduct, the entire reproductive tract and length of isthmus were statistically highest in T2 with mean values of 4.75±0.25g; 9.75±0.63g and 1.33±0.08mm respectively. These values were not statistically different from the mean values obtained in T1. The values for these parameters were however, low in the high stocking densities with T4 recording the lowest mean values of 3.75±0.25g and 8.25±0.75g for the weight of the oviducts and the entire reproductive tract respectively. Stocking density in this study thus seems to affect the

development of these gonadal parameters. The infundibulum was longest in T4 with mean value of 5.05±0.58mm and shortest in T1 with mean value of 3.80±0.44mm. The development of the ovary and the entire reproductive tract is under the control of gonadotropins apparently the follicle stimulating hormone (FSH) and luteinizing hormone (LH). The FSH initiates the process of follicular development in the ovary and the mobilization of yolk proteins and lipid into the pre-vitellogenic follicles thus increasing their number, size and mass (Leung and Armstrong, 1980). Significant differences (P≤0.05) were observed in the number of Graafian follicles which increased with increasing stocking density with T4 quails having the highest (3.00±0.41) number of Graafian follicles which was not statistically (P≥0.05) different from the mean value of 2.75±0.48 in T3. Number of pre-ovulatory follicles also differed significantly (P≤0.05) and was highest in T3 (2.75±0.48) and lowest in T2. Number of maturing follicles was the same in T1 and T2 (2.75±0.25) and not significantly different (P≥0.05) from T3 (2.50±0.29) while lowest value was observed in T4 with mean value of 2.25±0.48. Significant (P≤0.05) differences were observed in the number of pre-vitellogenic follicles which was highest in T1 (26.00±3.37) and lowest in T3 with the mean value of 17.75±1.25. The results showed significant differences (P≤0.05) in the diameter of the Graafian follicles which was highest in T1 (2.23±0.23cm) followed by T2 and T4 (1.95±0.06 and 1.85±0.87cm) respectively and lowest in T3 (1.63±0.15cm). Observations in this results may be due to the effects of heat stress created by the stocking density which might decrease ovarian activities in animal by increasing circulating prolactin (PRL) and decreasing gonadotropins (luteinizing hormone, LH and follicular stimulating hormone, FSH) in turkey poults (Opel and Proudman, 1982), laying hens (Johnson, 1981), and turkey hens (El Halawani *et al.,* 1985; Rozenboim *et al.,* 2004).

Hatchability of Japanese Quails Eggs Reared at different Stocking Densities.

Table 2 shows the fertility and hatchability of Japanese quails eggs reared at different stocking densities. The results of the hatchability of quail eggs during the transition period from rainy to dry season in table 2 indicated that all the parameters were significantly different (P≤0.05) across the stocking densities. The number of fertile egg was highest in T1 (70.00±0.05) and lowest in T4 (63.00±1.03). The number of infertile eggs, the percentage infertility and percentage of unhatched eggs to total eggs set (12.00±1.02, 16.00±2.13 and 34.67±2.15) respectively were highest at the highest stocking density T4. Number of chick hatched (63.00±3.27), percentage hatchability of fertile eggs (90.00±1.01) and percentage hatchability of total egg set (84.00±1.23) were respectively highest in T1 while late embryonic mortality was highest in the high stocking densities T3 and T4 (26.09±1.23 and 22.22±2.42) respectively. Fertility and hatchability of eggs is a major parameter used in measuring the economic efficiency of parent stocks and also to evaluate the genetic and reproductive fitness of individual birds and breed in a population. Hatchability which is the percentage of chick hatch to total fertile egg set is a very important trait in breeding program. It has a great economic impact in promoting the poultry industry as well as insuring the sufficiency of day-old chicks (Abou El-Ghar, 2013). The trends of the fertility and hatchability of Japanese quail eggs in this current study revealed that fertility and hatchability of quail egg were better at low stocking density. High cage density with associated increased cage temperature might reduce yolk size, albumen consistency and optimum calcium deposit in the egg. Jassim *et al.* (1996) deduced that, fertility and embryonic mortality in avian species are attributable to genetic, nutrition and management factors such as overcrowding.

Table 2: Hatchability of Japanese Quails Eggs Reared at different Stocking Densities.

Parameters	T1	T2	T3	T4
Number of egg set	75.00±0.00	75.00±0.00	75.00±0.00	75.00±0.00
Number of fertile egg	70.00±0.05^{a}	68.00±0.07^{b}	69.00±0.13^{a}	63.00±1.03^{c}
% Fertility	93.33±2.15^{a}	90.66±2.03^{b}	92.00±2.23^{a}	84.00±1.26^{c}
Number of infertile eggs	5.00±1.15^{c}	7.00±1.03^{b}	6.00±1.23^{b}	12.00±1.02^{a}
% Infertility	6.66±1.10^{d}	9.33±1.21^{b}	8.00±1.11^{c}	16.00±2.13^{a}
Number of unhatched eggs	12.00±1.21^{c}	16.00±1.32^{b}	24.00±1.22^{a}	26.00±1.03^{a}
Number of chick hatched	63.00±3.27^{a}	59.00±1 03^{b}	51.00±1.24^{c}	49.00±1.23^{d}
No. of fertile eggs not hatched	7.00±0.02^{c}	9.00±1.15^{c}	18.00±1.15^{a}	14.00±1.12^{b}
% Unhatched eggs to total eggs set	16.00±1.45^{d}	21.33±2.23^{c}	32.00± 1.26^{b}	34.67±2.15^{a}
% Hatchability of fertile eggs	90.00±1.01^{a}	86.76±1.00^{b}	73.91±1.03^{d}	77.78±1.01^{c}
% Hatchability of total egg set	84.00±1.23^{a}	78.67±2.12^{b}	68.00±1.43^{c}	65.33±1.23^{c}
% Late embryonic mortality	10.00±2.03^{d}	13.24±2.07^{c}	26.09±1.23^{a}	22.22±2.42^{b}

a,b,c,d = Means on the same rows but with different superscripts are statistically (P<0.05) significant.

Outside these, fertility and hatchability of avian eggs are also compromised by the age of a hen during reproduction which can significantly influence embryo development and hatching (Seker *et al.*, 2004). Hatchability of incubated eggs has also been observed to reduce as the age of birds increased (Elibol *et al*, 2002). Increased embryo mortality in eggs of older laying hens compared to younger ones was recorded (Sahan and Ipek, 2000). Farooq *et al*. (2001) reported that shell weight together with egg weight are the two important factors affecting hatchability while Alkan *et al*. (2008) noted that hatchability of incubated eggs decreased with increased in egg weight.

Table 3 presents the results of testicular morphometry and testicular homogenate parameters of male Japanese quails reared under different stocking densities at transition period of rainy to dry season. The results showed that there were no significant differences (P≥0.05) in left testicular volume, testicular sperm count, gonadal sperm reserve, daily sperm production, and Spermatogenic efficiency. Left testicular weight revealed significant difference (P≤0.05) and the weight decreased with increasing stocking densities with highest weight in T1 (3.28±0.13g) and lowest weight in T4 (1.73±0.40g) while in the right testicular weight, the highest weight was observed in T1 (3.30±0.24g) and decrease in T2 (1.95±0.28g) which was not statistically different (P≥0.05) from the mean value of T3 and T4 (2.23±0.30g and 1.76±0.12g) respectively.

Right testicular volume was highest in T1 (2.53±0.21ml) and lowest in T2 (1.73±0.26ml) which was not significantly different (P≥0.05) from the values of T3 and T4 (1.85±0.10ml and 1.76±0.12ml) respectively. Left testicular density was also different significantly (P≤0.05) and decreased with increasing stocking densities from T1–T4 (1.44±0.20g/ml, 1.30±0.04g/ml,1.02±0.07g/ml and 0.88±0.12g/ml) respectively. Paired testicular weight also decreased as the stocking densities increased with the highest mean value in T1 (6.58±0.36g) and the lowest mean value in T4 (3.49±0.32g). Average testicular weight also showed similar pattern with the highest mean value in T1 (3.29±0.18g) and lowest mean value in T4 (1.74±0.16g).

The assessment of the reproductive organs is one of the requirements for the assessment of and prediction of sperm, storage potential and fertilizing ability of breeder male (Egbunike, *et al.,* 1976). Heat stress affects all phases of semen production in breeder cocks (Banks *et al*., 2005). In a prolonged time, it depresses reproductive capacity due to a decrease in seminiferous epithelial cell differentiation. This is manifested by reduced semen quality and quantity (McDaniel *et al,* 1996; Obidi *et al,* 2008). Heat stress affects testicular function through inhibition of intracellular ion exchange (McDaniel *et al,* 1995; 1996).

Table 3: Testicular Morphometry and Testicular Homogenate Parameters of Male Japanese Quails Reared under different Stocking Densities

Parameters	T1	T2	T3	T4
Left testicular weight (g)	3.28±0.13^{a}	2.73±018^{ab}	2.33±0.20^{bc}	1.73±0.40^{c}
Right testicular weight (g)	3.30±0.24^{a}	1.95±0.28^{b}	2.23±0.30^{b}	1.76±0.12^{b}
Left testicular volume (ml)	2.48±0.50^{a}	2.10±0.18^{b}	2.29±0.18^{b}	1.98±0.35^{c}
Right testicular volume (ml)	2.53±0.21^{a}	1.73±0.26^{b}	1.85±0.10^{b}	1.76±0.12^{b}
Left testicular density (g/ml)	1.44±0.20^{a}	1.30±0.04^{ab}	1.02±0.07^{bc}	0.88±0.12^{c}
Right testicular density (g/ml)	1.32±0.09	1.14±0.08	1.22±0.17	1.00±0.00
Paired testicular weight (g)	6.58±0.36^{a}	4.68±0.40^{b}	4.55±0.50^{b}	3.49±0.32^{b}
Average testicular weight (g)	3.29±0.18^{a}	2.34±0.20^{b}	2.28±0.25^{b}	1.74±0.16^{b}
Testicular sperm count (x10^{8})	4.14±0.25	3.48±0.61	3.01±0.98	3.24±0.50
Gonadal sperm reserve (x10^{8})	27.24±1.01	16.29±1.54	13.70±2.73	11.31±1.83
Daily sperm production (x10^{8})	10.14±3.74^{a}	6.06±1.32^{b}	5.09±1.02^{b}	4.20±1.42^{c}
Spermatogenic efficiency (x10^{8})	1.54±0.67	1.29±0.09	1.12±0.85	1.20±0.79

a,b,c, = Means on the same rows but with different superscripts are statistically (P<0.05) significant. T1 = 252.20cm^{2}/bird (11 birds), T2 = 173.43cm^{2}/bird (16 birds), T3 = 132.10cm^{2}/bird (21 birds) and T4 = 106.73cm^{2}/bird (26 birds).

The results in table 3 showed significant differences (P<0.05) in left and right testicular weight (3.28±0.13 and 3.30±0.24), left and right testicular volume (2.48±0.50 and 2.53±0.21), left testicular density (1.44±0.20), paired testicular weight (6.58±0.36) and average testicular weight (3.29±0.18) which were all highest in T1. Significant differences were not observed in testicular sperm count, gonadal sperm reserve, gonadal sperm production and spermatogenic efficiency. However, the results revealed a positive relationship between testicular weight, testicular volume and testicular density on testicular sperm count, gonadal sperm reserve and spermatogenic efficiency which decreased with increasing stocking density. The weight of the testis is one of the standards for measuring sperm producing ability of animal and hence determines the reproductive efficiency of male stock selected for breeding (Okwun *et al.,* 1996; Aro *et al.,* 2011). The trend observed in this study indicated that increased testicular weight, testicular volume and testicular density all probably predisposed birds to higher sperm production. This support Aro *et al.,* (2012) that the heavier the testicle, the more the volume it will occupy in space and the larger the testicular volume, the larger the absolute volume of the seminiferous tubules and hence the higher their capacity for spermatogenesis. The result is also in accordance with the report of Oyeyemi and Okediran (2007) that larger testes without any abnormality produce more spermatozoa than smaller testes. High stocking density might impair spermatogenesis by reducing testicular germ cell proliferation and increasing apoptosis Kanter *et al.,* (2013). Environmental heat stress has also been reported to affect sperm head ellipticity in rams (Armengo *et al.,* 2015).

Conclusion

The results of this study revealed that the weight of the ovary was not different among the treatment level, the weight of the oviduct and entire reproductive tract were better at T2. However, the number of Graafian follicles, pre-ovulatory follicles and number of maturing follicles seems to be better at T3. Number of fertile egg and percentage fertility were highest in T1 and compared favourably with birds in T3 while the number of infertile eggs and percentage Infertility were both highest in T4. Number of chick hatched, percentage hatchability of fertile eggs and percentage hatchability of total egg set were negatively affected which was better in quail in T1. Stocking density does not affect testicular sperm count, gonadal sperm reserve, gonadal sperm production and spermatogenic efficiency. However, the results revealed a positive relationship between

testicular weight, testicular volume and testicular density on testicular sperm count, gonadal sperm reserve and spermatogenic efficiency which decreased with increasing stocking density. Notwithstanding, stocking density of T3 results compared favourably with the results of T2 and T1 and could therefore be considered for quail production during high environmental temperature without compromising quail welfare and reproductive performance.

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