BVG Trust

J. Sci. Trans. Environ. Technov. 2011, 4(3): 104-110

Scientific Transactions in Environment and Technovation

Egg production performance of pure line Japanese quail breeders under cage and deep litter systems of rearing

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Abstract

A study was conducted to assess the comparative egg production performance of meat type Japanese quail pure line breeders under deep litter and cage systems of management. Cage reared pure line grand parent breeders attained maturity significantly (Pd≤ 0.01) early compared to those reared on deep litter (64.17 ± 1.17 *vs* 71.50 ± 1.18 days) and also attained 50 per cent egg production faster compared to those reared on deep litter (9.16 *vs* 14.83 days). Per cent hen day egg production (13-32 wk) was significantly (P≤ 0.01) higher in cage reared birds compared to deep litter rearing (73.96 ± 0.71 *vs* 64.01 ± 0.87). Age effects and age - system interaction effects were also found to be significant (P≤ 0.01). Peak production was witnessed during 17-20 weeks of age of the breeders which declined as the age advanced. Mean feed efficiency per dozen eggs was not found to be significantly (P>0.05) different between the two systems. However, age effect was found to be significant (P≤ 0.01) and the best feed efficiency figures were noticed mostly between 17-28 weeks of age. Mean egg weight (g) was found to be 15.19 ± 0.03 and 15.45 ± 0.03 under deep litter and cage rearing respectively, and the difference was found to be significant (P≤ 0.01). Mean feed cost (Rs.) for 100 eggs was marginally higher for cage rearing, however the difference was not significant (P>0.05).

Keywords: breeder performance, egg production, egg weight, feed efficiency, Japanese quail

INTRODUCTION

Quail constitute the third largest avian species, in number next only to chicken and ducks, used for commercial poultry production (Agarwal, 1995). Since there is considerable shortage of meat and egg, there exists a scope for increasing the per capita consumption by rearing Japanese quail. Egg production is an important economic trait in poultry breeding that determines the efficiency of chick production for further rearing for meat. It is influenced by several factors *viz.*, nutrition, management, environment etc. Low heritability of egg production clearly points to the profound influence of environment, which necessitates extensive studies on the effect of various non-genetic factors under varied agro-climatic and managemental conditions. The housing system constitutes an important specific environment for the birds. In Japanese quail production also, specific environment under which the birds will have to perform should be kept in mind. Gowe, as early as in 1956, stressed that the efficiency of production is a function of both the genetic potential of the birds and the housing facilities available. The information on the role of housing system is meager in the emerging area of Japanese quail production and the present paper attempts to fulfill this lacuna to some extent.

MATERIALS AND METHODS

The study was undertaken in a commercial Japanese quail breeder farm in Palladam broiler belt in Coimbatore district, Tamil Nadu, India to assess the egg production performance of Japanese quail breeders under cage and deep litter systems of rearing. Pure bred grand parent breeders of meat type Japanese quail (under selection for high 4 week body weight) were reared under cage and deep litter systems of management from 5-32 weeks of age. A total of 1584 adult Japanese quail birds (1152 females and 432 males) were selected at the age of 4 weeks and randomly divided into two treatment groups of equal numbers. Birds under each treatment were further allotted randomly into 3 replicate groups with a breeding ratio of 8 females to 3 males and were reared upto 32 weeks of age under both cage and deep litter systems of management.

The breeder quails were housed in either deep litter or in multi-tier Japanese quail breeder cages, located in a well ventilated open sided poultry house built as per standard norms. A floor space of 225 cm^2 per bird was provided under deep litter system and under cage system, 8 females and 3 males were housed in a breeder cage unit of 2025 cm^2 each, offering a floor space of

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184 cm^2 per bird. Paddy husk was used as litter material in deep litter system of housing and was provided to a height of five cm. Droppings were allowed to stack at the bottom of the cage till the end of the study period. Adequate feeder and waterer space were made available. All the birds were fed with the same quail breeder ration with 19.00 % C.P. and 10.83 MJ/kg of ME *ad libitum* and had free access to wholesome water throughout the experimental period. A total of 15 hours photo period per day was ensured from 7-32 weeks of age.

Data on age and body weight at sexual maturity, age at 50% production, per cent hen day egg production, egg weight, feed efficiency per dozen eggs and feed cost per 100 eggs were collected and subjected to statistical analysis.

Statistical analysis

The data were grouped and subjected to analysis of variance. All the percentage values in the experiment were transformed to their arcsine roots before subjecting them to statistical analysis. The paired values were subjected to analysis following students 't' test. The procedures set out in Snedecor and Cochran (1989) were adopted for the purpose.

RESULTS

Age at sexual maturity

Mean (± S.E.) age and body weight at sexual maturity values obtained under deep litter and cage rearing are presented in table 1. Cage reared pure line parent breeders of Japanese quail attained maturity significantly (P≤0.01) early compared to those reared on deep litter (64.17 ± 1.17 *vs* 71.50 ± 1.18 days), and they also reached 50% egg production much quicker than their contemporaries reared on deep litter (9.16 *vs* 14.83 days) since attaining maturity.

Table 1. Mean (± S.E.) age and body weight at sexual maturity and age at 50% egg production in Japanese quail breeders under deep litter and cage system

Parameter	Deep Litter	Cage	't' value
Age at sexual maturity (days)	$71.50^{b} \pm 1.18$ (6)	$64.17^{a} \pm 1.17$ (6)	4.427**
Age at 50% egg production (days)	$86.33^{b} \pm 2.23$ (6)	$73.33^{a} \pm 1.41$ (6)	4.929**
Body weight at sexual maturity (g)	$343.20^{a} \pm 3.39$ (60)	$332.33^{b} \pm 2.45$ (60)	2.600*

** Highly Significant (P ≤ 0.01). * Significant (P ≤ 0.05). Means bearing different superscripts differ significantly among columns within each row. Figures in parentheses indicate respective number of observations.

Body weight at sexual maturity

The body weight at sexual maturity was lower for cage reared female breeders compared to deep litter reared breeders (332.33 ± 2.45 *vs* 343.20 ± 3.39) and the difference so observed was significant at five per cent level.

Egg production

Egg production among Japanese quail breeders was recorded from the day of attaining sexual maturity upto 32 weeks. As the breeders attained age at 50% production only between 10-12 weeks, egg production parameters were grouped for every 4-week period starting from 13-weeks of age upto 32 weeks and compared.

Per cent hen day egg production

Per cent hen day egg production from 13-32 weeks of age in cage reared birds averaged 73.96 ± 0.71 compared to 64.01 ± 0.87 among deep litter reared breeders. The same was found to be the highest between 17-20 weeks (76.71 ± 0.60) and the level of laying came down gradually thereafter to reach the lowest level of 61.10 ± 0.69 between 29-32 weeks of age (Table 2). The age effect was almost similar under both the systems of rearing even though the system effect was almost found to be nullified at 29-32 weeks of age with both the groups of birds under cage and deep litter rearing registering almost equal levels of laying intensity.

Table 2. Mean (± S.E.) per cent hen day egg production of Japanese quail breeders from 13 to 32 weeks of age under deep litter and cage system

Age in weeks	Deep Litter	Cage	Overall Mean (age)
13 - 16	$59.34^{Bc} \pm 1.29$ (84)	$83.17^{Aa} \pm 0.49$ (84)	$71.26^{b} \pm 1.15$ (168)
17 - 20	$71.19^{Ba} \pm 0.70$ (84)	$82.24^{Aa} \pm 0.48$ (84)	$76.71^{a} \pm 0.60$ (168)
21 - 24	$65.81^{Bb} \pm 0.81$ (84)	$75.18^{Ab} \pm 0.62$ (84)	$70.50^{b} \pm 0.63$ (168)
25 - 28	$62.11^{Bc} \pm 0.71$ (84)	$68.64^{Ac} \pm 0.61$ (84)	$65.37^{c} \pm 0.53$ (168)
29 - 32	$61.60^{c} \pm 0.89$ (84)	$60.61^{d} \pm 1.05$ (84)	$61.10^{d} \pm 0.69$ (168)
Overall Mean (system)	$64.01^{B} \pm 0.87$ (420)	$73.96^{A} \pm 0.71$ (420)	

Means bearing different superscripts in upper case alphabet differ significantly (P ≤ 0.01) among columns within each row. Means bearing different superscripts in lower case alphabet differ significantly (P ≤ 0.05) among rows within each column. Figures in parentheses indicate respective number of observations.

Egg weight (g)

Eggs produced by breeders kept in cages were significantly (P≤0.01) heavier than those laid by deep litter reared birds (15.45 ± 0.03 *vs* 15.19 ± 0.03 g). Age effect was also found to be significant (P≤0.01) with the heaviest eggs (15.73 ± 0.08 g) recorded at 12 weeks of age, which was significantly different from mean egg weights recorded at 20, 24, 28 and 32 weeks of age (Table 3). Age x system interaction effects were also significant (P≤ 0.01) and differences in mean egg weights between cage and deep litter reared birds were not significant at 16 and 20 weeks of age.

Table 3. Mean (± S.E.) egg weight (g) of Japanese quail breeders under deep litter and cage system

Age in weeks	Deep Litter	Cage	Overall Mean (age)
12	$15.49^{Ba} \pm 0.09$ (18)	$15.97^{Aa} \pm 0.10$ (18)	$15.73^{a} \pm 0.08$ (36)
16	$15.41^{a} \pm 0.18$ (18)	$15.47^{b} \pm 0.12$ (18)	$15.44^{ab} \pm 0.11$ (36)
20	$15.39^{a} \pm 0.07$ (92)	$15.39^{b} \pm 0.06$ (88)	$15.39^{b} \pm 0.05$ (180)
24	$14.99^{Bc} \pm 0.05$ (81)	$15.49^{Ab} \pm 0.05$ (76)	$15.23^{c} \pm 0.04$ (157)
28	$15.07^{Bb} \pm 0.06$ (49)	$15.40^{Ab} \pm 0.07$ (48)	$15.23^{c} \pm 0.05$ (97)
32	$15.07^{Bb} \pm 0.06$ (45)	$15.35^{Ab} \pm 0.07$ (43)	$15.21^{c} \pm 0.05$ (88)
Overall Mean (system)	$15.19^{B} \pm 0.03$ (303)	$15.45^{A} \pm 0.03$ (291)	

Means bearing different superscripts in upper case alphabet differ significantly (P ≤ 0.01) among columns within each row. Means bearing different superscripts in lower case alphabet differ significantly (P ≤ 0.05) among rows within each column. Figures in parentheses indicate respective number of observations.

Feed efficiency per dozen eggs

Mean (± S.E.) feed efficiency in terms of kg of feed required to produce one dozen eggs given in table 4 shows that the same did not differ significantly (P>0.05) between cage and deep litter rearing of Japanese quail breeders. Among age groups, feed efficiency was significantly (P≤0.01) poorer only during 29-32 weeks of age compared to all other early age groups. Age x system interaction effect was significant (P≤0.01) with feed efficiency for cage reared birds remaining better than the same under deep litter rearing during 13-16 weeks of age alone.

Feed cost for 100 hatching eggs (Rs.)

Mean (± S.E.) feed cost (Rs.) to produce 100 hatching eggs was arrived at by taking into account the data on mean egg production, feed consumption and cost of breeder ration at the time of experiment. No significant difference (P>0.05) in feed cost for 100 hatching eggs was observed between deep litter and cage systems of rearing with the respective values of 95.56 ± 3.17 and 96.80 ± 2.86 (Table 5). However, it became significantly (P≤0.01) costlier to get 100 hatching eggs at the older age of 29-32 weeks (Rs 111.16 ± 2.94) compared to all early age groups analysed. Age x system interaction effect was also found to significantly (P≤0.01) influence the above economics. Cost of getting hatching eggs was significantly costlier for deep litter rearing compared to cage rearing during early age of 13-16 weeks while the reverse was true during the older age of 29-32 weeks.

Table 4. Mean (± S.E.) feed efficiency (Kg of feed per dozen eggs) of Japanese quail breeders under deep litter and cage system

Age in weeks	Deep Litter	Cage	Overall Mean (age)
13 - 16	$1.34^{Bb} \pm 0.08$ (12)	$1.05^{Aa} \pm 0.02$ (12)	$1.20^{a} \pm 0.05$ (24)
17 - 20	$1.09^{a} \pm 0.02$ (12)	$1.14^{a} \pm 0.02$ (12)	$1.12^{a} \pm 0.02$ (24)
21 - 24	$1.04^{a} \pm 0.02$ (12)	$1.17^{a} \pm 0.02$ (12)	$1.11^{a} \pm 0.02$ (24)
25 - 28	$1.08^{a} \pm 0.03$ (12)	$1.14^{a} \pm 0.04$ (12)	$1.11^{a} \pm 0.02$ (24)
29 - 32	$1.30^{b} \pm 0.04$ (12)	$1.43^{b} \pm 0.06$ (12)	$1.36^{b} \pm 0.04$ (24)
Overall Mean (system)	1.17 ± 0.03 (60)	1.19 ± 0.02 (60)	

Means bearing different superscripts in upper case alphabet differ significantly (P ≤ 0.01) among columns within each row. Means bearing different superscripts in lower case alphabet differ significantly (P ≤ 0.05) among rows within each column. Figures in parentheses indicate respective number of observations.

Table 5. Mean (± S.E.) feed cost (Rs.) for 100 hatching eggs under deep litter and cage system

Age in weeks	Deep Litter	Cage	Overall Mean (age)
13 - 16	$109.31^{Bb} \pm 4.53$ (12)	$85.94^{Aa} \pm 1.21$ (12)	$97.63^{a} \pm 4.06$ (24)
17 - 20	$88.91^{a} \pm 0.95$ (12)	$93.18^{a} \pm 1.32$ (12)	$91.04^{a} \pm 1.21$ (24)
21 - 24	$85.28^{a} \pm 1.31$ (12)	$95.23^{a} \pm 1.37$ (12)	$90.26^{a} \pm 1.21$ (24)
25 - 28	$88.54^{a} \pm 1.75$ (12)	$93.08^{a} \pm 2.06$ (12)	$90.81^{a} \pm 1.93$ (24)
29 - 32	$105.78^{Ab} \pm 2.32$ (12)	$116.54^{Bb} \pm 3.17$ (12)	$111.16^{b} \pm 2.94$ (24)
Overall Mean (system)	95.56 ± 3.17 (60)	96.80 ± 2.86 (60)	

Means bearing different superscripts in upper case alphabet differ significantly (P ≤ 0.01) among columns within each row. Means bearing different superscripts in lower case alphabet differ significantly (P ≤ 0.05) among rows within each column. Figures in parentheses indicate respective number of observations.

DISCUSSION

Age at sexual maturity

Cage system of rearing was found to result in significantly (P≤0.01) early age at sexual maturity compared to deep litter rearing. The results are in conformity with the findings of Kundu *et al.* (2003) and Biswas *et al.* (2005) that cage rearing favoured early maturity. Easy access to feed and water, lack of competition and social order issues and proximity to source of light might have contributed to better nutrition and early initiation of physiological processes leading to attainment of early maturity in cage rearing.

The mean age at sexual maturity observed were higher than most of the earlier reports of 54.41 (Praharaj *et al.*, 1990), 44.55 (Prabakaran *et al.*, 1991), 42 (Mahipala *et al.*, 1998) and 45.2 days (Erensayin and Camci, 2003). As the basic stock used were of meat type Japanese quail breeders, selection for body weight and consequent higher growth rate might have evoked a correlated response in age at maturity. Marks (1996) and Suda and Okamoto (2003) also observed that long term selection for bodyweight negatively impaired sexual maturation. Gunes and Cerit (2001) too remarked that sexual maturity was delayed in high bodyweight group.

Age at 50% production

Deep litter reared birds attained age at 50% production significantly (P≤0.01) later than cage reared birds and hence, the attainment of early maturity under cage rearing hastened the age at 50% production also. Moreover, the number of days to reach 50% production after maturity was also found to be prolonged for deep litter rearing compared to cage rearing (14.83 *vs* 9.16). Reasons cited earlier like easy access to feed and water, lack of competition to such access and proximity to source of light might have contributed to lower age at 50% production under cage rearing.

Mean age at 50% production observed in this study were also relatively higher and delayed compared to earlier reports of 49 (Gildersleeve *et al.*, 1987), 56 and 60 (Phogat, 1983) and 47 days (Aktan *et al.*, 2003). As described earlier, the genetic differences might have contributed to the delay as meat type Japanese quail breeders selected for high 4-week bodyweight were involved in this study.

Body weight at sexual maturity

Body weight at sexual maturity (g) was significantly (P≤0.01) lower for cage reared birds than deep litter reared birds. As maturity was attained by deep litter birds a week later than cage reared birds, they would have gained in body weight during the period leading to the above difference. Body weight at sexual maturity of Japanese quail breeders involved in this study ranged between 332-343 g which was much higher than the earlier reports of 135.72-145.92 g (Prabakaran *et al.*, 1991), 169 g (Mahipala *et al.*, 1998), 255.35 g for females (Aktan *et al.*, 2003) and 258-262 g (Reddish *et al.*, 2003). The observations indicate that the lines were in fact selected for high growth rate and genetically superior to the lines reported so far.

Per cent hen day egg production

Mean per cent hen day egg production was found to be significantly (P≤0.01) higher for cage rearing than deep litter rearing of Japanese quail breeders. The results are in agreement with the findings of Viswanathan (1991), Kundu *et al.* (2003) and Biswas *et al.* (2005). Apart from comparatively easier access to feed and water and lesser social stress, the fact that the cage reared birds remain practically away from the micro-organisms that could be present in their droppings and find a way into the litter and relatively lower levels of ammonia at the bird level in cages compared to deep litter, as droppings of Japanese quail contain higher amount of uric acid, might have also contributed to better performance by cage reared birds.

Mean per cent hen day egg production observed in this study was in agreement with the earlier reports by Avci *et al.* (2005). However, Bhanja *et al.* (2006) and Yesilbag (2007) reported comparatively higher egg production while Chopra and Singh (1994) and Kundu *et.al.* (2003) reported lower values. Praharaj *et al.*, (1990) and Saini *et al.* (2005) had vouched that genetic differences consequent to selection could lead to variation in egg production among different lines. Sachdev and Ahuja (1986) concluded that the drop in egg production was very sharp in birds weighing more than 220 g. Age was also found to have significant (P£0.01) influence on per cent hen day egg production and peak production was achieved between 17-20 weeks of age irrespective of housing system and a gradual decline was noticed uniformly thereafter. Bhanja *et al.* (2006) also observed that 14-20 week production was much higher than 7-13 week production at all cage intensity levels.

Delayed age at maturity witnessed in deep litter reared breeders might have led to comparatively poorer per cent hen day egg production between 13-16 weeks resulting in significant (P≤0.01) age x system interaction effects in this experiment.

Egg weight

Mean egg weight (g) of Japanese quail breeders at different ages under the two systems of housing management ranged between 14.99-15.97 and the values were much higher than those reported by Asasi and Jaafar (2000) and Yesilbag (2007), indicating the genetic superiority of the stock employed. As egg weight is positively influenced by the body weight of females, selection for high 4-week body weight might have led

to higher adult body weight of female breeders and consequently resulted in higher egg weights too. Cage rearing resulted in significantly (P≤0.01) higher mean egg weights compared to deep litter rearing. Restricted movement of breeders in cages also might have resulted in higher adult body weight leading to higher egg weights also. Further, observations of Mahapatra *et al.* (1988), Kundu *et al.* (2003) and Biswas *et al.* (2005) are also in conformity with the findings that cage rearing resulted in comparatively higher mean egg weight.

It was quite peculiar to notice that mean egg weight significantly (P≤0.01) came down as age of Japanese quail breeders advanced. In chicken and most of the other poultry species, mean egg weight normally increases with advancing age as also adult bodyweight of females. Shrivastava *et al.* (1994), and Seker *et al.* (2005) also showed that egg weights in Japanese quail too had a positive relationship with age. However, Yannakopoulos and Tserveni-Gousi (1987) reported that peak egg weights were achieved at 10-14 weeks and Cerit and Altinel (1998) at 5 months of age.

Feed efficiency per dozen eggs

Mean feed efficiency per dozen eggs did not differ significantly (P>0.05) between deep litter and cage systems of rearing of Japanese quail breeders. It could be explained by the fact that, even though comparatively higher values for mean per cent hen day egg production were obtained for cage rearing over deep litter system, mean feed consumption per bird per day was also higher under cage rearing compared to deep litter rearing. As higher egg production levels were accompanied by higher level of mean feed consumption, the relative advantage got nullified and net feed efficiency figures for one dozen eggs did not ultimately differ among the two different systems.

Bandyopadhyay and Ahuja (1990) and Nagarajan *et al.* (1990) reported comparatively better feed efficiency figures under cage rearing. It could be explained by the difference in genetic potential of the breeders employed and meat type heavy breeders could only be expected to perform poorly in this count. Age effect on mean feed efficiency per dozen eggs was, however, found significant (P≤0.01) and the poorest feed efficiency was observed between 29-32 weeks, while the birds were the most efficient between 17-28 weeks of age when they reached their peak egg production level. Age x system effect was also significant (P≤0.01).

Feed cost for 100 hatching eggs

Mean feed cost required to produce 100 hatching eggs was not found to differ significantly (P>0.05) between the two rearing systems of deep litter and cage rearing. Even though, mean per cent hen day egg production was higher for cage rearing, higher mean feed consumption observed for this system had offset the advantage of high production leading to comparable feed cost to produce hatching eggs. However, age was found to have a significant (P≤0.01) bearing, with the mean feed cost for 100 hatching eggs found to be the highest at the oldest age of 32 weeks. It is explained by the fact that the rate of lay came down at this age while mean feed consumption remained higher. The above cost remained the least and comparable between 17-20, 21-24 and 25-28 weeks.

Age x system interaction was significant (P≤ 0.01) with the cage rearing favouring cheaper production of hatching eggs during 13-16 weeks while deep litter was being more favourable during 29-32 weeks of age. As deep litter reared birds attained maturity late and showed poor egg number between 13-16 weeks, the same would have caused higher feed cost for 100 hatching eggs at this age.

Mean feed cost for 100 hatching eggs obtained in this study for the deep litter and cage rearing averaged Rs.95.56 and Rs.96.80 and were almost double the cost reported by Sathish kumar (2003) involving cage rearing of Japanese quail breeders. The difference in genetic merit of the breeders used and consequent variation in mean egg production and ever rising cost of feed ingredients might have been responsible for the relatively higher costs in this study.

ACKNOWLEDGEMENT

The authors thank the Tamil Nadu Veterinary and Animal Sciences University, Chennai, Tamil Nadu for the facilities provided.

REFERENCES

Agarwal, S.K., 1995. Quail production in India. *In:Proc. XX World's Poultry Congress;* 1995 September 2-5; New Delhi, India. III: 705-710.

Aktan, S., Koskan, Ö., Özsoy, A.N. and Akcadag, H.I. 2003. Some egg production characteristics and phenotypic correlations in Japanese quail. *Hayvanalik Arastirma Dergisi*, 13: 57-59.

Asasi, K. and Jaafar, A.J. 2000. The effect of sex ratio on egg production, fertility and hatchability of Japanese quail. *Pajouhosh-va-sazandegi*, 4: 128-131.

Avci, M., Yerturk, M. and Kalpan, O. 2005. Effect of Vitamin E on egg production and egg quality in Japanese quail. *Indian Vet. J.*, 82: 969-971.

Bandyopadhyay, U.K. and Ahuja, S.D. 1990. Effect of cage density on some of the performance traits in Japanese quail. *Indian J. Poultry Sci.*, 25: 123-128.

Bhanja, S.K, Agarwal, S.K. and Majumdar, S. 2006. Effect of cage floor space on the egg production performance of Japanese quail during winter. *Indian J. Poultry Sci.*, 41: 205-207.

Biswas, P.K., Roy, S.P., Goswami, A. and Mondal, M.K. 2005. Studies on performances of Japanese quail under different system of rearing. *In: Proc. 23rd Indian Poultry Science Association Conference;* 2005 February 2-4; Hyderabad, India. 2: 215.

Cerit, H. and Altinel, A. 1998. Genetic and phenotypic parameters of various traits in the Japanese quail. *Veteriner Fakultesi Dergisi (Istanbul)*, 24: 111-136.

Chopra, S.K. and Singh, R.A. 1994. Effect of hatching season and housing system on the reproductive performance of Japanese quail. *Indian J. Poultry Sci.*, 29: 56-62.

Drbohlav, V. and Metodiev, S. 1996, Possibility of selection on laying intensity in Japanese quail. *Bulg. J. Agric. Sci.*, 2: 497-500.

Erensayin, C. and Camci, O. 2003. Effect of clutch size on egg production in Japanese quail. *Archiv fiir Geffliigelkunde* 67: 38-41.

Gildersleeve, R.P., Sugg, D. and McRee, D.I. 1987. Egg production in four generations of paired Japanese quail. *Poultry Sci.*, 66: 227-230.

Gowe, R.S., 1956. Environment and poultry breeding problems. 2. A comparison of the egg production of 7 single comb White Leghorn strains housed in lying batteries and floor pens. *Poultry. Sci.*, 35: 430-435.

Gunes, H. and Cerit, H. 2001. Interrelationships between age of sexual maturity, body weight and egg production in the Japanese quail. *Veter. Fak. Der. (Istanbul)*, 27: 191-198.

Kundu, A., Senani, S., Ahlawat, S.P.S., Rai, R.B., Yadav, S.P., Chatterjee, R.N., Saha, S.K., Kumar, S.J. and Jai Sunder, 2003. Performance of Japanese quail under cage and deep litter system of rearing in Andaman and Nicobar Islands. *Indian J. Poultry Sci.*, 38: 63-66.

Mahapatra, C.M., Sachdev, A.K. and Thomas, P.C. 1988. Effect of housing system on egg quality in Japanese quail. *Indian J. Anim. Sci.*, 58: 1125-1126.

Mahipala, M.B.P., Hashiguchi, M. and Kamisoyama, H. 1998. Body characteristics, development of reproductive organs, Carcass composition and onset of sexual maturity in the female Japanese quail. *Trop. Agric. Res.*, 10: 372-382.

Marks, H.L., 1996. Long-term selection for body weight in Japanese quail under different environments. *Poultry Sci.*, 75: 1198-1203.

Nagarajan, S., Narahari, D. and Alfred Jayaprasad, I. 1990. Laying performance of Japanese quail hens under different stocking densities. *Indian J. Anim. Sci.*, 60: 1467-1470.

Phogat, S.B., 1983. Effect of red and green light on growth and reproduction of Japanese quail. M.Sc. thesis, Haryana Agricultural University, Hisar, Haryana, India.

Prabakaran, R., Mujeer, K.A., Ahmed, M., Thangavel, A. and Sundararasu, V. 1991. Effect of photoperiod on the laying performance of Japanese quail. *J. Vet. Anim. Sci.*, 22: 5-8.

Praharaj, N.K., Ayyagiri, V. and Mohapatra, S.C. 1990. Studies on production and growth traits in quail. *Indian J. Poultry Sci.*, 25: 1-7.

Reddish, J.M., Nestor, K.E. and Lilburn, M.S. 2003. Effect of selection for growth on onset of sexual maturity in random-bred and growth-selected lines of Japanese quail. *Poultry Sci.*, 82: 187-191.

Sachdev, A.K. and Ahuja, S.D. 1986. Studies on the influence of bodyweight at sexual maturity on production traits in Japanese quail. *Indian J. Poultry Sci.*, 21: 66-68.

Saini, S., Brah, G.S. and Chaudhary, M.L. 2005. Effect of genetic selection for growth rate on egg production in Japanese quail. *In: Proc. 23rd Indian Poultry Science Association Conference;* 2005 February 2-4; Hyderabad, India. 2: 215.

Sathishkumar, A., 2003. Recycling of Japanese quail hatchery waste in their breeder diets. M.V.Sc. thesis, Tamil Nadu Veterinary and Animal Sciences University, Chennai, Tamil Nadu, India.

Seker, I., Kul, S., Bayraktar, M. and Yildirim, O. 2005. Effect of layer age on some egg quality characteristics and egg production in Japanese quail (coturnix coturnix japonica). *Veteriner Fakultesi Dergisi. (Istanbul)*, 31: 129-138.

Shrivastava, S.K., Ahuja, S.D., Singh, R.P. and Bandyopadhyay, U.K. 1994. Influence of rearing mixed and separate sexes of Japanese quail on egg production and egg quality. *Indian J. Poultry Sci.*, 29: 151-156.

Snedecor, G.W. and Cochran, W.G. 1989. Statistical Methods. 8th edition. Oxford and IBH Publishing Co., Calcutta.

Suda, Y. and Okamoto, S. 2003. Long term selection for small body weight in Japanese quail. II: Changes in reproductive traits from 60 to 65th generations. *J.Poult. Sci.*, 40: 30-38.

Viswanathan, K., 1991. Productive efficiency of Japanese quail. Ph.D. thesis, Tamil Nadu Veterinary and Animal Sciences University, Chennai, Tamil Nadu, India.

Yannakopoulos, A.L. and Tserveni-Gousi, A.S. 1987. Effect of breeder quail age and egg weight on chick weight. *Poult. Sci.*, 66: 1558-1560.

Yesilbag, D., 2007. The effects of dietary boric acid supplementation on growth performance and egg shell quality in layer quail. *Indian Vet. J.*, 84: 1058-1061.