Biotechnology in Animal Husbandry 31 (2), p 163-174 , 2015 ISSN 1450-9156
Publisher: Institute for Animal Husbandry, Belgrade-Zemun UDC 636.5'637.4
DOI: 10.2298/BAH1502163M

EFFECT OF SEX-LINKED DWARF GENE ON EXTERIOR APPEARANCE, PRODUCTIVE PERFORMANCE AND EGG CHARACTERISTICS IN A COLORED BROILER DAM LINE

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Original scientific paper

Abstract: The effect of sex-linked dwarf gene was investigated through comparison of dwarf hens with their full-sib normal sisters obtained by mating heterozygous males (DW/dw) to normal females (DW/_) from line F (used as maternal form for production of slow-growing colored chickens) with respect to the following traits: body weight, shank and keel length at 40 weeks of age, age of sexual maturity (at 50 % production), egg production, egg weight, feed intake, feed utilization, livability, fertility, hatchability and egg quality characteristics. The results demonstrated that the dw gene caused statistically significant reduction of body weight by 29.15 %, shank length by 20.17 %, keel length by 7 % and egg weight by 5.72 % ($p<0.001$). The hens with normal genotype attained sexual maturity 7 days earlier ($p<0.001$), but nevertheless, rate of lay was similar to that of mini forms. There were no considerable differences between both genetic groups with respect to livability percentage over the production cycle. Dwarf hens consumed by 23.38 % less feed ($p<0.01$) than normal sized hens and converted nutrients more efficiently by 12.69 % ($p<0.05$). The presence of dw gene in hen genotype increased the eggshell percentage, reduced egg yolk and albumen weights and had no effect on their quality. The positive effect of the sex-linked dwarf gene on economically important traits – feed intake and feed conversion, hatchability of eggs set, is a prerequisite for the development of more efficient broiler breeder hens for production of slow-growing chickens.

Key words: Sex-linked dwarf gene, broiler breeder hens, production traits, reproductive fitness

Introduction

Efficiency is a key factor in poultry breeding. One of the possible ways for its improvement is the utilization of mini-hens, carriers of a recessive gene located in the sex chromosome. On the basis of extensive literature data, *Merat (1990)* outlines that the so called dwarf gene, described by *Hutt (1959)*, results in reduction of body weight of birds by 33 % and feed consumption by 20-25 %. The existing interest towards the practical application of that gene is due to several advantages of mini hens: higher stocking density per square meter *(Charpentier, 2009)*, better utilization of dietary nutrients for egg production *(Galal and Younis, 2006; Galal et al. 2007)*, no need from application of restricted feeding programmes *(Decuypere et al., 2006; Dawkins and Layton, 2012)*, higher survival rate (*Garcês et al., 2001*), better reproduction ability *(Decuypere et al., 2012)*, better resistance to heat stress *(Gowe and Fairfull, 1995; Rashid et al., 2005; Islam, 2005*). These advantages resulted in using the dwarf gene in some broiler breeder maternal lines for production of standard broilers, chickens with medium growth or slow growth such as the Label rouge type. Data reported by *EFSA (2010)* showed that in Europe, female dwarf broiler breeders are 18-20 %, whereas in France, constitute the major part of broiler hens.

The production of broilers from mini maternal forms is based on the acknowledged fact that when the sire is from the standard DW/DW genotype, the progeny is of normal body size.

The most commonly used breeding scheme for production of dwarf maternal form is through crossing homozygous recessive dwarf male *dw*/*dw* with a standard female (*DW/_*). A second alternative is to use heterozygous *DW/dw* cocks, but this is related to extra costs and time.

The economically relevant differences between normal and mini-hens vary depending on the production type and genetic diversity of the population, in which the *dw* gene is introduced. The introduction of the gene in light populations leads to delayed sexual maturity and lower egg production (*Merat, 1990; Horst and Becker, 1991; Merat and Bordas, 1991; Merat et al., 1994; Garces et al., 2001; Missohou et al., 2003*), whereas in broiler hens, this negative effect is less pronounced or absent (*Marks, 1981; Kousiakis et al., 1985*). *Anonymous (2003)* reports about relatively higher egg production and higher number of eggs fit for incubation in dwarf breeders consequently to lower number of double-yolk eggs, eggs with soft or thin shell, irregular shape or other defect. After introduction of *dw* gene in broiler lines selected for high egg production, *Leenstra et al. (1986)* established that hens with normal genotype laid about 17 % of all ovulated follicles in defective eggs while for dwarf hens this percentage was only 2 %. The economic analysis of results from using a mini-maternal form for production of broiler chickens showed that financial costs for rearing of the breeder flock were reduced

by 15 %, and for production of one day-old chick – by 20 % (*Charpentier, 2009; Tudik et al., 2011*).

The objective of the present study was to evaluate the effect of sex-linked dwarf gene on exterior appearance and productive performance of hens of a colored broiler dam line used for production of slow-growing chickens.

Materials and methods

Stock, Husbandry and Traits measured

The experiment was performed in the Selection Base of the Poultry Breeding Unit, Agriculture Institute – Stara Zagora from December 2013 to June 2014. Dwarf hens and their normal sibs were used for the current study. They were obtained by mating heterozygous cocks (*DW/dw*) and hemizygous normal hens (*DW/_*) from line F which was developed in the Selection Base and used as maternal form for production of colored slow-growing broiler chickens. Dwarf and normal genotype birds were separated by visual appraisal on the basis of body size and shank length. At 20 weeks of age, two groups were formed - with normal (DW/_) and dwarf genotype (dw/_). Each group consisted of five replicates of 20 hens and 2 cocks, housed in floor pens. The birds were reared until 50 weeks of age under identical conditions, in the same laying house, on wooden shavings litter as required by the production system used in the Selection base, with free access to feed and water. They were fed a diet containing 16 % crude protein and 2750 kcal/kg metabolizable energy.

During the experiment the following parameters were observed:

Body weight and body measurements: Body weight was determined individually at 40 weeks of age for each genotype using a technical balance with precision of 5 g. At the same age, keel length (distance between the anterior and posterior end of the sternum) and shank length (from the top of hock joint to the foot pad) were determined with a measuring tape.

Egg production traits: The number of eggs laid and dead birds was recorded daily for each replicate. On this basis, the hen day egg production (%) was calculated for the entire experimental period. Sexual maturity was determined when 50 % egg production has been reached. Mean egg weight was monitored at 2-week intervals from the beginning of lay to the end of the trial via weighing the daily yield of all replicates of both genotypes. Egg mass was calculated on the basis of hen day egg production and mean egg weight.

Feed intake was recorded at the end of each week. Feed conversion ratio (FCR) was expressed as kg of feed consumed per kg of egg produced.

Egg quality traits were evaluated at 40 weeks of age. For this purpose, 30 eggs from each group (six eggs per replicate), laid within a day were examined.

The weights of the whole egg, albumen, yolk and eggshell (together with membranes) were determined with precision of 0.01 g. Eggshell weight, albumen weight and yolk weight were expressed as a percentage of the egg weight. The length and breadth of eggs were measured using a digital caliper with precision of 0.01 mm. Egg volume and egg surface area were calculated on the basis of exterior egg dimensions (*Narushin, 2005*). Albumen and yolk heights were measured with Ames micrometer (precision 0.01 mm), albumen and yolk diameters – with digital caliper (precision 0.01 mm), eggshell thickness together with the inner membrane – with micrometer (precision 0.001 mm) at three different points (top, middle, and bottom) and presented as average of the three measurements. Egg albumen quality was assessed through albumen index and Haugh units; yolk quality – via the yolk index.

For determination of the reproduction potential of dwarf hens and their full-sib normal sisters, 400 eggs from each group collected over 7 consecutive days at the end of the experiment, were set for incubation. The fertility rate, hatchability of eggs set and hatchability of fertile eggs were calculated on the basis of obtained results.

Statistical Analyses

The analysis of data was performed with Statistica software (Stat Soft), using one-way analysis of variance and the following linear model:

$$Yij = \mu + g_i + e_{ij}, \text{ where}$$

Yij – jth observation of the respective trait

μ - grand mean of the trait

g_i – fixed effect of the ith genotype (i=1,2)

e_{ij} – random error

Results and discussion

The data presented in Table 1 show that under the influence of the *dw* gene, the body weight of mini-forms was reduced by 29.15% as compared to those of their full-sib normal sisters. The dwarf gene does not reduce uniformly the growth of the different body parts. The length of metatarsus was most substantially reduced (20.17%), a reason for the so-called shortlegness of dwarf birds. *Hussain et al. (1982)* have established that the shank length in mini hens was 7-8 cm, while in those of normal size: 9.5-10.5 cm. This finding is in agreement with our results. The keel length changed less markedly (-7%) and the differences between both genotypes were proportional to the change in body weight. The reduction of body weight, shank length and keel length in the present study was confirmed by *Missohou et al. (2003), Chen et al. (2004) Younis and Galal (2006).*

Hens with normal genotype attained sexual maturity 7 days earlier than birds carrying the dwarfing gene (Table 2, p<0.001). This difference is limited by the reduction of body weight and feed intake (*Renden and Marple, 1986*), as well as by the body fat deposition level (*Zelenka et al., 1986*) and the related functional ovarian activity in maturing mini-hens. In their experiments with different polygenic combinations, *Khan and Verma (1983)* demonstrated ages of sexual maturity of 152 and 145 days for (dw) and (DW) broiler breeders, respectively. According to *Sharifi et al. (2010)***,** the sex-linked recessive gene prolonged this age by about two weeks. Opposite data are communicated by *Marks (1981)* and *Sadjadi et al. (1983),* which stated the lack of statistically significant difference between both genotypes. The advantage of mini-breeders vs normal breeders was also reported by *Anonymous (2003),* accounting for a difference of 14 days.

Table 1. Body weight, shank length and keel length of hens as affected by dwarf (dw) gene.

Trait[1]	Genotype		Reduction, %	Significance[2]
	DW/_	dw/_		
BW 40-wk, g	2701.82±69.90	1914.29±68.33	-29.15	***
ShL(cm)	10.36±0.12	8.27±0.10	-20.17	***
KL (cm)	12.86±0.09	11.96±0.15	-7.00	***

[1]BW= body weight, ShL= shank length, KL= keel length;
[2] Significant difference between normal and dwarf hens: *** p<0.001

There were no statistically significant differences between both genotypes with respect to the egg production rate and egg mass, which ranged between 57.23 - 61.63 % and 32.08 – 36.57 g, respectively. The lack of differences in egg production between normal and dwarf sibs is supported by *Marks (1981***).** Presented by *Islam (2005)* reports showed that laying rate decreased by about or more than 10% in strains with low body weight, while this parameter was unchanged or improved in heavy-type birds.

The data for egg weight (Table 2) showed that the presence of dw gene in the genotype of hens reduced considerably the weight of laid eggs by 3.4 g (-5.72%). This could be explained by the existing high positive correlation between body weight and egg weight, as well as the smaller reproductive tract of dwarf hens (*Katongole et al., 1990*). The effect of sex-linked dwarf gene on this trait is confirmed by *Missohou et al. (2003), Galal et al. (2007)***,** whose results provide evidence for lower egg weight by –9% and –4.8%, respectively. According to *Sadjadi et al. (1983)* the reduction of egg weight in birds from the egg-laying type was greater and ranged between –9.6 to –12.6%.

Feed intake and conversion are economically important traits. Under the conditions of this experiment, the presence of the *dw* gene, determining the dwarfism expression in birds, reduced substantially feed consumption by 23.38 %

($p<0.01$) as compared to their normal sibs (Table 2). Mini forms converted feed energy by 12.7% more efficiently ($p<0.05$) for egg mass synthesis. The effect of the gene with respect to these parameters is explained not only by the lower body weight, but also by reduced biochemical activity of the basic metabolism, the higher ratio between anabolic and catabolic processes compared to those in normal sibs, resulting in lower energy demands and more efficient dietary energy utilisation by mini-hens (*Kiselev and Nadalyak, 1985*). Our results are comparable to those reported by *Missohou et al. (2003), Galal and Younis (2006)* and *Galal et al. (2007)*, demonstrating lower feed intake and better feed utilisation under the influence of the dwarf gene.

Table 2. Egg production, feed intake and feed conversation ratio of hens as affected by dwarf gene

Trait	Genotype		Reduction, %	Significance[1]
	DW/_	dw/_		
Age (d) at 50 % lay	180.80±1.07	187.80±0.66	+3.87	***
Hen day egg production (%)	61.63±3.48	57.23±4.13	-7.14	NS
Mean egg weight (g)	59.25±0.13	55.86±0.39	-5.72	***
Egg mass (g/d/hen)	36.57±2.09	32.08±2.42	-12.28	NS
Feed intake (g/d/hen)	163.40±5.35	125.20±8.97	-23.38	**
Feed conversion ratio (kg/kg egg mass)	4.49±0.12	3.92±0.19	-12.69	*
Livability (%)	99.05±1.00	95.00±5.00	-4.09	NS

[1] Significant difference between normal and dwarf hens: * $p<0.05$; ** $p<0.01$; *** $p<0.001$; NS=Not significant

The presence of the *dw* gene in hens' genotype did not have a statistically significant effect on the livability within the duration of the present experiment, as the differences were insignificant. A similar conclusion was drawn by *Ipek et al. (1999)***.** In the view of *Garcês et al. (2001)* birds carrying the dw gene exhibited higher livability percentages than their normal sibs, and *Kousiakis et al. (1985)* reported a high mortality in dwarf hens during the production period.

The data from Table 3 present the results related to reproductive performance in both genotypes. It showed a statistically significant difference ($p<0.05$) only in hatchability from eggs set, higher in mini-forms (18.03%), as confirmed by the studies of *Ipek et al. (1999)***.** The fertility and hatchability of eggs set percentages varied within similar ranges, 86-88 % and 88-91%, respectively. The results of *Kousiakis et al. (1985)* showed a superiority of hens with normal genotype with regard to the fertility and hatchability of eggs set percentages although the hatchability of fertile eggs between the groups was not generally different. On the other hand, *Islam (2004)* and *Tahir et al. (2011)* observed a positive effect of the *dw* gene on fertility and hatchability of eggs. Investigating the fertility rate between dwarf hens and their normal sibs, *Marks (1983)* established identical values of both genotypes. The hatchability of fertile eggs according to the author was by about 10% higher in dwarf hens compared to those of normal sized.

Table 3. Hatching results as affected by dwarf gene

Trait	Genotype		Reduction, %	Significance[1]
	DW/_	dw/_		
Fertility (%)	85.81±0.81	88.00±0.47	+2.55	NS
Hatchability (%)				
- from set eggs	67.68±1.20	79.88±1.42	+18.03	*
- from fertile eggs	87.91±2.89	90.79±2.09	+3.28	NS

[1] Significant difference between normal and dwarf hens: * p<0.05; NS=Not significant,

The data about egg quality traits presented in Table 4 showed that the reduction of egg weight in mini-forms was accompanied by a proportional change in external egg quality characteristics – egg length and breadth, egg volume and egg surface area by -4.10% (p<0.001), -2.27% (p<0.01), -7.97% (p<0.001) and -5.53% (p<0.001) respectively. A marked and statistically significant tendency towards lower egg albumen and yolk weights – by -7.38 and -4.84 % respectively (p<0.05), was present. This was confirmed by *Garcês and Casey (2003)***.** The presence of *dw* gene had a substantial effect on eggshell weight and thickness, as well as on egg quality parameters related to yolk (yolk index) and albumen (Haugh units, albumen height and albumen index). Published data about the influence of the *dw* gene on internal egg quality traits are controversial. Comparing the eggs of hens of a normal genotype with eggs produced by dwarf dams *Islam (2005)* did not found differences in albumen height, similar to our results. *Garcês and Casey (2003)* reported about lower albumen height in eggs of dwarf hens, whereas *Galal et al. (2007)* affirmed that the egg albumen quality of mini-forms was higher.

Table 4. Egg quality traits as affected by dwarf gene

Trait[1]	Genotype		Reduction, %	Significance[2]
	DW/_	dw/_		
External egg quality				
EW (g)	59.75±0.80	54.84±0.89	-8.22	***
B (mm)	43.22±0.24	42.24±0.25	-2.27	**
L (mm)	56.82±0.46	54.49±0.34	-4.10	***
V (cm^3)	56.06±0.72	51.59±0.81	-7.97	***
S (cm^2)	70.68±0.61	66.77±0.70	-5.53	***
EST (mm)	0.304±0.006	0.311±0.005	+2.30	NS
ESW (g)	6.40±0.14	6.31±0.08	-1.41	NS
ESR (%)	10.72±0.20	11.55±0.15	+7.74	**
Internal egg quality				
AH (mm)	6.40±0.23	5.87±0.25	-8.28	NS
AW (g)	35.35±0.77	32.74±0.76	-7.38	*
AR (%)	58.94±0.73	59.44±0.57	+0.85	NS
AI	0.079±0.004	0.076±0.004	-3.79	NS
HU	78.70±1.65	76.52±1.72	-2.77	NS
YI	0.43±0.01	0.42±0.01	-2.33	NS
YW (g)	18.18±0.24	17.30±0.31	-4.84	*
YR (%)	30.47±0.48	31.55±0.51	+3.54	NS

[1]EW= egg weight; B=egg breadth; L=egg length; V=egg volume; S=egg surface area; EST= egg shell thickness; ESW= egg shell weight; ESR= egg shell ratio; AH= albumen height; AW= albumen weight; AR= albumen ratio; AI=albumen index; HU= Haugh unit; YI= yolk index; YW= yolk weight; YR= yolk ratio
[2] Significant difference between normal and dwarf hens: * $p<0.05$; ** $p<0.01$; *** $p<0.001$; NS= Not significant

The analysis of data about egg part proportions in normal and mini-hens, showed similar values for albumen (58.94-59.44 %) and yolk (30.47-31.55 %) proportions, whereas eggshell percentage changed considerably under the influence of the dwarf gene by 7.74 % ($p<0.01$). *Hussain et al. (1982)* and *Islam (2005)* also outlined on influence of the dwarf gene on albumen and yolk percentages, while *Galal et al. (2007)* found out that the presence of the *dw* gene increased considerably the proportion of the yolk and decreased that of albumen. According to the data of authors, the *dw* gene resulted in higher eggshell percentage similar to our findings, whereas *Kousiakis et al. (1985)* established no statistically significant difference between hens with or without the *dw* gene with respect to eggshell quality.

Conclusion

The positive effect of the sex-linked dwarf gene on economically important traits – feed intake and feed conversion, hatchability of eggs set, is a prerequisite for the development of more efficient broiler breeder hens for production of slow-growing chickens.

Uticaj polno vezanog gena za patuljavost na eksterijerne osobine, produktivnost i osobine jaja ženske linije brojlera obojenog perja

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Rezime

Uticaj gena za patuljavost ispitivan je poređenjem patuljaste kokoši sa normalnim sestrama dobijenim parenjem heterozigotnih muških grla (DW/dw) sa normalnim ženskim (DW / _) iz linije F (koristi se kao majčinska forma za proizvodnju sporo rastućih obojenih pilića), a u vezi sa sledećim osobinama: telesna masa, dužina golenjače i kobilice u uzrastu od 40 nedelja, uzrast polne zrelosti (u 50% proizvodnje), proizvodnja jaja, težina jajeta, konzumacija hrane,

korišćenje hrane, vitalnost, plodnost, procenat izleganja i osobine kvaliteta jaja. Rezultati su pokazali da dw gen izaziva statistički značajno smanjenje telesne težine od 29,15%, dužine golenjače od 20,17%, dužine kobilice za 7% i težine jajeta za 5,72% ($p < 0,001$). Ženke sa normalnim genotipom dostigle su polnu zrelost 7 dana ranije ($p<0,001$), ali ipak, stopa izleganja bila je slična onoj kod mini formi. Nije bilo značajne razlike između obe genetske grupe u odnosu na procenat vitalnosti u odnosu na proizvodni ciklus. Patuljaste kokoši troše 23,38% manje hrane ($p<0,01$) u odnosu na kokoške normalne veličine i pretvaraju hranljive materije efikasnije za 12,69% ($p<0,05$). Prisustvo dw gena u kokošijem genotipu uticao je na povećanje procenta ljuske jajeta, smanjenje težine žumanca i belanca i nije imao nikakvog uticaja na njihov kvalitet.

Pozitivan efekat polno vezanog gena za patuljavost na ekonomski važne osobine - konzumaciju hrane i konverziju hrane, procenat izleganja hatchability postavljenih jaja, je preduslov za razvoj efikasnijih brojlerskih roditelja za proizvodnju pilića sporijeg rasta.

References

ANONYM (2003): A Report on the growth hatching egg production performance of i-757 (sex-linked dwarf gene), Arbor Acres and MPK broilers strain in Bangladesh. Bhagalpur, Bajitpur,

CHARPENTIER, P. (2009): A new look at mini breeders. World Poultry, 25 (4)

CHEN, C.F., A. BORDAS, D. GOURICHON AND M. TIXIER- BOICHARD (2004): Effect of high ambient temperature and naked neck genotype on performance of dwarf brown-egg layers selected for improved clutch length. Br. Poult. Sci., 45: 346-354.

DAWKINS, M.S. AND R LAYTON (2012): Breeding for better welfare: genetic goals for broiler chickens and their parents. Animal Welfare, 21:147-155.

DECUYPERE, E., BOONEN, R, BRUGGEMAN, V., LI, Y., KOPPENOL, A., TAVERNIER, J., JANSSENS, S., BUYS, N. AND N. EVERAERT (2012): The broiler breeder paradox from an ethical, genetic and physiological perspectives and suggestions for solutions. XXIV World's Poultry Congress, Brazil.

DECUYPERE, E., HOCKING, P.M., TONA, K., ONAGBESAN, O., BRUGGEMAN, V., JONES, E.K.M., CASSY, S., RIDEAU, N. , METAYER, S., JEGO, Y., PUTTERFLAM, J., TESSERAUD, S., COLLIN, A. , DUCLOS, M. , TREVIDY, J.J. AND J. WILLIAMS (2006): Broiler breeder paradox: a project report. World's Poultry Science Journal, 62 : 443-453.

EFSA (2010): Scientific opinion on welfare aspects of the management and housing of the grand-parent and parent stock raised and kept for breeding purposes. The EFSA Journal 8: 1667.

GALAL, A. AND H.H. YOUNIS (2006): Minimizing residual feed intake by introducing dwarf and naked neck genes in laying chicken. Egypyt. Poult. Sci., 25: 677- 694.
GALAL, A., AHMED, A.M.H., ALI , U.M. AND H.H. YOUNIS (2007): Influence of Naked Neck gene on laying performance and some hematological parameters of dwarfing hens. International Journal of Poultry Science 6 (11): 807-813.
GARCÊS, A. AND N.H. CASEY (2003): Oviposition and egg quality traits of dwarf and naked neck layers. South African Journal of Animal Science, 33 (2): 105-110.
GARCÊS, A., CASEY, N.H. AND P. HORST (2001): Productive performance of naked neck (Na), frizzle (F) and dwarf (dw) laying hens under the climatic conditions of the tropical coastal plain of south-east Africa and two nutritional treatments. S. Afr. J. Anim. Sci. 31: 174-180.
GOWE, R.S. AND R.W. FAIRFULL (1995): Breeding for resistance to heat stress. In: Poultry Production in Hot Climates. Ed. N.J. Daghir, CAB International, UK, pp: 11-29.
HORST, P. AND C. BECKER (1991): Wechselwirkung zwischen Korperentwicklung und Legeleistung beim Huhn. Arch. Geflugelkd. 55:25–37.
HUSSAIN, S. A., P. HORST, T. K. MUKHERJEE AND E. S. TAWFIK (1982): Genotype-environment interaction in layers involving dwarf gene (dw) and its normal (Dw) allele. Animal Production and Health in the Tropics, pp. 195-198.
HUTT, E. B (1959): Sex-linked Dwarfism in the fowl. The Journal of Heredity 5:209-220.
IPEK, A., SAHAN, U., Y. YAGIZ (1999): A Comparison of the Dwarf (Ross) and Normal (Hubbard) Broiler Parents with Respect to Some Production Traits. Tr. J. of Veterinary and Animal Sciences 23 (2): 429-433.
ISLAM, M. A. (2004): Comparison between sex-linked dwarf and normal broiler breeder hens for fertility, hatchability and growth performances at hot-humid climate. Progressive Agriculture, 15 (2):61-66.
ISLAM, M. A. (2005): Sex-linked Dwarf Gene for Broiler Production in Hot-humid Climates. Asian-Aust. J. Anim. Sci, 18 (11) : 1662-1668.
KATONGOLE, J.B.D., OCHETIM, S. AND P. HORST (1990): Effect of dwarf (dw) and naked neck (Na) genes on performance of layers under Zambian conditions. Zambian J. Agric. Sci., 1: 30-39.
KHAN, A.G. AND A.K. VERMA (1983): Influence of dw gene on egg production of 'Normada-XL' egg layer, dwarf and normal broiler pullets. Ind. J. Anim. Sci. 53:978-984.
KISELEV, A.F., E.A. NADALYAK (1985): Bulletin of the VNIIFBiP of farm animals. 1 (77): 51-57.
KOUSIAKIS, D., ANDREWS, L.D., AND L. STAMPS (1985): Comparison of dwarf and normal broiler breeder hens. Poult. Sci. 64(5): 795-802.

LEENSTRA, F.R.,VAN MIDDELKOOP, J.H., VEREIJKEN, P.F., AND H. ABPLANALP (1986): Influence of the sex-linked dwarfing gene dw on yolk and egg production in normal and superovulating laying hens. Arch. Geflugelk 50, (2): 65-68.
MARKS, H.L. (1981): The sex-linked dwarf gene as expressed in two meat-type control lines of chickens. Poult. Sci. 60(6): 1127-1131.
MARKS, H.L. (1983): Selection for body weight at eight weeks of age in dwarf and normal meat-type chickens originating from a common control population background. Poult. Sci. 62(2): 227-234.
MERAT, P. (1990): Associated effects and utilization of major genes reducing body size in the fowl. Productions Animales, 3: 151-158.
MERAT, P., F. MINVIELLE, A. BORDAS, AND G. COQUERELLE (1994): Heterosis in normal versus dwarf hens. Poult. Sci. 73:1–6.
MERAT, P.AND A. BORDAS (1991): Caracteristiques de ponte comparees pour des poules naines (*dw*) et de taille normale (*Dw*) dans une lignee Leghorn Blanche et dans un croisement de 1re generation Leghorn × Fayoumi. Genet. Sel. Evol. 23:455–460.
MISSOHOU, A., A. DIENG, P. HORST, V.A. ZARATE, T. NESSEIM AND K. TCHEDRE (2003): Effect of dwarf (dw) and frizzle (F) genes on the performance of layers under Senegalese conditions. Trop. Anim. Health Prod., 35: 373-380.
NARUSHIN, V. G. (2005): Egg geometry calculation using the measurements of length and breadth. Poultry Science, 84: 482-484.
RASHID, M.A., M.A.R. HOWLIDER, J. ALAM, M. ABDUR RAHID, M.H. KAWSAR AND S.A. AZMAL (2005): Effect of dwarfism on reproductive and meat yield parameters of crossbred chicken. Int. J. Poult. Sci., 4: 372-377.
RENDEN J.A. AND D.N. MARPLE (1986): Body composition and other physical parameters as determinants of age at sexual maturity and performance efficiency in dwarf hens divergently selected for body weight. Poult. Sci., 65 (8): 1429-1436.
SADJADI, M., BENOFF, F.H., ROWE, K.E., RENDEN, J.A. AND J.A. HARPER (1983): Effects of the sex-linked dwarfing gene (dw) on growth and reproduction in White Leghorn hens. Poult. Sci., 62(10): 1921-1930.
SHARIFI, A.R., HORST, P., AND H. SIMIANER (2010): The effect of frizzle gene and dwarf gene on reproductive performance of broiler breeder dams under high and normal ambient temperatures. Poult. Sci., 89: 2356-2369.
TAHIR, M., CERVANTES, H., FARMER, C.W., SHIM, M. Y. AND G. M. PESTI (2011): Broiler performance, hatching egg, and age relationships of progeny from standard and dwarf broiler dams. Poult. Sci., 90: 1364-1370.
TUDIK, K., MICHARD, G, SIEDIN, G., M. GAYNA (2011): Mini-crosses – a new opportunity for reduction of losses. Animal Science of Russia, 10-12.
YOUNIS, H.H. AND A. GALAL (2006): Impact of dwarf (dw), rapid feathering (k+) and naked neck (Na) genes on growth and egg production of laying hen

chickens. Egypt. Poult. Sci., 26: 17-38. ZELENKA, D.J., DUNNINGTON, E.A., AND P.B. SIEGEL (1986): Growth to sexual maturity of dwarf and nondwarf White Rock chickens divergently selected for juvenile body weight. Theoretical and Applied Genetics**,** 73(1): 61-65.

Received 2 April 2015; accepted for publication 21 May 2015