Journal of Applied Animal Research

ISSN: 0971-2119 (Print) 0974-1844 (Online) Journal homepage: http://www.tandfonline.com/loi/taar20

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To cite this article: M. K. Padhi, R. N. Chatterjee, U. Rajkumar, M. Niranjan & S. Haunshi (2016) Evaluation of a three-way cross chicken developed for backyard poultry in respect to growth, production and carcass quality traits under intensive system of rearing, Journal of Applied Animal Research, 44:1, 390-394, DOI: 10.1080/09712119.2015.1091336

To link to this article: http://dx.doi.org/10.1080/09712119.2015.1091336

Published online: 17 Oct 2015.

JOURNAL OF APPLIED ANIMAL RESEARCH, 2016
VOL. 44, NO. 1, 390–394
http://dx.doi.org/10.1080/09712119.2015.1091336

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Evaluation of a three-way cross chicken developed for backyard poultry in respect to growth, production and carcass quality traits under intensive system of rearing

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ABSTRACT

Objective of the work was to develop a three-way cross for egg-type backyard chicken using male and female lines developed from exotic chickens. To improve the egg production further and to get colour plumage pattern, the two-way cross PD1 X IWI males were crossed with PD3 females to produce three-way cross (PD1 X IWI X PD3). The crossbred was evaluated for different traits upto 72 weeks of age. Sexual dimorphisms were evident from two weeks onwards for body weights and shank length differ significantly ($P < .05$) between male and female at 8, 12 and 16 weeks of age. Male were reared upto 16 weeks of age, and at 16 weeks, body weight of male and female were 1670 and 1096 g, respectively. Carcass quality measured at 16 week of age recorded 66.12% eviscerated carcass yield, 4.84% giblet and 0.30% abdominal fat. Egg production performance recorded from 17 to 72 weeks of age at 4 weeks interval showed significant ($P < .05$) difference between different periods, and peak egg production was recorded during 29–32 weeks. At 69–72 weeks period, the egg production per bird was 14.78 eggs. Egg production upto 40, 52, 64 and 72 weeks of age were 91.71, 105.84, 204.88 and 233.28 eggs, respectively. Age and weight at sexual maturity were 163.14 days and 1702 g, respectively. Egg weight recorded at 4 weeks interval starting from 20 weeks of age showed linear increase upto 56 weeks of age with significant differences at different ages. The results indicate that the cross may be of use for egg-type poultry in the backyard. However, before large-scale propagation, the cross has to be evaluated in the field.

ARTICLE HISTORY
Received 18 December 2014
Accepted 4 May 2015

KEYWORDS
Three-way cross; backyard egg-type chicken; body weight; carcass quality; egg production

1. Introduction

Backyard poultry farming is being practised in many countries in rural and tribal areas where the basic infrastructure for industrial poultry farming is lacking. Backyard poultry farming can be taken up as an integral component in agriculture as supporting activity to crop farming. Backyard poultry serves as an inexpensive means for households to generate highly nutritious food items at minimal cost (Pica-ciamarra & Otte 2010). The requirements for a backyard poultry variety are birds having desirable plumage colour with high performance compared to local indigenous birds with very little change in husbandry practices that is followed for the indigenous fowl.

In addition to indigenous fowl, crossbreds produced using exotic breeds are being utilized for backyard poultry farming (Khan 2008; Das et al. 2008; Padhi et al. 2012a). Different pure lines are being developed through selection and are being crossed to develop crossbreds for backyard poultry farming (Ayyagari 2008; Khan 2008; Padhi et al. 2012a). Crossbreeding is widely used in commercial production as a means of exploiting heterosis when the desired phenotype is a combination of existing lines/breeds or to impose the efficiency of the operation through the use of specialized sire and dam lines. Higher shank length with moderate body weight of a bird helps the birds to run faster, thus protecting themselves from the predator. One such line PD1 is being developed for higher shank length to be used as male parent for backyard poultry. The performances of PD1 in respect to different traits were reported in literature (Padhi et al. 2012a, 2012b; Padhi & Chatterjee 2012; Padhi et al. 2013a). The use of PD1 for different two-way crosses was reported (Padhi et al. 2013b; Padhi & Chatterjee 2013; Padhi et al. 2014a). However, there is requirement of three-way cross to supply parent stocks easily and to exploit heterosis. Keeping this in view, a three-way cross was produced using PD1 X IWI male and PD3 female. The PD1 X IWI X PD3 was evaluated for different traits under intensive system of rearing.

2. Materials and methods

2.1. *Experimental population*

PD1 was used as a male line for the production of two-way cross PD1 X IWI cross. This line is being developed from a low-performing coloured Cornish population (Ayyagari 2008). It has been selected for higher shank length at six weeks of age since the last eight generations. IWI is a white leghorn population being developed by selection for higher 64 weeks egg production since last two generation. PD1 X IWI cross was produced and evaluated upto 72 weeks of age (Padhi et al. 2013b) and as the performance of the cross was good but the plumage colour was white, the male of this cross were crossed with PD3 line female to produce the three-way cross PD1 X IWI X PD3 for colour plumage and better egg production. PD3 having red colour plumage is developed from Dhalem Red population and being selected for higher egg mass upto 40 weeks of age

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since last three generation. A total of 336 chicks were produced in a single hatch. The birds were having multicolour plumage.

2.2. *Rearing and management practices*

The chicks were wing banded and brooded on a deep litter system, with a decreasing temperature schedule from 33°C during first week to 23°C at the end of fifth week in an open-sided house with standard management practices. Chicks were provided *ad libitum* layer starter ration (2800 kcal/kg of ME and 20% CP on calculated basis) up to 8 weeks of age followed by grower ration (2600 kcal/kg of ME and 16% CP on calculated basis) till 16 weeks of age. A total of 161 females were shifted to individual cages at 16 weeks of age and kept there upto 72 weeks of age. The female were provided with layer ration with CP 18% and ME 2700 kcal/kg from 16 weeks onwards *ad libitum* during laying period. The layer ration was supplemented with extra shell grit so that the calcium content made up 3.5% of the ration. The chicks were vaccinated against Marek's disease, Newcastle disease, infectious bursal disease and fowl pox.

2.3. *Traits measured*

Body weight was measured at 0 day, 2, 4, 6 and 8 weeks of age during starter period and at 10, 12 and 16 weeks of age during growing period in both the sexes. Body weights at 20, 24, 40 and 72 weeks of age were recorded in female. Age and weight at sexual maturity were also recorded. Shank lengths were measured at 8, 12 and 16 weeks of age in both the sexes and at 20 and 40 weeks of age in female. Feed consumption was recorded upto 8 weeks of age and the feed conversion ratios (FCRs) were calculated from 0 to 8 weeks. Mortality (if any) was recorded daily and mortality % was calculated from 0 to 8, 9 to 16 and 17 to 72 weeks of age. Egg production was recorded daily from start of lay of each bird upto 72 weeks of age. The bird survived upto 72 weeks of age was taken into consideration for calculation of egg production and other traits like age at sexual maturity, weight at sexual maturity, and body weight and shank length at 40 weeks of age. First egg weight and egg weight at 4 weeks interval starting from 20 weeks upto 72 weeks of age were recorded. Egg productions in 14 four-weeks period starting from 17–20 to 69–72 weeks of age were calculated along with egg production upto 40, 52, 64 and 72 weeks of age. Different carcass quality parameters were measured in 16 male sacrificed at 16 weeks of age as per the standard procedure. Sexing of chicks was done by physical appearance at eight weeks of age and the birds survived upto eight weeks of age were taken for the analysis of juvenile data.

2.4. *Statistical analysis*

Means and standard error of various traits were calculated using standard statistical methods (Snedecor & Cochran 1994). Data were subjected to analysis of variance (ANOVA). Single factor ANOVA model was used to assess the effect of age on different traits. All statements of statistical difference were based on $P \leq .05$.

3. Results and discussion

3.1. *Body weights*

Average body weights measured at starter, growing and laying period are presented in Table 1. Body weights showed sexual dimorphisms from two weeks on wards and the males recorded significantly ($P < .05$) higher body weights than females. Only day-old body weights did not differ significantly between male and female. During starter period, the maximum weight gain was observed from 6 to 8 weeks of age. The sexual dimorphisms observed in the present study in this period were in agreement with the findings of Ajayi and Ejiofor (2009) and Padhi et al. (2012a). The body weights observed in male and female were in agreement with the reports of Padhi et al. (2012a) in Vanaraja male chicks. Growing period body weights differ statistically ($P < .05$) between male and female and in female the gain in body weight is still slower compared to male. The body weights observed at 12 weeks of age is comparable to Gramapriya as reported by Haunshi et al. (2009) and at 16 weeks of age was comparable to a 2-way cross as reported by Padhi et al. (2014a). Laying period body weight showed that the female gain weight upto 72 weeks of age and weight at sexual maturity was at 1702 g of age indicating that the body weight was lower than the body weight in four two-way crosses developed for backyard poultry as reported by Niranjan et al. (2008). The higher body weights of this type birds at 72 weeks of age may fetch better sale price at the end of the laying cycle for the farmers.

Table 1. Body weights at different ages in male and female.

	Body weight (g)		Shank length (mm)	
Traits	Male	Female	Male	Female
Juvenile period, weeks				
Day old	39.05 ± 0.37 (147)	38.45 ± 0.33 (168)		
2	80.59^{a} ± 1.08 (147)	75.30^{b} ± 1.09 (168)		
4	182.60^{a} ± 3.22 (147)	160.08^{b} ± 3.58 (168)		
6	382^{a} ± 6 (147)	322^{b} ± 6 (168)		
8	624^{a} ± 9 (147)	511^{b} ± 8 (168)	78.49^{a} ± 0.70 (147)	71.84^{b} ± 0.46 (168)
Growing period, weeks				
10	820^{b} ± 11 (146)	640^{b} ± 10 (166)		
12	1207^{a} ± 45 (23)	826^{b} ± 12 (166)	108.63^{a} ± 1.89 (23)	91.65^{b} ± 0.44 (166)
16	1670 ± 62^{a} (23)	1096^{b} ± 14 (161)	122.25^{a} ± 1.82 (23)	98.85^{b} ± 0.47 (161)
Laying period, weeks				
20	–	1409 ± 17 (138)		99.57 ± 0.39 (138)
24	–	1709 ± 21 (138)		
WSM	–	1702 ± 20 (125)		
40	–	1971 ± 26 (119)		98.40 ± 0.37 (119)
72	–	2182 ± 33 (106)		

Notes: WSM, Weight at sexual maturity. Values in parentheses are number of observations. Means showing different superscript in a row differ significantly ($P < .05$). During laying period, only female body weight were recorded as all the male were discarded after 16 weeks of age.

3.2. *Shank length*

Shank length, which is an important attribute for any backyard poultry variety, was measured at different weeks of age in the present study (Table 1). Shank length showed significant ($P < .05$) difference between male and female at all the age of measurements. It was observed that in both sexes the maximum gain was observed from 8 to 12 weeks of age and at 16 weeks of age it attained the maximum length (Table 1). In female after 16 weeks of age, there is not much change in shank length and it decreased a little at 40 weeks of age. The shank length observed in the present study at 40 weeks of age in female was higher than both Vanaraja and Gramapriya backyard poultry varieties as observed by Haunshi et al. (2009). The shank length observed in the present study at 20 and 40 weeks of age in female was lower than the report in purelines PD1 (Padhi & Chatterjee 2012).

3.4. *Feed conversion ratio*

The FCR recorded in pooled sex in a group from 0 to 8 weeks of age was found to be 3.089. The FCR observed in the present study was better than the reported FCR in Gramapriya by Haunshi et al. (2009).

3.5. *Carcass quality*

In the development of any backyard layer variety, the carcass quality of male is important, as the male in a layer type chicken is to be consumed for meat purpose. The pre-slaughter body weight of the male was 1723 g, which seems to be appropriate for the backyard poultry (Table 2). Higher pre-slaughter body weight at 18 weeks of age in different two-way crosses was reported by Padhi and Chatterjee (2013). Different parameters of the carcass quality study observed in the present study are presented in Table 2. The blood % of 3.88 was lower than R and W two-way cross as reported by Padhi and Chatterjee (2013). Feather % was higher than that reported by Padhi and Chatterjee (2013). Eviscerated carcass % was higher than the report of male Nicobari (Padhi et al. 1999a) and White leghorn (Padhi et al. 1999b) and comparable to Vanaraja pooled sex at 12 weeks of age (Ahmed et al. 2006). Lower dressing % in different genetic groups than the present finding was reported by Jaturasitha et al. (2008) at 16 weeks of age in Thai Native, Barred Plymouth Rock and its cross. Giblet % was lower than the report of Padhi et al. (1999a, 1999b); Padhi and Chatterjee (2013) in different genetic stocks of chickens. Abdominal fat % was low in the present study; lower abdominal fat in newly developed two-way cross backyard poultry reared in intensive system was also reported (Padhi & Chatterjee 2013). Low abdominal fat indicates the leanness of the male birds and may be very useful for the consumers who prefer lean meat of the local birds. Cutup parts expressed as per cent of eviscerated carcass weight revealed that highest cutup % was leg followed by breast, back, wing and neck. Similar observation in different two-way cross under intensive system was reported by Padhi and Chatterjee (2013). Leg and breast cut % observed in the present study were comparable to A and B two-way cross as reported by Padhi and Chatterjee (2013). However, it is to be mentioned here that the age and type of cross use for comparison of the results are different than the present cross. But as this cross is new, it is observed that the eviscerated carcass % and giblet % are comparable to those of other backyard variety and may be useful to slaughter the male at 16 weeks of age for meat purpose.

Table 2. Carcass quality traits of 3-way cross male at 16 weeks of age.

Traits	Mean ± SE
Pre-slaughtered live weight (g)	1723 ± 46
As percentage (%) of live weight	
Blood	3.88 ± 0.26
Feather	7.86 ± 0.37
Head	3.77 ± 0.09
Shank	4.40 ± 0.09
Eviscerated Carcass	66.12 ± 0.36
Heart	0.40 ± 0.01
Liver	1.93 ± 0.03
Gizzard	2.51 ± 0.09
Giblet	4.84 ± 0.10
Abdominal fat	0.30 ± 0.07
Cut up parts (percentage of carcass weight)	
Breast	23.23 ± 0.52
Back	22.64 ± 0.49
Leg	33.19 ± 0.33
Wing	14.49 ± 0.23
Neck	7.21 ± 0.33
Cutting loss	1.24 ± 0.31

3.6. *Production performance*

Age at sexual maturity was 163.14 days, which is lower than the Gramapriya and Vanaraja as reported by Haunshi et al. (2009) and higher than that reported in a two-way cross variety by Niranjan et al. (2008). Egg production at different weeks of age (Table 3) indicates that the birds are laying good number of eggs at different weeks of age and the egg production was better than the report of Niranjan et al. (2008) in various two-way crosses except in Gramapriya, which was produced 237.35 eggs upto 72 weeks of age. However, the three-way cross performed well in respect to this traits. Egg production obtained in this three-way cross was better than the two-way crosses as per the report of Padhi et al. (2013b). The egg production in present three-way cross was similar to the three-way crosses involving two local breeds of Egypt and Lohman brown by Ghanem et al. (2012). Egg production at 4 weeks of interval starting from 17 to 72 weeks of age indicated that the peak production was observed between 29 and 32 weeks of age (Table 4). There exists significant ($P < .05$) difference for the egg production between different four-weeks intervals. Second peak production was observed during 37–40 weeks of age. Higher egg production was observed between 29 and 44

Table 3. Production performance at different ages.

Traits	Number of observation	Mean ± SE
Age at sexual maturity (day)	125	163.14 ± 1.33
EP40 (no)	106	91.71 ± 1.37
EP52 (no)	106	150.84 ± 1.93
EP64 (no)	106	204.48 ± 2.50
EP72 (no)	106	233.28 ± 3.18

Note: EP40, Egg production at 40 weeks of age; EP52, Egg production at 52 weeks of age; EP64, Egg production at 64 weeks of age; EP72, Egg production at 72 weeks of age.

Table 4. Egg production and egg weight (g) at 4 weeks interval starting from 17 weeks of age.

Period (weeks)	Egg number per bird	Week/period	Mean ± SE (g)
		First egg weight	47.06 ± 0.50^{e}
17–20	3.83 ± 0.79^{h}	20	39.20 ± 0.65^{f}
21–24	9.74 ± 0.71^{g}	24	45.77 ± 0.54^{e}
25–28	17.73 ± 0.48^{e}	28	51.25 ± 0.37^{d}
29–32	23.43 ± 0.39^{a}	32	54.49 ± 0.43^{c}
33–36	21.43 ± 0.35^{bc}	36	55.49 ± 0.39^{bc}
37–40	23.16 ± 0.39^{ab}	40	57.15 ± 0.39^{b}
41–44	21.21 ± 0.44^{bc}	44	59.41 ± 0.41^{a}
45–48	18.92 ± 0.30^{de}	48	59.90 ± 0.44^{a}
49–52	19.94 ± 0.48^{cd}	52	60.05 ± 0.47^{a}
53–56	19.31 ± 0.44^{cde}	56	60.29 ± 0.49^{a}
57–60	18.31 ± 0.47^{de}	60	59.40 ± 0.55^{a}
61–64	17.40 ± 0.47^{e}	64	59.20 ± 0.44^{a}
65–68	15.38 ± 0.59^{f}	68	59.21 ± 0.55^{a}
69–72	14.78 ± 0.57^{f}	72	59.56 ± 0.46^{a}

Note: Means having common superscript in a column did not differ significantly ($P < .05$).

weeks of age and then it reduced significantly and continues upto 64 weeks of age. The egg production from 65 to 72 weeks of age reduced and in last 4 weeks of age the egg production was 14.78 eggs, which was little more than 50% production. Decrease in egg production towards later part of cycle was reported in PD1 by Padhi and Chatterjee (2012). However, it is to be mentioned that the present cross was evaluated first time in the institute.

3.7. *Egg weight*

Egg weights recorded at different weeks of age starting at 20 weeks of age are presented in Table 4, including the first egg weight. Significant ($P < .05$) difference between egg weights at different weeks of age was observed and are in agreement with the reports of Padhi et al. (2014b) and Padhi et al. (2013a) in the same cross and PD1 for the eggs used for egg quality study. First egg weight was more than the egg weight at 24 weeks of age because all the birds not starts laying at 24 weeks of age, and the birds that lay eggs at older age may have produced larger first egg with higher egg weight compared to early producing birds. The age at first egg ranged from 132 to 209 days with a standard deviation of 14.84. The egg weight at 28 weeks of age was 51.25 g, which was comparable to Gramapriya and lower than Vanaraja as reported by Niranjan et al. (2008). The egg weight at 40 weeks of age (57.14 g) was better than Vanaraja and Gramapriya as reported by Haunshi et al. (2009). From the result on egg weight it was observed that the egg weight increased up to 48 weeks of age and there after the egg weight remain stable and statistically non-significant.

3.8. *Mortality*

The mortality during 0–8, 9–16 and 17–72 weeks of age were 6.11%, 2.65% and 17.39%, respectively. The mortality during starter and growing period was in the admissible range but the mortality during laying period was on higher side, which was one of the negative finding in this crosses. Higher mortality in laying periods in a two-way cross under field condition was reported by Padhi et al. (2014a) and upto 20 weeks of age in different crosses under field condition (Padhi et al. 2003).

4. Conclusion

The study revealed that the performance of this cross in respect to different traits is on desirable direction for its utilization as an egg-type cross for backyard poultry; however, before commencing large-scale use of these birds, its field evaluation has to be done under farmer's field under backyard system. The multicolour plumage of the bird with brown egg shell and better egg weight may make it popular as an egg-type chicken under backyard system and helps the poor farmers to increase their income from backyard poultry farming. The male birds from this cross may be used for meat purpose at 16 weeks of age.

Acknowledgements

We are grateful to the ICAR Directorate of Poultry Research, Hyderabad, India for supporting this study as an institute project.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

Ahmed FA, Ghosh MK, Pathak PK, Bhattacharya M. 2006. Carcass quality of Vanaraja birds. Indian Vet J. 83:1315–1316.

Ajayi FO, Ejiofor O. 2009. Effect of genotype X sex interaction on growth and some development characteristics of ross and anak broiler strains in the high rain forest zone of Nigeria. Asian J Poult Sci. 3:31–56.

Ayyagari V. 2008. Development of varieties for rural poultry. Souvenir seminar on sustainable poultry production: rural and commercial approach. 3 March, Hyderabad, India, p. 1–5.

Das SC, Chowdhury SD, Khatun MA, Nishibori M, Isobe N, Yoshimura Y. 2008. Poultry production profile and expected future projection in Bangladesh. World's Poult Sci J. 64:99–118.

Ghanem HH, Attia YA, El-Tahawy WS, Nawar AN. 2012. Developing a three-way cross of chicken for improving egg production traits 1 – heterosis effect and analysis of DNA polymorphism using RAPD-PCR. Egypt Poult Sci. 32:833–849.

Haunshi S, Doley S, Shakutala I. 2009. Production performance of indigenous chicken of northeastern region and improved varieties developed for backyard farming. Indian J Anim Sci. 79:901–905

Jaturasitha S, Kayan A, Wicke M. 2008. Carcass and meat characteristics of male chickens between Thai indigenous compared with improved layer breeds and their crossbred. Archiv Tierzt Dummerstorf. 51:283–294.

Khan AG. 2008. Indigenous breeds, crossbreds and synthetic hybrids with modified genetic and economic profiles for rural family and small scale poultry farming in India. World's Poult Sci J. 64:405–415.

Niranjan M, Sharma RP, Rajkumar U, Reddy BLN, Chatterjee RN, Bhattacharya TK. 2008. Comparative evaluation of production performance in improved chicken varieties for backyard farming. Int J Poult Sci. 7:1126–1131.

Padhi MK, Chatterjee RN. 2012. Inheritance of body weight, shank length and production traits in PD1 (Vanaraja male line). Indian J Poult Sci. 4:269–273.

Padhi MK, Chatterjee RN. 2013. Carcass quality traits in four different crossbreds developed for backyard poultry and the effect of age on carcass quality under intensive system of rearing. Indian J Anim Sci. 83:1102–1108.

Padhi MK, Chatterjee RN, Haunshi S. 2014b. Age effect on egg quality traits in a 3-way cross egg type chicken developed for backyard poultry farming. J Poult Sci Tech. 2:52–55.

Padhi MK, Chatterjee RN, Haunshi S, Rajkumar U. 2013a. Study on effect of age on egg quality in chicken. Indian J Poult Sci. 48:122–125.

Padhi MK, Chatterjee RN, Niranjan M, Haunshi S, Rajaravindra KS, Rajkumar U. 2013b. Production performance of four different crossbreds developed for backyard poultry farming under intensive system of rearing. Proceeding of XXX Conference and National Symposium of Indian Poultry Science Association; 2013 Nov 22–23; Izatnagar, India: CARI. PGB 001:1.

Padhi MK, Chatterjee RN, Rajkumar U. 2014a. A study on performance of a crossbred chicken developed using both exotic and indigenous breeds under backyard system of rearing. J Poult Sci Tech. 2:26–29.

Padhi MK, Rajkumar U, Haunshi S, Niranjan M, Panda AK, Bhattacharya TK, Reddy MR, Bhanja SK, Reddy BLN. 2012a. Comparative evaluation of male line of Vanaraja, control broiler, Vanaraja commercial in respect to juvenile and carcass quality traits. Indian J Poult Sci. 47:136–139.

Padhi MK, Rajkumar U, Niranjan M, Haunshi S, Bhanja SK. 2012b. Genetic studies of juvenile traits in Vanaraja male line a dual purpose backyard chicken. Indian J Poult Sci. 47:234–236.

Padhi MK, Panda BK, Sahoo SK, Mohapatra CM, Giri SC. 2003. Evaluation of different hybrids under free range system of poultry keeping in coastal Orissa. Indian J Poult Sci. 38:121–125.

Padhi MK, Senani S, Rai RB, Saha SK. 1999b. Carcass characteristics of white leghorn cockerels. J Indian Society Coastal Agr Res. 17:226–228.

Padhi MK, Rai RB, Chandra P, Senani S, Saha SK. 1999a. Effect of age on carcass characteristics of male Nicobari fowl. Indian J Poult Sci. 34:71–73.

Pica-ciamarra U, Otte J. 2010. Poultry food security and poverty in India: looking beyond the farm-gate. World's Poult Sci J. 66:309–320.

Snedecor GW, Cochran WG. 1994. Statistical methods. 8th ed. Ames (Iowa), USA: The Iowa State University Press.