BUKTI KORESPONDENSI AVR

BUKTI KORESPONDENSI DENGAN PENGELOLA JURNAL Tahun 2022 dengan Judul: "Morphometric Traits of Imported Rabbits and Their Progenies".

No.	Tanggal	Keterangan
1.	13 April 2022	[AVR] Submission Acknowledgement for submitting the manuscript, "Morphometric traits of imported rabbits and their progenies" to Journal of Advanced Veterinary Research.
2.	20 Mei 2022	[AVR] Editor Decision: a decision regarding our submission to Journal of Advanced Veterinary Research, "Morphometric traits of imported rabbits and their progenies". the decision is: Revisions Required
3.	21 Mei 2022	**Sutopo:** we have revised the manuscript according to reviewer comments, and the responses are marked in yellow colour attached manuscript file and figure
4.	4 Juni 2022	[AVR] Editor Decision: a decision regarding our submission to Journal of Advanced Veterinary Research, "Morphometric Traits of Imported Rabbits and Their Progenies". The editor are pleased to inform me that our manuscript, "Morphometric Traits of Imported Rabbits and Their Progenies" **has been accepted for publication in Journal of Advanced Veterinary Research.**
5.	4 Juni 2022	[AVR] New notification from Journal of Advanced Veterinary Research: I have been added to a discussion titled "UNCORRECTED PROOF" regarding the submission "Morphometric Traits of Imported Rabbits and Their Progenies".

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Prof. Mahmoud Rushdi <ed... Wed, Apr 13, 11:55 AM

to me

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Thank you for submitting the manuscript, "Morphometric traits of imp rabbits and their progenies" to Journal of Advanced Veterinary Rese With the online journal management system that we are using, you v able to track its progress through the editorial process by logging in t journal web site:

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Prof. Mahmoud Rushdi

Editor-In-Chief

Prof. Mahmoud Rushdi

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[AVR] Editor Decision

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Editor-In-Chief Prof. ... Fri, May 20, 12:58 AM

to Setiaji, Lestari, Kurnianto, me

Dr. Setiaji, Lestari, Kurnianto, Sutopo Sutopo:

We have reached a decision regarding your submission to Journal o
Advanced Veterinary Research, "Morphometric traits of imported rab
and their progenies".

Our decision is: Revisions Required

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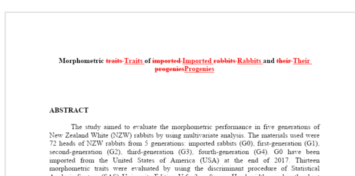

Morphometric ~~traits~~ Traits of ~~imported~~ Imported ~~rabbits~~ Rabbits and ~~their~~ Their ~~progenies~~ Progenies

ABSTRACT

The study aimed to evaluate the morphometric performance in five generations of New Zealand White (NZW) rabbits by using multivariate analysis. The materials used were 72 heads of NZW rabbits from 5 generations: imported rabbits (G0), first-generation (G1), second-generation (G2), third-generation (G3), fourth-generation (G4). G0 have been imported from the United States of America (USA) at the end of 2017. Thirteen morphometric traits were evaluated by using the discriminant procedure of Statistical Analysis System (SAS) University Edition V.6p.2. software. Head width, ear length, chest

B-reviewMorpho ...

dr sutopo <drsutopo36@g... Sat, May 21, 5:43 PM

to Editor-In-Chief

Morphometric ~~traits~~ Traits of ~~imported~~ Imported ~~rabbits~~ Rabbits and ~~their~~ Their ~~progenies~~Progenies

ABSTRACT

The study aimed to evaluate the morphometric performance in five generations of New Zealand White (NZW) rabbits by using multivariate analysis. The materials used were 72 heads of NZW rabbits from 5 generations: imported rabbits (G0), first-generation (G1), second-generation (G2), third-generation (G3), fourth-generation (G4). G0 have been imported from the United States of America (USA) at the end of 2017. Thirteen morphometric traits were evaluated by using the discriminant procedure of Statistical Analysis System (SAS) University Edition V.6p.2. software. Head width, ear length, chest width, radius-ulna length, femoris length, and Hip width were significant ($P<0.05$) among generations. Radius-ulna length, femoris length, and hip width showed the greatest contribution as distinguishing factors between generations based on canonical structure. Imported rabbits confirmed specific characteristics in morphometric traits, which differed from their progenies.

Keywords**:** Canonical structure, Discriminant procedure, Multivariate analysis, New Zealand White.

Introduction

Rabbit is the potential animal to be developed in Indonesia. Rabbits have high prolificacy, fecundity, profitability, short generation interval, and high feed conversion efficiency (Lebas *et al.*, 1997; Daader *et al.*, 2016). Most of ~~the~~ rabbits raised by ~~the~~ farmers in Indonesia have been imported from Europe and the United States of America. One of the imported commercial breeds is New Zealand White (NZW), Rex, California, Satin, Hayla and Hycole.

Evaluation is important for assessing the adaptability of imported rabbit and their progenies. Growth, reproductive, carcass, and physiological traits were commonly used for evaluation programs (Marai *et al*., 2005; Zerrouki *et al*., 2008; Fathi *et al.*, 2017; Jimoh and Ewoula, 2018). Facts on morphometrics traits are an essential element of comparative studies of development. Morphometrics let~~s~~ in the rigorous quantitative analysis of variants in organismal size and shape, and ~~is increasingly being~~ utilized increasingly in developmental contexts (Klingenberg, 2002). The study of the morphometric traits to evaluate among generations is limited. This study was conducted to evaluate the morphometric performance in five generations of NZW rabbits through multivariate analysis.

Material and methods

The data was obtained from 72 heads of NZW rabbits from 5 generations: imported rabbit (G0) (n=7), first-generation (G1) (n=17), second-generation (G2) (n=20), third-generation (G3) (n=16), fourth-generation (G4) (n=15). G0 have been imported to Indonesia from the American Rabbits Breeder Association (ARBA), United States of America (USA) at the end of 2017. G1 was the progenies of G0, G2 was the progenies of G1, and so on. The rabbits were raised in an intensive rearing system. The unsex rabbits with more than 12 months old were chosen. The morphometric evaluation was performed by measuring a total of 13 quantitative characteristics~~. (Figure 1)~~. Morphometric traits measured ~~are comprising 1)~~included head length (HL), ~~2)~~ head width (HW), ~~3)~~ ear length (EL), ~~4)~~ ear width (EW), ~~5)~~ chest circumference (CC), ~~6)~~ chest depth (CD), ~~7)~~ chest width (CW), ~~8)~~ radius-ulna length (RU), ~~9)~~ femoris length (FM), ~~10)~~ tibia length (TB), ~~11)~~ humerus length (HM), ~~12)~~ hip width (HP), and ~~13)~~ body length (BL). The descriptive statistic of morphometric data is presented in Table 1.

Statistical analysis

Morphometric data was analyzed using Statistical Analysis System (SAS) University Edition V.6p.2. software (SAS, 2014). One-Way ANOVA was used for analyzing the effect of generation on body morphometric traits. Duncan's multiple ranges was used at 5% of probability. Discriminant analysis was performed to determine discriminant variables, canonical structure, mahalanobis distance, and distribution mapping among generations. The variance components are the discrimination from individual structure of canonical and distance of mahalanobis. The model was as follow:

$$C = \mu + \mu_0 y_0 + \mu_1 y_1 + \mu_2 y_2 + \mu_3 y_3 + \mu_4 y_4$$

Where; μ_0, μ_1, μ_2, μ_3, and μ_4 are the estimate of canonical coefficients, and y_0, y_1, y_2, y_3, and y_4 indicated the generations of NZW rabbits.

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Results

The least-square means (LSM) and their standard deviations (SD) for the morphometric traits of NZW rabbits according to generations are presented in Table 2. A significant difference (P<0.05) between different generations was observed for HW, EL, CW, RU, FM, and HP. G0 showed the highest of HW, CW, RU, FM, and HP, whereas G2 ~~has~~ had the highest of EL. G0 was similar with G1 for HW, EL, and CW; with G2 for CW, FM, HP; with G3 and G4 for EL, CW, and FM.

Table 3. presented eigenvalues, and their contribution in each factor. The eigenvalues of the three factors were 0.43, 0.36, and 0.28, and cumulative variations were 0.31, 0.61, and 0.82, respectively for the first, second and third factors. Table 4. shows the canonical analysis based on morphometric traits, allowing identification of canonical variables (CAN1, CAN2, and CAN 3). The greatest contribution in each canonical was FM, HP, and RU, respectively for CAN1, CAN2, and CAN 3.

Distance of Mahalanobis between the populations are presented in Table 5. The longest distance showed between G2 and G3. ~~Figure~~ Fig. ~~2~~1. shows the same morphometric traits of G1, G2, G3, and G4 were similar to each other but different with G0.

Discussion

Based on the LSM, HW, RU, and HP have become the most prominent traits for which distinguish between imported breed and their progenies. This difference can be associated with the influence of environment, feed quality, and management techniques (Elamin *et al.*, 2012; Arandas *et al.*, 2017). On the other hand, HL, EW, CC, CD, TB, HM, and BL were not different between generations. CD, TB, and BL were similar; CC and HM were longer; HL and EW were shorter compared with morphometric of NZW reported by Brahmantiyo *et al.* (2021) in Indonesian Research Institute for Animal Production, Ciawi, Bogor, West Jawa.

Third factors of eigenvalue explained the highest total variance (82%) of morphometric traits. Setiaji *et al.* (~~2013~~2012), studied morphometric traits on Flemish Giant, English Spot, Angora, and Rex breeds of rabbits, found three factors that explained 84% of the total variation. The result was within range of total variance for morphometric traits reported in other species (Yakubu *et al.*, 2011; Ajayi *et al.*, 2012; Birteeb *et al.*, 2013) in goat, chicken, and sheep, respectively. RU, FM, and HP showed the greatest contribution in the three canonical variables. This suggests that three traits are important in defining generational patterns (Yang *et al.*, 2006). That was different with the greatest contribution EL, CC, BL reported by Setiaji *et al.* (~~2013~~2012) in grouping four breeds of rabbit.

The result of Mahalanobis distance indicates that despite belonging to the same rabbit breed and same farm, there are differences among generations. The sensitivity and specificity of Mahalanobis distance were calculated for the results of the discrimination of morphometric traits in the validation group across generations (Rossi *et al.*, 2010). Furthermore, the progeny with the shortest distance to G0 was G1, and due to the fact that G1 got a large direct genetic effect from the G0. Whereas, the longest was between G0 and G2. G2 of NZW rabbits have not adapted well to the environment and nutritional conditions. Then in G3 and G4 have been adapted well with the results that the morphometric traits were nearly the same to which of G0.

As shown in ~~Figure~~ Fig. ~~2~~1, highlighting a connection the NZW rabbits between generations was observed. Morphological similarity showed possibility of close relationships among generations (Hamilton *et al.*, 2005). In this study, G0 located on top side showed the small size category, in which it differed from their progenies.

Conclusions

Imported rabbit showed different characteristic in morphometric and was classified into small size category which differed from their progenies. The longest genetic distance was shown between imported and second-generation progeny. Radius-ulna length, femuris length, and hip width showed the greatest contribution as distinguishing factors between generations.

Conflict of interest

The authors declare that they have no conflicts of interest.

Acknowledgments

This research was funded by Hibah Dana Penelitian Universitas Diponegoro Semarang with Contract No. 36/UN7.5.5.2/PP/2021. The authors thank Mr. Hary Suharyanto the owner of "Rumah Kelinci Pleret" Farm for his kind collaboration on data inquiry and collection.

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Table 1. Descriptive statistic for morphometric data of New Zealand White rabbits

Trait[1] (cm)	N[2]	Minimum	Maximum	Mean	SD[3]
HL	72	8.69	13.34	10.85	0.88
HW	72	4.41	6.35	5.36	0.41
EL	72	9.20	12.80	11.20	0.76
EW	72	5.40	7.30	6.52	0.36
CC	72	34.4	44.80	39.05	2.32
CD	72	7.99	11.83	10.14	0.86
CW	72	8.58	12.67	10.34	0.86
RU	72	7.95	12.10	9.55	0.80
FM	72	11.73	16.90	14.13	0.92
TB	72	12.25	16.60	15.04	0.89
HM	72	9.16	12.30	10.79	0.66
HP	72	9.34	13.93	12.07	0.95
BL	72	33.31	41.10	37.53	1.59

[1]HL: Head Length; HW: Head Width; EL: Ear Length; EW: Ear Width; CC: Chest Circumference; CD: Chest Depth; CW: Chest width; RU: Radius-ulna Length; FM: Femoris Length; TB: Tibia Length; HM: Humerus Length; HP: Hip Width; BL: Body Length. [2]N: number of rabbits measured. [3]SD: standard deviation.

Table 2. Least square means of morphometric traits at different generations

Traits[1] (cm)	Generations[2]				
	G0	G1	G2	G3	G4
HL	10.35 ± 1.08	10.88 ± 1.01	11.00 ± 0.85	10.53 ± 0.52	11.11 ± 0.99
HW	5.74 ± 0.24^{a}	5.49 ± 0.43^{ab}	5.30 ± 0.28^{b}	5.31 ± 0.45^{b}	5.26 ± 0.46^{b}
EL	10.60 ± 0.65^{b}	11.14 ± 0.78^{ab}	11.41 ± 0.73^{a}	11.27 ± 0.67^{ab}	11.09 ± 0.85^{ab}
EW	6.72 ± 0.29	6.42 ± 0.49	6.58 ± 0.36	6.51 ± 0.19	6.53 ± 0.34
CC	39.80 ± 0.69	39.68 ± 2.64	39.44 ± 2.41	38.36 ± 1.92	38.37 ± 2.34
CD	10.38 ± 0.26	9.96 ± 0.75	10.22 ± 0.87	9.99 ± 1.01	10.34 ± 0.93
CW	10.98 ± 0.81^{a}	10.34 ± 0.51^{ab}	10.58 ± 0.83^{ab}	9.95 ± 1.02^{b}	10.26 ± 0.90^{ab}
RU	10.55 ± 1.03^{a}	9.65 ± 0.91^{b}	9.48 ± 0.74^{b}	9.18 ± 0.59^{b}	9.64 ± 0.72^{b}
FM	14.65 ± 0.68^{a}	13.72 ± 0.79^{b}	14.22 ± 0.73^{ab}	14.18 ± 0.93^{ab}	14.27 ± 1.21^{ab}
TB	15.22 ± 0.14	15.07 ± 0.84	15.32 ± 0.80	14.85 ± 0.99	14.80 ± 1.01
HM	10.90 ± 1.27	10.84 ± 0.59	10.72 ± 0.71	10.70 ± 0.47	10.90 ± 0.74
HP	13.14 ± 0.59^{a}	11.77 ± 0.96^{b}	12.37 ± 0.91^{ab}	12.07 ± 0.56^{b}	11.76 ± 1.18^{b}
BL	37.55 ± 1.35	37.80 ± 1.62	37.88 ± 1.71	37.79 ± 1.12	36.48 ± 1.67

[1]HL: Head Length; HW: Head Width; EL: Ear Length; EW: Ear Width; CC: Chest Circumference; CD: Chest Depth; CW: Chest width; RU: Radius-ulna Length; FM: Femoris Length; TB: Tibia Length; HM: Humerus Length; HP: Hip Width; BL: Body Length.

[2]G0: imported rabbits; G1: first-generation; G2: second-generation; G3: third-generation; G4: fourth-generation.

[a-b]Means within the same row having different upper case letters differ significantly ($P<0.05$) between generations.

Table 3. Eigenvalues, and its contribution in each factor

Factors	Eigenvalues	Proportion variation (%)	~~Comulative~~ Cumulative variation (%)
First	0.43	0.33	0.31
Second	0.36	0.27	0.61
Third	0.28	0.22	0.82

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Table 4. Canonical structure for each morphometric traits

Traits[1]	CAN 1	CAN 2	CAN 3
HL	0.12	-0.24	0.43
HW	-0.35	0.43	0.11
EL	0.02	-0.29	-0.21
EW	0.24	0.29	-0.04
CC	-0.31	0.24	0.17
CD	0.27	0.13	0.19
CW	-0.01	0.44	0.32
RU	-0.05	**0.56**	**0.49**
FM	**0.42**	0.26	-0.11
TB	-0.11	0.21	0.02
HM	0.01	0.04	0.23
HP	0.14	**0.62**	-0.26
BL	-0.39	0.13	-0.43

[1]HL: Head Length; HW: Head Width; EL: Ear Length; EW: Ear Width; CC: Chest Circumference; CD: Chest Depth; CW: Chest width; RU: Radius-ulna Length; FM: Femoris Length; TB: Tibia Length; HM: Humerus Length; HP: Hip Width; BL: Body Length.
Add abbreviation for CAN

Table 5. Distance of Mahalanobis, based on morphometric traits of NZW rabbits between generations

Generations[1]	G0	G1	G2	G3	G4
G0	1.00				
G1	0.13	1.00			
G2	0.22	0.18	1.00		
G3	0.16	0.19	0.41	1.00	
G4	0.14	0.07	0.35	0.25	1.00

[1]G0: imported rabbits; G1: first-generation; G2: second-generation; G3: third-generation; G4: fourth-generation.

Figure Legends

~~Figure 1: Morphometric traits of rabbits (Brahmantiyo, 2006).~~

~~Figure~~ Fig. ~~2~~1~~: .~~ Scattering diagram of five generations based on canonical structure of the morphometric traits.

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Dr. Setiaji, Lestari, Kurnianto, Sutopo Sutopo:

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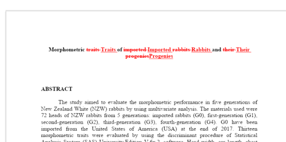
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ABSTRACT

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Dear Prof Mahmoud Rushdi

Thank you for your suggestion,
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Morphometric Traits of Imported Rabbits and Their Progenies

Asep Setiaji, Dela Ayu Lestari, Edy Kurnianto, Sutopo Sutopo*

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ABSTRACT

The study aimed to evaluate the morphometric performance in five generations of New Zealand White (NZW) rabbits by using multivariate analysis. The materials used were 72 heads of NZW rabbits from 5 generations: imported rabbits (G0), first-generation (G1), second-generation (G2), third-generation (G3), fourth-generation (G4). G0 have been imported from the United States of America (USA) at the end of 2017. Thirteen morphometric traits were evaluated by using the discriminant procedure of Statistical Analysis System (SAS) University Edition V.6p.2. software. Head width, ear length, chest width, radius-ulna length, femoris length, and Hip width were significant ($P<0.05$) among generations. Radius-ulna length, femoris length, and hip width showed the greatest contribution as distinguishing factors between generations based on canonical structure. Imported rabbits confirmed specific characteristics in morphometric traits, which differed from their progenies.

Keywords**:** Canonical structure, Discriminant procedure, Multivariate analysis, New Zealand White.

Introduction

Rabbit is the potential animal to be developed in Indonesia. Rabbits have high prolificacy, fecundity, profitability, short generation interval, and high feed conversion efficiency (Lebas *et al.*, 1997; Daader *et al.*, 2016). Most of rabbits raised by farmer in Indonesia have been imported from Europe and the United States of America. One of the imported commercial breeds is New Zealand White (NZW), Rex, California, Satin, Hayla and Hycole.

Evaluation is important for assessing the adaptability of imported rabbit and their progenies. Growth, reproductive, carcass, and physiological traits were commonly used for evaluation programs (Marai *et al*., 2005; Zerrouki *et al*., 2008; Fathi *et al.*, 2017; Jimoh and Ewoula, 2018). Facts on morphometrics traits are an essential element of comparative studies of development. Morphometrics let in the rigorous quantitative analysis of variants in organismal size and shape and utilized increasingly in developmental contexts (Klingenberg, 2002). The study of the morphometric traits to evaluate among generations is limited. This study was conducted to evaluate the morphometric performance in five generations of NZW rabbits through multivariate analysis.

Material and methods

The data was obtained from 75 heads of NZW rabbits from 5 generations: imported rabbit (G0) (n=7), first-generation (G1) (n=17), second-generation (G2) (n=20), third-generation (G3) (n=16), fourth-generation (G4) (n=15). G0 have been imported to Indonesia from the American Rabbits Breeder Association (ARBA), United States of America (USA) at the end of 2017. G1 was the progenies of G0, G2 was the progenies of G1, and so on. The rabbits were raised in an intensive rearing system. The age of rabbits chosen was more than 12 months old. The morphometric evaluation was performed by measuring a total of 13 quantitative characteristics. Morphometric traits measured included head length (HL), head width (HW), ear length (EL), ear width (EW), chest circumference (CC), chest depth (CD), chest width (CW), radius-ulna length (RU), femoris length (FM), tibia length (TB), humerus length (HM), hip width (HP), and body length (BL). The descriptive statistic of morphometric data is presented in Table 1.

Statistical analysis

Morphometric data was analyzed using Statistical Analysis System (SAS) University Edition V.6p.2. software (SAS, 2014). One-Way ANOVA was used for analyzing the effect of generation on body morphometric traits. Duncan's multiple ranges was used at 5% of probability. Discriminant analysis was performed to determine discriminant variables, canonical structure, mahalanobis distance, and distribution mapping among generations. The variance components are the discrimination from individual structure of canonical and distance of mahalanobis. The model was as follow:

$$C = \mu + \mu_0 y_0 + \mu_1 y_1 + \mu_2 y_2 + \mu_3 y_3 + \mu_4 y_4$$

Where; μ_0, μ_1, μ_2, μ_3, and μ_4 are the estimate of canonical coefficients, and y_0, y_1, y_2, y_3, and y_4 indicated the generations of NZW rabbits.

Results

The least-square means (LSM) and their standard deviations (SD) for the morphometric traits of NZW rabbits according to generations are presented in Table 2. A significant difference (P<0.05) between different generations was observed for HW, EL, CW, RU, FM, and HP. G0 showed the highest of HW, CW, RU, FM, and HP, whereas G2 had the highest of EL. G0 was similar with G1 for HW, EL, and CW; with G2 for CW, FM, HP; with G3 and G4 for EL, CW, and FM.

Table 3. presented eigenvalues, and their contribution in each factor. The eigenvalues of the three factors were 0.43, 0.36, and 0.28, and cumulative variations were 0.31, 0.61, and 0.82, respectively for the first, second and third factors. Table 4. shows the canonical analysis based on morphometric traits, allowing identification of canonical variables (CAN1, CAN2, and CAN 3). The greatest contribution in each canonical was FM, HP, and RU, respectively for CAN1, CAN2, and CAN 3.

Distance of Mahalanobis between the populations are presented in Table 5. The longest distance showed between G2 and G3. Fig. 1. shows the same morphometric traits of G1, G2, G3, and G4 were similar to each other but different with G0.

Discussion

Based on the LSM, HW, RU, and HP have become the most prominent traits for which distinguish between imported breed and their progenies. This difference can be associated with the influence of environment, feed quality, and management techniques (Elamin *et al.*, 2012; Arandas *et al.*, 2017). On the other hand, HL, EW, CC, CD, TB, HM, and BL were not different between generations. CD, TB, and BL were similar; CC and HM were longer; HL and EW were shorter compared with morphometric of NZW reported by Brahmantiyo *et al.* (2021) in Indonesian Research Institute for Animal Production, Ciawi, Bogor, West Jawa.

Third factors of eigenvalue explained the highest total variance (82%) of morphometric traits. Setiaji *et al.* (2012), studied morphometric traits on Flemish Giant, English Spot, Angora, and Rex breeds of rabbits, found three factors that explained 84% of the total variation. The result was within range of total variance for morphometric traits reported in other species (Yakubu *et al.*, 2011; Ajayi *et al.*, 2012; Birteeb *et al.*, 2013) in goat, chicken, and sheep, respectively. RU, FM, and HP showed the greatest contribution in the three canonical variables. This suggests that three traits are important in defining generational patterns (Yang *et al.*, 2006). That was different with the greatest contribution EL, CC, BL reported by Setiaji *et al.* (2012) in grouping four breeds of rabbit.

The result of Mahalanobis distance indicates that despite belonging to the same rabbit breed and same farm, there are differences among generations. The sensitivity and specificity of Mahalanobis distance were calculated for the results of the discrimination of morphometric traits in the validation group across generations (Rossi *et al.*, 2010). Furthermore, the progeny with the shortest distance to G0 was G1, and due to the fact that G1 got a large direct genetic effect from the G0. Whereas, the longest was between G0 and G2. G2 of NZW rabbits have not adapted well to the environment and nutritional conditions. Then in G3 and G4 have been adapted well with the results that the morphometric traits were nearly the same to which of G0.

As shown in Fig. 1, highlighting a connection the NZW rabbits between generations was observed. Morphological similarity showed possibility of close relationships among generations (Hamilton *et al.*, 2005). In this study, G0 located on top side showed the small size category, in which it differed from their progenies.

Conclusions

Imported rabbit showed different characteristic in morphometric and was classified into small size category which differed from their progenies. The longest genetic distance was shown between imported and second-generation progeny. Radius-ulna length, femuris length, and hip width showed the greatest contribution as distinguishing factors between generations.

Conflict of interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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Table 1. Descriptive statistic for morphometric data of New Zealand White rabbits

Trait[1] (cm)	N[2]	Minimum	Maximum	Mean	SD[3]
HL	72	8.69	13.34	10.85	0.88
HW	72	4.41	6.35	5.36	0.41
EL	72	9.20	12.80	11.20	0.76
EW	72	5.40	7.30	6.52	0.36
CC	72	34.4	44.80	39.05	2.32
CD	72	7.99	11.83	10.14	0.86
CW	72	8.58	12.67	10.34	0.86
RU	72	7.95	12.10	9.55	0.80
FM	72	11.73	16.90	14.13	0.92
TB	72	12.25	16.60	15.04	0.89
HM	72	9.16	12.30	10.79	0.66
HP	72	9.34	13.93	12.07	0.95
BL	72	33.31	41.10	37.53	1.59

[1]HL: Head Length; HW: Head Width; EL: Ear Length; EW: Ear Width; CC: Chest Circumference; CD: Chest Depth; CW: Chest width; RU: Radius-ulna Length; FM: Femoris Length; TB: Tibia Length; HM: Humerus Length; HP: Hip Width; BL: Body Length. [2]N: number of rabbits measured. [3]SD: standard deviation.

Table 2. Least square means of morphometric traits at different generations

Traits[1] (cm)	Generations[2]				
	G0	G1	G2	G3	G4
HL	10.35 ± 1.08	10.88 ± 1.01	11.00 ± 0.85	10.53 ± 0.52	11.11 ± 0.99
HW	5.74 ± 0.24^{a}	5.49 ± 0.43^{ab}	5.30 ± 0.28^{b}	5.31 ± 0.45^{b}	5.26 ± 0.46^{b}
EL	10.60 ± 0.65^{b}	11.14 ± 0.78^{ab}	11.41 ± 0.73^{a}	11.27 ± 0.67^{ab}	11.09 ± 0.85^{ab}
EW	6.72 ± 0.29	6.42 ± 0.49	6.58 ± 0.36	6.51 ± 0.19	6.53 ± 0.34
CC	39.80 ± 0.69	39.68 ± 2.64	39.44 ± 2.41	38.36 ± 1.92	38.37 ± 2.34
CD	10.38 ± 0.26	9.96 ± 0.75	10.22 ± 0.87	9.99 ± 1.01	10.34 ± 0.93
CW	10.98 ± 0.81^{a}	10.34 ± 0.51^{ab}	10.58 ± 0.83^{ab}	9.95 ± 1.02^{b}	10.26 ± 0.90^{ab}
RU	10.55 ± 1.03^{a}	9.65 ± 0.91^{b}	9.48 ± 0.74^{b}	9.18 ± 0.59^{b}	9.64 ± 0.72^{b}
FM	14.65 ± 0.68^{a}	13.72 ± 0.79^{b}	14.22 ± 0.73^{ab}	14.18 ± 0.93^{ab}	14.27 ± 1.21^{ab}
TB	15.22 ± 0.14	15.07 ± 0.84	15.32 ± 0.80	14.85 ± 0.99	14.80 ± 1.01
HM	10.90 ± 1.27	10.84 ± 0.59	10.72 ± 0.71	10.70 ± 0.47	10.90 ± 0.74
HP	13.14 ± 0.59^{a}	11.77 ± 0.96^{b}	12.37 ± 0.91^{ab}	12.07 ± 0.56^{b}	11.76 ± 1.18^{b}
BL	37.55 ± 1.35	37.80 ± 1.62	37.88 ± 1.71	37.79 ± 1.12	36.48 ± 1.67

[1]HL: Head Length; HW: Head Width; EL: Ear Length; EW: Ear Width; CC: Chest Circumference; CD: Chest Depth; CW: Chest width; RU: Radius-ulna Length; FM: Femoris Length; TB: Tibia Length; HM: Humerus Length; HP: Hip Width; BL: Body Length.

[2]G0: imported rabbits; G1: first-generation; G2: second-generation; G3: third-generation; G4: fourth-generation.

$^{a-b}$Means within the same row having different upper case letters differ significantly ($P<0.05$) between generations.

Table 3. Eigenvalues, and its contribution in each factor

Factors	Eigenvalues	Proportion variation (%)	Cumulative variation (%)
First	0.43	0.33	0.31
Second	0.36	0.27	0.61
Third	0.28	0.22	0.82

Table 4. Canonical structure for each morphometric traits

Traits[1]	CAN 1	CAN 2	CAN 3
HL	0.12	-0.24	0.43
HW	-0.35	0.43	0.11
EL	0.02	-0.29	-0.21
EW	0.24	0.29	-0.04
CC	-0.31	0.24	0.17
CD	0.27	0.13	0.19
CW	-0.01	0.44	0.32
RU	-0.05	**0.56**	**0.49**
FM	**0.42**	0.26	-0.11
TB	-0.11	0.21	0.02
HM	0.01	0.04	0.23
HP	0.14	**0.62**	-0.26
BL	-0.39	0.13	-0.43

[1]HL: Head Length; HW: Head Width; EL: Ear Length; EW: Ear Width; CC: Chest Circumference; CD: Chest Depth; CW: Chest width; RU: Radius-ulna Length; FM: Femoris Length; TB: Tibia Length; HM: Humerus Length; HP: Hip Width; BL: Body Length.
CAN 1: first canonical; CAN 2: second canonical; CAN 3: third canonical.

Table 5. Distance of Mahalanobis, based on morphometric traits of NZW rabbits between generations

Generations[1]	G0	G1	G2	G3	G4
G0	1.00				
G1	0.13	1.00			
G2	0.22	0.18	1.00		
G3	0.16	0.19	0.41	1.00	
G4	0.14	0.07	0.35	0.25	1.00

[1]G0: imported rabbits; G1: first-generation; G2: second-generation; G3: third-generation; G4: fourth-generation.

Figure Legends

Fig. 1. : Scattering diagram of five generations based on canonical structure of the morphometric traits.

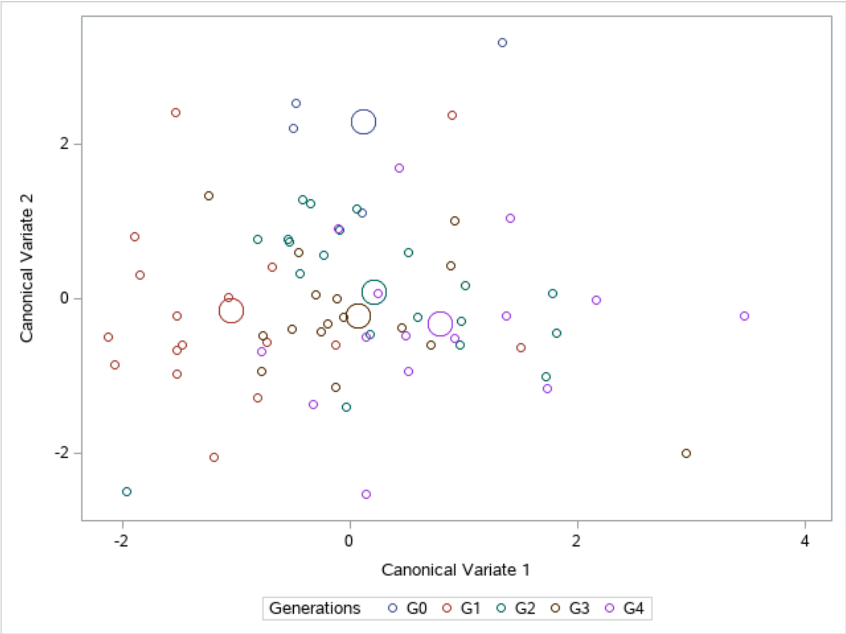

Fig. 1. Scattering diagram of five generations based on canonical structure of the morphometric traits.

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Original Research

Morphometric Traits of Imported Rabbits and Their Progenies

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Abstract

The study aimed to evaluate the morphometric performance in five generations of New Zealand White (NZW) rabbits by using multivariate analysis. The materials used were 72 heads of NZW rabbits from 5 generations: imported rabbits (G0), first-generation (G1), second-generation (G2), third-generation (G3), fourth-generation (G4). G0 have been imported from the United States of America (USA) at the end of 2017. Thirteen morphometric traits were evaluated by using the discriminant procedure of Statistical Analysis System (SAS) University Edition V.6p.2. software. Head width, ear length, chest width, radius-ulna length, femoris length, and Hip width were significant (P<0.05) among generations. Radius-ulna length, femoris length, and hip width showed the greatest contribution as distinguishing factors between generations based on canonical structure. Imported rabbits confirmed specific characteristics in morphometric traits, which differed from their progenies.

KEYWORDS
Canonical structure, Discriminant procedure, Multivariate analysis, New Zealand White.

INTRODUCTION

Rabbit is the potential animal to be developed in Indonesia. Rabbits have high prolificacy, fecundity, profitability, short generation interval, and high feed conversion efficiency (Lebas *et al.*, 1997; Daader *et al.*, 2016). Most of rabbits raised by farmer in Indonesia have been imported from Europe and the United States of America. One of the imported commercial breeds is New Zealand White (NZW), Rex, California, Satin, Hayla and Hycole.

Evaluation is important for assessing the adaptability of imported rabbit and their progenies. Growth, reproductive, carcass, and physiological traits were commonly used for evaluation programs (Marai *et al.*, 2005; Zerrouki *et al.*, 2008; Fathi *et al.*, 2017; Jimoh and Ewoula, 2018). Facts on morphometrics traits are an essential element of comparative studies of development. Morphometrics let in the rigorous quantitative analysis of variants in organismal size and shape and utilized increasingly in developmental contexts (Klingenberg, 2002). The study of the morphometric traits to evaluate among generations is limited. This study was conducted to evaluate the morphometric performance in five generations of NZW rabbits through multivariate analysis.

MATERIALS AND METHODS

The data was obtained from 75 heads of NZW rabbits from 5 generations: imported rabbit (G0) (n=7), first-generation (G1) (n=17), second-generation (G2) (n=20), third-generation (G3) (n=16), fourth-generation (G4) (n=15). G0 have been imported to Indonesia from the American Rabbits Breeder Association (ARBA), United States of America (USA) at the end of 2017. G1 was the progenies of G0, G2 was the progenies of G1, and so on. The rabbits were raised in an intensive rearing system. The age of rabbits chosen was more than 12 months old. The morphometric evaluation was performed by measuring a total of 13 quantitative characteristics. Morphometric traits measured included head length (HL), head width (HW), ear length (EL), ear width (EW), chest circumference (CC), chest depth (CD), chest width (CW), radius-ulna length (RU), femoris length (FM), tibia length (TB), humerus length (HM), hip width (HP), and body length (BL). The descriptive statistic of morphometric data is presented in Table 1.

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Statistical analysis

Morphometric data was analyzed using Statistical Analysis System (SAS) University Edition V.6p.2. software (SAS, 2014). One-Way ANOVA was used for analyzing the effect of generation on body morphometric traits. Duncan's multiple ranges was used at 5% of probability. Discriminant analysis was performed to determine discriminant variables, canonical structure, mahalanobis distance, and distribution mapping among generations. The variance components are the discrimination from individual structure of canonical and distance of mahalanobis. The model was as follow:

$$C=\mu+\mu_0 y_0+\mu_1 y_1+\mu_2 y_2+ \mu_3 y_3+\mu_4 y_4$$

Where; μ_0, μ_1, μ_2, μ_3, and μ_4 are the estimate of canonical coefficients, and y_0, y_1, y_2, y_3, and y_4 indicated the generations of NZW rabbits.

RESULTS

The least-square means (LSM) and their standard deviations (SD) for the morphometric traits of NZW rabbits according to generations are presented in Table 2. A significant difference (P<0.05) between different generations was observed for HW, EL, CW, RU, FM, and HP. G0 showed the highest of HW, CW, RU, FM, and HP, whereas G2 had the highest of EL. G0 was similar with G1 for HW, EL, and CW; with G2 for CW, FM, HP; with G3 and G4 for EL, CW, and FM.

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EL	72	9.2	12.8	11.2	0.76
EW	72	5.4	7.3	6.52	0.36
CC	72	34.4	44.8	39.05	2.32
CD	72	7.99	11.83	10.14	0.86
CW	72	8.58	12.67	10.34	0.86
RU	72	7.95	12.1	9.55	0.8
FM	72	11.73	16.9	14.13	0.92
TB	72	12.25	16.6	15.04	0.89
HM	72	9.16	12.3	10.79	0.66
HP	72	9.34	13.93	12.07	0.95
BL	72	33.31	41.1	37.53	1.59

[1]HL: Head Length; HW: Head Width; EL: Ear Length; EW: Ear Width; CC: Chest Circumference; CD: Chest Depth; CW: Chest width; RU: Radius-ulna Length; FM: Femoris Length; TB: Tibia Length; HM: Humerus Length; HP: Hip Width; BL: Body Length. 2N: number of rabbits measured. 3SD: standard deviation.

Table 2. Least square means of morphometric traits at different generations

Traits[1]	Generations[2]				
(cm)	G0	G1	G2	G3	G4
HL	10.35 ± 1.08	10.88 ± 1.01	11.00 ± 0.85	10.53 ± 0.52	11.11 ± 0.99
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EL	10.60 ± 0.65^{b}	11.14 ± 0.78^{ab}	11.41 ± 0.73^{a}	11.27 ± 0.67^{ab}	11.09 ± 0.85^{ab}
EW	6.72 ± 0.29	6.42 ± 0.49	6.58 ± 0.36	6.51 ± 0.19	6.53 ± 0.34
CC	39.80 ± 0.69	39.68 ± 2.64	39.44 ± 2.41	38.36 ± 1.92	38.37 ± 2.34
CD	10.38 ± 0.26	9.96 ± 0.75	10.22 ± 0.87	9.99 ± 1.01	10.34 ± 0.93
CW	10.98 ± 0.81^{a}	10.34 ± 0.51^{ab}	10.58 ± 0.83^{ab}	9.95 ± 1.02^{b}	10.26 ± 0.90^{ab}
RU	10.55 ± 1.03^{a}	9.65 ± 0.91^{b}	9.48 ± 0.74^{b}	9.18 ± 0.59^{b}	9.64 ± 0.72^{b}
FM	14.65 ± 0.68^{a}	13.72 ± 0.79^{b}	14.22 ± 0.73^{ab}	14.18 ± 0.93^{ab}	14.27 ± 1.21^{ab}
TB	15.22 ± 0.14	15.07 ± 0.84	15.32 ± 0.80	14.85 ± 0.99	14.80 ± 1.01
HM	10.90 ± 1.27	10.84 ± 0.59	10.72 ± 0.71	10.70 ± 0.47	10.90 ± 0.74
HP	13.14 ± 0.59^{a}	11.77 ± 0.96^{b}	12.37 ± 0.91^{ab}	12.07 ± 0.56^{b}	11.76 ± 1.18^{b}
BL	37.55 ± 1.35	37.80 ± 1.62	37.88 ± 1.71	37.79 ± 1.12	36.48 ± 1.67

[1]HL: Head Length; HW: Head Width; EL: Ear Length; EW: Ear Width; CC: Chest Circumference; CD: Chest Depth; CW: Chest width; RU: Radius-ulna Length; FM: Femoris Length; TB: Tibia Length; HM: Humerus Length; HP: Hip Width; BL: Body Length.
[2]G0: imported rabbits; G1: first-generation; G2: second-generation; G3: third-generation; G4: fourth-generation.
[a-b]Means within the same row having different upper case letters differ significantly (P<0.05) between generations.

Table 3. Eigenvalues, and its contribution in each factor.

Factors	Eigenvalues	Proportion variation (%)	Cumulative variation (%)
First	0.43	0.33	0.31
Second	0.36	0.27	0.61
Third	0.28	0.22	0.82

Table 4. Canonical structure for each morphometric traits

Traits[1]	CAN 1	CAN 2	CAN 3
HL	0.12	-0.24	0.43
HW	-0.35	0.43	0.11
EL	0.02	-0.29	-0.21
EW	0.24	0.29	-0.04
CC	-0.31	0.24	0.17
CD	0.27	0.13	0.19
CW	-0.01	0.44	0.32
RU	-0.05	0.56	0.49
FM	0.42	0.26	-0.11
TB	-0.11	0.21	0.02
HM	0.01	0.04	0.23
HP	0.14	0.62	-0.26
BL	-0.39	0.13	-0.43

[1]HL: Head Length; HW: Head Width; EL: Ear Length; EW: Ear Width; CC: Chest Circumference; CD: Chest Depth; CW: Chest width; RU: Radius-ulna Length; FM: Femoris Length; TB: Tibia Length; HM: Humerus Length; HP: Hip Width; BL: Body Length.
CAN 1: first canonical; CAN 2: second canonical; CAN 3: third canonical.

Table 5. Distance of Mahalanobis, based on morphometric traits of NZW rabbits between generations.

Generations[1]	G0	G1	G2	G3	G4
G0	1				
G1	0.13	1			
G2	0.22	0.18	1		
G3	0.16	0.19	0.41	1	
G4	0.14	0.07	0.35	0.25	1

[1]G0: imported rabbits; G1: first-generation; G2: second-generation; G3: third-generation; G4: fourth-generation.

greatest contribution in each canonical was FM, HP, and RU, respectively for CAN1, CAN2, and CAN 3.

Distance of Mahalanobis between the populations are presented in Table 5. The longest distance showed between G2 and G3. Fig. 1. shows the same morphometric traits of G1, G2, G3, and G4 were similar to each other but different with G0.

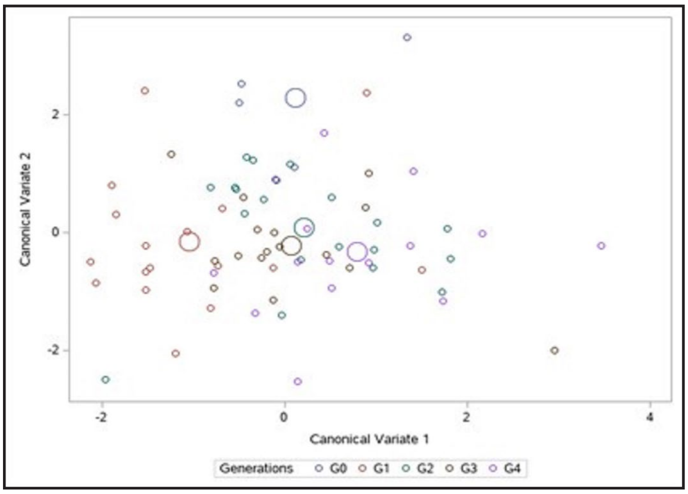

Fig. 1. Scattering diagram of five generations based on canonical structure of the morphometric traits.

DISCUSSION

Based on the LSM, HW, RU, and HP have become the most prominent traits for which distinguish between imported breed and their progenies. This difference can be associated with the influence of environment, feed quality, and management techniques (Elamin *et al*., 2012; Arandas *et al*., 2017). On the other hand, HL, EW, CC, CD, TB, HM, and BL were not different between generations. CD, TB, and BL were similar; CC and HM were longer; HL and EW were shorter compared with morphometric of NZW reported by Brahmantiyo *et al*. (2021) in Indonesian Research Institute for Animal Production, Ciawi, Bogor, West Jawa.

Third factors of eigenvalue explained the highest total variance (82%) of morphometric traits. Setiaji *et al*. (2012), studied morphometric traits on Flemish Giant, English Spot, Angora, and Rex breeds of rabbits, found three factors that explained 84% of the total variation. The result was within range of total variance for morphometric traits reported in other species (Yakubu *et al*., 2011; Ajayi *et al*., 2012; Birteeb *et al*., 2013) in goat, chicken, and sheep, respectively. RU, FM, and HP showed the greatest contribution in the three canonical variables. This suggests that three traits are important in defining generational patterns (Yang *et al*., 2006). That was different with the greatest contribution EL, CC, BL reported by Setiaji *et al*. (2012) in grouping four breeds of rabbit.

The result of Mahalanobis distance indicates that despite belonging to the same rabbit breed and same farm, there are differences among generations. The sensitivity and specificity of Mahalanobis distance were calculated for the results of the discrimination of morphometric traits in the validation group across generations (Rossi *et al*., 2010). Furthermore, the progeny with the shortest distance to G0 was G1, and due to the fact that G1 got a large direct genetic effect from the G0. Whereas, the longest was between G0 and G2. G2 of NZW rabbits have not adapted well to the environment and nutritional conditions. Then in G3 and G4 have been adapted well with the results that the morphometric traits were nearly the same to which of G0.

As shown in Fig. 1, highlighting a connection the NZW rabbits between generations was observed. Morphological similarity showed possibility of close relationships among generations (Hamilton *et al*., 2005). In this study, G0 located on top side showed the small size category, in which it differed from their progenies.

CONCLUSION

Imported rabbit showed different characteristic in morphometric and was classified into small size category which differed from their progenies. The longest genetic distance was shown between imported and second-generation progeny. Radius-ulna length, femuris length, and hip width showed the greatest contribution as distinguishing factors between generations.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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