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PARTIAL DIALLEL CROSS FOR ASSESSING GENETIC MERIT OF LOCAL RABBIT BREED

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Abstract: This study was carried out to estimate general combining ability (GCA) and specific combining ability (SCA) of pre-and post-weaning traits from a partial diallel cross in three rabbit breeds: Local rabbit (L), Flemish Giant (F), and Rex (R). Body weight at 0 (BW_0), 30 (BW_{30}), 42 (BW_{42}), and 63 (BW_{63}) days of age, average daily gains from 0 to 30 d of age (ADG_{0-30}), from 30 to 42 d of age (ADG_{30-42}), from 42 to 63 d of age (ADG_{42-63}), and from 30 to 63 d of age (ADG_{30-63}), litter size at birth (LS_0) and at weaning (LS_{42}), and mortality at weaning (MR_{42}) were studied in crossing LL, FF, RR, LF, LR, and FR. Local breed had the highest GCA for BW_0, BW_{30}, BW_{42}, and average daily gain before weaning (ADG_{0-30}, and ADG_{30-42}) compared to Flemish Giant and Rex, while GCA of Local breed for average daily gain after weaning (ADG_{42-63}), litter size (LS_0, and LS_{42}), and mortality (MR_{42}) was higher than for Rex and similar to that of Flemish Giant. Crossing LF and LR showed higher SCA for BW_{30}, BW_{42}, BW_{63}, ADG_{0-30}, ADG_{42-63} and ADG_{30-63} than FR. In conclusion, based on GCA and SCA, the Indonesian Local breed has a high genetic potential in the crossing with Flemish Giant and Rex breeds.

Key Words: rabbit, combining ability, Flemish Giant, Indonesian Local rabbit, Rex.

INTRODUCTION

Crossbreeding could be an excellent tool to take advantage of the complementarity between two breeds (Mínguez *et al.,* 2015). The diallel cross is a strategy that is commonly used in rabbits being bred for reproductive (Ragab *et al.,* 2014) and growth traits (Abdel-hamid, 2015; Mínguez *et al.,* 2015), in order to exploit the combining ability (GCA) and specific combining ability (SCA) (Kurnianto *et al.*, 1999). GCA is used to designate the average performance of an inbred line in hybrid combinations, while SCA is used to designate those cases in which certain combinations do relatively better or worse than would be expected based on the average performance of the lines involved (Murphy *et al.,* 2008).

In Europe, crossbreeding is performed between two maternal lines, in order to generate prolific crossbred females that are mated to male-line males selected for high growth rate (Brun and Baselga, 2005; Ragab and Baselga, 2011; Mínguez *et al.,* 2015). In tropical countries, crossbreeding is performed between imported lines and local breeds, intending to reach a compromise between the performance of the imported lines and the adaptation to heat stress of local breeds (El-Raffa *et al.,* 2005; Al-Saef *et al.,* 2008; Youssef *et al.,* 2009).

The problem of rabbit developing programmes in Indonesia is mostly that the rabbit was imported from United States and Europe (Setiaji *et al.*, 2022). They cannot successfully be adapted to the tropics. One strategy to improve genetic

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merit is crossbreeding between the imported line with the Local breed that has long been adapting to Indonesian conditions (Sartika and Rahardjo, 2008). The main objective of this study is to estimate GCA and SCA of the pre-and post-weaning traits of Local breed compared with two imported breeds, namely Flemish Giant and Rex.

MATERIALS AND METHODS

The data came from 220 kits originating from crossing of 12 males and 36 females. Six Indonesian Local (L), four Flemish Giant (F), and two Rex (R) male rabbits were mated to six L, twelve F, and eighteen R female rabbits. Males were more than 12 mo old and females were between 6-12 mo old. Diallel cross method II by Griffing (1956) was used as a crossing design in this study. The type of crossing with the number of kits is presented in Table 1. The total duration of the study was 100 d. Each female was placed in an individual cage until the kits were born and weaned at 42 d of age. The data on reproductive events were recorded for each female. Body weights of kits were recorded individually at 3-d intervals from 0 to 63 d of age.

Study traits

The traits studied were body weight (BW, g) at 0 (BW_0), 30 (BW_{30}), 42 (BW_{42}), and 63 (BW_{63}) days of age, average daily gains (ADG, g/d) from 0 to 30 d of age (ADG_{0-30}), from 30 to 42 d of age (ADG_{30-42}), from 42 to 63 d of age (ADG_{42-63}), and from 30 to 63 d of age (ADG_{30-63}). BW and ADG were individually measured in kits. Litter size (LS, kits) was considered as the total number of kits born (LS_0) and the total number of kits weaned (LS_{42}). Mortality at weaning (MR_{42}, %) was measured as:

$$\frac{\text{offspring mortality until 42 d in each female}}{LS_0}\times 100\%$$

Based on the fact that males and females were able to be separated after 20 d of age and the low sexual dimorphism for BW and ADG, the data collection was not carried out separately for the different sexes.

Statistical analysis

The model used in the analysis for BW_0, ADG_{0-30}, LS_0, LS_{42}, and MR_{42} was:

$$y_{ij}=T_i+e_{ij} \quad (1)$$

where T_i is the fixed effect of type of crossing and e_{ij} is the random residual effect.

The following model was used for BW_{30},BW_{42},BW_{63}, ADG_{30-42}, ADG_{30-63}, and ADG_{42-63}:

$$y_{ijkl}=T_i+X_j+b_k+e_{ijkl} \quad (2)$$

T_i is as described in the previous model; X_j is the fixed effect of sex; b_k is the random effect of number born alive, and e_{ijkl} is the random residual effect.

Value of GCA and SCA were estimated by using the diallel cross method II formula (Griffing, 1956) as follows:

$$\hat{g}_i=\frac{1}{p+2}(X_{i.}+x_{ii}-\frac{2}{p}X_{..}) \quad (3)$$

Table 1: Partial Diallel Cross model of three breeds of rabbit.

Breeds as parents		Male		
		Indonesian Local (L)	Flemish Giant (F)	Rex (R)
Female	Indonesian Local (L)	LL (n=24)	-	-
	Flemish Giant (F)	LF (n=38)	FF (n=43)	-
	Rex (R)	LR (n=34)	FR (n=49)	RR (n=32)

n: number of kits in each type of crossing.
The first letter of the breed name corresponds to the male line and the second one to the female line name.

$$\hat{s}_{ij}=x_{ij}-\frac{1}{p+2}(X_{i.}+x_{ii}+X_{j.}+x_{jj})+\frac{2}{(p+1)(p+2)}X_{..} \quad (4)$$

where: $\hat{g}_i$= GCA value for i[th] linebreed; $\hat{s}_{ij}$=SCA for crossbred of the i[th] male and the j[th] female; P=total of inbreed line.

$$X_{i.}=\sum_j x_{ji}=x_{j1}+x_{j2}+x_{j3} \quad (5)$$

$$X_{j.}=\sum_i x_{ij}=x_{i1}+x_{i2}+x_{i3} \quad (6)$$

$$X_{..}=\sum\sum_{i\leq j} x_{ij}=x_{11}+x_{21}+x_{22}+x_{31}+x_{32}+x_{33} \quad (7)$$

where x_{ij}=the offspring from crossing between male of the i[th] breed and the female of the j[th] breed; x_{ii}=the offspring from crossing between male of the i[th] breed and the female of the i[th] breed; x_{jj}=the offspring from crossing between male of the j[th] breed and the female of the j[th] breed

RESULTS AND DISCUSSION

The descriptive statistics for all traits studied are presented in Table 2. The mean birth BW_0 was lower than the range of birth weights of Hycole, Hyla, New Zealand White, Rex, Satin and Reza and FZ-3 (between 50.4 and 56.6 g) reported in Indonesia (Brahmantiyo *et al.,* 2013; Brahmantiyo *et al.,* 2017). BW_{30}, BW_{42} and BW_{63} were lower than the bodyweights of New Zealand white, California, and Rex rabbit reported by Marai *et al.* (2008) and Abdel-Hamid (2015) in Egypt. ADG was lower compared with the average of ADG obtained in European lines (Bolet *et al*., 2004; Mínguez *et al.,* 2015).

LS_0 was within the range of litter size at birth reported in European lines (Poigner *et al.,* 2000; Piles *et al*., 2006; Blasco *et al.,* 2017). However, LS_{42} observed in this study was lower than found by Ragab and Baselga (2011) at 28 d of age. Compared with mortality from birth to weaning of eight breeds reported by Bolet *et al.* (2004), MR_{42} was higher than in Chinchilla, English, Fauve de Bourgogne and Himalaya, but lower than in Argente de Champagne, Belgian Hare, Thuringer and Vienna White. A high percentage of MR_{42} in this study could be caused by poor adaptation of local breed females to intensive breeding.

The type of crossing had a significant effect (P<0.05) on BW, ADG, LS, and MR (Table 3). LF and LR showed similar values for BW_0, BW_{30}, BW_{42}, $ADG_{30\text{-}42}$, LS_0, LS_{42}, and MR_{42}. In contrast, BW_{63}, $ADG_{42\text{-}63}$, and $ADG_{30\text{-}63}$ were higher in LF than that for LR. The result indicated that the LF and LR had similar performance before weaning but LF was better than LR after weaning. The better performance of LF may be caused by the fact that the female Flemish Giant is

Table 2: Descriptive statistics for body weight (BW[1], g), average daily gain (ADG[2], g/d), litter size (LS[3], kit), and mortality (MR[4], %).

Traits	N[5]	Mean	SD[6]	Minimum	Maximum
$BW_{0(birth)}$	220	45.93	10.01	26	84
BW_{30}	184	291.71	58.06	151	439
$BW_{42(weaning)}$	177	420.03	89.27	177	620
BW_{63}	169	647.89	150.45	309	900
$ADG_{0\text{-}30}$	184	8.16	1.74	3.87	12.6
$ADG_{30\text{-}42}$	177	10.67	3.96	1	21.75
$ADG_{42\text{-}63}$	169	10.73	4.28	2.66	21.33
$ADG_{30\text{-}63}$	169	10.71	3.37	1	21.75
$LS_{0(birth)}$	36	6.11	2.19	1	11
$LS_{42(weaning)}$	36	5.03	1.44	0	9
MR_{42}	36	19.64	20.44	0	100

[1]BW, body weight at 0, 30, 42 and 63 d of age. [2]$ADG_{0\text{-}30}$, average daily gain from 0 to 30 d of age; $ADG_{30\text{-}42}$, average daily gain from 30 to 42 d of age; $ADG_{42\text{-}63}$, average daily gain from 42 to 63 d of age; $ADG_{30\text{-}63}$, average daily gain from 30 to 63 d of age. [3]LS, litter size at birth, and weaning. [4]MR_{42}, mortality at 42 days. [5]N, number of offsprings. [6]SD, standard deviation.

Table 3: Bodyweight (BW[1], g), average daily gain (ADG[2], g/d), litter size (LS[3], kit), and mortality (MR[4], %) of offspring as the result of crossing (±standard error).

	Type of crossing					
Traits	LL	FF	RR	LF	LR	FR
$BW_{0(birth)}$	51.14±2.52[ab]	54.47±1.82[a]	48.20±1.02[ab]	42.82±1.28[b]	47.62±1.57[ab]	41.08±0.99[b]
BW_{30}	245.37±6.33[b]	322.53±8.01[a]	309.87±7.34[ab]	285.97±7.94[ab]	318.01±14.19[a]	244.29±9.88[b]
$BW_{42(weaning)}$	353.98±7.03[c]	478.80±12.15[a]	441.56±12.14[a]	395.52±12.82[ab]	466.94±13.21[a]	341.72±15.61[c]
BW_{63}	443.88±2.68[c]	770.29±22.29[a]	691.93±23.06[ab]	704.96±18.60[a]	657.33±15.52[b]	529.91±22.61[bc]
$ADG_{0\text{-}30}$	6.68±0.13[b]	8.90±0.24[a]	8.75±0.23[a]	8.08±0.23[ab]	9.32±0.31[a]	6.74±0.31[b]
$ADG_{30\text{-}42}$	8.79±0.30[c]	11.58±1.84[a]	10.16±0.67[ab]	12.42±0.78[a]	10.63±0.82[ab]	7.94±0.54[c]
$ADG_{42\text{-}63}$	4.25±0.25[c]	13.77±0.53[a]	12.02±0.93[ab]	12.81±0.78[a]	9.40±0.35[b]	9.06±0.36[b]
$ADG_{30\text{-}63}$	5.94±0.13[c]	13.57±0.47[a]	11.41±0.61[ab]	12.63±0.44[a]	9.76±0.33[b]	8.65±0.39[b]
$LS_{0(birth)}$	5.00±0.37[c]	6.83±0.34[ab]	5.33±0.19[bc]	6.33±0.26[b]	5.67±0.18[b]	8.17±0.22[a]
$LS_{42(weaning)}$	3.95±0.18[c]	6.59±0.35[a]	5.13±0.15[b]	5.45±0.21[ab]	4.85±0.17[b]	5.60±0.14[ab]
MR_{42}	33.53±5.49[a]	21.93±2.91[b]	9.92±4.30[c]	19.24±2.29[b]	19.92±2.53[b]	32.15±0.66[a]

The first letter of the breed name corresponds to the male line and the second one to the female line name. L: Indonesian Local; F: Flemish Giant; R: Rex.

[1]BW, body weight at 0, 30, 42 and 63 d of age.

[2]$ADG_{0\text{-}30}$, average daily gain from 0 to 30 d of age; $ADG_{30\text{-}42}$, average daily gain from 30 to 42 d of age; $ADG_{42\text{-}63}$, average daily gain from 42 to 63 d of age; $ADG_{30\text{-}63}$, average daily gain from 30 to 63 d of age.

[3]LS, litter size at birth, and weaning.

[4]MR_{42}, mortality at 42 d.

[a,b,c]Different superscripts within a row show significant different (P<0.05).

bigger than the Rex and maternal effect is shown after weaning (Rashwan and Marai, 2000; Szendrő *et al.,* 2019). In the previous study on growth performance, Setiaji *et al.* (2013) reported that the difference between Flemish Giant and Rex was after 30 d of age. Compared with FR, LF showed higher performance for BW_{42}, BW_{63}, $ADG_{30\text{-}42}$, $ADG_{42\text{-}63}$ and $ADG_{30\text{-}63}$ than FR and LR showed higher values for $BW_{30,}$ $BW_{42,}$ $ADG_{0\text{-}30,}$ $ADG_{30\text{-}42}$ than FR Both types of crossing displayed lower LS_0 and lower $MR_{42.}$ These result indicated that the crossing male of Local breed was superior to Flemish Giant when mated with a Rex doe for preweaning traits. Youssef *et al.* (2009) reported that the cross between Local Baladi Red rabbit and imported breed showed superior for BW and average daily gain from 4 to 12 wk of age.

LF showed better performance than LL for BW_{42}, BW_{63}, $ADG3_{30\text{-}42}$, $ADG_{42\text{-}63}$, $ADG_{30\text{-}63,}$ $LS_{0,}$ LS_{42}, and MR_{42}. Almost all traits of LF indicated the same performance as FF.

LF and LR showed better performance than LL for BW_{42}, BW_{63}, $ADG3_{30\text{-}42}$, $ADG_{42\text{-}63}$, $ADG_{30\text{-}63,}$ $LS_{0,}$ LS_{42}, and MR_{42} and exhibited similar performance for almost all traits with RR. However, LF and LR showed a higher mortality (MR_{42}) than RR. The result indicated that kits of crossing between male of Local breed with the female of the imported breed has performed similar with performance of kits from imported pure breed. These kits of crossing are expected to show better performance than kits of the pure line due to the advantage of heterosis and complementarity in pre and post-weaning traits (Orengo *et al.,* 2004; Ragab, 2012).

Table 4 presents the combining ability values for BW, ADG, LS, and MR. The estimated GCA for BW_0, BW_{30}, BW_{42}, BW_{63} of the Local breed had the greatest value (P<0.05) compared to Flemish Giant and Rex. The positive value of GCA was found for BW_0 of Local breed. The positive value of GCA indicated that Local breed has greater capacity for passing better genes of BW_0 to the offspring than other breeds. The value of SCA for BW_0 on crossing LF was similar to that on crossing FR and higher than on LR. Furthermore, LF and LR showed higher values of SCA for BW_{30}, BW_{42}, BW_{63} than FR. The SCA of body weights was higher than observed by Gupta *et al.* (2001) in New Zealand White, Chinchilla, and Flemish Giant. For ADG before weaning ($ADG_{0\text{-}30}$ and $ADG_{30\text{-}42}$), Local breed had the higher GCA than Flemish Giant and Rex; and for ADG after weaning ($ADG_{42\text{-}63}$ and $ADG_{30\text{-}63}$), Local breed showed similar GCA to Flemish Giant and higher GCA than Rex. Crossing LF and LR displayed higher values of SCA for $ADG_{0\text{-}30}$, $ADG_{42\text{-}63}$ and $ADG_{30\text{-}63}$ than FR. The results for SCA indicated that LF and LR would be good crosses for improvement in BW and ADG.

Table 4: Combining ability for body weight (BW[1], g), average daily gain (ADG[2], g/d), litter size (LS[3], kit), and mortality (MR[4], %).

Traits	Combining ability					
	$\hat{g}_L$	$\hat{g}_F$	$\hat{g}_R$	$\hat{s}_{LF}$	$\hat{s}_{LR}$	$\hat{s}_{FR}$
$BW_{0(birth)}$	0.51[a]	-8.04[b]	-18.76[b]	02.46[x]	00.59[y]	02.59[x]
BW_{30}	-12.53[a]	-49.60[b]	-107.52[c]	50.42[x]	36.26[x]	-0.38[y]
$BW_{42(weaning)}$	-16.38[a]	-70.61[b]	-53.85[b]	58.66[x]	62.35[x]	-8.65[y]
BW_{63}	-56.43[a]	-92.34[a]	-229.67[b]	185.67[x]	72.93[y]	-18.58[z]
ADG_{0-30}	-0.31[a]	-1.55[b]	-2.96[c]	1.59[x]	1.30[x]	-0.03[y]
ADG_{30-42}	-0.08[a]	-1.98[b]	-4.14[c]	3.33[x]	0.88[xy]	0.09[y]
ADG_{42-63}	-2.03[ab]	-0.85[a]	-3.36[b]	4.73[x]	0.89[y]	-0.64[z]
ADG_{30-63}	-1.41[a]	-1.10[a]	-3.69[b]	4.02[x]	0.86[y]	-0.56[z]
$LS_{0(birth)}$	-0.84[a]	-0.48[a]	-2.71[b]	-	-	-
$LS_{42(weaning)}$	-0.57[a]	-0.46[a]	-2.16[b]	-	-	-
MR_{42}	3.02[a]	-3.02[ab]	-14.26[b]	-	-	-

The first letter of the breed name corresponds to the male line and the second one to the female line name. L: Indonesian Local; F: Flemish Giant; R: Rex.

[1]BW, body weight at 0, 30, 42 and 63 d of age.

[2]ADG_{0-30}, average daily gain from 0 to 30 d of age; ADG_{30-42}, average daily gain from 30 to 42 d of age; ADG_{42-63}, average daily gain from 42 to 63 d of age; ADG_{30-63}, average daily gain from 30 to 63 d of age.

[3]LS, litter size at birth, and weaning.

[4]MR_{42}, mortality at 42 d.

[5]$\hat{g}_L$, GCA of Indonesian Local breed; $\hat{g}_F$, GCA of Flemish Giant, $\hat{g}_R$, GCA of Rex; $\hat{S}_{LF}$, SCA of crossing LF; $\hat{s}_{LR}$, SCA of crossing LR; $\hat{s}_{FR}$, SCA of crossing FR.

[a,b]Different superscripts within a row show significant differences in GCA ($P<0.05$).

[x,y]Different superscripts within a row show significant differences in SCA ($P<0.05$).

GCA for LS_0, LS_{42}, and MR_{42} of Local breed was similar to that of Flemish Giant, but higher than that of Rex. The breed with the greatest GCA expected would give larger LS (Okoro and Mbajiorgu, 2017). The higher GCA indicated that Local breed would have a larger litter size at birth. However, mortality of offspring would be high because of the higher GCA of MR_{42}. SCA cannot estimate these traits because both litter size and mortality are traits of the female, and the female is a pure breed. Overall, the Local breed has a high potential based on the GCA and SCA values.

CONCLUSION

Indonesian Local breed has a high genetic potential in the crossing with Flemish Giant and Rex breeds.

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