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Original Article

Performance of Bali Cattle by the Implementation of Quadruple Helix Participatory-Based Breeding Programs in Optimizing the Potential of Smallholder Cattle Farms

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Abstract

Objective: This study aims to determine the impact of implementing a participatory-based breeding program on productivity as represented by cattle morphometric measures, technical coefficients and supporting factors among smallholder farmers in Barru District, South Sulawesi Province.
Methods: The research method used 1,040 cattle recordings from 2017 to 2022 in Barru district, South Sulawesi Province, Indonesia, with the following sub-districts being included: Tanete Riaja, Tanete Rilau, Balusu, Barru, and Mallusetasi. The study employed descriptive analysis, a paired-sample T test, and an analysis of the interaction between breeding variables using the general linear model.
Results: The results showed that the morphometric size of participatory-based breeding programs (PBBP) had higher CG values ($p<0.01$) than non-participatory breeding programs (NPBBP).. The NI PBBP value was found to be in the low category (33.82%), while the NPBBP value was found to be 6.94%. A further impact was observed, whereby male and female calves exhibited distinct differences in WH, BL and CG each year between 2020-2022, with statistical significance ($p<0.01$).
Conclusions: This study showed that factor breeding program models (PBBP and NPBBP) significantly influenced the morphometric size ($p < 0.01$). The implementation of the PBBP scheme has had a positive impact, as evidenced by the application of the Quadruple Helix model.

Keywords: Bali cattle; Barru; breeding scheme; morphometric; farmer stakeholder.

INTRODUCTION

The beef cattle rearing methods employed in Indonesia are distinctive. In fact, over 98% of beef cattle are dispersed and maintained by smallholder breeders in limited numbers. Although cattle are traditionally raised with suboptimal management by smallholder farmers, this condition still has considerable potential to support the beef cattle population in Indonesia. In the year 2021, the beef cattle population is estimated to reach 18.05 million heads, representing an increase of 5.55% compared to the previous year [1]. As a point of comparison, the population increase in Australia in June 2022 is estimated to be between 3 and 5 percent [2].

A community-based cattle farming model based on traditional management requires a model of cattle breeding that can be applied in different areas to produce similar outcomes.

A number of breeding methods have been developed on a community basis, including closed nucleus programs, open nucleus programs, dispersed nucleus programs, and community-based breeding programs [3], [4]. One potential approach to the issue of livestock breeding in Indonesia is the implementation of community-based breeding programs (CBBP). This method involves the direct involvement of farmers in the breeding process, with the support of experts [5]. It appears to be challenging to implement completely self-sustained community-based breeding programs [5]. The PBBP scheme, which involves four key stakeholders (the Quadruple Helix), represents a novel approach with significant potential for application in community cattle breeding. The quadruple helix represents a conceptual framework for the integration of academics, entrepreneurs, government, and civil society in the domain of innovation and knowledge [6], [7], [8]. The disparity in the performance of cattle can be employed as a metric to assess the efficacy of a cattle breeding program. The implementation of a cattle breeding program has resulted in changes in morphometric size. A cattle breeding program, namely the participatory-based breeding program (PBBP), is currently being implemented in Barru Regency, South Sulawesi. One of the key developments in the programme is the involvement of smallholder farmers as one of the main programme executors.

MATERIALS AND METHODS

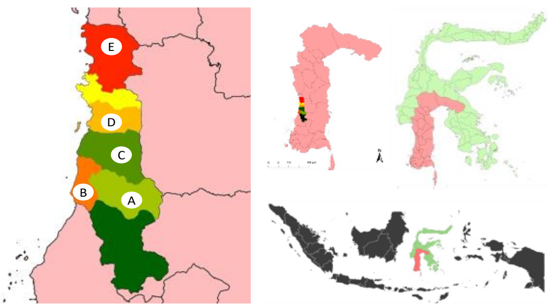

Figure 1. The research site was located in five regencies in South Sulawesi Province, Indonesia. These were: A. Tanete Riaja, B. Tanete Rilau, C. Barru, D. Balusu and E. Mallusetasi.

Study area

This research was conducted from 2017 to 2022 in Barru district in South Sulawesi province, Indonesia, with the following sub-districts being included: Tanete Riaja, Tanete Rilau, Balusu, Barru, and Mallusetasi (Figure 1). The South Sulawesi province is situated at latitudes 4°05'49" and 4°47'35" South and longitudes 119°35'00" and 119°49'16" East. The humidity ranges from 79% to 98%, with temperatures between 26°C and 28°C and annual rainfall between 245 and 860 mm. Indonesia is classified as a tropical Asian country.

Procedures

A total of 1,040 cattle were utilized in this study, comprising 783 cows and 257 calves. The data set comprised age and morphometric traits. Age was identified based on the farmer's records and validated using a number of pairs of permanent incisors (PPI). A measuring tape and vernier caliper were employed for the purpose of measuring animals. The body measurements are taken during the birth season, which lasts from the month of July to the month of October each year.

The body measurements comprised withers height (WH), which was taken from the ground level to the highest point of the withers; body length (BL), which was taken from the point of the shoulder to the pin bone; and chest girth (CG), which was the circumference around the chest at the fourth rib [9]. The birth weight (BW) of the calf was recorded at 24 hours postpartum.

The farmer characteristics and cattle-farming methods profiles were evaluated using twelve different components. A total of 323 respondents consisting of 127 farmers in participatory breeding programs (PBBP) and 196 farmers in smallholder livestock production systems and categorized in non-participatory breeding programs (NPBBP). Farmer characteristics data were farmer profile (farmer area distribution, farmer age, farmer education level, and years in the program). Profile of cattle farming methods data including: forage feeding systems, land area for growing forage, problems in relation to reproduction, types of problems in relation to reproduction, mating system, service per conception, constraints to the use of artificial insemination (AI) system, and caging system.

The population structure in this study was calculated and analyzed according to [10] as follows:

$$Number\ of\ adult\ cattle\ (\%) = \frac{Number\ of\ adult\ cattle}{Number\ of\ population} x100\% \ ...(1)$$

$$Calving\ rate\ based\ on\ adult\ female\ cattle\ or\ calf\ crop\ (\%) = \frac{Number\ of\ calves}{Number\ of\ adult\ female\ cattle} x100\% \ ...(2)$$

$$Calving\ rate\ based\ on\ population\ (\%) = \frac{Number\ of\ calves}{Number\ of\ population} x100\% \ ...(3)$$

$$Mortality\ (\%) = \frac{Number\ of\ death\ cattle}{Number\ of\ population} x100\% \ ...(4)$$

$$Natural\ increase\ (\%) = Calving\ rate\ based\ on\ population\ (\%) - Mortality\ (\%) ...(5)$$

$$Number\ of\ young\ cattle\ (\%) = \frac{Number\ of\ young\ cattle}{Number\ of\ population} x100\% ...(6)$$

$$Requirement\ of\ cattle\ replacement\ (\%) = \frac{Number\ of\ adult\ cattle\ (\%)}{Breeding\ lenght\ (years)} ...(7)$$

$$Remains\ of\ young\ cattle\ (\%) = \frac{Percent\ of\ young\ cattle\ (\%)}{Requirment\ of\ cattle\ replacement\ (\%)} \ ...(8)$$

$$Number\ of\ culled\ cattle\ (\%) = Requirement\ of\ cattle\ replacement\ (\%) ...(9)$$

$$Output\ (\%) = Number\ of\ culled\ cattle\ (\%) + Remains\ of\ young\ cattle\ (\%) ...(10)$$

$$Net\ Replacement\ Rate\ (\%) = \frac{Number\ of\ young\ cattle\ (heads)}{Remains\ of\ young\ cattle\ (heads)} x100\% \ ...(11)$$

Data analysis

Data were analyzed using IBM SPSS 28 to obtain mean, standard deviation, coefficient of variation, minimum/maximum, and percentage of data. The differences in the morphometric values of PBBP and NPBBP were analyzed using the paired sample T-test. The interaction between the difference in the year of measurement and the difference in the breeding model is analyzed using the general linear model with the following models:

$$Y_{ijk} = \mu + A_i + B_j + AB_{ij} + \varepsilon_{ijk}$$

Where Y_{ijk} = dependent variable (WH, BL, CG); μ = general average; A_i = effect of the i-th increase each year; B_i = effect of the j-th breeding program models; AB_i = interactions between factors A and B; ε_{ijk} = random error. The NI value consisted of three categories such as low (NI<50%), moderate (51%<NI<80%) and high (NI>50%) as reported by [10]. Farmer characteristics were analyzed using descriptive methods.

RESULTS

Morphometric traits of cows

Data of morphometric traits in Bali cows are shown in (Table 1) (PBBP) and (Table 2) (NPBBP). These data showed that the morphometric traits on PBS were higher than NPBBP in every category. WH on PBBP shows an increase at each age of the cow, as well as on BL and CG. In NPBBP, on the other hand, the increase in morphometrics with age did not have a significant increase. The WH value of PBBP at 4 years of age (109.07 cm) was higher than that of NPBS (106.39 cm) (p<0.01), the same result for 5 years of WH. While the difference in WH values at the age of 6 years (p<0.05). The WH value in this study was higher than in other studies of 108.35 cm [11] and 107.29 cm [12], but lower than 111.6 cm [13] and 111.46 [14]. BL value in PBBP is higher than NPBBP (p<0.01). BL values in other studies were 106.00 cm [12], 108.40 cm [11], and lower than [14] (112.00 cm). CG values were different between PBBP and NPBBP (p<0.01).

Calving rate is higher in PBBP than in NPBBP. Mortality is higher in NPBS than in PBBP (Table 3). Bali cattle on NPBS maintenance in the West Timor region of Indonesia showed a high value of 11.06-23.27% [15]. High calf mortality reduces the productivity of Bali cattle, especially in NPBBP. Many calves were found to have died due to lack of milk [15]. The population structure in this study showed that the natural increase (NI) value was in the low category (33.82%) as shown in (Table 3). As reported by [10], the NI value consisted of three categories such as low (NI<50%), moderate (51%<NI<80%) and high (NI>50%).

Table 1. Mean, standard deviation, minimum and maximum for withers height, body length and chest girth of Bali cows with different ages at participatory-based breeding system

Measurement	N	Mean (cm)	SD	Min. (cm)	Max. (cm)
Cow (4 years) Recording at 2020					
Withers height (WH)	138	107.12	3.79	102	116
Body length (BL)	138	110.06	6.45	95	123
Chest girth (CG)	138	141.09	7.89	112	158
Cow (5 years) Recording at 2021					
Withers height	127	109.07	3.98	100	116
Body length	127	110.62	6.15	91	125
Chest girth	127	143.59	8.41	114	160
Cow (6 years) Recording at 2022					
Withers height	172	109.29	5.00	101	125
Body length	172	113.47	6.43	101	144
Chest girth	172	146.79	10.04	120	194
Replacement Cow (2 to 3 years)					
Withers height	74	101.48	5.07	87	116
Body length	74	102.05	8.74	81	128
Chest girth	74	133.46	12.27	107	178

Note: N: number of observations; SD: standard deviation; Min: minimum value; max: maximum value.

Table 2. Mean, standard deviation, minimum and maximum for withers height, body length and chest girth of Bali cows with different ages at non- partisipatory-based breeding system

Measurement	N	Mean (cm)	SD	Min. (cm)	Max. (cm)
Cow (4 years) Recording at 2017					
Withers height	86	107.51	5.65	79	119
Body length	86	109.27	7.69	76	123
Chest girth	86	140.14	12.05	98	168
Cow (5 years) Recording at 2018					
Withers height	96	106.39	4.09	97.5	118
Body length	96	106.25	6.89	92	131

Chest girth	96	133.16	8.19	115	160
Cow (6 years) Recording at 2019					
Withers height	90	107.57	4.69	97	120
Body length	90	106.49	9.28	81	125.5
Chest girth	90	139.79	14.04	117	182

Note: N: number of observations; SD: standard deviation; Min: minimum value; max: maximum value.

Table 3. Technical coefficient for output estimation of Bali cattle in PBBP and NPBBP at South Sulawesi Province of Indonesia

Component	Value	
	PBBP	NPBBP
Number of adult females (%)	58.09	62.50
Number of adult male (Heads)	18	3
Calving rate based on adult female cattle (%)	64.58	26.67
Calving rate based on population (%)	37.50	16.67
Mortality (%)	3.68	9.72
Natural increase (%)	33.82	6.94
Percentage of adult cattle (%)		
Male	4.4	21.08
Female	58.09	81.25
First mating age (years)		
Male	3	3
Female	2.5	3
Breeding length (years)		
Male	3	3
Female	7	5
Sex ratio (male/female)	13/38	2/18
Number of population observed (heads)	408	144

Morphometric traits of calves

The implementation of the cow breeding program has an impact on the morphometric size of the calves. The resulting birth weight in PBBP was not significantly different between those born in 2020 and 2021, for both male and female calves (Tables 4 and 5). Nevertheless, the birth weight of calves in PBBP increased each year. Compared to calf birth weights in other studies, the resulting birth weights in PBBP were relatively higher. In male calves, the measurement results showed differences in WH, BL and CG each year ($p<0.01$). There was a significant increase in all morphometric parameters in the third year. In female calves, the measurement results showed differences in WH, BL and CG each year ($p<0.01$). There was a significant increase in the implementation of PBBP in the third year.

Table 4. Mean, standard deviation, minimum and maximum for withers height, body length and chest girth of Bali male calves with different birth years at partisipatory-based breeding system

Measurement	N	Mean (cm)	SD	Min. (cm)	Max. (cm)
Calves Recording at 2020					
Birth weight	35	15.17	2.93	10	22
Withers height	40	56.45	4.81	42	67

Body length	40	49.5	5.02	40	62
Chest girth	40	55.8	4.81	40	63
Calves Recording at 2021					
Birth weight	17	16.53	2.87	10	21
Withers height	28	56.75	7.31	48	84
Body length	28	57.46	4.87	48	67
Chest girth	28	54.71	10.26	40	94
Calves Recording at 2022					
Birth weight	17	17.88	8.01	15	25
Withers height	25	60.08	8.01	42	97
Body length	25	56.02	8.50	45	84
Chest girth	25	62.54	9.37	49	84

Note: N: number of observations; SD: standard deviation; Min: minimum value; max: maximum value.

Table 5. Mean, standard deviation, minimum and maximum for withers height, body length and chest girth of Bali female calves with different birth years at partisipatory-based breeding system

Measurement	N	Mean (cm)	SD	Min. (cm)	Max. (cm)
Calves Recording at 2020					
Birth weight	57	14.54	2.69	10	27
Withers height	61	54.67	4.07	48	67
Body length	61	48.90	4.59	41	61
Chest girth	61	54.84	4.66	46	69
Calves Recording at 2021					
Birth weight	39	15.21	3.19	10	27
Withers height	53	56.98	5.21	48	74
Body length	53	56.62	6.41	37	80
Chest girth	53	51.53	6.17	41	75
Calves Recording at 2022					
Birth weight	17	16.18	1.85	14	20
Withers height	33	59.49	5.68	49	69
Body length	33	57.49	6.38	42	69
Chest girth	33	60.45	6.84	47	74

Note: N: number of observations; SD: standard deviation; Min: minimum value; max: maximum value.

Farmer characteristics

Livestock production in Indonesia is mostly integrated with agriculture, such as rice fields and plantations. This has an impact on the method of providing feed to livestock. The combination of grazing patterns and the cut and carry system is the most common choice in providing feed, where the PBBP (76.2%) and NPBBP (48.4%) (Table 6). To improve the quality of forage, it can be through the introduction of new types of forage suitable for grazing land in the tropics [16]. The main problem with smallholder livestock is the variable quantity and quality of feed available throughout the year [17]. The area of land used for planting fodder grass is highest in the area <0.25 ha, where PBBP (30.8%) and NPBBP (64.7%). Most of the farmers are engaged in animal husbandry as a sideline business while their main business is agriculture. Traditionally, farmers still consider local cattle as a side business, although they are a mainstay in supporting national (Indonesia) beef demand [18].

Table 6. Farmer management livestock system of PBBP and NPBBP

Component	PBBP (%)	NPBBP (%)
Forage feeding systems		
Feed from grazing land	17,5	22,2
Cut and carry system	6,3	29,4
combination feeding system	76,2	48,4
Land area for growing forage		
< 0,25 ha	30,8	64,7
0,26 - 0,5 ha	25,0	16,9
0,51 - 1 ha	28,3	14,0
> 1 ha	15,8	4,4
Problems in in the aspect of reproduction		
Yes	29,3	37,1
No	70,7	62,9
Types of problems in the aspect of reproduction		
Absence of bulls	22,7	42,6
Absence of AI officers	1,3	40,7
Cows never show signs of heat	50,6	1,9
Farmers don't know when to mate their cows	25,3	14,8
Mating system		
Artificial Insemination (AI)	63,1	0,0
Natural mating	36,4	98,6
Combination system	0,5	1,4
Service per conception		
1	43,5	50,0
2	43,5	
3	13,0	50,0
Constraints to the application of AI system		
No problem	63,5	0,0
Farmers find it difficult to observe cows in heat	25,0	50,0
Difficult to contact the inseminator officer	0,0	50,0
Does not have a cow barn	11,5	0,0

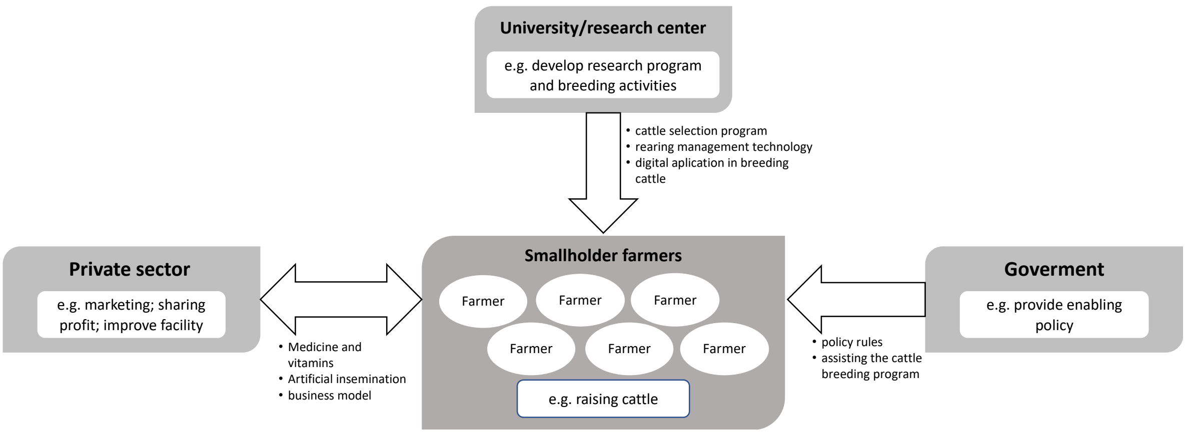

Figure 2. Stakeholder of quadruple helix model in participatory-based breeding programs

Bali cattle, as the main indigenous cattle in Indonesia, have contributed greatly to the national meat supply. The issue of Bali cattle development should no longer be limited to the conservation of indigenous Indonesian germplasm, but to its function as the main ruminant meat producer. Therefore, one focus of development efforts is to increase the capacity of smallholder farmers to become small-scale breeders. The constraints faced by smallholder breeders will be addressed through the involvement of multiple stakeholders. The quadruple helix model is an attempt to bring together multiple breeding stakeholders who work together to help overcome the limitations of smallholder farmers (Figure 2). The quadruple helix includes (1) smallholder farmers who are responsible only for raising cattle, (2) a university or research center responsible for technology dissemination and breeding activities, (3) the government, together with universities, responsible for overseeing the implementation of breeding and supporting it through regulations, and (4) the private sector responsible for economic activities that include marketing cattle and sharing the proceeds of sales.

The breeding method used is participatory-based breeding programs (PBBP), which is a modification of community-based breeding programs (CBBP). In PBBP, breeding activities involve four main stakeholders. The modification is based on increasing the number of stakeholders according to the quadruple helix model. The distribution of tasks among stakeholders is an important point in this model. Breeding activities are carried out by universities or research centers, the private sector and the government. Meanwhile, smallholder farmers play a role only in cattle rearing. Educational capacity, land resources owned by smallholders are very limited, so their role in breeding activities is minimized. Recording, medical and mating activities are carried out by the university or research center, the private sector and the government.

DISCUSSION

The results showed (Table 1 and 2) differences between the morphometric measurements of PBBP and NPBBP. The difference between PBBP and NPBBP was also obtained by [14]. Variables of increasing morphometric size each year, differences in breeding program models and interactions between the two variables, showed the effect ($p<0.01$) on CG parameters. Every year there is an increase in the morphometric size of PBBP, which is caused by organized cattle breeding system. The high sale of bulls in farms in Indonesia has led to a shortage of bulls and has an impact on stunted males that mate with cows [14]. This is exacerbated by conditions that are not supported by alternative AI mating systems in NPBBP. Unlike the case with PBBP, where the quadruple helix model makes the role of AI officers very strong to support the mating system in cows. The results of this study indicate that the factor breeding program models has an effect on morphometric size ($p<0.01$).

The low NI is due to the calving rate of 64.58% despite the low mortality rate (3.68%) (Table 3). Compared to the NPBBP, the NI is lower (6.94%) due to the lower calving rate (26.67%). The number of bulls in NPBBP is very low, which is a separate problem in NPBBP. The NI value was reported to be low in some indigenous Indonesian cattle in 2015, such as 16.35% for Bali breed, Pesisir (27.80%) and Ongole (16.22%) [19]. The NI value depends on calf crop and mortality values. Increasing calf crop and decreasing mortality values will cause the increase of NI value [9]. The conditions for first mating age in PBBP and NPBBP are relatively the same, although the breeding period of cows is longer in PBBP. Due to different breeding management, the potential of Bali cattle in NPBBP is not as optimal as in PBBP.

The birth weight of Bali cattle in South Sulawesi was 12.3 kg [20], while during PBBP, the birth weight was 16.53 kg for male calves and 15.21 kg for female calves (Table 4 and 5). The results of another study showed that the birth weight of male calves was 16.13 kg in Lombok Island and 13.81 kg in Sumbawa Island, and the birth weight of female calves was 15.33 kg in Lombok Island and 13.15 kg in Sumbawa Island [21]. The difference in BW of Bali calves may be caused by a different management system. The semi-intensive management and AI method may cause the BW in Lombok island to be higher than in Sumbawa island [21].

In the multi-stakeholder PBBP (quadruple helix model), the AI method is prioritized in cattle breeding. This is supported by a system that involves industry and local government to increase the number of AI acceptors. In addition, intensive management in PBBP prioritizes the use of AI in cattle mating.

The availability of fodder is linked to the timing of the farming business, where November to April is the rice planting season, so the cows are confined and fodder is prepared using a cut and carry system. After the rice planting season, the cows are grazed in the paddy fields. The breeding season of cattle is strongly influenced by the season of agricultural land use, which affects the availability of fodder in the fields. In subtropical regions, the mating season is in late spring and early summer, taking advantage of favorable pasture conditions for milk production [18].

The reproductive aspect of cattle is very important to farmers because the goal is to produce calves (Table 6). In PBBP, 70.7% said they had no problems with the reproductive aspects of their cows, while 37.1% said they had problems in NPBBP. Cows never showing signs of heat is the biggest problem in PBS, while the lack of bulls and AI agents is the biggest problem in NPBBP. Bulls are kept by only a small proportion of farmers and most breeders rely heavily on accurate oestrus observations by farmers for timely AI services [22]. In PBBP, the absence of bulls and AI officers is the first thing to be solved. Private and government involvement in providing AI officers is included in the Quadruple Helix model's commitment to collaboration. Improved herd management contributes significantly to cattle reproductive performance [23].

Strengthening smallholder institutions and improving reproductive aspects of PBBP has a 63.1% impact on the number of AI acceptors. The increase in the number of AI acceptors was influenced by the increase in knowledge of breeders. Breeders who are part of the group implementing the breeding program are aware of the increase in income from investments using breeding technology [24]. Case study in tropical region (Ethiopia) the AI services and its constraints in are highly influenced by under farmer management and genetics [25], [26].

In Indonesia, the natural mating system of cattle is strictly avoided. Because the bulls that are available as and are small-sized cows. Bulls are prioritized for fattening, leaving small-sized cows. In addition to the mating system, the impact of PBBP can be seen on the S/C value, which is 1 -2 and 63.5% of respondents think there are no problems with the implementation of AI. Cows in the NPBBP cannot mate with bulls. This is because the cows are kept in a semi-intensive system. Cattle are grazed during the day then farmed at night (semi-intensive) or even fully grazed throughout the day (extensive) especially during the harvest season [30].

The main objective of the community cattle breeding program is to improve cattle performance. Cattle performance can be measured by increasing the morphometric size of cows and calves. Genetic improvement in cattle could be achieved by using body measurements such as CG and BL as indirect selection criteria. Referring to the results of other studies prior to the implementation of the Bali cattle breeding program, the birth weight of calves in South Sulawesi was 12 kg [20], 8 kg in Boak and Sukadamai [27], 9.9 kg in Maros, South Sulawesi and 10.5 kg in Timor Island [28].

While the results of calf birth weight in the application of PBBP reached 15-16 kg (Tables 4 and 5). The increase in calf birth weight is a contribution from the increase in cow performance, which has also increased (Tables 1 and 2). Even though the location of breeding is on smallholder farms, if management is improved and supported by various stakeholders, it will lead to an increase in morphometric size. The initial objective of PBBP is to improve the performance of calves sired by improved performance cows. Calf performance, which includes birth weight and morphometric measurements, correlates with adult cow performance [30]. Therefore, the next stage of breeding in the future is to produce replacement cows as a result of the initial breeding stage.

The weakness of the cattle rearing method for smallholder farmers is the low NI value (NI<50%). The low NI is due to the low calving rate of indigenous cattle and the high mortality of calves, especially those between 0 and 1 year of age. The low calving rate of Bali cattle is mainly due to the very limited availability of bulls for natural mating and farmers' limited access to artificial insemination.

The mating season for Bali cattle generally occurs during the dry season, resulting in calving at the peak of the rainy season, which also causes high calf mortality. At the peak of the rainy season, in tropical areas such as Indonesia, there is high humidity, which indicates a high incidence of disease in calves. Mating timing can only be done if the breeding method is strictly applied.

CONCLUSION

The results of cattle morphometric measurements on the PBBP were higher than the NPBBP. The PBBP can be an alternative breeding program for smallholder farmers and local cattle. The quadruple helix model supports the implementation of PBBP, especially in overcoming the limitations of smallholder farmers.

CONFLICT OF INTEREST

The authors declare no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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