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Research article

Impact of selection based on mature equivalent body weight of buffalo bulls and cows on calf body weight at different ages in Thanh-Chuong district, Nghe-An province, Vietnam

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Abstract

The objectives of this research were to assess the impact of buffalo bull and cow selection on calf body weight at different ages from birth to age 12 mth. In total, 916 buffaloes (18 bulls, 370 cows, and 528 calves) were used from 334 households in Thanh-Chuong district, Nghe-An province, Vietnam. Calves were weighed at birth and the weight of growing calves was estimated based on technical measurements of chest girth and body length. Data were analyzed using a generalized linear model. The results indicated that selection of buffalo bulls and cows based on mature equivalent weight (MEW) strongly influenced calf weight from birth to age 12 mth. Buffalo bull selection influenced calf weight by from 20.27% to 53.94%, and weight variation of calves accounted for 12.00% to 22.24%. When buffalo bulls and cows were simultaneously selected, calf weight variation was highest (from 40.86% to 75.49%). When the MEW of buffalo bulls increased by 100 kg, the body weight of calves from birth to age 12 mth increased by 4.02–32.87 kg. When the MEW of buffalo cows increased by 100 kg, the body weight from birth to age 12 mth of calves increased by 1.97–26.71 kg. When the MEW of both buffalo bulls and cows increased by 100 kg, the body weight of calves from birth to age 12 mth increased by 5.39–48.76 kg. Selection of the bull increased calf weight more than the cow selection and the combined selection of the bull and cow increased calf weight the most for the different ages considered.

Introduction

Buffalo development has special advantages compared to other grazing livestock as they may more efficiently utilize and convert nutritionally poor forage and feeds into beef and milk, they are more environmentally well-adapted and they can contribute to social and cultural aspects (Food and Agriculture Organization of the United Nations, 2000; Kandeepan et al., 2009; Marai and Habeeb, 2010; da Luz et al., 2013; Hamid et al., 2017). As with other livestock breeding, the performance of calves depends on the genetic merit from both sires and dams, with each parent contributing 50% of the genetic material. The availability of the best genotyped bulls is a fundamental requirement to boost genetic gains (García-Ruiz et al., 2016; Selokar, 2018). Genetically superior bulls that able to produce large numbers of progeny in a breeding program play an important role (Dahiya and Singh, 2013) and thus, proper bull selection is the most rapid way to make genetic improvements to the herd. Performance testing provides valuable information that can be used to select superior breeding animals (Sanjeet and Sushant, 2017).

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In Vietnam, the population size of (swamp) buffaloes has gradually declined by 1.8% annually and consequently, a suitable solution is required to maintain numbers (Department of Livestock Production, 2019). There are several buffalo breeding zones in Vietnam, but buffaloes raised in Thanh-Chuong district, Nghe-An province are regarded as a rare genetic resource, especially regarding reproductive performance (Gioi et al., 2018a). However, farmers are rarely interested in their choices of bulls for mating with their cows and heifers and to date, there has been little mention of mating of bulls and females based on their body weights and on the impact on the weight of their progeny. The objective of this research was to determine the efficiency of buffalo bull and cow selection based on the mature equivalent weight (MEW) on the body weight of calves at different ages.

Materials and Methods

Animals

Based on the records from 334 households from January 2015 to December 2017, 916 buffaloes were selected, of which 18 were stud breeding bulls for natural mating, 370 were buffalo cows and 528 were growing buffalo calves were born these bulls and cows. All these buffaloes were in the controlled natural mating system in Thanh-Chuong district, Nghe-An province, a coastal zone of Vietnam.

Mating management

All the stud buffalo bulls and cows were observed in a controlled mating system. All stud bulls were managed by their respective owners, and when females were detected to be in oestrous, they were brought to the specific stud bulls for natural mating. Females who did not become pregnant were represented to the bulls again until they were successfully impregnated

Estimation of body weight for bulls and cows

The body weights of bulls and reproductive cows (1–1.5 mth after calving) were estimated using a linear measurements of heart girth and body length based on the formula described by Thac et al. (2006), as shown in Equation 1:

$$BW = HG^2 \times BL \times 88.4 \quad (1)$$

where *BW* is the estimated body weight, *HG* is the measurement of heart girth and *BL* is the body length with both determined using a technical tape and 88.4 is the standard coefficient for Vietnamese swamp buffaloes.

Groupings of bulls and cows

Grouping of stud bulls: Buffalo bulls were assigned into two groups (large and small) based on the MEW, adjusted to body weight at age 8 yr when the bulls reached peak body weight, adjusted by the coefficient based on actual variability in bull weights in the population (Table 1).

The actual weight was converted to the mature equivalent weight MEW (body weight at age 8 yr) based on Equation 2:

$$MEW = BW_a \times AC \quad (2)$$

Where, MEW is the mature equivalent body weight or peak body weight (body weight at age 8 yr), BWa is the actual body weight at the specified age at the time of measurement and AC is the adjusted coefficient (Table 1).

After being adjusted for body weight, stud bulls were divided into two groups based on MEW: small = buffalo bulls with low body weights (MEW ≤ 500 kg) and big = buffalo bulls with high body weights (MEW > 500 kg).

Grouping of cows

The buffalo cows were divided into two groups (small and big), based on body weight after having been adjusted to MEW or peak weight (body weight at fifth parity), converted to MEW (body weight at age 8 yr) based on Equation 3:

$$MEW = BW_a \times AC \quad (3)$$

where MEW is the mature equivalent body weight or peak body weight (body weight at fifth parity), Bwa is the actual body weight at the measured parity and AC is the adjusted coefficient (Table 1).

After adjustment for body weight, the cows were divided into two groups based on MEW: small = buffalo cows with low body weights (MEW less than or equal to the overall mean) and big = buffalo cows with high body weights (MEW greater than the overall mean).

The descriptive statistics based on MEW from groups are presented in Table 2.

Table 1 Adjusted coefficients for body weight of bulls and cows according to various age classes

Parities	Actual body weight of beast for various age classes and parities					Age (yr)	Adjusted coefficient	Adjusted age for bulls and cows (yr)
	N	Mean	SD	Minimum	Maximum			
1	63	364	49	283	516	3.42	1.159	3 to < 4
2	61	394	48	285	540	4.62	1.073	4 to < 5
3	105	407	61	274	615	5.83	1.037	5 to < 6
4	73	408	58	292	602	6.97	1.035	6 to < 7
5	45	422	61	303	577	8.18	1.000	7 to < 9
6	39	412	67	292	570	9.39	1.024	9 to <10
7+	42	401	59	260	571	10.59	1.052	Over 10

Table 2 Descriptive statistics of mature equivalent body weight for stud bulls and cows in two sizes

Grouping by sex	Size	N	Mean	SD	Minimum	Maximum
Stud bulls	Small	9	456.49	20.83	420	484
	Big	9	562.40	32.20	520	612
Cows	Small	231	379.74	31.37	273	422
	Big	197	472.07	45.35	424	638

Data collection on calf growth

Neonatal calves were weighed on scales to determine their body weights. The body weights of growing calves were determined using a linear measurement with a technical tape and was estimated based on Equation 1 from Thac et al. (2006). The calf data calves were gathered 2–4 times a year.

The body weight at a specific period of the closest stage was imputed using a method of International Committee for Animal Recording (2020) for different ages: birth weight and at ages 3 mth, 6 mth, 9 mth and 12 mth weights. Adjustments were made based on Equation 4 according to International Committee for Animal Recording (2020):

$$P = \frac{WG - BW}{AW} \times RA + BW \quad (4)$$

where P is the calf body weight in the research periods (ages 3 mth, 6 mth, 9 mth and 12 mth), WG is the calf body weight at measurement, BW is the average calf birth weight, AW is the calf age at weighing and RA is the research age, for the age period in days— 90 d (3 mth), 180 d (6 mth), 270 d (9 mth) and 360 d (12 mth).

Data analysis

The dataset was prepared in the Excel 2013 software package (Microsoft Corp; Redmond, CA, USA). The SAS9.0 software (SAS Institute Inc., 2002) was used for data analysis with 'Proc means' used for computation of basic statistical parameters and 'Proc GLM' was applied for major data analysis and to compare differences among least square means.

Body weight traits on calves for different research periods were analyzed using 'Proc GLM' in SAS9.0, as shown in Equation 5:

$$Y_{ijk} = \mu + BG_i + CG_j + (BG \times CG)_{ij} + e_{ijk} \quad (5)$$

where, Y_{ij} is the body weight in the different research periods of the k^{th} buffalo calf, born from the i^{th} bulls group and j^{th} cows group, BG_i is the fixed effect of the i^{th} bulls group (i=2: for big size and small size), CG_j is the fixed effect of the j^{th} cows group j (j=2 for big size and j = 1 for small size), $(BG \times CG)_{ij}$ is the interaction between the i^{th} bulls group and the j^{th} cows group and e_{ijk}: is the random residual error, $N \sim (0, \sigma^2_e)$.

To determine the variance of the bull selection group, cow selection group or the bull and cow combined group, 'Proc Varcomp' and the MIVQUE method in SAS9.0 were used for estimation of the variance components in the model shown in Equation 6:

$$Y_{ij} = \mu + G_i + e_{ij} \quad (6)$$

where Y_{ij} is the body weight in different research periods of the j^{th} buffalo calf born from the i^{th} bull or cow selection group, G_i is the random effect of the i^{th} bull or cow selection group (i=2 for big size and I = 1 for small size) *and* e_{ij} is the random residual error, $N \sim (0, \sigma^2_e)$. The percentage of variance component of bulls, cows or bulls and of the bulls and cows combined groups was determined using Equations 7–9:

$$H\%_{Bulls} = \frac{Variance\ (Bulls)}{Variance\ (Bulls) + Variance\ (Errors)} \times 100\% \quad (7)$$

$$H\%_{Cows} = \frac{Variance\ (Cows)}{Variance\ (Cows) + Variance\ (Errors)} \times 100\% \quad (8)$$

$$H\%_{(Bulls\ +\ Cows)} = \frac{Variance\ (Bulls\ +\ Cows)}{Variance\ (Bulls\ +\ Cows) + Variance\ (Errors)} \times 100\% \quad (9)$$

where $H\%_{Bulls}$ is the percentage of the bull group variance in the total variance, $H\%_{Cows}$ is the percentage of the cow group variance in the total variance, and $H\%_{(Bulls\ +\ Cow)}$is the percentage of bull and cow group variance in the total variance.

To determine the influence level of bulls and cows when their body weights were increased by 100 kg, linear single and multiple variable equations were applied using 'Proc Reg' in SAS9.0 based on Equation 10:

$$Y_{ij} = a + b(X) + e_{ij} \quad (10)$$

where Y_{ij} is the calf body weight in the research period, a is an intercept, b is a slope, X is the mature equivalent body weight of bulls or cows divided by 100 kg and e_{ij} is the random residual error, $N\ (0, \sigma_e^2)$.

To determine the influence level of the bull and cow combined group when their body weights were both increased by 100 kg, the same approach was adopted as for Equation 10, using in Equation 11:

$$Y_{ij} = a + b_1(X_1) + b_2(X_2) + e_{ij} \quad (11)$$

where Y_{ij} is the calf body weight at different periods , a is an intercept, b_1 is the slope on line representing bull MEW divided by 100 kg, b_2 is the slope on the line representing cow MEW divided by 100 kg, X_1 is the bull MEW divided by 100 kg, X_2 is the cow MEW divided by 100 kg and e_{ij} is the random residual error, $N\ (0, \sigma_e^2)$.

Significant differences were tested at the ($p < 0.05$) level.

Results and Discussion

Impacts of bull and cow selection on calf body weight.

The body weight traits of buffalo calves in the bull and cow selection groups from birth to age 12 mth are shown in Table 3. In the buffalo bull selection group, calves born from big-sized bulls had an average body weight of 29.54 ± 0.28 kg/calf that was significantly ($p < 0.05$) higher than for calves born from small-sized bulls (25.37 ± 0.52 kg/calf). Similarly, in the cow selection group, calves born from big-sized cows had an average body weight of 28.93 ± 0.46 kg/calf that was significantly higher than for calves born from small-sized cows (25.97 ± 0.36 kg/calf). For the interaction between the two selection groups of bulls and cows, those calves born from a mating couple of a big-sized bull and big-sized cow had an average body weight of 30.02 ± 0.38 kg/calf that was largest for the groups. Calves born from the mating of a big-sized bull and small-sized cow had an average body weight of 29.06 ± 0.42 kg/calf and calves born from a small-sized bull and big-sized cow had an average body weight of 27.85 ± 0.85 kg/calf, with the lowest body weight being for calves born from the mating of a small-sized bull and small-sized cow with a mean body weight of 22.88 ± 0.60 kg/calf. Furthermore, the differences in body weight among these calf groups were significant.

Table 3 Least square means (LSM) of calf body weight traits from bull and cow selection groups at various ages

Traits	Groups	Categories	N	LSM±SE
W0	Bulls	SS	39	25.37±0.52^{a}
		BS	118	29.54±0.28^{b}
	Cows	SS	79	25.97±0.36^{a}
		BS	78	28.93±0.46^{b}
	Bulls×Cows	SS×SS	26	22.88±0.60^{a}
		SS×BS	13	27.85±0.85^{b}
		BS×SS	53	29.06±0.42^{bc}
		BS×BS	65	30.02±0.38^{c}
W3	Bulls	SS	71	74.88±2.01^{a}
		BS	215	85.67±1.12^{b}
	Cows	SS	156	74.42±1.44^{a}
		BS	130	86.14±1.79^{b}
	Bulls×Cows	SS×SS	45	68.06±2.44^{a}
		SS×BS	26	81.71±3.20^{b}
		BS×SS	111	80.77±1.55^{b}
		BS×BS	104	90.56±1.60^{c}
W6	Bulls	SS	71	113.13±3.10^{a}
		BS	137	130.16±2.06^{b}
	Cows	SS	117	112.20±2.26^{a}
		BS	91	131.09±2.95^{b}
	Bulls×Cows	SS×SS	49	100.55±3.45^{a}
		SS×BS	22	125.71±5.14^{bc}
		BS×SS	68	123.85±2.93^{b}
		BS×BS	69	136.47±2.90^{c}
W9	Bulls	SS	48	144.06±5.69^{a}
		BS	123	168.64±3.23^{b}
	Cows	SS	84	147.89±3.88^{a}
		BS	87	164.81±5.27^{b}
	Bulls×Cows	SS×SS	35	131.65±5.92^{a}
		SS×BS	13	156.47±9.72^{b}
		BS×SS	49	164.13±5.01^{b}
		BS×BS	74	173.15±4.07^{b}
W12	Bulls	SS	66	177.27±6.06^{a}
		BS	129	210.41±4.28^{b}
	Cows	SS	87	183.65±4.86^{a}
		BS	108	204.03±5.60^{b}
	Bulls×Cows	SS×SS	46	162.23±6.67^{a}
		SS×BS	20	192.32±10.11^{b}
		BS×SS	41	205.07±7.06^{bc}
		BS×BS	88	215.75±4.82^{c}

W0 = birth weight; W3 = weight at age 3 mth; W6 = weight at age 6 mth; W9 = weight at age 9 mth; W12 = weight at age 12 mth; SS = small size; BS = big size. In the same trait and group, LSM values with different lowercase superscripts are significantly different ($p < 0.05$).

At age 3 mth, calves born from big-sized bulls were significantly heavier at age 3 mth (W3) than calves born from small-sized bulls (85.67 ± 1.12 kg/calf and 74.88 ± 2.01 kg/calf, respectively). Calves born from big-sized cows were significantly heavier at W3 (86.14 ± 1.79 kg/calf) than calves born from small-sized cows (74.42 ± 1.44 kg/calf). On the other hand, calves born from the mating of big-sized bulls and big-sized cows had the greatest value for W3 (90.56 ± 1.60 kg/calf), followed by calves born from the mating of small-sized bulls and big-sized cows (81.71 ± 3.20 kg/calf) and then calves born from big-sized bulls and small-sized cows (80.77 ± 1.55 kg/calf), with the lowest weights for calves born from the mating of small-sized bulls and small-sized cows (68.06 ± 2.44 kg/calf). Differences at W3 among these four groups of calves were significant.

The weight at age 6 mth (W6) of calves from the two selection groups of bulls and cows had relative differences, with calves sired from big-sized bulls weighing significantly more (130.16 ± 2.06 kg/calf) than calves sired from small-sized bulls (113.13 ± 3.10 kg/calf). Calves born from the two groups of cows were also relatively different at W6, with calves from big-sized cows weighing significantly more (131.09±2.95 kg/calf) than calves born from small-sized cows (112.20 ± 2.26 kg/calf). Calves born from the mating of big-sized bulls and big-sized cows had the heaviest body weight (136.47 ± 2.90 kg/calf), followed by the calves born from small-sized bulls and big-sized cows (125.71 ± 5.14 kg/calf) and then calves born from big-sized bulls and small-sized cows (123.85 ± 2.93 kg/calf), with the lowest body weight being for calves born from small-sized bulls and small-sized cows (100.55 ± 3.45 kg/calf). These differences at W6 among these groups of calves were significant.

The results for the weight at age 9 mth (W9) was similar to the above. Calves born from big-sized bulls were significantly heavier (168.64 ± 3.23 kg/calf), whereas calves born from small-sized bulls weighed only 144.06 ± 5.69 kg/calf. Calves from big-sized cows were significantly heavier (164.81 ± 5.27 kg/calf) than claves from small-sized cows (147.89 ± 3.88 kg/calf). Similarly, calves born from the mating of big-sized bulls and big-sized cows had the highest body weight (173.15 ± 4.07 kg/calf), followed by calves born from big-sized bulls and small-sized cows (164.13 ± 5.01 kg/calf), calves from the mating of small-sized bulls and big-sized cows (156.47 ± 9.72 kg/calf) and the lowest W9 body weight was for calves born from small-sized bulls and small-sized cows (131.65 ± 5.92 kg/calf). The differences among these four groups were significant.

The results for the weight at age 12 mth (W12) were also similar to the above Calves born from big-sized bulls had significantly higher weights (210.41 ± 4.28 kg/calf) than calves born from small-sized bulls (177.27 ± 6.06 kg/calf). Calves born from big-sized cows had significantly higher weights (204.03 ± 5.60 kg/calf) than from small-sized cows (183.65 ± 4.86 kg/calf). Calves born from big-sized bulls and big-sized cows had the highest weight (215.75 ± 4.82 kg/calf) followed by calves born from big-sized bulls and small-sized cows (205.07 ± 7.06 kg/calf) and then calves born from big-sized cows and small-sized bulls (192.32 ± 10.11 kg/calf), with the lowest weight being for calves born from small-sized bulls and small-sized cows (162.23 ± 6.67 kg/calf). The differences among these four groups were significant.

Variance components of calf body weight traits by bull and cow selection groups at various ages

Buffalo calves born from bull selection groups, cow selection groups or from an interaction between them showed differences in body weights at various ages. However, the contribution efficiency provided further information on the relative weight gains for the different mixes of parents and are provided in Table 4.

Table 4 Variance components of calf body weight by bull and cow groups

Selection groups of bulls and cows	Variance components and percentages (H%)	W0	W3	W6	W9	W12
Bulls Groups	Variance(Bulls)	12.55	74.76	232.10	467.90	816.72
	Variance(Error)	10.72	294.09	649.64	1,261.70	2,106.60
	Variance(Total) = Variance(Bulls) + Variance(Error)	23.27	368.85	881.73	1,729.60	2,923.32
	$H\%_{Bulls}$	53.94%	20.27%	26.32%	27.05%	27.94%
Cows Groups	Variance(Cows)	3.28	66.25	189.04	185.31	396.60
	Variance(Error)	13.78	289.12	661.01	1,358.60	2,277.20
	Variance(Total) = Variance(Cows) + Var(Error)	17.06	355.38	850.05	1,543.91	2,673.80
	$H\%_{Cows}$	19.22%	18.64%	22.24%	12.00%	14.83%
Both Bulls and Cows Groups	Variance(Bulls and Cows)	25.20	249.48	634.86	836.02	1,398.70
	Variance(Error)	8.18	233.32	592.53	1,189.30	2,024.80
	Variance(Total) = Variance(Bulls and Cows) + Variance(Error)	33.39	482.80	1,227.39	2,025.32	34,23.50
	$H\%_{(Bulls + Cowa)}$	75.49%	51.67%	51.72%	41.28%	40.86%

W0 = birth weight; W3 = weight at age 3 mth; W6 = weight at age 6 mth; W9 = weight at age 9 mth; W12 = weight at age 12 mth; H% = percentage of selection group variance in total variance component.

At birth, based on MEW, bulls accounted for 53.94% of the total variation in calf body weight accounted for 53.94%, whereas, cow selection accounted for 19.22% and when both bulls and cows were simultaneously selected, the contribution efficiency reached 75.49% for calf weight variation in the population.

At age 3 mth, bull selection affected 20.27% of the total variation in calf body weight, cow selection was 18.64% and both bull and cow simultaneously had a contribution efficiency of 51.67% of the total variation of calf body weight.

At age 6 mth, bull selection accounted for 26.32% of the total variation in calf weight variation, cow selection influenced 22.24% and both bulls and cows simultaneously selected accounted for 51.72% of the variation in calf body weight.

At age 9 mth, bull selection accounted for 27.05% of the total variation of calf body weight, cows accounted for 12.00% and when both bulls and cows were selected, they accounted for 41.28% of the total variation of calf body weight.

At age 12 mth, bull selection accounted for 27.94% of calf body weight variation, cows selection influenced 14.83% and when both bulls and cows were selected, the weight variation accounted for 40.86% of the total variation.

These findings indicated that bull selection influenced calf weight variation from 20.27% to 53.94% and was usually higher than when cows were selected at different ages. The weight variation of calves only accounted for 12.00% to 22.24%. Selection of both the bull and cows had the highest range from 40.86% to 75.49%.

Calf body weight traits when bull and cow MEW increased by 100 kg

An increment of 100 kg in the MEW for the bull resulted in a positive increase on calf MEW being 4.02 ± 0.49 kg at birth and reaching a maximum increase of 32.87 ± 5.57 kg at age 12 mth. The weight increment increased with calf age Similarly, when the MEW for the cow increased by 100 kg, the weight of calves increased by 1.97 ± 0.51 kg at birth to 26.71 ± 4.91 kg at age 12 mth.

When the MEW was increased by 100 kg for both the bull and cow, the calf weight increased from 5.39 kg at birth to 48.76 kg at age 12 mth. Increments were much higher than when only the bull or the cow had increased MEW by 100 kg. On the other hand, the results also showed that when the MEW of both the bull and cow were increased by 100 kg the bull contributed from 3.82 ± 0.47 kg at birth to 27.52 ± 5.46 kg at age 12 mth and accounted for 54.81% up to 70.87% of the calf weight. The contribution from the cow was from 1.57 ± 0.43 kg at birth to 21.24 ± 4.76 kg at age 12 mth and accounted for 29.13% at birth up to 45.19% at age 3 mth, which was much lower than from the bull (Table 5).

Based on this research, selection based on the bull's MEW usually had more influence than the cow's MEW regarding calf body weight at different ages from birth to age 12 mth.

In Vietnam, swamp buffaloes in Thanh-Chuong district were bigger than in some other regions. Local buffaloes in Ha-Giang, Viet-Nam had a birth weight in the range 23.23–22.18 kg, and at age 12 mth in the range 148.1–144.5 kg in males and females (Sanh et al., 2008). Swamp buffaloes in Ha-Noi had a reported birth weight range of 26.13–23.92 kg and age 12 mth of 155.6–147.91 kg in males and females (Gioi et al., 2018b). Both these studies had weights much lower than in the current research. Compared to swamp buffaloes in other countries, the birth weight of calves in the current research was higher than the birth weight of buffaloes (24.12–24.28 kg in males and females) in Bangladesh (Karim et al., 2013), but a little lower than for buffaloes (29.90–30.48 kg for males and 27.6–29.45 kg for females) in Thailand (Na and Allen, 2000; Thevarnanoharan et al., 2001).

The progeny generated from various buffalo bull and cow groups in the current study had comparatively different body weights. At birth, age 9 mth and age 12 mth, calves born from big-sized bulls had higher body weights than for calves born from big-sized cows. These results may be explained by the inherent breeding potential of the bulls, as the bull MEW on average was much higher than for a cow (562.40 kg and 472.07 kg, respectively). However, the weights of calves at ages 3 mth and 6 mth, born from big-sized cows, were negligibly higher than for calves born from big-sized bulls; this phenomenon may be explained by big-sized cows perhaps lactating than the other cows, so that the calves born from big-sized cows inherited a greater maternal environment effect than calves born from small-size cows. In the following periods (age 9 mth and age 12 mth), when the calves were not affected by the maternal environment effect anymore (that is in the grazing period), then

Table 5 Respective regression coefficient (b) ±SE of weight increment Efficiency of weight increment of calf when bull, cow or both increased their mature equivalent weight by 100 kg

Selection group		W0	W3	W6	W9	W12
Bull increment by 100 kg MEW		4.02±0.49	9.32±2.04	20.65±3.10	27.36±4.83	32.87±5.57
Cow increment by 100 kg MEW		1.97±0.51	7.68±1.66	14.53±2.90	18.03±4.11	26.71±4.91
Simultaneous increment of bull and cow MEW by 100 kg	Distribution from bulls (kg)	3.82±0.47	9.01±1.97	19.20±2.96	25.01±4.66	27.52±5.46
	Percentage of distribution from bulls (%)	70.87%	54.81%	60.06%	61.78%	56.44%
	Distribution from cows (kg)	1.57±0.43	7.43±1.60	12.77±2.66	15.47±3.83	21.24±4.76
	Percentage of distribution from cows (%)	29.13%	45.19%	39.94%	38.22%	43.56%
	Total distribution (kg)	5.39	16.44	31.97	40.48	48.76

W0 = birth weight; W3 = weight at age 3 mth; W6 = weight at age 6 mth; W9 = weight at age 9 mth; W12 = weight at age 12 mth; MEW = mature equivalent weight
SE = standard error of respective regression coefficient

benefits were completely based on the breeding merit of the bull and cow. Considering the different bull and cow groups from birth to age 12 mth, the ranking based on the body weight of the calves was often in a definite order, namely that calves born from mating a big-sized bull and big-sized cow usually had the highest weight, followed by calves born from mating big-sized bulls and small-sized cows, then calves born from mating small-sized bulls and big-sized cows, and lastly from small-sized bulls and small-sized cows. However, during the period age 3 mth and age 6 mth, this order was changed, with calves born from big-sized cows having a higher weight than from small-sized cows, irrespective of the size of the bull. This phenomenon may be explained by the combination of the maternal environment effect and the cow's breeding potential being higher than the inherent breeding potential of the bull. Thus, the bull's impact remained important and accounted for most of the calf weight. On the other hand, calves born from small-sized cows showed little weight difference from calves born from small-sized bulls, although the MEW of small-sized bulls (456.49 kg/bull) was much higher than the MEW of small-sized cows (379.74 kg/cow), the deviation is 76.75 kg, the difference in the MEW was nearly equivalent to the difference in the MEW between big-sized bulls and big-sized cows. This finding showed that bulls below 500 kg did not contribute to incremental calf weight any more than small-sized cows with an MEW of 379.74 kg, though the latter made a better contribution to calf weight than small-sized bulls. Thus, bulls with MEW less than 500 kg should not be selected for breeding.

The percentage of the bull selection group variance of the total variance component was usually higher than from the cow selection group, showing that the influence of bull selection was higher for than of the cow. However, when a combination selection was applied (both bull and cow were selected), the percentage of this selection group was much higher than for the bull only or cows only.

When the bull MEW was increased by 100 kg, the calf weight increases was greater than for an increase of 100 kg in the cow, showing that the MEW of the bull should be preferentially included in a buffalo breeding program. However, when an increase in the MEW of both the bull and the cow by 100 kg, the efficiency of calf weight increment was much higher than for a single selection, and the contribution from bulls was usually more than from cows. These results indicated that to achieve the expected efficiency in a buffalo breeding scheme, it is necessary to combine the simultaneous selection of both bulls and cows, though overall there should be more emphasis on bull selection.

In conclusion, selection of bulls and cows based on MEW strongly influenced calf weight from birth to age 12 mth. The bull selection group had a greater influence on calf weight and accounted for a greater percentage than cow selection. A combination of selection of both the bull and cow produced higher calf weight increases; however, again, the bull's contribution was greater than the cow's contribution. Bulls with MEW less than 500 kg should not be used for buffalo breeding.

Conflict of Interest

The authors declare that there are no conflicts of interest.

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References

da Luz, P.A., Santos, P.R., Andrighetto, C., Jorge, A.M., de Assis Neto, A.C. 2013. The correlation between age, body weight and testicular parameters in Murrah buffalo bulls raised in Brazil. J. Reprod. Dev. 59: 14–17. doi.org/10.1262/jrd.2012-021

Department of Livestock Production. 2019. Report of actual situation of grazing livestock on period of 2016–2018 and development orientation 2019–2025. In: Proceedings of the Conference on Development of Grazing Livestock. Ministry of Agriculture and Rural Development. Hanoi, Vietnam, pp. 2–29. [in Vietnamese]

Dahiya, S.S., Singh, P. 2013. Nutritional and other management practices for optimum semen production in buffalo bulls. Buffalo Bull. 32: 277–284.

Food and Agriculture Organization of the United Nations. 2000. Water buffalo: An asset undervalued. FAO Regional Office for Asia and the Pacific. Bangkok, Thailand.

García-Ruiz, A., Cole, J.B., VanRaden, P.M., Wiggans, G.R., Ruiz-López, F.J., Van Tassell, C.P. 2016. Changes in genetic selection differentials and generation intervals in US Holstein dairy cattle as a result of genomic selection. Proc. Natl. Acad. Sci. U.S.A. 113: E3995–E4004. doi: 10.1073/pnas.1519061113.

Gioi, P.V., Son, P.V., Hoang, T.T.M. 2018a. Reproductive performance of female buffaloes (*Bubalus bubalis*) in controlled natural mating system in Thanh-Chuong district, Nghe-An province, Vietnam. Philipp. J. Vet. Med. 55: 147–152.

Gioi, P.V., Tuan, T.A., Truong, L.G., Trang, L.T. 2018b. Growth performance of swamp buffaloes in Thach-That, Ha-Noi. Science and Technical Journal of Animal Husbandry 229: 28–34. [in Vietnamese]

Hamid, M.A., Zaman, M.A., Rahman, A., Hossain, K.M. 2017. Buffalo genetic resources and their conservation in Bangladesh. Res. J. Vet. Sci. 10: 1–13. doi: 10.3923/rjvs.2017.1.13

International Committee for Animal Recording. 2020. International agreement of recording practices: Guidelines Approved by the General Assembly. http://pecuaria.pt/docs/Guidelines_2014.pdf, 11 August 2020.

Kandeepan, G., Biswas, S., Rajkumar, R.S. 2009. Buffalo as a potential food animal. Int. J. Livest. Prod. 1: 1– 5.

Karim, M.R., Hossain, M.Z., Islam, M.R., Parvin, M.S., Matin, M.A. 2013. Reproductivity, productivity and management system of indigenous buffalo (*Bubalus bubalis*) cows in coastal area of Pirojpur and Borguna district of Bangladesh. Progress. Agric. 24: 117–122. doi.org/10.3329/pa.v24i1-2.19113

Marai, I.F.M., Habeeb, A.A.M. 2010. Buffaloes' reproductive and productive traits as affected by heat stress. Trop. Subtrop. Agroecosyst. 12: 193–217.

Sanjeet, K., Sushant, S. 2017. Testicular biometry and its correlation with body weight and semen output in Murrah bull. Buffalo Bull. 36: 105–113.

Sanh, M.V., Chien, N.K., Cuong, V.C., Maillard J.C. 2008. Selection of big size bulls for breeding to improve body size of local swamp buffalo in Ha Giang province. J. Anim. Sci. Technol. 2008: 78–84.

SAS Institute Inc. 2002. Using SAS software in your operating environment. Proprietary Software Version 9.00. SAS Institute Inc., Cary, NC, USA. \

Selokar, N.L. 2018. Cloning of breeding buffalo bulls in India: Initiatives & challenges. Indian J. Med. Res. 148: S120–S124. doi: 10.4103/ijmr.IJMR_2103_17.

Thac, N.D., Vuc, N.V., Thieu, C.V., Nhi D.L. 2006. Vietnamese Buffaloes. Social Labourel Publisher. Hanoi, Vietnam. [in Vietnamese]

Thevarnanoharan, K., Vandepitte, W., Mohiuddin G., Chantalakhana, C. 2001. Environmental factors affecting various growth traits of swamp: Buffalo calves. Pak. J. Agr. Sci. 38: 5–10.