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Potentiality of Growth Traits for Selection to Improve Productivity in Nilotic Cattle

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Abstract, Selection for traits of economic importance is crucial for improving productivity and reproductivity in livestock, including cattle. We investigated the prospects of using growth traits; viz: live-body weight (BW), absolute growth rate (AGR), relative growth rate (RGR), absolute maturing rate (AMR), and Kleiber ratio (KR) as bases for selection in Nilotic cattle, by examining the phenotypic correlations among these traits, using 125 male and 136 female calves reared under traditional husbandry system. In the experimental procedure, the heart girth (HG) and body length (BL) of each calf was measured at birth, and at the age of 2, 4, 6, 8, 10, 12, 14, and 16 months; then the BW at each age was derived, and used for estimating AGR, RGR, AMR, KR, and dry matter intake for maintenance (DMI_m). AGR, RGR, AMR, or KR was calculated from 0~8 months (AGRα, RGRα, AMRα, KRα), 8~12 months (AGRβ, RGRβ, AMRβ, KRβ), and 12~16 months (AGRγ, RGRγ, AMRγ, KRγ). Phenotypic correlations were determined using the Pearson's correlation method. The results revealed that, BW, AGR, RGR, AMR, KR, and DMI_m were inter-correlated. In particular, calf weaning weight (WW) at 8 months, AGRβ, RGRβ, AMRβ, and KRβ were positively correlated among themselves and with post-weaning BW, but negatively correlated with birth weight and DMI_m, and thus, considered the most appropriate selection indices in Nilotic cattle, since these would decrease calf birth weight, thereby reducing dystocia incidences, and increase post-weaning growth, with less DMI_m. These results provide the first evidence for possible selection using growth traits to improve productive efficiency in Nilotic cattle.

Keywords*:* absolute growth rate, absolute maturing rate, Kleiber ratio, live-body weight, relative growth rate

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1. Introduction

Selection of replacement sires and dams is crucial for herd build-up and continuity in the farming business in both traditional and modern livestock production systems. The need for selection arises from differences in reproductive success caused by genetic and/or phenotypic variations among individual animals within a herd. Among cattle, for example, calves that grow more rapidly before weaning tend to grow and mature more slowly after weaning than those that grow more slowly before weaning [1], [2] and [3].

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Early maturing cows calve for the first time at an early age, and thus produce more offspring and milk in their lifetime, compared to late maturing cows [4]. Small cows are more efficient in growth, feed conversion, and in producing milk than large cows, which on the contrary require more feed for maintenance and reach puberty later in life, thereby increasing the maintenance cost per unit weight gain and milk produced [5], [6] and [7]. Tall cows tend to produce more milk than short ones [3] and [8]. Likewise, cows with twins produce more milk, fat and protein, and give birth to more offspring in their life time compared to cows with single calves at every parity [9]. Amongst males, bulls with large testes mature earlier, produce more and high quality sperm, and their siblings have earlier puberty and better fertility compared to bulls with small testes [10]. Therefore, it is necessary to identify indicators of superior performances early in life to ensure selection of animals that are more productive within limited available resources.

The Nilotic cattle, which belong to the East Africa Sanga family are a breed of indigenous cattle in South Sudan that are reared mainly by the *Dinka*, *Nuer*, and *Shilluk* tribes, and support the socio-economic livelihoods of these and other communities [11] and [12]. Despite insufficient evidence, the productivity of these cattle is claimed to be very poor [11], [13] and [14]. Moreover, the prospects for improving them through institutional selective breeding and/or crossbreeding with exotic breeds are not feasible at the present time. One reason is the absence of a standard scheme for selecting superior animals. Even though Nilotic cattle owners do practice some sort of selective breeding, they firmly put more emphasis on cultural values, with very little or no consideration for production capacity [15]. For instance, the *Dinka* select breeding bulls on the basis of fur colour, horn shape and size, or body size; the *Nuer* seem to consider disease resistance and milk yield, while the *Shilluk* prefer animals with small head, to avoid calving problems, such as dystocia [11]. Thus, it is important to explore conventional markers of selection from the perspective of functional reproductive and productive traits in Nilotic cattle.

To date, numerous functional traits, including those related to growth, such as live-body weight (BW), absolute growth rate (AGR), relative growth rate (RGR), absolute maturing rate (AMR), and Kleiber ratio (KR) have extensively been suggested as useful indices for designing selective breeding programs to improve growth and lactation performances, feed conversion efficiency, as well as disease resistance and survival rate [1] and [16–26]. Just recently, we have investigated the AGR, RGR, AMR, and KR of the Nilotic cattle, and demonstrated that these cattle grow and mature faster during the pre-weaning periods, with males growing faster than females, and females maturing faster than males, and that AGR, RGR, AMR, and KR fluctuate in a generally similar pattern from birth onwards, suggesting that these traits are inter-correlated [27]. Therefore, a major step toward promoting the notion that AGR, RGR, AMR, KR, and BW are useful selection indices in Nilotic cattle would be to provide evidence of their genetic and/or phenotypic inter-relationships with respect to production outcomes.

The objective of the present study was to investigate the potential use of BW, AGR, RGR, AMR, or KR measurements as a selection criterion in Nilotic cattle, by determining the phenotypic inter-correlations of these traits, and identifying the correlations that are relevant to improving productivity.

2. Materials and Methods

2.1. Animals and Study Location

This study used the growth records of 125 male and 136 female Nilotic calves that were raised from birth up to the age of 16 months by *Dinka*, *Nuer*, or *Shilluk* families in the rural villages of Tunga County (Malakal) in South Sudan from the year 2004 to 2007. The husbandry system as well as the climatic conditions under which these cattle are reared have previously been described in detail [12], [27] and [28].

2.2. Determination of Growth Traits

The investigated growth traits, namely; BW, AGR, RGR, AMR, and KR were estimated as previously described [27]. Briefly, BW was estimated from heart girth (HG) and body length (BL) measurements taken at birth, and at the age of 2, 4, 6, 8, 10, 12, 14, and 16 months. Calf weaning weight (WW) was adjusted to 8 months (240 days) by linear interpolation of birth weight, actual weaning weight, and the age at weaning [29]. AGR, RGR, AMR, and KR were calculated from birth to weaning at 8 (0~8) months (AGRα, RGRα, AMRα, and KRα), 8~12 months (AGRβ, RGRβ, AMRβ, and KRβ), and 12~16 months (AGRγ, RGRγ, AMRγ, and KRγ) intervals. All RGR, AMR, and KR values were multiplied by 100 to avoid scaling problems. In addition to the above mentioned growth performance traits, the dry matter intake for maintenance (DMI_m) for each calf at the age of 4, 8, 10, 12, 14, or 16 months was calculated from the corresponding BW. The formulas used for calculating BW, WW, AGR, AMR, RGR, KR, and DMI_m, respectively, are described in Table 1.

Table 1. Formulas Employed for Calculating Target Growth Traits

Formula	Description
$\mathrm{BW} = \frac{\mathrm{HG}^2 \times \mathrm{BL}}{6600}$	***(BW)*** is live-body weight (kg). ***(HG)*** = heart girth (chest) circumference just behind the forelegs, and ***(BL)*** = body length from the point of the shoulder to the pin bone, both in cm [27].
$\mathrm{A} = \frac{\mathrm{B} - \mathrm{C}}{\mathrm{D}} \times 240\mathrm{days} + \mathrm{C}$	***(A)*** is the 240-days adjusted calf weaning weight ***(CWW)***, ***(B)*** = actual weaning weight, ***(C)*** = birth weight, all in kg, and ***(D)*** = actual age at weaning in days [29].
$AGR = \frac{(y_{t_2} - y_{t_1})}{(t_2 - t_1)}$	***AGR*** is expressed as kg/day; y_{t1}= weight at age t_1, *and* y_{t2} = weight at age t_2. [1].
$AMR = \frac{1}{A}\frac{(y_{t_2} - y_{t_1})}{(t_2 - t_1)} \times 100$	***AMR*** is expressed as percent kg/day; ***(A)*** = mature weight, y_{t1} = weight at age t_1, and y_{t2} = weight at age t_2. [1]. For Nilotic cattle, ***(A)*** averaged 292.8 kg in bulls and 146.4 kg in cows [28].
$RGR = \frac{\mathrm{AGR}}{\frac{1}{2}(yt_1 + yt_2)} \times 100$	***RGR*** is equivalent to AMR; y_{t1}= weight at age t_1, and, y_{t2} = weight at age t_2 [1].
$\mathrm{KR} = \frac{\mathrm{AGR}}{\mathrm{BW}^{0.75}} \times 100$	***KR*** is the percent ratio of AGR per kg metabolic weight ($BW^{0.75}$) at a given age [19].
$DMI_{m} = 0.05011 \times BW^{0.75}$	DMI_m is the product of net energy for maintenance of the diet for Zebu cattle (0.5011) and metabolic weight ($BW^{0.75}$) at a given age [22].

2.3. Correlations and Statistical Analyses

The Pearson's correlation coefficient (r) was used to determine the strength of the phenotypic relationship among BW, AGR, RGR, AMR, KR, and DMI_m. All calculations were performed using the *GB-Stat* 10 (Dynamic Microsystems, Silver Spring, MD, USA) and *JMP 10* (SAS Institute, Cary, NC, USA) statistical software, wherein $p<0.01$[**] and $p<0.05$ [*] were set as the levels of significance.

3. Results and Discussion

To clarify the hypothesis that BW, AGR, RGR, AMR, and KR measurements are potential markers for selection in Nilotic cattle, first we determined whether these traits are inter-correlated as follows:

3.1. Correlations among AGR, RGR, AMR, and KR

AGR, RGR, AMR, and KR at 0~8 months (α), 8~12 months (β), and 12~16 months (γ) age intervals were found to be phenotypically inter-correlated, as expected [Table 2]. Specifically, AGRα was negatively correlated with AGRβ, but positive with AGRγ in both sexes. Similar correlations were also seen among pre- and post-weaning RGRs, AMRs, or KRs. In addition, correlations among AGR, RGR, AMR, and KR over the same age interval were positive and significant in both sexes, indicating that growth and maturing rates are interrelated in Nilotic cattle. These results are consistent with those of other studies that reported genetic and/or phenotypic correlations among AGR, RGR, and/or KR in Bonsmara, Nellore, Hanwoo, and Japanese Black cattle [19], [25] and [31], and support the view that faster growth at one age interval is often followed by a slower growth in the subsequent age interval and vice versa [1], [4] and [16].

Table 2. Pearson Correlations Among Growth AGR, RGR, AMR, and KR in Male (below the diagonal) and Female (above the diagonal) Calves

	AGRα	AGRβ	AGRγ	RGRα	RGRβ	RGRγ	AMRα	AMRβ	AMRγ	KRα	KRβ	KRγ
AGRα		-0.37**	0.07	0.80**	-0.50**	0.05	0.99**	-0.37**	0.07	0.95**	-0.47**	0.06
AGRβ	-0.26**		0.13	-0.09	0.97**	0.10	-0.37**	0.99**	0.13	-0.46**	0.98**	0.09
AGRγ	0.30**	0.29**		0.09	0.01	0.99**	0.07	0.13	0.99**	0.03	0.11	0.98**
RGRα	0.13	-0.10	0.22*		-0.13	0.09	0.82**	-0.09	0.09	0.85**	-0.12	0.09
RGRβ	-0.49**	0.94**	0.12	-0.19*		0.08	-0.50**	0.97**	0.10	-0.55**	0.99**	0.07
RGRγ	-0.26**	-0.13	0.64**	0.11	-0.10		0.05	0.10	0.99**	0.03	0.09	0.99**
AMRα	0.99**	-0.26**	0.30**	0.15	-0.49**	-0.26**		-0.37**	0.07	0.95**	-0.47**	0.06
AMRβ	-0.26**	0.99**	0.29**	-0.10	0.94**	-0.13	-0.26**		0.13	-0.46**	0.98**	0.09
AMRγ	0.30**	0.29**	0.99**	0.22*	0.12	0.63**	0.30**	0.29**		0.03	0.11	0.98**
KRα	0.86**	-0.60**	0.10	0.08	-0.76**	-0.18	0.86**	-0.60**	0.10		-0.52**	0.01
KRβ	-0.41**	0.95**	0.14	-0.16	0.97**	-0.13	-0.41**	0.95**	0.14	-0.75**		0.08
KRγ	-0.10	0.01	0.81**	0.15	-0.02	0.96**	-0.10	0.01	0.81**	-0.10	-0.04	

AGR = absolute growth rate; RGR = relative growth rate; AMR = absolute maturing rate; KR = Kleiber ratio.
Age intervals: α = Birth~8 months (weaning); β = 8~12 months; γ = 12~16 months
** Significant at $p<0.01$; * Significant at $p<0.05$

3.2. Correlations of AGR, RGR, or KR with BW at Different Ages

The correlations of AGR, RGR, or KR with BW are presented in Table 3. AGRα was negatively correlated with BW at birth and positive at other ages, except at 4 months in males, and at 2, 4, and 10 months in females. Similarly, the correlations of AGRβ and AGRγ with BW at different ages varied between sexes. All the pre- and post-weaning correlations between AMR and BW corresponded to those observed between AGR and BW (data not shown), implying that changes in both growth and maturing rates are associated with changes in BW. The correlations between RGR and BW were very low, and in most cases negative and non-significant in both sexes. Interestingly, RGRα, RGRβ and RGRγ were negatively correlated with birth weight in females, but not in males. Similarly, the correlations of KR with BW varied between sexes; but perhaps of most interest was the correlation between KRα and BW, which was negative at birth and positive from the age of 6 months onwards, and corresponded to the results reported in Hereford cattle [1].

Table 3. Pearson Correlations of AGR, RGR, and KR with BW at Different Ages

	BW	AGRα	AGRβ	AGRγ	RGRα	RGRβ	RGRγ	KRα	KRβ	KRγ
Males	Birth	-0.36**	0.03	0.03	0.49**	0.07	0.19*	-0.39**	0.04	0.15
	2 M	0.33**	-0.02	0.03	-0.58*	-0.10	-0.19*	0.26**	-0.07	-0.13
	4 M	0.19	-0.06	-0.04	-0.13	-0.11	-0.18*	0.18	-0.11	-0.15
	6 M	0.54**	-0.11	0.13	0.10	-0.22**	-0.26**	0.49**	-0.19*	-0.16
	8 M	0.99**	0.26**	0.32**	0.24**	0.51**	-0.24**	0.83**	0.42**	-0.08
	10 M	0.74**	0.40**	0.48**	0.10	0.14	-0.25**	0.36**	0.23	-0.04
	12 M	0.75**	0.43**	0.49**	0.16	0.16	-0.31**	0.37**	0.25**	-0.07
	14 M	0.74**	0.44**	0.52**	0.16	0.17	-0.28**	0.37**	0.25**	-0.04
	16 M	0.73**	0.44**	0.63**	0.18*	0.17	-0.16	0.35**	0.25**	0.09
Females	Birth	-0.57**	-0.11	-0.08	-0.95**	-0.12	-0.09	-0.66**	-0.12	-0.09
	2 M	-0.04	0.01	-0.04	-0.07	-0.01	-0.03	-0.04	0.01	0.03
	4 M	0.05	-0.04	0.16	-0.02	-0.06	0.16	0.04	-0.05	0.16
	6 M	0.34**	-0.04	0.02	0.08	-0.15	-0.02	0.20*	-0.12	-0.01
	8 M	0.75**	0.53**	0.12	0.21*	0.70*	-0.01	0.62**	0.66**	0.01
	10 M	0.11	-0.05	0.13	-0.01	-0.07	0.12	0.04	-0.06	0.12
	12 M	0.49**	0.34**	0.15	0.16	0.12	0.08	0.26**	0.18*	0.09
	14 M	0.39**	0.19*	0.65**	0.14	0.05	0.59**	0.19*	0.09	0.59**
	16 M	0.33**	0.29**	0.83**	0.15	0.14	0.79**	0.17	0.18*	0.78**

BW = live-body weight; AGR = absolute growth rate; RGR = relative growth rate; KR = Kleiber ratio; M = month; 8M = calf weaning weight adjusted to 8 months. Age intervals: α = Birth~8 months (weaning); β = 8~12 months; γ = 12~16 months

** Significant at $p<0.01$; * Significant at $p<0.05$

3.3. Correlations among Body Weight (BW) Measurements at Different ages

The inter-age correlations of BW at 0, 2, 4, 6, 8, 10, 12, and 16 months are shown in Table 4. All correlations between BW at birth and BW at other ages were mostly negative or close to zero and non-significant in both sexes, except at 8 and 10 months in males. Also, in both sexes, all correlations among BW at the age 6, 8, 10, 12, and 16 months were positive and significant, except for the correlation between 10 and 12 months in females, which was positive and non-significant. Particularly, in males, the correlations among BW at the age 6, 8, 10, 12, and 16 months increased with increasing age. These results are in full agreement with those reported in other cattle breeds [1], [4] and [16].

Table 4. Pearson Correlations among BW Measurements at Different Ages in Male (below the diagonal) and Female (above the diagonal) Calves

	BW (0)	BW (2)	BW (4)	BW (6)	CWW (8)	BW (10)	BW (12)	BW (14)	BW (16)
BW (0)		0.07	0.04	0.09	-0.03	0.07	0.02	0.03	-0.04
BW (2)	-0.07		-0.13	-0.01	0.02	-0.10	0.01	-0.05	-0.03
BW (4)	0.04	0.35**		0.21*	0.10	0.32**	0.07	0.26**	0.16
BW (6)	-0.12	0.29**	0.23**		0.48**	0.61**	0.5**	0.62**	0.29**
CWW (8)	-0.2*	0.33**	0.20*	0.54**		0.19**	0.62**	0.44**	0.36**
BW (10)	-0.19*	0.3**	0.13	0.39**	0.74**		0.17	0.55**	0.19*
BW (12)	-0.17	0.29**	0.15	0.43**	0.76**	0.97**		0.67**	0.67**
BW (14)	-0.16	0.28**	0.14	0.43**	0.75**	0.96**	0.99**		0.87**
BW (16)	-0.14	0.27**	0.12	0.41**	0.74**	0.95**	0.99**	0.99**	

Values were calculated from 125 males and 136 females. Numbers in parenthesis denote the age of animals in months. BW=live-body weight; CWW (8) = calf weaning weight adjusted to 8 months
** Significant at $p<0.01$; * Significant at $p<0.05$

Next, we sought to identify which of the correlations among the growth performance traits examined above offer the best selection option in Nilotic cattle, because selections based on growth traits sometimes yield undesirable outcomes. One of such undesirable outcomes is increased incidences of dystocia caused by increased birth weight, which often leads to the calf`s and/or mother`s death [32] and [33]. Indeed, dystocia is not uncommon in Nilotic cattle, although its rate of occurrence and causes remained uninvestigated [34]. It is also a major consideration in selecting breeding bulls, especially among *Shilluk* pastoralists [11]. The present findings, therefore suggest that incidences of dystocia associated with increased birth weight in Nilotic cattle could be averted by selection for pre-weaning AGR(AGRα), AMR(AMRα), KR(KRα), post-weaning AGR(AGRβ), AMR(AMRβ), KR(KRβ), or post-weaning BW (8~16 months). Moreover, this kind of selection would improve growth and maturing rates during the pre- and/or post-weaning period, since AGR, AMR and KR are positively correlated among themselves at the same age interval [Table 2], and with BW [Table 3], thereby supporting the theory that selection for growth traits at a given age would make animals somewhat heavier and more mature on average at that age and at adjacent ages [1]. Additionally, selection for post-weaning BW, particularly at puberty in Nilotic heifers, might improve fertility and milk production, because BW at puberty is positively correlated with fertility outcomes and lifetime production ability in cows [35] and [36]. Furthermore, selection for KRα, KRβ, or RGRγ might improve both feed and growth efficiencies, as proposed in other cattle breeds [19] and [20]. As for RGRγ, our present findings suggest that its effectiveness for selection in Nilotic cattle would be limited to heifers only, since RGRγ correlations with BW are negative at birth and positive at 14 and 16 months in female calves, but not in males [Table 3]. This hypothesis offers support to the view of another study in Hereford, Angus, and Shorthorn cattle, which found post-weaning RGR to be negatively correlated with birth weight, but positive with post-weaning BW, and suggested that RGR is more appropriate for selecting maternal stock than for selecting sire stock [37].

Another undesirable outcome from selection for growth traits is the increased cost of maintaining animals, due to increased feed intake. For instance, a study in Nellore cattle reported that animals selected for higher post-weaning BW, despite gaining more weight and better AGR and KR, consumed more metabolizable energy than animals selected based on null selection differential [38]. Moreover, there is a compelling body of evidence that selection for growth traits to improve growth, feed conversion efficiency or both could also increase appetite and feed intake, causing excessive deposition of body fat, with adverse consequences, including decreased milk production [4], [7], [8], [22] and [39]. For this reason, we examined whether AGR, RGR, KR and BW are correlated with DMI_m, which is the measure of the proportion of the energy an animal uses for non-productive purposes [30]. Interestingly, the correlations of DMI_m with WW at the age of 8 months, AGRβ, RGRβ, KRβ (at 8~12 months' age interval) or RGRγ (at 12~16 months' age interval) were negative and significant in both sexes [Table 5]. We therefore proposed that selection for calf WW, AGRβ, AMRβ, or KRβ, and perhaps, also RGRγ, would be the most appropriate criteria in Nilotic cattle, because this would decrease calf birth weight, thereby reducing dystocia incidences, and maximize post-weaning growth, with reduced DMI_m. This means that Nilotic cattle would be able to efficiently utilize much of their feed for production purposes, such as growth and milk production, thereby increasing their production efficiency under the constraints of the limited feed resources in the traditional husbandry system, where they are typically reared [28].

Table 5. Pearson Correlations of AGR, RGR, KR, and BW with DMI_m in Nilotic Calves

		AGRα	AGRβ	AGRγ	RGRα	RGRβ	RGRγ	KRα	KRβ	KRγ	BW (4)	WW (8)	BW (10)	BW (12)	BW (14)	BW (16)
Males	DMI_m (4)	0.18*	-0.06	-0.05	-0.14	-0.10	-0.19*	0.18	-0.10	-0.16	0.99**	0.20	0.13	0.15	0.14	0.12
	DMI_m (8)	0.99**	-0.25**	0.32**	0.24**	-0.50**	-0.24**	0.83**	-0.42**	-0.08	0.20	-0.92**	0.75**	0.76**	0.76**	0.74**
	DMI_m (10)	0.73**	0.42**	0.48**	0.11	0.15	-0.25**	0.35**	0.24**	-0.04	0.13	0.73**	0.99**	0.96**	0.96**	0.95**
	DMI_m (12)	0.75**	0.44**	0.49**	0.15	0.17	-0.32**	0.37**	0.26**	-0.08	0.15	0.75**	0.96**	0.99**	0.99**	0.99**
	DMI_m (14)	0.74**	0.44**	0.52**	0.16	0.18*	-0.29**	0.36**	0.26**	-0.05	0.14	0.75**	0.96**	0.99**	0.99**	0.99**
	DMI_m (16)	0.72**	0.44**	0.62**	0.18*	0.17	-0.16	0.35**	0.27**	0.08	0.12	0.73**	0.95**	0.99**	0.99**	0.99**
Females	DMI_m (4)	0.05	-0.04	0.16	-0.02	-0.06	0.16	0.04	-0.05	0.16	0.99**	0.10	0.31**	0.08	0.26**	0.17
	DMI_m (8)	0.75**	-0.53**	0.02	0.21*	-0.70**	-0.01	0.62**	-0.66**	0.02	0.10	-0.94**	0.19*	0.62**	0.45**	0.36**
	DMI_m (10)	0.10	-0.06	0.13	0.01	-0.08	0.12	0.04	-0.07	0.12	0.31**	0.18*	0.99**	0.14	0.54**	0.18*
	DMI_m (12)	0.49**	0.33**	0.14	0.16	0.12	0.08	0.26**	0.17*	0.08	0.07	0.62**	0.18*	0.99**	0.68**	0.66**
	DMI_m (14)	0.37**	0.19*	0.65**	0.14	0.05	0.59**	0.19*	0.09	0.59**	0.26**	0.45**	0.56**	0.67**	0.99**	0.87**
	DMI_m (16)	0.33**	0.28**	0.84**	0.15	0.14	0.80**	0.17	0.18*	0.80**	0.16	0.36**	0.20*	0.66**	0.86**	0.99**

4. Conclusion

Up to now, the practice of selecting breeding Nilotic bulls or cows is still so primitive that it upholds cultural and tribal values over production/reproduction efficiency. Moreover, the potentiality of well-known scientifically-based selection methods in Nilotic cattle has so far remained uninvestigated. Thus, the present evaluation, based on BW, AGR, RGR, AMR, or KR measurements might represent an effective means by which conventional selection of superior sires and dams in Nilotic cattle can be achieved at the age of 8~12 months from the standpoint of production/reproduction attributes, while embracing the continuity of traditional values. We expect that proper application of the selection schemes proposed herein, would improve the reproductive and productive efficiency of the Nilotic cattle, and eventually improve food security, increase household income, and uplift the living standard of rural communities.

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