Long-term growth of male and female Bali cattle fed *Sesbania grandiflora*

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Abstract. This study examined the long-term growth of male and female Bali cattle (*Bos javanicus*) fed a diet consisting solely of *Sesbania grandiflora* (sesbania) or sesbania with rice bran. Twelve male (71.6 ± 2.2 kg mean liveweight and standard error of the mean; LW) and six female (80.3 ± 2.8 kg LW) weaned Bali cattle, ~6 months of age at the commencement were used in this experiment. LW, wither height (WH), hip height and chest circumference (girth) were measured from ~6 to 27 months of age. Dry matter intake and the concentration of glucose, urea and insulin-like growth factor-1 in the plasma were measured at ~9, 18 and 27 months of age. There was no difference in LW gain of male and female Bali cattle between 6 and 18 months of age but males had a greater average LW gain (0.40 kg/day) than females (0.22 kg/day) between 18 and 27 months of age. Overall females displayed a curvilinear growth path in LW, WH and girth but curvilinear in WH over the same age. Dry matter intake did not differ with stage of development or between male and female cattle. The plasma urea concentration declined in male Bali cattle with stage of development but was constant in female cattle across the experiment. The concentration of insulin-like growth factor-1 in the plasma increased with age and tended to be greater in male (268 ng/mL) than female (222 ng/mL) Bali cattle. In conclusion, Bali cattle display sexual dimorphism in growth after ~18 months of age, which is important to consider when developing feeding strategies across the full growth path.

Additional keywords: body dimensions, insulin-like growth factor-1, liveweight gain, sexual dimorphism.

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Introduction

An understanding of the long-term growth path of livestock species is important to develop nutritional strategies that are appropriate for the different stages of development of the animal. Male cattle are typically leaner at a given age compared with female cattle managed under the same conditions. Bali cattle (*Bos javanicus*) are indigenous to Indonesia and are the dominant cattle species across eastern Indonesia. Bali cattle are of significant economic importance to Indonesia due to their high fertility, high adaptability to various environmental conditions and suitability to smallholder management systems (Wiriosuhanto 1997).

Female Bali cattle have a low mature liveweight (LW) (211 to 270 kg for mature cows across eastern Indonesia; Talib et al. 2003; Julianto et al. 2010). The mature LW of male Bali cattle is less clear, with the majority of male cattle sold for slaughter being between 250 and 350 kg LW, although Julianto et al. (2010) suggest males may exceed 750 kg. Growth rates of Bali cattle under village conditions are low (0.2 kg/day; Jelantik et al. 2008; Marsetyo et al. 2012) primarily due to insufficient supply of high-quality feeds.

Increasingly grains are in demand for human consumption and in the production of biofuels with decreasing quantities of grain being available for inclusion in ruminant diets. Tree legumes are a ruminant feed source that are high in protein (20–25%), easily established and persist throughout the dry season and may be one feed option available to smallholder farmers to increase growth rates of Bali cattle across eastern Indonesia. Dahlanuddin et al. (2005) reported that *Sesbania grandiflora* (sesbania) is the dominant tree legume on the island of Lombok, Indonesia. In two short-term feeding trials (10 and 12 weeks in duration), the LW gain (LWG) of male Bali cattle fed sesbania as the sole diet was 0.33 and 0.44 kg/day (Dahlanuddin et al. 2014). No information is available on the long-term growth of male and female Bali cattle fed sesbania as the sole or main component of the diet. The objective of this experiment was to investigate growth paths of male and female Bali cattle from weaning to maturity.

Materials and methods

Experimental design, animals and diets

The procedures in this experiment were conducted in accordance with the guidelines of the Australian Code of Practice for the Care and Use of Animals for Scientific Purposes and were reviewed and approved by the University of Queensland Animal Ethics Committee.
The experiment was conducted at the University of Mataram, Teaching and Research Farm, Lingsar, West Lombok, Indonesia (8°31’48”S, 116°11’41” E) for 21 months from March 2007. Twelve male (71.6 ± 2.2 kg LW) and six female (80.3 ± 2.8 kg LW) weaned Bali cattle, ~6 months of age were used in this experiment. The weaners were weighed and allocated to individual pens in a randomised block design, with two males and one female allocated to each block. The weaners were treated for internal and external parasites with Ivomec (Merial, Mumbai, India) before commencement of the experiment. All cattle were maintained in individual pens throughout the experiment and were offered a diet of sesbania (861 g OM, 115 g CP, 541 g NDF/kg DM) ad libitum from 6 to 24 months of age and were offered sesbania (861 g OM, 115 g CP, 541 g NDF/kg DM) ad libitum plus 5 g rice bran (RB) DM/kg LW.day from 24 to 27 months of age. Water was available ad libitum throughout. Two male cattle were removed from the experiment; one was diagnosed with malignant catarhal fever (at 12 months of age) and died and the other developed depressed feed intake over a period of 2 weeks (24 months of age) and was removed as there were no signs of a return to previous intake levels. These animals were excluded from the data analysis. Two female cattle were found to be ~4 months pregnant at the conclusion of the experiment. Data from these two animals between 18 and 27 months of age were excluded from the subsequent analysis. At 18 months of age four of the 10 male cattle were surgically castrated under local anaesthesia (lignocaine HCl, 20 mg/mL), resulting in six intact males, four castrated males and four females between 18 and 27 months of age.

Measurements
Liveweight was recorded before feeding at the same time each week and WH and girth were recorded once each month throughout the experiment at the same time as LW measurements; hip height (HH) was measured every month from 12 to 27 months of age.

Daily DM intake was measured over seven consecutive days at ~12, 18 and 27 months of age. The cattle were offered sesbania three times each day (0700 hours, 1200 hours, 1900 hours), with ad libitum feeding set at the previous day’s intake plus 20%, as fed. When RB was included as a supplement, it was offered before sesbania, with sesbania offered after the full allocation of RB was consumed. Samples of sesbania and RB offered were collected every day during the DM intake measurement periods and with duplicate sub-samples dried to a constant weight at 65°C. Daily feed residues were weighed, bulked across the seven consecutive days, with the bulk residue weighed and mixed thoroughly and duplicate sub-samples collected and dried to a constant weight at 65°C.

Blood samples were collected upon completion of the DM intake measurement periods. Blood samples were collected from the jugular vein into lithium heparin coated vacutainers before feeding on each occasion. Blood samples were stored on ice before centrifugation at 1300g for 10 min, with plasma stored in duplicate aliquots at −20°C before analysis.

Plasma analysis
Plasma glucose and urea concentrations were determined in single on an Olympus AU400 auto-analyser (Beckman Coulter Diagnostic Systems Division; Melville, NY, USA) using Beckman Coulter Diagnostic Systems reagents and quality controls. The concentration of and insulin-like growth factor-1 (IGF1) in the plasma was determined in duplicate using a commercial radioimmunoassay kit according to the manufacturer’s instructions (IGF-1 RIA Kit; Bioclone, Sydney, NSW, Australia), which included an acid-ethanol extraction to remove binding proteins. Radioactivity was counted on a Perkin Elmer 2470 gamma counter. The concentration of IGF1 was within the detectable range of the kit. All samples were analysed within a single assay kit with an intra-assay co-efficient of variation of 6.5%.

Statistical analyses
Average daily LWG, WH, HH and girth data were calculated within each stage of development by regression over time. Main effects (stage and sex) and their interaction were included in the overall model and analysed using the GLM procedure; the interaction term was removed from the model if P > 0.1 and significant differences of main effects were accepted at P < 0.05. Differences between sexes within a stage of development were also assessed by one-way ANOVA. Relationships between LW and body dimensions and age, and LW and height and girth were analysed using the GLM procedure, with quadratic and linear responses tested; the quadratic term was removed if P > 0.1. Differences in response equations between male and female cattle were determined by ANOVA. All statistical analysis was conducted using the Statistical Analysis Software (SAS, 1999).

Results
There was no difference in change of body dimensions of male or female Bali cattle between 6 and 12 months of age and 12 and 18 months of age (Table 1), with the exception of a higher rate of change in HH of males between 12 and 18 months of age. Between 18 and 27 months of age males continued to grow at 0.40 kg/day, whereas LWG of females declined to 0.22 kg/day over this period, with castrates having an intermediate LWG (0.30 kg/day). At 18 months of age intact males (208 ± 7 kg LW) were not significantly heavier than females (186 ± 10 kg LW), while at 27 months of age intact males (318 ± 11 kg LW) were significantly heavier than both castrated males (289 ± 14 kg LW) and females (247 ± 14 kg LW). Withers and hip heights appeared to have plateaued at ~120 cm at 27 months of age, with males significantly taller than females (121 vs 114 cm at withers, 122 vs 116 cm at hips).

Dry matter intake was the same at each stage of the experiment at which it was measured and did not differ between male and female Bali cattle at any stage of the experiment (Table 1). The plasma glucose concentration was unchanged throughout the experiment and was similar between male and female Bali cattle at all stages. The plasma urea concentration declined with increasing age in male Bali cattle but remained constant for female cattle. The concentration of IGF1 in the plasma increased with increasing age but was not influenced by sex.
There were significantly different growth paths for LW, WH and girth between intact male and female Bali cattle fed the same diet between 6 and 27 months of age (Table 2). Female cattle displayed a curvilinear growth pattern in LW, WH and girth, indicative of slowing growth as mature size was approached. Intact male cattle generally displayed linear growth over the period of the experiment, suggesting that animals were still in a rapidly growing phase of development and they were not approaching mature size.

There were significant relationships between LW and WH and girth. For females, girth appears to be a better predictor of LW than WH. For males, there appear to be little differences between WH and girth for predicting LW, over the 6–27 months of age studied in the current experiment, as all measured dimensions were increasing in a linear fashion over the duration of the experiment.

### Discussion

The current experiment examined the growth of male and female Bali cattle for 21 months under conditions where management and nutrition were controlled. The average LWG of males remained relatively constant at ~0.4 kg/day from 12 to 27 months of age, whereas there was a sharp decrease in LWG of females after 18 months of age compared with LWG from 6 to 18 months of age. Bali cattle have low daily LWG with a maximum rate of 0.65 kg/day reported for intact males fed a maize grain and soybean meal-based diets (Quigley et al. 2014). The LWG of intact male Bali cattle was comparable to Ongole cattle (Bos indicus) but was significantly lower than Bos indicus × Bos taurus cattle when fed the same diet (Moran 1985). This difference in LWG of male and female Bali cattle at around an age and LW when puberty is thought to occur demonstrates that LWG of Bali cattle is under sexually dimorphic regulation. While breed differences in cow-calf production efficiency due to sexual dimorphism have been reported (Schoeman 1996), the ratio of bull mature weight : cow mature weight is much lower for other cattle breeds (1.4; Taylor et al. 1985) than what might be expected for Bali cattle (2–3, based on mature LW of 250 and 750 kg for cows and bulls, respectively).

The response equations for LW, WH and girth measured here were different between male and female Bali cattle from 6 to 27 months of age, further demonstrating differences in growth between the sexes. The curvilinear response of LW, WH and girth in female cattle suggests they were approaching mature body size by the end of the experiment: 247 kg LW at a height of 114 and 116 cm at the withers and hips, respectively. Intact male Bali cattle displayed a linear increase in LW (0.4 kg/day) from 12 to 27 months of age, with no signs of reaching maturity at 318 kg LW at 27 months of age. The curvilinear response in WH for intact male cattle suggests they were approaching mature heights (121 cm) by 27 months of age. Unfortunately mature LW for intact male Bali cattle could not be estimated in the current experiment as the animals were still growing in a linear fashion at the end of the experiment. The determination of the mature LW of male Bali cattle is an area of research that is warranted despite the long-term nature of such an experiment.

Relationships between LW and height and girth were developed for male and female Bali cattle from 6 to 27 months.

### Table 1. Liveweight gain (LWG), change in wither height (WH), hip height (HH) and chest girth (TG), dry matter intake (DMI), dry matter intake (DMI), and the concentration of glucose, area and insulin-like growth factor-1 (IGF1) in the plasma of intact (EM) and castrated male (CM) and female (F) Bali cattle during growth from 6 to 27 months of age.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Stage of age</th>
<th>Sex</th>
<th>Overall significance (P-value)</th>
<th>E</th>
<th>M</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>LWG (kg/day)</td>
<td>6–12 months</td>
<td>E</td>
<td>–</td>
<td>0.33 ± 0.03</td>
<td>0.40 ± 0.04</td>
<td>0.29 ± 0.03</td>
</tr>
<tr>
<td>WH (mm/100 days)</td>
<td>6–12 months</td>
<td>E</td>
<td>–</td>
<td>37.9 ± 7.2</td>
<td>38.2 ± 6.4</td>
<td>37.5 ± 5.9</td>
</tr>
<tr>
<td>HH (mm/100 days)</td>
<td>6–12 months</td>
<td>E</td>
<td>–</td>
<td>58.3 ± 4.1</td>
<td>58.4 ± 4.1</td>
<td>58.5 ± 4.2</td>
</tr>
<tr>
<td>TG (mm/100 days)</td>
<td>6–12 months</td>
<td>E</td>
<td>–</td>
<td>116 ± 16.6</td>
<td>118 ± 17.6</td>
<td>116 ± 16.6</td>
</tr>
<tr>
<td>DMI (g/kg LW.day)</td>
<td>6–12 months</td>
<td>E</td>
<td>–</td>
<td>27.5 ± 0.7</td>
<td>27.6 ± 0.7</td>
<td>27.6 ± 0.7</td>
</tr>
<tr>
<td>Glucose (mmol/L)</td>
<td>6–12 months</td>
<td>E</td>
<td>–</td>
<td>3.3 ± 0.1</td>
<td>3.3 ± 0.1</td>
<td>3.3 ± 0.1</td>
</tr>
<tr>
<td>LW : WH (kg/cm) A</td>
<td>6–12 months</td>
<td>E</td>
<td>–</td>
<td>1.40 ± 0.04</td>
<td>1.40 ± 0.05</td>
<td>1.87 ± 0.05</td>
</tr>
<tr>
<td>IGF1 (ng/mL)</td>
<td>6–12 months</td>
<td>E</td>
<td>–</td>
<td>0.30 ± 0.02b</td>
<td>0.40 ± 0.02c</td>
<td>0.30 ± 0.02b</td>
</tr>
</tbody>
</table>

Values are least-square means and standard error of the mean. NM, not measured during this stage of the experiment. Different letters across a row, within each stage of the experiment, indicate significant difference between sexes (at P = 0.05).
of age. These relationships can be used by researchers, extension officers, farmers and traders to predict LW of cattle under village conditions where cattle scales are not commonly available. Relationships between body dimensions and LW are influenced by the age, sex and breed of cattle and will change over time as genetic selection occurs and body dimensions may evolve (Heinrichs et al. 1992). As a single measurement, chest girth is considered a better predictor of LW than other body dimensions measured in this experiment, when all parameters measured were still increasing. It is recommended that girth be adopted as a means to estimate LW of Bali cattle when cattle scales are not available. The relationship between WH and LW is likely to be unreliable in mature Bali cattle that are likely to cease growing in height while continuing to gain LW.

Insulin-like growth factor-1 is present in the circulation and acts locally to promote proliferation and differentiation in a range of cells and stimulates glucose and amino acid uptake by tissues. The primary site of IGF1 production is the liver, with specific binding proteins in the circulation regulating its activity. Circulating IGF1 concentration responds to nutritional status of the animal (Wu et al. 2008), protein content of the diet (Liu et al. 1998), and to the administration of hormonal growth promotants (Pampusch et al. 2003) and bovine somatotropin (Lemal et al. 1989). The current experiment appears to be the first reporting the concentration of IGF1 in the circulation of growing Bali cattle. The IGF1 concentration measured in this experiment was within the range reported for growing Bos taurus cattle (>100 ng/mL; Moore et al. 2005; Wu et al. 2008), but more than that measured in growing Bos indicus steers (15–60 ng/mL; Quigley and Poppi 2013). In the current experiment IGF1 concentration increased with increasing age and LW, and tended to be higher in males than females across the entire experiment, but not at any one stage at which it was measured. These findings are similar to those reported elsewhere (Plouzek and Trenkle 1991) where IGF1 concentration increased with age and is generally higher in bulls compared with steers and heifers.

The results of the current experiment suggest that IGF1 may be implicated in sexually dimorphic growth of Bali cattle after puberty and further work in this area may be warranted.

The LWG of intact males in this long-term study was similar to the LWG of Bali cattle fed sesbania in short-term feeding trials (Dahlanuddin et al. 2014) or those supplemented with ~30% sesbania on the farm (Dahlanuddin et al. 2012). However, this LWG was lower than the LWG of 0.65 kg/day reported by Quigley et al. (2014) for Bali cattle fed a soybean and maize grain-based diet containing ~180 g CP/kg DM. Nevertheless, the results demonstrate that sesbania can be fed as the sole component of the diet for extended periods of time with no adverse effects on male or female Bali cattle.

**Conclusions**

The current experiment demonstrated the sexually dimorphic control of post-pubertal growth in Bali cattle, with males having a significantly higher LWG after puberty than that of females. This information is important when considering the LWG response of Bali cattle reported elsewhere and also in determining age and LW production targets for Bali cattle and developing the nutritional strategies to achieve these targets.

**Acknowledgements**

We gratefully acknowledge the Australian Centre for International Agricultural Research and The University of Queensland for providing funds for this experiment. We thank the technical staff at The University of Mataram for assistance with cattle management.

**References**


Dahlanuddin, Yanuarianto O, Poppi DP, McLennan SR, Quigley SP (2014) Liveweight gain and feed intake of weaned Bali cattle fed grass and tree

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**Table 2. Prediction equations describing liveweight (LW), with height (WH) and chest circumference (girth) of intact male and female Bali cattle from 6 to 27 months of age and the relationships between LW and other body dimensions**

<table>
<thead>
<tr>
<th>Term</th>
<th>Equation</th>
<th>r²</th>
<th>RMSE</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intact male (6–27 months of age)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LW (Y, kg) and age (x, months)</td>
<td>Y = 12.43x – 15.87</td>
<td>0.92</td>
<td>23.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>WH (Y, cm) and age (x, months)</td>
<td>Y = –0.020x² + 2.29x + 74.35</td>
<td>0.87</td>
<td>4.0</td>
<td>0.046</td>
</tr>
<tr>
<td>Girth (Y, cm) and age (x, months)</td>
<td>Y = 3.80x + 76.47</td>
<td>0.95</td>
<td>5.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LW (Y, kg) and WH (x, cm)</td>
<td>Y = 0.01x² – 13.64x + 507.4</td>
<td>0.96</td>
<td>16.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LW (Y, kg) and girth (x, cm)</td>
<td>Y = 3.26x – 264.7</td>
<td>0.97</td>
<td>15.2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Female (6–27 months of age)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LW (Y, kg) and age (x, months)</td>
<td>Y = –0.134x² + 12.77x + 0.25</td>
<td>0.94</td>
<td>13.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>WH (Y, cm) and age (x, months)</td>
<td>Y = 0.016x² + 1.76x + 78.6</td>
<td>0.86</td>
<td>3.1</td>
<td>0.064</td>
</tr>
<tr>
<td>Girth (Y, cm) and age (x, months)</td>
<td>Y = –0.033x² + 4.11x + 78.32</td>
<td>0.94</td>
<td>4.6</td>
<td>0.011</td>
</tr>
<tr>
<td>LW (Y, kg) and WH (x, cm)</td>
<td>Y = 6.03x – 450.2</td>
<td>0.87</td>
<td>19.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LW (Y, kg) and girth (x, cm)</td>
<td>Y = 2.74x – 202.5</td>
<td>0.96</td>
<td>9.7</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>


